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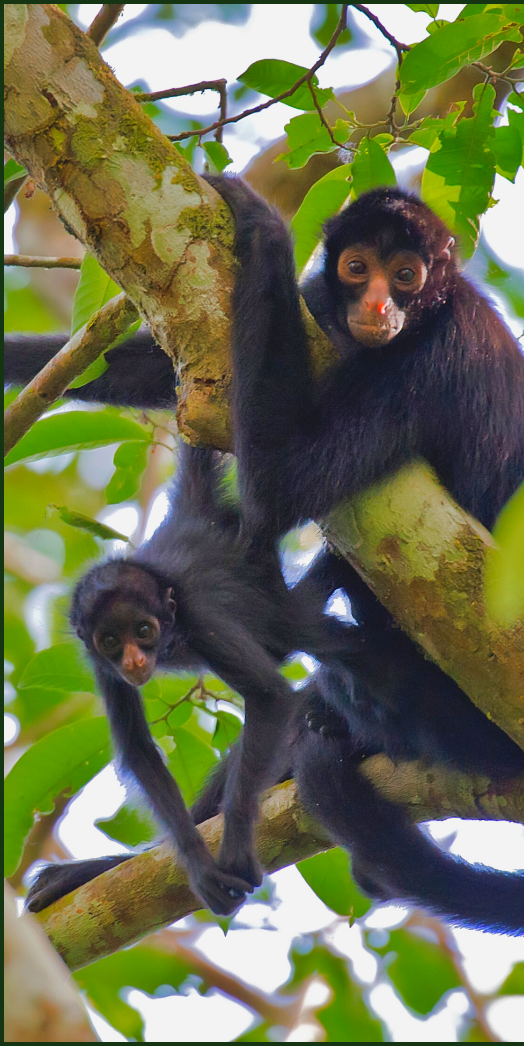

58TH ANNUAL MEETING OF THE ASSOCIATION FOR TROPICAL BIOLOGY AND CONSERVATION

Conserving Tropical Biodiversity and Achieving Socio-Ecological Resilience in the Anthropocene: Opportunities and Challenges

JULY 10-14, 2022

CARTAGENA DE INDIAS, COLOMBIA

58th Annual Meeting of the
Association for Tropical Biology and Conservation

Conserving Tropical Biodiversity and Achieving
Socio-Ecological Resilience in the Anthropocene:
Opportunities and Challenges

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Proceedings of the 58th Annual Meeting of the Association for Tropical Biology and Conservation

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Opportunities and Challenges

Introduction

The Association for Tropical Biology and Conservation (ATBC) is dedicated to advancing the scientific understanding and conservation of tropical ecosystems, and the annual ATBC meeting is a key platform for exchanging knowledge and building collaboration within the community.

We are delighted to present the abstract book for the 58th Annual Meeting of the ATBC held from July 10-14, 2022 in Cartagena, Colombia. This meeting was an opportunity for scientists, conservationists, policy-makers, and local communities to exchange knowledge and collaborate towards a sustainable future for tropical ecosystems.

The program for ATBC2022 was diverse and engaging, with a mix of plenary sessions, poster sessions, symposia, oral sessions, field trips, workshops, and field courses. The meeting provided ample opportunities for participants to exchange ideas and build new connections, with 83.2% of delegates attending in-person and 16.2% participating virtually.

The success of ATBC2022 was made possible by the hard work and dedication of many individuals and organizations, including the logistics team, the scientific committee, our volunteers, the University of el Rosario, the Conferences Committee of the ATBC, and all the members of the Local Organizing Committee. We are particularly grateful for the contributions of our volunteers, who helped to ensure a smooth and successful meeting.

We hope that you found the 58th Annual Meeting of the ATBC to be a valuable and enriching experience, and that you will continue to be engaged and active in advancing the scientific understanding and conservation of tropical ecosystems.

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Part I

Symposia

Addressing the drivers of resilience: Understanding functional biodiversity and underlying processes that determine ecosystem health

Changing Climate: Increase in Dry Season Temperature in the Amazon Basin

Ana Carolina M. Pessôa[1], João B. dos Reis[2], Nathália C. Carvalho[1], Celso Henrique Leite Silva Junior[3], Liana O. Anderson[4]

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Changes in global temperature are already affecting many ecosystems. Several studies have already evaluated climate trends in different regions of the world. Regionally, studying Amazon is fundamental due to its important role in regulating regional and global climate. Depicting the recent trends in climate variables, such as temperature, can help understand the magnitude of the observed changes in the Amazon to address and infer how they can affect the socio-environmental systems. Therefore, this study aimed to quantify the annual trends of spatial and temporal temperature variability during the dry season from 2003 to 2020 in the Amazon basin. We used the dry season onset and duration to calculate spatially explicit mean temperature during this period for each year. Temperature data was acquired from the MODIS/NASA MOD11A2 product, aggregated into 5 km^2 grid pixels. We first calculated the mean temperature per year for the entire study area to evaluate the general trend. Secondly, we performed a grid cell linear regression to obtain the trend analysis. We observed a positive increase in the average temperature during the dry season in the Amazon Basin from 2003 to 2020. Most of the southern Amazon, known as the Brazilian arc of deforestation and epicenter of commodities production, is exposed to increased temperatures. Central Amazon, harboring pristine forests and many traditional populations, is the second region with the highest positive trend. On the other hand, regions with a negative trend represent only 2% of the basin area. The absolute increase detected is 0.6°C compared 2020 to 2003, with an average rise of 0.03°C per year. If temperature continues to rise at the current rate, we estimate an increase of 1.23°C and 2°C by 2030 and 2050, respectively, compared to 2003. As a global effort, national targets set in the context of COP26 are not enough to limit global warming to the 1.5°C level. Regionally, it is already possible to observe temperature increases exceeding the global mid-century goal. Furthermore, reducing rainfall accompanied by temperature increases could lead the ecosystems to a continually changing fire-prone environment during the dry season. Our results highlight the importance of short-term actions and policies to adapt and mitigate the impacts that climate change is already imposing on Amazonian ecosystems. **Keywords:** Amazon, climate change, Tropical forest, adaptation, drought global, warming, COP26

Increased Specialised Functional Traits of Soil Microorganisms Implicate a Vivid Functional Redundancy after Anthropogenic and Natural Stress

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Introduction: Biodiversity controls soil functions, but the expansion of the agricultural frontier and natural threats like prolonged drought periods impose risks to biodiversity and soil functions possibly causing the crossing of tipping points (TP). Therefore, a major challenge in modern research is to find suitable proxies for determining TP. In tropical soils, Phosphorus (P) acquisition of microorganisms is particularly prone to be affected by disturbances. P is sequestered in mineral and organo-mineral complexes and is therefore hardly bioavailable. In pristine and, therefore, functionally diverse forests, specialized microorganisms can mobilize sequestered P and relocate it to the living biomass, thus, keep it in the nutrient cycling. By losing overall biodiversity under stress, it is highly likely that these organisms and thus the P cycle are impaired. Its effects could also cascade into Carbon and Nitrogen cycles. **Objectives:** We propose that one of the main losses in functional diversity affecting tropical ecosystems is the loss of mobilization of P from hardly accessible organic sources. To test this, we selected the bacterial *phoD* functional gene as a proxy for potentially altered P acquisition functionality as *phoD* is directly affected by the availability of P. Methods: We took soil samples in Madre de Dios, Peru, along a gradient of above-ground biodiversity (from pristine and degraded forests to monoculture and pasture vegetation) with and without artificial rain exclusion using rain-out shelters and analysed the abundance and diversity of the *phoD*-bearing microbial communities at two sampling time points. **Results:** Contrary to our expectations, we show that reduced above-ground biodiversity and drought significantly increased the abundance and diversity as well as altered the overall community composition of the *phoD*-gene bearing communities. The results mirror altered P acquisition strategies and the communities' necessity to adapt to stressful drought and disturbed conditions compared to pristine forests. We assume that the presence of the *phoD* gene poses a clear advantage of survival for microbes in tropical soils as it helps to overcome P-limiting conditions after disturbances. **Implications:** Microbial marker genes can be used as an indicator to evaluate alterations in the functional biodiversity of soils after anthropogenic and natural stress. While we cannot conclude about the crossing of TP due to currently only two sampling time points, the results indicate a surprisingly flexible and vivid functional redundancy within the microbial P cycle especially on the disturbed sites and an uncertain fate of these ecosystems. **Keywords:** Functional redundancy, Phosphorus cycle, phoD gene, tipping points, Peru

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Ant Assemblages Response to a Forest Cover Gradient in Southwestern Brazilian Amazon

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The partitioning of gamma diversity into its alpha and beta components has been used to quantify the effects of natural habitat reduction on species diversity and distribution. Ant assemblages respond to anthropogenic changes, allowing their use as an indicator of biodiversity conservation in human-modified landscapes. Additionally, ant species present different habitat-uses, such as forest specialists, open-habitat specialists and generalists that can live in both habitat types. These different ant groups can present distinct responses to the same human impact. Southwestern Brazilian Amazon, has experienced high levels of forest shifting to human land-use systems, mainly pastures, since 70-80s. Thus, we investigated how gamma, alpha, beta diversity, and habitat-use guilds react to a forest cover gradient in Assis Brasil, AC, Brazil. We carried out the ant sampling in 12 circular areas of 785.000 m^2, which forest cover percentage range from 13 to100%. In each circular area, we sample ants along transects at the four radials and in each transect, we installed four pitfall traps at ground level (100 m apart). Gamma diversity (?) was the general number of ant species sampled in each circular area, alpha diversity (?) as the average number of species per transect within each sampling area, and beta diversity (?) as a proxy for species composition change among the four transects within each sampling area, which was calculated as Bray-Curtis dissimilarity index (?Bray) and additionally partitioned into its turnover (?Bray.bal) and nestedness (?Bray.gra) components, the first referring to species replacement and the last to gain or loss of species. Additionally, we accounted for the number of species of each ant group of habitat affinity, forest specialist, open-habitat specialist, and generalist. Gamma and beta diversity increased along the forest cover gradient. Whereas alfa diversity does not. Turnover was the main component of beta diversity and increased with forest cover. The species number of ant forest specialists increased, open-habitat decreased, and generalists did not change. Thus, areas with little forest cover harbor a small number of ant species. These species have a high distribution leading to a weak difference in species composition within the same landscape. Forest cover decrease plays a selective effect on ant habitat-use guilds. The generalists and open-habitat specialists probably do not play the same ecological roles as forest ant species specialists. Therefore, the forest cover reduction simplifies ant assemblages, becoming less speciose and dominated by generalist species. **Keywords:** Biodiversity, land-use change, Southwestern Amazon, ants

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How to Cope with Increasing Risk of Wildfires in Amazonia?

Liana O. Anderson[1], Camila Silva[2], Celso Henrique Leite Silva Junior[3], Sonaira S. Silva[4], N. Galia Selaya[5], Wesley Campanharo[1], Thiago Morello[6], João B. dos Reis[7], Ana Carolina M. Pessôa[6], Gleiciane Pismel[8], Yara de Paula[8], Nathália C. Carvalho[6], Monique R. Maia[9], Luiz Aragão[8]

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Wildfires are currently a major driver of change in Amazonian carbon stocks and biodiversity, as well as an important threat to the wellbeing of its ~25 million inhabitants. In the Amazon, the extent of degraded forests has already surpassed the total deforested area. If forest degradation is not curbed, we predict reaching a tipping point characterized by a pronounced reduction of ecosystemic resilience and an irreversible loss of ecological service provision, damaging the local economy, and society. Here we present a synthesis from multidisciplinary research illuminating pathways to avoid such plausible scenarios, focusing on: i) advancing the knowledge on the socioeconomic and environmental impacts of fires, ii) the developing of new technologies to improve the wildfires risk management and operational routines to guide decision making, iii) a diagnostic of fire governance in a transnational context and iv) knowledge dissemination strategy, focused on school communities and social media. Our on-the-ground results demonstrated that even after 30 years since fires, burned forests store 25% less carbon than intact forests. Furthermore, remote sensing (RS) analysis demonstrated that forest fire incidence and intensity co-vary with levels of forest fragmentation at the landscape level. An integrated analysis combining RS and census data revealed: a) the economic loss by fires can amount to at most 7% of regional GDP, and during extreme droughts, these values can be 15 fold larger, b) a total of 5% of respiratory hospitalizations were estimated to be attributable to fire-induced pollution. Given the scarcity of financial resources in Amazonian countries for fire monitoring, it is essential to focus efforts on critical months of the fire calendar: the Spatio-temporal distribution of fire is related to the end of the dry season in the Amazon, varying between August and April. New technologies, such as online platforms to integrate multiple data sources, are helpful for both decision-makers and the general public. However, capacity building may be challenging, primarily if pursued virtually. An online survey on stakeholders' and broader society's perception of the fire problem revealed that the principal vulnerabilities are institutional, environmental, and sociocultural. Finally, to transform reality, it is necessary to act locally. We performed dissemination, training, and capacity building, presenting our research results. The scientific communication of our results was translated to social media platforms, using dissemination strategies and standardization for each communication vehicle. We conclude that multisectoral actions are required to effectively reduce fires and their impacts on the Amazon.
Keywords: Wildfires, Amazon, carbon stocks, health, governance, engagement, society, impacts

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Lessons Learned from Forest Health Participatory Action Research in Chico Mendes Extractive Reserve

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Forest health is under threat because of deforestation and degradation, which negatively impact biodiversity and provision of ecosystem services. Changes in climatic regimes appear to modify and shape tropical vegetation structure, leading to changes in species composition and mortality rates. Further, forests with distinct forest dynamics, such as the ones in the southwestern Amazon (SWA), suffer great environmental stress because they have a high density of bamboo culms and were subject to severe droughts in 2005 and 2010. These factors contribute to a high tree mortality and loss of carbon stock, which highlights the importance of minimizing the anthropic pressure under SWA forests. The above-mentioned threats have prompted initiatives for the active participation of rural peoples in monitoring forest health. Community forest monitoring programs are a way to engage rural people in contribute actively to scientific evidence generation about forest health. If rural people understand the importance of monitoring forest health and learn how to implement it, they will take steps to make sustainable use of forest resources. We implemented participatory workshops to train young leaders in using scientific instruments as a foundation for documenting vegetation characteristics. The training included implementing permanent plots, forest inventory, and information technologies. We had to overcome three challenges to align the "Forest Health" program with the priorities of rural communities: (1) understanding community political cultures and practices, (2) logistics to access communities in the CMER, and (3) managing expectations of community members. We pursued some strategies to adapt our project to the priorities of local communities and thereby improve the scale and quality of participation in our workshops. These strategies included to focus the capacity building on young leaders, broaden project's communication to include all constituencies, such as women, and incorporate project activities into associations assemblies. Additionally, there were broader structural challenges at play that were beyond the scope of our program. Despite the challenges and difficulties faced, it is important that programs of this kind keep existing, especially in inhabited forests of the SWA. Enhancing the environmental conscious of rural peoples is a way to contribute with forest health resilience at the southwestern part of the Amazon basin. **Keywords:** Amazon, capacity building, community, forests

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Functional Diversity and Ecosystem Services: Indicators for Policy Options

Oliver Frör

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Introduction and background: Ecosystem services represent the benefits society receives from ecosystems, natural or modified by human use. We hypothesize that functional diversity impacts ecosystem processes potentially leading to the surpassing of tipping points and, consequently, abrupt system state changes. Thus, it is vital to assess to what extent this will also affect thresholds in socio-economic systems, i.e. in the provision of ecosystem services. In the Amazon MAP region (Madre de Dios, Peru, Acre, Brazil, Pando, Bolivia) it has been hypothesized that further loss of ecosystem services may drastically impact social-ecological systems. Objectives The objective of the socio-economic study is to assess which ecosystem services are critically affected and may, therefore, constitute a surpassing of tipping points, and which are expected to be stable as functional diversity shows large changes due to land use intensification. We aim at developing and assessing indicators allowing us to detect the criticality of components of the systems in the MAP region. **Methods:** We apply a suite of methods comprising participatory systems analysis as well as household surveys. Two rounds of workshops with key stakeholders were conducted in each MAP country in a standardized procedure and analyzed regarding the main system characteristics of the identified components. To assess the relation between ecosystem characteristics and socio-economic variables we are conducting a representative survey with 300 households in each MAP region country following a transect of land use with decreasing biodiversity (as proxy for functional diversity) from forests to intensive pastures or crop fields. **Results:** We find that the components of the social-ecological systems differ substantially between the regions in the three MAP countries. In all three countries we find that most components are already considered critical for system behavior as modelled based on stakeholder assessments. Data from the household surveys are forthcoming. Preliminary results indicate that non-market and intangible ecosystem services are perceived to be critical with decreasing biodiversity of land use systems studied along the transects. **Implications/Conclusions:** Our study demonstrates the conceptual basis and empirical application of a method to distinguish the criticality of components in social-ecological systems and relate functional diversity to ecosystem services in the context of nearing tipping points. Once the complete results of the study are available this will serve both scientists and policy makers to target those components that are critical for system behavior and develop strategies to strengthen buffering processes and system components to increase the systems resilience. **Keywords:** Ecosystem services, systems, criticality, tipping points

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Analysing the effects of armed conflict on forest cover, land-use and biodiversity conservation in Colombia

Forests, Coca, and Conflict: Grass Frontier Dynamics and Deforestation in the Amazon-Andes

Liliana Davalos[1], Eleonora Davalos[1], Jennifer S. Holmes[1], Clara Tucker[1], Dolors Armenteras[1]
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Population growth with weak economic development can promote tropical deforestation, but government infrastructure investment can also open new frontiers and thus increase deforestation. In the Andean region of South America, population growth has been a leading explanation for both deforestation and coca cultivation, but coca generates armed conflict and attracts counter-drug measures, obscuring the differences between population-driven and frontier-open- ing models of deforestation. Using a 15-year panel from Colombia, we model deforestation, coca cultivation, and conflict victims as interrelated responses with a suite of covariates encompass- ing land cover, land cover changes, population, population changes, counter-drug measures, and government infrastructure spending. Infrastructure spending suppresses coca, coca and eradi- cation by aerial fumigation both increase conflict, and conflict promotes deforestation and is associated with depopulation. But the strongest predictor of deforestation is pasture growth, which covaries with coca. While these models show that infrastructure spending can help reduce coca, and coca's influence on deforestation is indirect and mediated by conflict, the models also reveal the most important challenge to forest conservation is neither coca nor conflict, but an insatiable appetite for land that expresses itself through pasture growth. **Keywords:** Amazon-Andes, Colombia, development, infrastructure, coca, armed conflict, pastures

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Mapping Illicit Land Activities in the Colombian Andes Amazon Region

Paulo Murillo
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Illegal land activities account for more than 40% of deforestation worldwide. Earth Observation technologies offer the capacity to objectively monitor the land-use changes associated with these important activities, but it is difficult to clearly identify and characterize specific land-use changes as "illicit." I tackle this problem by building hypotheses based on observed illicit land patterns and then differentiating them through state-of-the-art algorithms over satellite imagery. I first hypothesize that unique, observable spatial patterns can be linked to known historical and institutional processes that drive them. Second, I leverage known observations of illicit activities to classify pixel patterns or objects that exhibit statistically similar variables using a deep learning (DL) algorithm. Using the Colombian Amazon region as a hotspot of biodiversity but also affected by illicit land activities, I detect a recent, explosive conversion of forests to cattle ranching outside the agricultural frontier and within protected areas since the negotiation phase of the Colombian peace accord. In contrast, coca farming is remarkably persistent across time, in which crop substitution programs remain ineffective to stop the expansion of coca farming deeper into Protected Areas such as Macarena, Nukak-Maku, La Paya, and Tinigua. My conceptual contribution indicates key insights. First, countering common narratives, there is very little evidence that coca farming precedes cattle ranching. Second, spatiotemporal dynamics of illicit activities reflect how land agrarian policies encourage people to ranch cattle showing a linear increase during conflict (1985-2011) but an acute increase during post-conflict (2012-2019). Third, Colombia's war on drugs (i.e.,

aerial fumigation and substitution programs) attenuated coca within the legal frontier, but expansion now is deeper into hotspots of biodiversity. The peace accord motivates different actors to expand illicit land activities at a rate never seen before. Finally, the theoretical framework allows linkage between patterns of illicit activities to build hypotheses that are then corroborated by deep learning models. This framework can be extended to many other issues associated with illicitness, such as illegal fishing, illegal mining, illegal commercial agriculture (e.g., soy, oil palm), and illegal lumber harvesting. **Keywords:** Coca, cattle ranching, deep learning, Landsat, armed conflict, forest

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Conservation in an Armed Conflict Setup. Finding Paths to save Colombia's Biodiversity.

Pablo J. Negret
University of Queensland, Australia

Colombia, after decades of civil unrest, is transitioning to a post-conflict era. But the peace agreement signed in 2016 between the Colombian government and FARC-EP is impacting the country's biodiversity. New pressures are being imposed on areas of high biodiversity that previously were off-limits for development. This makes the generation of conservation plans urgent. These plans need to be informed by an understanding of changes in risks to areas of high biodiversity importance, and the effectiveness of conservation efforts such as protected areas (PA). The aim of this talk is to contribute knowledge to improve the effectiveness of conservation decisions in Colombia through a better understanding of 1) the threats to forest ecosystems and the species that inhabit them, 2) the effectiveness of land protection for biodiversity conservation, and 3) identifying areas to expand the coverage of PAs to improve the retention of species habitat. I will first go through the results of an analysis of the spatial association between deforestation drivers and forest cover change in the country, with a focus on the effect of armed conflict and coca plantations. Also, I will show the results of another analysis on the impact of future deforestation projections on forest dependent birds in Colombia. Then I will show the results of two recent analysis of the effectiveness of PAs in Colombia and other tropical areas and identify factors that influence tropical PA effectiveness. Finally, I will share some preliminary results from my latest project on the implications of not accounting for the impact of PAs in retaining species habitat in the landscape when taking decisions on PA expansion. To do this we used Colombia's 69 regionally endemic forest dependent bird species and their habitat as a case study. We measured the level of additional protection needed to retain a certain percentage of the habitat of all the species under three prioritization scenarios, 1) maximize species representation, 2) maximize species representation while increasing the protection of areas with higher deforestation risk, 3) maximize species representation while increasing the protection of areas with lower deforestation risk. Then, we simulated the spatial distribution of future deforestation to assess the projected level of habitat retained by 2050 for each forest species under the different protection scenarios and compared them to a business-as-usual scenario (BAU), of no expansion of PAs, as a measure of the projected additionality of each potential PA expansion scenario. **Keywords:** Illegal armed groups, National Parks, tropical deforestation, species richness

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What Peace Means for Deforestation

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Using Colombia as a case study, this analysis provides insights on deforestation dynamics in times of conflict and peace and the different factors driving these dynamics. We performed time series clustering of yearly deforestation data (2001–2018) from 708 out of 1,122 mainland Colombian municipalities (accounting for 98% of the total deforestation areas in Colombia) and produced regression models using a gradient tree boosting framework (XGBoost) to identify drivers that explain varying, local-level deforestation dynamics. Municipalities were characterized by seven categories of deforestation dynamics, with the Amazon region being largely represented by only four categories and the Andes region displaying all categories of deforestation dynamics. Notably, six of the seven representative categories exhibit substantial increases in deforestation in the years following the peace agreement. The regression analysis revealed that coca cultivation area, number of cattle, and municipality area are the top three drivers of deforestation dynamics at national, regional, and category levels. However, the importance of the different variables varied according to the different spatial dimensions. Results provide further understanding on how the drivers of deforestation change not only at a regional scale, as assumed by much of the current literature about drivers of deforestation, but also at a lower scale of analysis (intraregional and intradepartmental variation in the case of Colombia). Insights from this study can be used to understand deforestation dynamics in other countries experiencing times of conflict and peace and will support decision-makers in creating programs that align actions for peacebuilding, climate change mitigation, and biodiversity conservation more effectively. **Keywords:** Peace, deforestation, Colombia,

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Beyond Deforestation: Refining the Analysis of Forest Cover Change Processes after the Peace Agreements in Colombia

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Introduction: The signing of the Peace Agreement is a breaking point for Colombia and for the department of Guaviare, from which it is interesting to understand the evolution of forest cover on regard of the political and social transitions. From a long-term social and historical analysis perspective, seeing a before and after transition can bring inputs about forest management strategies and governance, acknowledging that the analysis of the evolution of forest cover has focused mainly on deforestation but not on forest degradation. **Objectives:** To compare the data offered by national and international databases on deforestation and forest degradation processes for the 2015-2020 period in Guaviare and to advance in the understanding of variations in deforestation and forest degradation trends from a social and historical analysis for the 2015-2020 period in Guaviare. **Methods:** Information sourcing from the JRC database and comparison with official data sources IDEAM and SINCHI in the period 2015-2020 for the department of Guaviare. Semi-structured interviews with regional and local institutions and farmers of one of the deforestation hotspots, bordering the Serranía del Chiribiquete National Park. **Results:** A strong increase in forest degradation in Guaviare is evident for the period 2015-2020 overcoming deforestation, which coincides with the transition period after the signing of the Peace Agreement. Problems visible over the historical trajectory and conflict persistence affect local actors' perceptions of forest management strategies and territorial governance, making it difficult to implement concerted strategies aimed at preventing deforestation. **Conclusions:** It is necessary to combine complementary methods and sources of information to address both deforestation and forest degradation processes, beyond deforestation, it is important to advance in the understanding of forest degradation in the Colombian Amazon, some conflicts persist despite the signing of the peace agreement and some specificities of socioecological context can prevent the effectiveness of concerted strategies aimed at preventing deforestation. **Keywords:** Deforestation, forest degradation, peace agreement, Guaviare department, socio-ecological context

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Forest Cover Changes and Public Policy: A Literature Review for Post-conflict Colombia

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Tackling deforestation remains a significant challenge in tropical countries and even more so in those affected by armed conflicts. This is partly because of the limited local understanding of the causes of forest cover changes (FCC) and how these causes relate to development. In this study, we use Colombia as a model to contribute to the understanding of the links between the causes of FCC in conflict-affected countries and policies aimed at achieving sustainable development by targeting the agriculture, forestry and other land use (AFOLU) sectors. Specifically, we reviewed studies reporting on causes of FCC from 1995 to 2019 to build a state-of-the-art review. We then identified relevant public policies targeting AFOLU sectors and used them as a proxy for development. Finally, we discussed the links between these public policies and FCC. From the reviewed literature, it is clear that research on FCC in Colombia has focused on understanding the causes of forest cover losses while disregarding forest cover gains. Although cattle ranching and agriculture dominate the literature as proximate causes of deforestation and policy and institutional factors as underlying causes of deforestation, the relative importance of proximate and underlying causes of FCC in Colombia has changed over time. The main categories of policies that have been linked to FCC deal with conflict and post-conflict issues, coca eradication and, more recently, the implementation of the peace agreement. Another set of policies frequently mentioned are those related to productive activities. In Colombia, these policies' effects on forests will depend on how the state will regulate extractive activities in a post-conflict scenario. Therefore, it is imperative to review and

update policies to tackle FCC, mainly deforestation, to successfully achieve sustainability targets in Colombia.
Keywords: Deforestation, public policy, peacebuilding, post-conflict drivers, Colombia

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Peace and the Environment at the Crossroads: Elections in a Conflict-troubled Biodiversity Hotspot

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Introduction. Protection of the environment often depends on governmental policies and their enforcement. In democracies around the world, elections can have major consequences for the environment. In Colombia, the 2022 presidential elections will take place at a time when progress towards peace has stalled and socioeconomic, security, and environmental conditions have deteriorated. In preparation for elections like this, we believe that it is important for scientists with relevant backgrounds to highlight relationships between political events and the environment, to enrich the political debate, help prioritize public resources, and inform policy-making. **Objective.** Provide a multidisciplinary analysis of links between governmental and socio-economic conditions, as well as environmental consequences in Colombia. **Methods.** We review different socioeconomic and environmental trends that can help inform the public and decision-makers. **Results.** Recent declines in the socioeconomic (e.g., indicators of poverty and inequality), security, and environmental conditions (increase in greenhouse gas emissions) in Colombia largely coincide with the change of government after the 2018 elections, and the associated rise to power of a party that boycotted the peace negotiations from the beginning. In this sense, 2018 marked the end of a decade of improvements in societal factors that can interact with the environment in multiple ways. A spike in assassinations of land and environmental defenders in 2019 and 2020 has also made Colombia one of the most dangerous places in the world for environmentalists. **Implications.** With the 2022 presidential election, Colombians will once again decide who will govern the country and what new social, economic, and environmental policies will be implemented. We intend for this analysis to be useful not only in Colombia, but also to other societies under similar situations, managing biodiversity-rich ecosystems in socio-political environments of increasing violence, poverty, and inequality. **Keywords:** Colombia, peace, poverty, inequality, elections, climate change

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What Is Resilient in a Country Chronically at War? An Application of the Adaptive Cycle to Understand the Socio-Ecological System

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Resilience is a key concept to understand socioecological systems – SES- worldwide, massively implemented in public policies as a positive concept to reach. The application of this concept in war countries has been used by psychologist to understand the trauma during and after wars, or social and environmental problems excluding war impacts. One of the ways to understand resilience is to use the adaptive cycle metaphor to study SES dynamics. Here, based on secondary sources such as books, scientific articles, and press articles, we use this metaphor to understand the resilience of Colombia SES and its different war-peace trajectories. And, also, after a content analysis of the environmental public policies at national scale, we analyze the public policies since the 20th century using the adaptive cycle metaphor. The use of the adaptive cycle and the description of the different phases show that war in Colombia has been long and the Colombian SES trajectory was not transformed. A national-scale war is part of the SES identity and peace works as the collapse phase in the adaptive cycle. Colombia's SES suffered two cycles of war while the policies were static and supported deforestation. Peace processes have ignored forests' key role during the war as protectors of local communities and guerrillas, and as an unlimited provider of resources for the country. These conditions have allowed the country to engage in multiple wars and made inequality and deforestation the resilient features of the system. During the growth phase of the adaptive cycle, civil society, the state, illegal armed groups, and rural communities are connected for the unequal access to resources and power raising gradually the sense of injustice mixed with a military culture. The economic growth does not care for forests and rural dynamics. Until the 90

decades, forests were mainly considered as lands to be exploited and, local communities were took-for incapable of exploiting them, which justified their exclusion from the economic model implemented. Thus, we argue that one part of the Colombian SES is adapted to the war to survive, and another one, -the powerful one- is resilient to peace. The comprehension of the public policies with the adaptive cycle lens allows understanding of how policies are made for the national levels and how slow they influence the negative tendencies, taking ages to change the trajectory of the system to a socio-ecological sustainable one. **Keywords:** Adaptive cycle, Environmental public policies, peace, war, Colombia

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Two Decades of Land Change Dynamics within and around the National Natural Park System of Colombia. A Remote Sensing Approach

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The number and extent of Protected Areas (PAs) have increased in the last decades particularly in the tropics in response to habitat loss and degradation by anthropogenic land use among other threats to biodiversity. Despite this, PAs and their buffer zones are often vulnerable to anthropogenic pressures, threatening their effectiveness for the preservation of biological diversity and the provision of vital ecosystem services. In Colombia, a megadiverse country, many studies have shown that PAs are effective in reducing habitat loss and degradation in some regions, but important rates of deforestation that are increasing by the post-conflict and current socio-economic transitions facing the country, still impacting within and around PAs. However, to date, it is not available an analysis of the land-use and land-cover change (LUCC) trajectories of the Colombian PAs and their buffer areas, including PAs from all its biogeographical regions and covering most of the terrestrial PAs of the System of National Natural Parks (SPNN), and more importantly, not limited only to deforestation trajectories. We mapped and analyzed the LUCC trajectories of 51 PAs of the SPNN and their buffer zones within a time that includes conflict, peace negotiation and post-conflict periods (2000-2018), using multi-year Landsat composites and a majority voting ensemble classification approach. Overall, our results show that although the loss of natural vegetation was greater in the PAs 10-km buffer than inside them, all the 51 PAs experienced loss of natural vegetation. Contrary to recent studies, we found that PAs of Caribbean region lost on average more natural vegetation than the ones of the other regions, whereas PAs of Amazon and Orinoquia regions lost on average less natural vegetation. The Sierra de la Macarena National Natural Park (NNP) and Tinigua NNP, two of the PAs located in one of the historical national deforestation hotspots, experienced some of the most important natural vegetation loss in the last two decades. This threatens this highly biodiverse area that acts as natural corridor between these two biogeographical regions and allows gene flow and species dispersal, playing a major role in the origin and maintenance of neotropical biodiversity. This information is crucial in the context of Colombian post-conflict, for its potential contribution to land planning and management, and for the identification of the PAs which are more exposed to habitat loss and ecological isolation due to both legal and illegal land use activities within and around the SPNN. **Keywords:** Land cover change, protected areas, Colombia, classification, majority voting ensemble.

Before and-after tropical forest restoration across different landscapes

Restoring Seed Dispersal Processes in a Tropical Agricultural Landscape

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Introduction / Background / Justification: The Los Tuxtlas Biosphere Reserve includes a large area of agricultural landscape that over the years has gained more land and has reduced the extension of the tropical rainforest in the region. High historical deforestation and fragmentation is threatening biodiversity and have caused the loss of many ecosystem services. Today, not only the conservation of biodiversity is at risk, but also the main livelihood of the communities that live within the reserve. With this scenario in mind, in 2006 we established 24 experimental restoration plots immersed in an active pasture. **Objectives:** The main objective of the project was to restore biological interactions to favor the conservation of biodiversity and landscape connectivity. **Methods:** Each plot had one of three treatments: 1) plots under natural succession, 2) plantations of tree species dispersed by wind, or 3) plantations of tree species dispersed by animals. For 15 years we have evaluated soil attributes (e.g., fertility, litter), performance (e.g., survival and growth) and functional attributes (e.g., leaf traits) of planted species. Additionally, we assessed seed dispersal, seedling recruitment and its limitation (e.g., demographics, phylogenetic and functional diversity, fruiting, establishment limitation) and the presence of animals (e.g., birds, bats, beetles). **Results:** Each treatment revealed distinct restoration pathways that favored different biological interactions. For example, in plots with animal-dispersed trees we found a greater diversity of bats and had earlier seedling growth peeks while plots planted with wind-dispersed trees, seedling abundances recruitment was favored. *Nevertheless, the abundance and richness of recruits that are bird-dispersed, late successional seedlings*, such as Red Listed *Ocotea uxpanapana*, were favored in both planted treatments. On the other hand, in natural succession we found more recruits with diameters greater than 30 cm, greater fruiting rates compared to planted plots and greater abundance of insectivorous birds, yet, these plots also had the highest areas covered with invasive ferns. Here, we show a synthesis of 30 parameters evaluated over 15 years of ecological restoration. In the current scenario, the design of multifunctional landscapes through different strategies that allow the optimization of resources will be essential for adaptation to climate change. **Implications/Conclusions:** The results of this project can inform larger scale strategies for the region and for other areas with similar climatic and biological characteristics, as well as contribute to a National Restoration Plan. **Keywords:** Restoration ecology, agricultural landscapes, seed dispersal, seedling establishment, conservation, connectivity

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Upscaling Seedling Abundance Predictions to Landscape Restoration Projects Size

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Introduction: Predicting Forest recovery at landscape scales can help to integrate natural regeneration as a forest restoration strategy. The first step for a successful forest recovery is recruitment, so predicting tree recruit abundance could assist efforts to identify sites with high potential for natural regeneration. One prerequisite for recruitment is seed sources. However, previous work has revealed wide variation in the effect of landscape seed sources on seedling abundance, from positive to no effect. **Objective:** The objectives of this study are (1) to quantify the relationship between adult tree seed sources and tree recruits and (2) to predict where natural recruitment would occur in a fragmented, tropical, agricultural landscape. **Methods:** We used a hierarchical Bayesian zero-inflated model to predict landscape-scale recruit abundance. We then used a map of species-specific tree crowns derived from hyperspectral and lidar imagery to characterize landscape seed sources. We also used property ownership data to represent different management strategies and collected recruitment field data from five species to describe the recruitment abundance in the study area. **Results**: Our models revealed that species-specific maps of tree crowns improved recruit abundance predictions compared with a model without the species-specific maps of tree crowns. The conspecific crown area had a stronger impact on recruitment abundance (8.00% increase in recruit abundance when conspecific tree density increases from zero to one tree, 95% CI: 0.80 to 11.57%) compared with the heterospecific crown area (0.03% increase with the addition of a single heterospecific tree, 95% CI: -0.60 to 0.68%). The best performing model had varying effects of the conspecific and the heterospecific crown area on recruit abundance depending on individual property ownership, which indicates that individual property ownership was also an important predictor of recruit abundance. **Conclusions:** We showed how novel high-resolution remote sensing could be combined with field data and cadastral data to generate landscape-level maps of tree recruit abundance. Spatial models parameterized with the field, cadastral, and remote sensing data are poised to assist decision support for forest landscape restoration. **Keywords:** Agricultural landscape, forest landscape restoration, hyperspectral imagery, natural regeneration

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Forest Recovery in a Montane Landscape, Future Insights to Restore Degraded Lands

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Introduction: Non-sustainable agricultural activities have impacted the Mountain Cloud Forest (MCF), favoring the expansion of invasive species in degraded landscapes. In the Andes, the bracken ferns, *Pteridium* spp., suppress the natural recovery of the MCF by maintaining bracken-invaded areas in a permanently degraded state. The limiting factors to the natural regeneration of native plant species include long-distance dispersal syndromes and an ability to compete with invasive species. **Objective:** Our research investigates the vegetation recovery on degraded bracken fern invaded areas using a combination of field data and remote sensing imagery. **Methods:** Using a high-resolution Planet Dove satellite image (3 m), we cataloged the boundaries of bracken fern patches. Next, matching Landsat pixels with bracken fern patches, we set up plots of 0.5 m and 2 m around pixels centroid to collect field data on the abundance of woody seedlings and take high-resolution drone photos (0.53 - 1.06 cm/pixel). We then used multilevel Bayesian analysis to estimate seedlings of native perennial vegetation at different percent cover of bracken ferns in the invaded areas. **Results:** Our analysis reveals that seedlings of woody plants respond differently to habitat characteristics and bracken ferns show a wide range of percent cover on degraded patches. Some distinctive Andean woody plants of taxonomic families like Rubiaceae, Chloranthaceae, Myrtaceae, Combretaceae, and Lauraceae are more likely to be found in forested areas. While, Ericaceae, Melastomataceae, and Clusiaceae are more frequent in degraded areas with different percent of bracken fern coverage. **Implications:** We discuss how our results in landscape geospatial characteristics can inform where dispersal limitation may occur and where active restoration may be crucial to aid vegetation recovery. **Keywords:** Cloud Forest, seedlings, drone, bracken fern, natural regeneration, degraded patches

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Designing Forest Restoration Strategies to Mitigate Wildfire Damage in Eastern Madagascar

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Introduction: Wildfires pose a growing threat to tropical rain forests throughout the world, including Madagascar, an island nation that contains 5% of the world's known species, roughly 90% of which are endemic. In January 2021, wildfires near the port city of Toamasina burned three 0.25-hectare forest restoration areas. These areas were part of an experiment manipulating density, composition, and size of restoration plantings. As such, the wildfires created a unique opportunity to study how basic properties of restored/regenerating forests affect fire intensity (i.e., heat production), severity (i.e., damage to vegetation), and resulting tree mortality. **Objectives:** We compared fire intensity, severity, and native tree mortality to test four predictions about wildfire and restoration design. We predicted that fire damage would be lower in the interior of plantings compared to the edges, in larger plantings (625 m^2) compared to smaller plantings (81 m^2), in plantings with a border of species with fire-retardant adaptations, and in denser (1-m spacing) versus sparser (4.5-m spacing) plantings. **Methods:** We measured fire intensity and severity using established indices based on damage to tree tags and planting posts (e.g., scorching, melting). Tree mortality was measured after several rain events to account for resprouting. We analyzed data using GLMER. **Results:** 82% of 756 planted trees were killed by wildfires. Fire intensity was typically great enough to melt plastic tree tags and sometimes to turn metal tree tags to cinder. Planted trees typically had charred leaves and scorched stems. Tree mortality varied among species (47-100%, $p<0.001$), independent of initial size ($p=0.391$), and was strongly related to severity and intensity (both $p<0.001$). Intensity and severity were reduced in denser plantings ($p<0.001$) and plantings with a border of fire-retardant species ($p<0.001$), and there was weak evidence that planting density reduced native tree mortality ($p=0.061$). Contrary to expectations, larger plantings were associated with greater intensity (but not severity/mortality). There was no evidence that planting position affected intensity, severity, or mortality. **Implications:** We demonstrate that densely-planted restorations were less fire-damaged than sparse plantings. This is probably because dense plantings better suppressed flammable ferns (*Dicranopteris linearis*) and palms (*Ravenala madagascariensis*). Also, planting a border of native, fire-retardant species (e.g., *Intsia bijuga*) decreased fire intensity and severity, though not tree mortality. The statistical power of these comparisons will increase as two additional sites burned in early 2022. Designing strategies to reduce wildfire damage will help Madagascar achieve its goal of restoring four million hectares by 2030. **Keywords:** Nucleation, burn, survival, reintroduction, plants, Africa, rainforest, lowland, Paleotropics

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Secondary Forest Trees Are Better than Pioneer Treelets at Restoring Montane Forest through Nucleation in Old Fields

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Planting of trees forming islands, known as nucleation, is a cost-effective way to enhance forest recovery. Nonetheless, information on the influence of factors such as species choice is still scarce despite broadly accepted criteria like inclusion of fast-growing species dispersed by fauna. To address this gap, we established an experiment in two different sites at montane wet forest in Colombia invaded by non-native grasses. Our hypothesis was that, inside nuclei, different assemblages of planted species had a different effect on responses linked to restoration goals: (1) vegetation structure and diversity, (2) abundance of invasive graminoids and, (3) survival and growth of endangered tree species. In each site (11 – 13 Ha), we established 48 nuclei placed 30 to 40 meters apart. Each one was 25 m diameter (491 m^2), planted with 543 seedlings of early and mid-successional species along with 23 seedlings of late successional stages. These latter were selected by locals due to overexploitation. Grasses were removed just before planting and later twice at a monthly frequency. One of four assemblages was planted in each nucleus, Type 1 – trees and treelets commonly found in forest edges and gaps, Type 2 – treelets colonizing old fields, Type 3 – Fabaceae trees typical of secondary forests, and Type 4 – combination from all the others. Control plots were interspersed between nuclei and reference plots were placed at the adjacent hydrological basin. Monitoring was 19 – 26 months after planting. Overall, all assemblages are effective restoring structure and diversity to values found in reference ecosystem. However, nuclei Type 1 and Type 3 are significantly better at reducing the highly abundant invasives *Panicum maximum* and *Brachiaria sp.* Likewise, Type 1 and Type 3 nuclei dominated by *Heliocarpus americanus*, *Erythrina*

poeppigiana and *Inga sp.* respectively, were more effective at promoting the performance of endangered tree species like *Carapa guianensis*, *Margaritaria nobilis* and *Nectandra sp.* Our results ratify that nucleation is a successful strategy at restoring old fields originally occupied by montane forest in the tropics. However, the use of trees found at intermediate successional stages would be preferable to using treelets that colonize old fields like *Piper callosum*, *Miconia sp.* and *Vismia baccifera*. By this mean, multiple outputs might be achieved. Namely, structure, diversity, control of invasive plants, establishment of late successional species and carbon sequestration. A large competitive effect on invasive grasses might be the underlying mechanism but further studies are necessary to test this hypothesis. **Keywords:** Restoration, plant interactions, invasive species, nucleation, functional identity

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Impacts of Forest Restoration on Dead Wood Decomposition and Associated Arthropod Communities

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Introduction: Coarse woody debris stores 8% of the global carbon stocks and releases it to the atmosphere through decomposition. Climate change increases global temperatures, and thus might increase the activity of bacteria, fungi, and insects. Forest restoration can enhance the recovery of dead wood and associated insect communities, but its effects on dead wood decomposition in tropical regions are unknown. Objectives and **Hypotheses:** Our objective was to evaluate the role of insect colonization and forest restoration on dead wood decomposition. We first hypothesized that dead logs colonized by insects would decompose faster than dead logs not colonized by insects. Second, we hypothesized that dead logs would decompose faster in natural regeneration, because natural regeneration sites had a more open canopy and likely had higher temperatures that should increase decomposer activity. **Methods:** We introduced freshly cut logs of *Inga edulis* (N = 180 total, 30 per treatment combination), into three restoration treatments: natural regeneration, restoration plantations, and old-growth forests. Within each of these restoration treatments, we further assigned logs to one of three exclusion treatment: logs inside exclusions, logs inside exclusions with holes drilled in them to mimic physical damage by insects, and control logs without exclusions. We collected the logs after one year, extracted arthropods using modified Berlese funnels, and counted and identified all arthropods. We then estimated the proportion of log mass loss. **Results:** Decomposer arthropod abundance was higher in logs inside exclusions with holes in restoration plantations only and was significantly affected by log treatment (X^2=18.2, $p<0.001$), restoration treatment (X^2=26.6, $p<0.001$), and their interaction (X^2=17.18, $p<0.01$). Log mass loss was 1.1 times higher in the natural regeneration treatment compared to plantations (Z=-2.08, $p=0.09$) and old-growth forests (Z=-2.25, $p=0.06$). **Implications and conclusions:** Our results suggest that fungi and bacteria are responsible for the average 38% mass loss seen in this experiment for *Inga edulis* during the first year of decomposition. We also show that the conditions in natural regeneration do allow slightly faster decomposition than in restoration plantations and reference forest. Our study demonstrates that even though natural regeneration can contain less dead wood, it can fulfill the same functions as plantations in terms of dead wood decomposition and small arthropod communities. **Keywords:** Dead wood, decomposition, arthropods, tropical forest restoration

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Biological diversification in the Andean-Amazon region

Relative Importance of Abiotic and Biotic Factors in Driving Local Adaptation in the Hyper Diverse Rainforest Tree Genus Inga

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Introduction: A longstanding goal of ecological research is to understand the mechanisms that allow many species of organisms to co-exist in the same habitat. Ecological theory states that, in order to co-exist at the same site, species must differ in traits of ecological importance. If not, a few species would emerge as winners. A second major goal is to understand the mechanisms by which populations of a species evolve and diverge in their traits and, eventually, form new species. In tropical rainforests, these ecological and evolutionary questions may have related answers. **Objectives:** As a model for Amazon tree diversification, we are analyzing adaptive responses to abiotic and biotic stresses within and between species in a diverse genus of trees, *Inga* (Fabaceae) in Amazonian Ecuador. **Methods:** Using a set of focal species that are a) habitat generalists, b) sub-populations with abiotic habitat preferences and/or divergent defensive traits, and c) sister species with local adaptations, we are extensively quantifying defensive and resource acquisition traits that vary across this range of phylogenetic divergence. Herbivores feeding on leaves are recorded to determine host choice. Reciprocal transplant gardens are assessing whether trait differences are genetic or environmentally determined. **Results:** Preliminary results show that in general, *Inga* pairs are divergent in defensive traits, even for pairs that are occurring in the same habitat. For pairs that occur in different habitats, traits related to abiotic challenges are divergent. Insect herbivores show high specialization and pairs with more similar defenses, share more similar herbivore communities. Reciprocal transplants in periodically flooded vs terra firme habitats, show that periodically flooded specialist populations grew faster than terra firme specialists in both habitats when protected from herbivores. However, all saplings of the terra firme population died when transplanted to the periodically flooded forest, suggesting a lack of adaptation to flooding stress. Saplings of the flooded population, on the other hand, only survived in the terra firme sites if they were protected from herbivores suggesting that biotic pressures could be a key filter. **Conclusions:** The comparisons of *Inga* within and across habitats, and across a range of potential divergence times is allowing us to determine the extent to which traits contribute to initial stages of divergence. This unique comparison of both defenses and abiotic adaptations will test for synergy between herbivory and habitat heterogeneity in shaping niche evolution and local adaptation in plants in tropical forests. **Keywords:** Divergence, traits, defenses, Inga, habitat specialization, niche, local adaptation

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The Brazil Nut Family, Lecythidaceae, as a Window into Historical Assembly, Ecological Dominance and Conservation of Amazon Tree Communities.

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The Brazil-nut family is an important clade of trees in Neotropical forests, with at least 230 species and a center of diversity in the Amazon basin. The family includes the Brazil nut tree (*Bertholletia excelsa*) and other important timber and ornamental species, as well as a disproportionate number of hyperdominant species in Amazon forests. These hyperdominant species, such as *Eschweilera coriacea*, are found in both flooded and *terra firme* habitats and contribute disproportionately to tree numbers and biomass in Amazon rainforest. In this talk I use the Lecythidaceae as a model system to address some key questions about Amazon tree diversity. Where did the main lineages of the family originate? How have local ecological communities assembled geographically? What explains the hyperdominance of some Lecythidaceae species? This work is based on recent phylogenomic analyses. I will also present recent work on the demography of Lecythidaceae that may inform sustainable logging efforts in the Central Amazon region. **Keywords:** Lecythidaceae, Amazon, rainforest, systematics, phylogeny, demography, conservation, trees, biogeography

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Continuous Colonisation of the Atlantic Coastal Rain Forests of South America from Amazonia

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The two main extensions of rain forest in South America are the Amazon and the Atlantic rain forest (Mata Atlantica) of Brazil. These are separated by a wide 'dry diagonal' of seasonal vegetation formations, which includes the dry forests of the Brazilian caatinga and the savannas of the cerrado. Here, we used *Inga*, a species-rich genus of trees in neotropical rain forests, to study past connections between the Amazon and Mata Atlantica, in order to test the idea that dispersals between the two forests have been clustered during specific time periods corresponding to past, humid climates. We performed hybrid capture sequencing of 810 nuclear loci for 453 *Inga* accessions representing 164 species that included 62% of Mata Atlantica species and estimated dated phylogenies using maximum likelihood for all accessions and a species-level tree using coalescent methods, with subsequent temporal calibration. We find that there have been 18-21 colonisations of the Mata Atlantica from the Amazon, with only one dispersal in the reverse direction. These dispersal events have occurred over the evolutionary history of Inga, and we find no evidence for clustering of dispersal events into any specific time period, both based on comparing models of alternative biogeographic histories and null simulations that show the temporal distribution of dispersal events matches a random expectation. Time-specific biogeographic corridors do not need to be invoked to explain dispersal between the Amazon and Mata Atlantica for rain forest trees such as *Inga*, which are likely to have used a dendritic net of gallery forests to cross the dry diagonal.
Keywords: Vicariance, Biogeography, South America, Dispersal, Inga, Leguminosae/Fabaceae, Mata Atlantica

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Diversification in the Tropical Andes Biodiversity Hotspot: A Bird´s Eye View, with Glimpses from Frogs and Fishes

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Montane regions of South America are hotspots of biological diversity and endemism in various groups. Thus, understanding the factors promoting high diversity in this region is central to biogeography and macroecology. Because present-day diversity reflects not only contemporary and local conditions but also historical and regional processes, the high diversity of the Neotropics may be partly explained by high opportunities for evolutionary diversification. Therefore, an adequate understanding of tropical biodiversity requires considering mechanisms promoting species coexistence as well the influence of processes of speciation, extinction, and dispersal. In this talk I will present examples of my studies on biogeography, and speciation of Neotropical birds and other vertebrates to illustrate historical processes that may have led to their high diversity, with a focus on the origin of elevational replacements and on the role of contemporary climate as a driver of evolutionary diversification via its influence on the breeding seasons of animals. **Keywords:**Biological diversity, Endemism, Biogeography, Macroecology, Evolutionary diversification

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Extinction at the End-Cretaceous and the Origins of Modern Neotropical Rainforests.

Monica Carvalho

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Introduction: The end-Cretaceous event (66 Ma) set an ecological catastrophe that reshaped plant communities worldwide. Yet, until recently, the fate of tropical forests following the K/Pg boundary had been largely unknown. Methods: We quantified plant extinction and ecological change in tropical forests resulting from the end-Cretaceous event using fossil pollen (>50,000 occurrences) that span the Maastrichtian and Paleocene (72–56 Ma), and leaves (>6,000 specimens) from pre- and post-extinction localities in Colombia. **Results:** Late Cretaceous (Maastrichtian) rainforests were mixed assemblages of ferns, conifers, and flowering plants, characterized by an open canopy and diverse plant–insect interactions. Insect-feeding behavior, evidenced through feeding-damage, showed high levels of host-plant specificity across communities of insect herbivores. At the K/Pg boundary, plant diversity declined by 45% and did not recover for ˜6 million years, setting a long interval of unusual low plant diversity in the Neotropics. Paleocene forests resembled modern Neotropical rainforests, with a closed canopy, multistratal structure, dominated by angiosperms. These post-extinction forests were ecologically diverse and included coastal rainforests with periodic flooding and inland forests growing in well-drained soils in which legume trees were consistently the most abundant and diverse group of plants. Insect feeding-damage was far more generalized across host plants than in pre-extinction assemblages. **Conclusions:** The post-extinction assembly of multistratal, closed canopies, and the establishment of legumes as major biomass producers, hints towards fundamental changes in carbon fixation, evapotranspiration, and nutrient cycling in tropical environments. The extinction at the end-Cretaceous ultimately enabled the assembly of modern ecosystems and established the initial stages in the evolution of Neotropical rainforests. **Keywords:** Paleobotany, Fossil Plants, Leaves, Pollen, Colombia, Insect Damage

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Topographic Continuity and Species Dispersal Accross the Northern Andes

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The longstanding view of Andean uplift as a promoter of species diversification has become superfluous in the last decades given it would make no sense to suggest an alternative hypothesis, i.e. that the Andes have not promoted species diversification. Because we know that the Andes harbors an enormous proportion of endemics and that the Andes have evolved in the last millions of years when much of or extant biodiversity has also evolved, we know that both obligately coincide. However, we are lacking conceptual and empirical frameworks where geological and biological processes and events are causally linked through testable hypotheses. In this presentation, we show our recent work with two Andean lineages of palms, where we show that temporally and spatially constrained geological events linked to Andean uplift underlie the biogeographical processes that we infer by genomic sampling. Altogether, we sample 195 individuals of the *Geonoma undata* species complex and 129 individuals of genus *Ceroxylon*, in the tropical Andes, with a focus on the Colombian Cordilleras. We used hybrid sequence capture of nuclear regions, of where we extracted variant sites that we then used to perform multivariate statistics, coancestry analysis, phylogenetic analyses, and demographical and biogeographical model selection. We use geological cartography, petrography, and geochronology to test two main hypotheses: that the northern Andes have been disconnected in the past, to later connect by volcanic eruptions, or alternatively, that they have always been continuous and have gradually uplifted. Our biological results support a discontinuous past with repeated late Plio-Pleistocene colonization of the Colombian Cordilleras. Our geological results support 1) heavy faulting in the area of the Colombian Massif, possibly creating topographic discontinuities, and 2) a volcanic eruption of great magnitude that could have connected cordilleras by valley filling and isostatic rebound occurring in that area in the Plio-Pleistocene boundary. The observed biogeographical processes (dispersal, and divergence in the Plio-Pleistocene through the Colombian Massif) in these two lineages of palms coincide temporally and spatially with traceable geological features and events. Our studies highlight the importance of establishing causality between processes in the Earth and Life sciences under comparable geographical and temporal scales. **Keywords:** Biogeography Ceroxylon Geonoma Geochronology Topographic evolution Phylogeny Target sequence capture

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Andean Uplift, Drainage Basin Connections through Time, and the Evolution of Plants in Rivers in Northern South America

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The uplift of the Andes reconfigured rivers in northern South America, one of the most species-rich regions on Earth. However, the impacts of these landscape changes on the evolution of aquatic plants had so far been overlooked. I will explore the role of Andean uplift and subsequent drainage basin formation on the evolution of riverweeds (*Marathrum,* Podostemaceae). *Marathrum* live attached to rocks in fast-flowing aquatic ecosystems from central America through northern South America. Phylogenomic, population structure, and divergence-dating analyses using target enrichment data show that the isolation of populations of *Marathrum* located in rivers across the Andes occurred in conjunction with major pulses of uplift. In addition, drainage basin reconfiguration resulted in secondary contact of previously isolated populations. Hybrids show the phenotype of one of the parental lines. Based on the results, I will present a proposal for timing and pattern of drainage basin formation across the Andes in northern South America and a novel perspective on the processes that shaped the evolution of the flora in the region. I will discuss how the botanical collections made in this study and the historical records of *Marathrum* provide perspectives on the conservation of riverweeds and rivers.
Keywords: Aquatic plants, rivers, Neotropics, northern South America, Andes, hybridization

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Neotropical Mountains and Species Diversification in Escallonia: When Species Limits Matter

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The plant genus Escallonia is widely distributed in the Neotropical mountains, from Costa Rica to Southern Chile and from sea level to the paramos. This broad geographic distribution provides an excellent opportunity to assess the influence of geographical and ecological isolation in the diversification of montane plant taxa. Biogeographic analyses revealed a deep signal of phylogenetic geographic structure indicating that geographic isolation was a major factor during the early evolutionary history of Escallonia. This pattern is consistent with the hypothesis of allopatric speciation plausibly induced by ancient niche conservatism. Although "geographic clades" later diversified in isolation, there is not strong support for the hypothesis of ecological speciation induced by niche evolution across environmental gradients along elevation. Alternatively, these findings might suggest that species limits as proposed in the current taxonomy are problematic. Combining genomic and phenomic analyses with state of the art species discovery approaches, I show that taxonomic species in Escallonia correspond poorly with the pattern of variation shown by individuals in nature as predicted by species descriptions. Moreover, I show that genomic and phenomic data rarely delimit congruent entitles suggesting that the assumption that the species delimited by traditional taxonomists are evolutionary and ecologically meaningful entities is questionable. It is plausible that the patterns recovered in Escallonia are rampant across many groups. If so, relying on taxonomic species without empirical evidence of their biological reality can have relevant implications in ecology, evolution, and conservation. **Keywords:** Netropics, species delimitation, speciation, Andes, Escalloniaceae

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Origins of Amphibian Diversity within and across the Eastern Cordillera of the Colombian Andes.

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Background A major focus of biogeography is understanding the causal factors that explain the spatial patterns of biodiversity and the current distribution of species. The primary formation of species is a key component of the origin of local and regional biodiversity. The division of an ancestral species by vicariance is one of the simplest and widely applicable models for speciation, whether by mountain uplift or by climate fluctuations. Objectives: Using frogs and other tetrapods, we will look at two case studies of the factors driving species diversity in and around the Eastern Cordillera (EC) of Colombia. First we will use comparative phylogeographic data to evaluate the impact of the uplift of the EC on the isolation and divergence of lowland taxa. Second, we will infer the biogeographic origins of montane frogs in the EC and investigate the spatial patterns of diversification. Methods: We evaluated the role of the EC in lowland divergence using mitochondrial DNA (mtDNA) sequence data from 37 lineages of tetrapods and analyzed the data using population genetic and phylogenetic tools to evaluate relative and absolute divergence times. To evaluate the role of orogeny in the origin and diversification of montane frogs, we amassed the largest molecular phylogeny of frogs of the genus *Pristimantis* (Anura: Craugastoridae) to date and applied standard phylogenetic and biogeographic analyses to estimate the spatial and temporal components of species diversification within the EC. **Results:** Coalescent analyses revealed general asynchrony in divergence times and recent divergences overall among lowland taxa, plus extensive non-monophyly of mtDNA sequences with respect to the EC. Biogeographic reconstruction of *Pristimantis* history revealed a mixture of a few independent colonizations of the EC and at least one example of an in situ radiation within high-elevation frogs of the EC. Divergence times among montane frogs tend to predate the Pleistocence. **Implications:** Clearly the Andes are a hotspot of species diversity, yet the mechanisms driving or preserving this diversity are well understood only for a handful of lineages. Montane uplift is still cited as a driver of lowland vicariances, yet our integrative re-analyses of diverse datasets revealed very little support for this model, at least among recent divergences. Pliestocene climate fluctuation is often cited as a driver of montane diversification, yet frog species seem much too old. Denser spatial and phylogenetic sampling of amphibians are needed to further test these findings. **Keywords:** Andes, biogeography, Colombia, divergence time, orogeny, phylogenetics, phylogeography, speciation, vicariance.

Revealing the Origins of the Most Intensively Studied Tropical Forest in the World: Barro Colorado Island, Panama

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Introduction: Barro Colorado Island (BCI) is the most intensively studied tropical forest in the world. Despite the wide understanding of its plant composition and ecological dynamics, its past diversity is still unknown. Recently, numerous silicified wood samples were found in the island. **Objective:** This study aims to characterize this newly found fossil megaflora using taphonomic, taxonomic, biogeographic, and paleoecologic approaches. **Methods:** One hundred and twenty-one silicified wood samples were mapped and collected in BCI. Radiometric dating analyses were performed to determine the age of the fossiliferous locality. Thin sections of the fossil material with good preservation were prepared for identification purposes and ecosystem reconstructions. **Results:** Dating analyses indicate that fossils were deposited during the early Miocene, around 20 to 23 million years ago. During a time in which Central Panama did not have a continuous land connection with South America, was a newly emerged land and was undergoing an intense volcanic activity. Geological analyses suggest that the fossils were deposited under a volcanic lahar flow, but only minor transportation occurred. Anatomical analyses of the prepared samples show that around 80% of the samples belong to the same morphotype, including multiple large trees. This morphotype has anatomical traits that are shared with the Southeast Asian mangrove genus: *Sonneratia* (Lythraceae). Today, this genus is between 10 to 30 m tall, however, tree height estimations of the fossil woods suggest that this morphotype could have reached up to 39 m of height. **Conclusions:** Diversity and spatial comparisons of the fossil forest of BCI indicate a stark contrast with the modern flora and allow us to hypothesize that during the early Miocene BCI had a coastal ecosystem with no modern analogs. Currently 191 samples from another locality from the Barro Colorado Nature Monument are being analyzed and will widen our understanding of the ecological and evolutionary history of this emblematic flora. **Keywords:** Tropical paleoecology, Barro Colorado Island, Miocene, biogeography, diversity change

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An Integrative Approach towards Understanding the Assembly and Evolution of Biotas: A Case Study from the Amazon

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Introduction: Amazonia is Earth's most iconic hotspot of diversity and endemism and, arguably, the most crucial terrestrial biome for its contributions to global systems ecology. To understand the importance and future of Amazonian biodiversity to Earth's systems biology, it is essential to place the present-day Amazonian biome in its historical context. Our understanding of how Amazonian biodiversity has been generated and assembled taxonomically and ecologically remains surprisingly meager, as is knowledge about how Amazonian ecosystems have responded to historical environmental change. There are also significant uncertainties about the paleogeography, age, and extent of its immense fresh-water and terrestrial ecosystems. **Objective/Hypotheses:** This study aims to further understand our understanding of the assembly and evolution of the Amazon biota. While some models posit that Amazonian ecosystems were established in the Middle to Late Miocene, others see them as Plio-Pleistocene in age. **Methods:** We reconstructed multiple time-calibrated trees of plant, vertebrate, and invertebrate taxa and combined this information with new geological and environmental data to test the current hypotheses on the age of Amazonian taxa and ecosystems. **Results:** The Amazon biota has ancient roots, going back to the Paleocene or even to the Late Cretaceous, with high diversification rates after the K-Pg extinction. Many of the living Amazon vertebrate, invertebrate, and plant species diversity originated during the Plio-Pleistocene, with some lineages going back to the Late Miocene. The origin of several components of the Amazonian biota appears to relate to the establishment of the Amazon River drainage. **Implications:** Resolving these historical uncertainties, as well as addressing how biotas within Amazonia have responded to past paleogeographic and climatic events, have significant implications for understanding past and present environmental change, for predicting the future of ecosystem structure and function at different spatiotemporal scales, and for understanding the generation and maintenance of biodiversity. **Keywords:** Amazonian Biota, Assembly of Biotas, Diversification, Speciation, Extinction, Neotropical Biodiversity.

Communal territory management and its implications in the conservation of biodiversity in the Andes

Resilience from Whom: Understanding Social-ecological Key Processes in the Andean Region.

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Land-use legacies in the Andean region have substantially modified land covers locally, unfolding significant changes over critical social and ecological processes. Although this transformation has been widely documented in some specific contexts, there are still knowledge gaps related to the underlying mechanisms that explain such social-ecological transformation patterns. There is no doubt that effective conservation in the Andes region should recognize the historical and social dimensions that enable social-ecological resilience: the system's ability to deal with change without losing its structure, function, and identity. However, while specific resilience approaches in conservation continue incorporating analysis centered on the response of a system to specific drivers of change, dimensions linked to the benefits of such measures remain unattended. This presentation aims to introduce the resilience approach to our symposium 'Communal territory management and its implications in the conservation of biodiversity in the Andes' using a case study on the resilience and transformation of social-ecological systems in the paramo ecosystems of the Mamapacha-Bijagual complex in Boyacá, Colombia. We collected historical data (semi-structured interviews in paramo communities) on "slow" variables related to key social-ecological processes at the landscape level that explain resilience and provide insights into the benefits of conservation practices perceived by local communities. Our results show that resilience and vulnerability are historical constructions strictly linked to conservation practices and biodiversity use (and production) in the paramo ecosystems. Although conservation practices based on social-ecological systems confer resilience to this Andean landscape, the benefits of such a journey are not always relevant in social terms and are practical leveraging long-term conservation. We draw attention to the need to integrate complex thinking and the social-ecological resilience framework guiding effective conservation practices in Andean landscapes.
Keywords: Resilience, social-ecological systems, Andean Region, Páramo, ecosystems

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Targeting Socioecological Resilience through Integral Communal Territory Management – A Case Study from the Southeast of the Peruvian Andes

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The high-Andean peasant communities in the southeast of the Cusco region (Peru) invest their principal economic activity into camelid breeding. Their territories lie above 4000 m a.s.l. and are of collective property, managed by boards of directors that are elected for a period of two years. Around the grazing activities, an administrative system has developed that is based on their cultures and traditions, organized in specialized commissions for the management of water and pasture resources which involves natural infrastructure interventions. Grazing is the principal economic activity in the study area and its benefit depends on the conservation status of the ecosystem(s) which depends on the type of (ecosystem) management realized by the community. The objective of the present study is to understand the sociocultural dynamics of grazing and its effects on high-mountain ecosystems. Historical data were collected through conducting interviews and the revision of

community documents. For the characterization of the current status of grazing, interviews and participatory workshops and mapping were developed. For the evaluation of changes in the landscape structure and the vegetation cover, satellite imaginary was used. Three main moments have been identified that have generated significative changes in the landscape and in the way the territory is used. The principal drivers of change inside the community are the erosion of the communal administrative system, the temporal labor migration and programs of technical assistance. The latter responds to adopted state politics for the adaptation to global change. Two out of the five evaluated communities have completely transformed, in reference to the traditional organization system, and the other three communities are in distinct degrees of change. The changes in landscape structure and vegetation cover keep relationship with the dynamic of the pastoral system. Despite of territories being consecutive, the territorial administrative system can vary significantly, creating mosaics of soil coverage that are distinctive in a single watershed. In this context the communal organization system functions like a buffer for external situations which can affect the territory, and at the same time it acts like a filter which selects the processes that occur inside the territories, which not necessarily will be positive for the conservation and maintenance of ecosystem services. **Keywords:** Socioecological resilience, Andean communities, integral communal territory management, Ausangate, Cusco - Perú

Participatory Mapping of the Multiple Values of Nature's Contributions to People in an Agricultural Area of the Colombian Andes

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Andean rural communities have historically modified the landscapes they live in to obtain a range of ecosystem services, or nature's contributions to people (NCP), crucial to their wellbeing. However, ongoing agricultural intensification has caused significant structural changes in traditional landscapes, leading to serious declines in biodiversity, impacting NCP provision, and ultimately local wellbeing. In order to improve decision making on land use and rural intensification, it is crucial to understand how local people identify and value the NCP provided by these changing landscapes. Our aim was to conduct a spatially explicit and participatory assessment of NCP provided by the intensive agriculture-dominated Andean landscape of the Colombian municipality of Aquitania, considering multiple value dimensions (economical, ecological and sociocultural), and considering the perspectives of different local actors, thus identifying key areas for NCP provision and conservation. We first conducted semi-structured interviews and participatory mapping with six key local and collective social actors to identify the number and location of NCP they identified, what value dimensions they associated with these NCP, and how important they considered them to be. Then, we used a spatial multi-criteria evaluation (MCE) to determine priority areas for NCP provision and conservation. We found that local actors were able to identify a large number of NCP. However, there were important differences between actors: environmentalists identified significantly more regulating NCP than other actors, and tourism entrepreneurs focused on the economic value of non-material NCP, while big farmers assigned a lower average importance to regulating and non-material NCP than small-scale farmers. We also found spatial differences across the territory, with natural ecosystems, especially the high-mountain moorland of the *páramos*, being most important for regulating and non-material NCP. Buffer zones, key for regulating NCP, were often not recognised by actors making direct use of the land, who favoured these areas for agricultural production-related material NCP. Our results show the importance of spatialising different points of view in NCP valuation exercises, as this is crucial for identifying trade-offs between different actors and NCP groups. As such, we present a participatory methodology that can be replicated in data scarce areas, providing information that can be used to strengthen land use decisions, taking into account priority areas for NCP provision and conservation. Local stakeholders should play an active part, improving the legitimacy of these decisions. **Keywords:** Ecosystem services, nature's contributions to people, spatial assessment, stakeholder participation

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Current Status and Potential of Community-managed Bofedales as Integral Part of Adaptation Strategies to the Impacts of Accelerated Climate Change

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Bofedales are Tropical high-Andean wetlands that can be found from Chile and northern Argentina to Ecuador, Colombia and Venezuela, with its main distribution in Bolivia and Peru. They provide important ecosystem services, like e.g. the regulation and (temporal) retention of water flows, carbon sequestration, and fodder production for mainly alpaca herding. There is a strong link and mutualism between these ecosystems and local, peasant communities. Nevertheless, relatively few of these interactions are documented in the scientifc literature. Therefore, it is important to review also dispersed information about the use and management of bofedales in technical reports of public and private institutions and other kind of grey literature. Recently, bofedales have gained more attention in the frame of climate change adaptation and mitigation strategies and in the context of concepts like nature-based solutions and/or natural infrastructure for water security. The main objective of the current study is to systematize the evidence about the importance of bofedales in the actual climate change adaptation debate, and more concretely the specific practices applied in bofedales management by local communities. I will apply a systematic review of scientific and grey literature, using also a broad information search in google. The information obtained will be sistematized in order to give preliminary answers to the following, main research questions: a) What is the current status of community-managed bofedales in the frame of current climate change adaptation strategies? b) What concrete practices are applied to bofedales ecosystems in order to strengthen resilience towards the negative impacts of climate change? c) What is the potential of community-managed bofedales to fill important gaps in future climate change adaptation strategies? The results of this systematization will help policy-makers to better understand the crucial role that Andean (traditional) communities play in the sustainable management of bofedales ecosystems and how these contributions, in the near future, could be recognized through mechanisms of payment for ecosystem services, considering also the Nationally Determined Contributions (NDC) in the frame of the Paris Climate Agreement. **Keywords:** Bofedales, Andean communities, water and bofedales management, climate change adaptation

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Underutilized and Resilient to Climate Change Food Plants in High Andean Communities of the Anta Province, Cusco, Perú

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The ancient knowledge of the use of underutilized food plants, their transformation and conservation is still practiced in some communities of the Anta province, finding this knowledge in clear danger of extinction, due to the gradual loss of the cultural identity of the young population that is directly linked to the conservation of this knowledge. The study was carried out during the years 2018-2019 in order to reassess the use of these plants that still survive in the Province through descriptive and qualitative ethnobotanical studies. The method of free listing and ethnobotanical walks was applied, touring the study area in the company of key informants for the collection of botanical samples, taking note of the uses, parts used and forms of conservation, as well as the validity or current permanence. of these knowledges. Interviews were conducted with 127 residents of the districts of Mollepata, Limatambo and Chinchaypujio, determining that traditional knowledge about underutilized food plants in the province of Anta still exists, being mainly housewives who play a leading role in the transmission of this knowledge (84%). It was possible to register 96 species of phanerogams and 17 of cryptogams, with the families Fabaceae, Asteraceae, Rosaceae, Solanaceae, Amaranthaceae, Lamiaceae, Cactaceae and Basidiomycetes fungi being the taxonomic groups with the largest number of species. In the same way, 19 forms of transformation and conservation were found, the same ones that still preserve the native Quechua name of origin, knowledge that has been maintained over time. **Keywords:** Conservation, food security, underutilized plants, resilience, Anta, Cusco -Perú

Land Ownership History, Ethnicity, Payment for Ecosystem Services and the Challenges of the Conservation in Tropical Mountains

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Conservation of tropical mountains in the Andes faces multiple challenges, from the expansion of mining driven by commodity prices to climate change. The conservation strategies toolkit has been intensively applied to this ecosystem with mixed results. Strategies have ranged from specific legislation aimed at limiting land uses incompatible with conservation, informal land use agreements in organized communities, restriction on the marketing of agricultural products, and, more recently, conservation strategies financed by payment of ecosystem services focused on climate mitigation and adaptation. Ecosystem services are usually associated with those services that improve the quality of life of the human population and are often difficult to quantify from an economic point of view. At the heart of ecosystem services is the principle of conservation, management or restoration of natural landscapes, which implies an intervention in the territory where the local population lives. Since ecosystem services are associated with the use of the land, the payment for those services goes to the owner of the land, creating a source of conflict within the communities. Our experience in the Colombian Andes has given rise to conflicts that date back to the disposition of land by letters from the Spanish crown to indigenous communities of lands that lacked aptitude for development. Our experience in the Colombian Andes has brought to light conflicts that date back to the adjudication of land by letters from the Spanish crown to indigenous communities of lands that lacked aptitude for development. In addition, there have been challenges framed in the mistrust that exists in some communities, where conflicts over control of the territory have worsened with the presence of armed groups. However, the emergence of incentives that payment for ecosystem services brings generates a renewed interest in lands that were previously ignored. Our experience has highlighted the relevance of informed and participatory processes between the different actors and an adaptive strategy. Projects dedicated to improving the livelihoods of local communities in remote tropical mountain locations should include a preliminary assessment of local and regional organizations, a better understanding of the interactions between local actors: farmers, indigenous communities, landowners of medium or large land.
Keywords: Ecology, rural communities, Andean region, ethnicity, environmental services, social conflict

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Conservation of Oak-Dominated Ecosystems in the Tropics: Opportunities and Challenges

The Oaks of Guatemala, Current State of Knowledge and Implications for Their Conservation.

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Introduction / Background / Justification: The oaks (Quercus: Fagaceae) in Guatemala, make up one of the most important elements of the structure of the forests. They are associated with three of the strategic ecosystems for the country, and that together cover more than 50% of the national territory. In addition to their ecological importance, these are also relevant from a cultural perspective, given the ecosystem services they provide to the population. However, knowledge of this group was incipient before 2015**. Objective(s)/Hypothesis(es):** Update the knowledge of oaks for Guatemala, considering at the same time the cultural perspective from the valuation of this group by the Indigenous Peoples. **Methods:** 24 field trips were carried out, establishing 136 plots of vegetation in 15 of the 22 departments of Guatemala (2015-2019), complementing the information with collections in the routes and herbariums. The plots were selected considering gaps in information, accessibility, security, state of conservation and the authorization of the owners. In 14 they carried out participatory workshops in communities near the collection sites, with the aim of documenting the knowledge, use and valuation of oak forests. All data were analyzed descriptively. **Results:** For Guatemala, 33 species have been documented, 20 sect. Lobatae and 13 sect. Quercus, with more than 1,500 records deposited in national herbaria, doubling the number of species registered in most departments. Regarding the cultural perspective, it has been recorded that oak forests are a primary source of firewood and charcoal, likewise, they associate these forests as an important source of other services such as oxygen, water, construction materials, shelter for animals, medicine and edible mushrooms. Regarding conservation data, 61% of the records are currently located in degraded forests, with mixed pine-oak forests showing the greatest anthropic pressure. **Implications/Conclusions:** This project has made it possible to visualize Quercus as a priority group in landscape conservation and restoration strategies. In recent years, workshops on the identification of these species have been given to field technicians, who are responsible for dictating plans for the management and use of forests in Guatemala. Although there is still work to be done, the implementation of forest nurseries is currently being encouraged through public-private partnerships to strengthen the conservation of this group.
Keywords: Oaks, ecosystem, Mesoamerican region, traditional knowledge, threatened species

Conservation Genetics of Two Threatened Mexican Oak Species

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Introduction / Background / Justification: According to the red list of oaks 2020, approximately 31% of Quercus species are threatened with extinction worldwide. Mexico stands out as the country with the highest oak species richness, but also as the second one with the largest number of threatened species (32). Unfortunately, for most of these threatened species there is a lack of demographic, genetic and ecological information that would be essential for their conservation. **Objective(s)/Hypothesis(es):** In this study, we focused on the population genetics of two threatened Mexican oak species, Quercus brandegeei and Q. hirtifolia, that represent contrasting evolutionary and ecological contexts, but both with restricted geographical ranges and reduced population sizes. **Methods**: Most known populations of both species were sampled. Genetic diversity was assessed using nuclear simple sequence repeats (nSSRs) and chloroplast DNA (cpDNA) sequences. Standard measures of genetic variation and differentiation were estimated and complemented with landscape genetics analyses used to assess environmental and topographical factors influencing pollen and seed-mediated gene flow. **Results:** Genetic variation at nuclear DNA was moderate and low at cpDNA in both species. There was evidence of low effective population size, reduced genetic connectivity and significant effects of genetic drift and inbreeding in the two oaks, but particularly in *Q. brandegeei*. **Implications/Conclusions:** The comparison of our results with those obtained in other endangered and non-endangered oak species provides an opportunity to identify genetic erosion processes that may further compromise the long-term survival of threatened species and to propose informed management actions. **Keywords:** Quercus, effective population size, genetic variation, gene flow

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Opportunities and Challenges to Preserve Montane Cloud Forest Ecosystems

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Introduction: Oaks are one of the most important biological groups in the Neotropical forest. In Mexico, oaks are key elements of highly threatened and biodiverse ecosystems such as the Montane Cloud Forest (MCF). A representative species of the treats currently faced by both, oak species and the cloud forest, is Quercus insignis. Such species characterizes by a highly fragmented distribution from Mexico down to Panama, small and low-density populations associated to several land use change drivers such as agriculture and cattle rising. **Objectives:** Our main objective is to set the bases for the study and conservation of MCF, bringing together several approaches such as population ecology, landscape ecology and genetics, using Quercus insignis as a model species. Particularly, we aimed to describe the species population structure, characterize its genetic diversity and structure, to test for possible changes in the genetic diversity along age-stages and, and to identify the effectiveness of in situ conservation strategies. **Methods:** Floristic survey was developed in order to characterize floristic composition and structure of the MCF, using transects following Gentry's methodology. Plants were taxonomically identified and measured for DBH and height. Demographic monitoring was carried out using plots, where all Q. insignis individuals were measured and tagged. Height and DBH were documented yearly for each individual, and distances among nearest individuals were recorded. Genetic characterization was performed using high quality DNA. We used nuclear and chloroplast microsatellites in order to genotype the species variation. Genetic structure and diversity were evaluated. Also, genetic erosion was tested by comparing the values of genetic diversity between seedlings, juvenile and adult stages. Finally, ecological niche modelling was used in order to test for changes in the species habitat suitability under climate change scenarios, an to estimate the degree of connectivity between populations. **Implications:** Demographic studies suggest that species has a low-density structure. Also, genetic diversity is comparable to other oak species with high genetic variation. However, genetic structure results shown strong differentiation between the species populations. We did not find evidence of genetic erosion between the development stages for the species. Finally, we detected a well-defined reduction of climatic suitable areas for the species under climate change scenarios, as well as contrasting connectivity scenarios. Despite the growing treats for the species, genetic diversity and demographic data suggest that the species still maintain conditions to favor its conservation. However, there is a growing need to improve the conditions to favor the species connectivity, and therefore, its persistence in the future.
Keywords: *Quercus*, montane cloud forest, conservation, ecology, genetics

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Phylogeography and Functional Biology of Threatened and Broadly Distributed Tropical and Subtropical Live Oaks (*Quercus* Section *Virentes*)

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Introduction / Background / Justification: The tropical and subtropical live oaks *(Quercus section Virentes)* span Central America as far south as Guanacaste Costa Rica, the Caribbean (Cuba), and the coastal regions of Mexico and the southeastern US as far north as Virginia. They consistently occur in lowland and maritime forests with well-drained soils. They have the highest density wood of any oaks, can withstand hurricanes and contribute important ecosystem services. **Objective(s)/Hypothesis(es):** In this study, we review the phylogeography and evolutionary history of the lineage, the functional ecology and adaptive differentiation of populations within and among of the seven Virentes species and discuss the prospects and challenges for conservation. **Methods:** Populations of all seven Virentes species were sampled to determine population genetic structure, evolutionary relationships, divergence times, and effective population sizes. Leaf morphology, cold and freezing tolerance and drought tolerance were evaluated within and among populations and species in common garden experiments. Results: Population-level differentiation in freezing and drought stress are associated with differential performance and survival. *Quercus sagraena* in Cuba, *Quercus brandegeii* in Southern Baja California, Mexico, and *Quercus minima* in the southeastern US have low effective population sizes and very limited climatic ranges and/or specific fire regimes, making them susceptible to extinction. Moreover, the Costa Rican population of the broadly distributed Quercus oleoides may be a cryptic species and is highly threatened by increasing drought due to climate change. *Quercus fusiformis* in Texas is threatened by the oak wilt fungus (*Bretziella fagacearum*), *Quercus virginiana* has been overharvested, and Quercus geminata has declined due to removal of the maritime forest. Implications/Conclusions: The tropical and subtropical live oaks (*Quercus* section *Virentes*) contain three species that face extinction risk. All species within the lineage face risks due to changing climate, fire suppression, invasive pathogens, overharvesting, and land-use change. Thus, long term persistence of this unique lineage of coveted lowland oak species will require concerted management efforts.
Keywords: *Quercus* section *Virentes*, effective population size, tree threats, adaptive differentiation

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Role of Quercus Species in Biogeochemical Cycles in Western Panama

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Tropical montane forests (TMF) are unique ecosystems with remarkable contributions to global diversity, nutrient, and carbon cycle regulation. In Central America as elevation increases, tree ectomycorrhizal (EM) associations become more common, to the extent that the EM-associated genus *Quercus* can be dominant. The nutrient acquisition pathways of EM fungi are associated with greater soil organic matter (SOM) accumulation and reduced inorganic nitrogen (N) availability. In the Volcán Barú National Park in western Panama, we used a transplant experiment to evaluate whether patches of *Quercus* forest affect soil nutrient availability and to measure its implications for seedling growth. We predicted that *Quercus* forest would have lower soil inorganic N and slower growth of non EM-associated seedlings due to plant–soil feedbacks (PSFs). We found *Quercus* forest had significantly lower N availability and the soil organic layer was deeper when compared to mixed, non-*Quercus* forest. Foliar N was lower for AM seedlings growing in *Quercus* forest than in mixed forest, but did not differ for *Quercus* seedlings. We found non-EM-associated seedlings grew slower in *Quercus* forest, consistent with lower foliar N concentration and low light availability. Our results suggest that changes in soil nitrogen availability have a limited effect on seedling growth. Under a global change scenario, studies predict future upslope migration of trees that may result in tree communities encountering unfavorable soil conditions generated by EM-dominated canopies. While longer-term experiments are needed, our results suggest that non-EM-associated seedlings may not be able to tolerate the low N conditions associated with EM-forests
Keywords: Arbuscular mycorrhizae, ecomycorrhizae, nitrogen, Panama, Quercus, seedling growth.

Quercus brandegeei: a Transdisciplinary Effort for Its Conservation and Sustainable Use

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The arroyo oak (*Quercus brandegeei*) is a micro-endemic species in the Cape Region in Baja California Sur, Mexico. Although the species had a wider distribution historically, it is currently confined to the riparian zone of ephemeral streambeds or "arroyos" within the Sierra La Laguna Biosphere Reserve. Due to its narrow distribution and declining populations the species has been assessed as Endangered in the IUCN Red List of Threatened Species. Since 2018, a team of scientists, land managers, and members of the community within the biosphere reserve have been working together to better understand the causes of decline, and develop a science-based, stakeholder-inclusive conservation, recovery and management plan for this important and iconic species. One of the main issues is the lack of seedling recruitment, leading to a population structure dominated by old individuals. To better understand barriers to regeneration we conducted germination and propagation trials with acorns from three different provenances. We also conducted a seedling exclosure experiment to quantify the impact of free-roaming farm animals on seedling survival and growth, as well as to assess the role that microclimate (specifically canopy openness) has on seedling establishment. Results from the >6,000 acorn germination trial revealed a 78.43% average germination rate with 19 average days of latency and 29 days to reach 50% of germination. Although there were differences in acorn morphology and germination across provenance regions, most of the variability was captured at the level of the individual mother tree. The seedling exclosure experiment showed a significant impact of farm animal grazing and trampling for seedlings growing in unprotected areas versus those transplanted to fenced plots. At the 150th day of the study, seedlings under closed canopy had higher mortality rates than those in open cnaopy (P=0.036), however, by the end of the study (1 year after transplant), seedlings growing under open canopy had significantly higher mortality than those grown in the shade, likely because sites protected by canopy had less extreme temperatures (3.64-52.72 °C) than open canopy sites (0.9-59.93°C). Overall, our research revealed that (1) acorn production and germination for this species are high, (2) livestock grazing and trampling are significant barriers to seedling survival, at least near ranches, and (3) extreme temperatures and drought are an important cause of seedling mortality, mainly during hot summer months. Conserving *Q. Brandegeei* requires working with multiple stakeholders, including ranchers, to find innovative ways to manage and recover *Q. Brandegeei* populations. **Keywords:** Acorns, germination, drought, livestock

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Conserving the world's macroflora - from tree Red List assessments to tree conservation in action

The Global Tree Assessment: State of the World's Trees

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Introduction / Background / Justification: Trees are of vital importance ecologically, culturally and economically. The interlinked biodiversity crisis and challenge of global climate change cannot be addressed without informed management of tree species. Objective(s)/Hypothesis(es): The Global Tree Assessment aims to compile extinction risk information on the c. 60,000 tree species worldwide. The outcomes of these analyses provide prioritization information to ensure that conservation efforts for trees are effective. Methods: The Global Tree Assessment has been made possible over the past five years by a global network of over 60 institutional partners and over 500 experts. Through collaboration with experts, Red List Authorities and specialist groups all over the world, including CNCFlora in Brazil, Asociación Colombiana de Herbarios in Colombia and Provita in Venezuela, we have produced conservation assessments, assessing the risk of the species becoming extinct. The final data set consists of IUCN Red List assessments and existing National and Regional assessments. Results: In September 2021 the State of the World's Trees report was published. We now know 30% of tree species are threatened with extinction, and at least 142 tree species are recorded as extinct or extinct in the wild. The information collected is visualized on the GlobalTree Portal, showing statistics on a global, national and species level. The main threats to tree species are forest clearance and other forms of habitat loss, direct exploitation for timber and other products and the spread of invasive pests and diseases. Climate change is also having an impact. It was found that over two-thirds of tree species are recorded in at least one protected area. About a third of tree species exist in botanic gardens or seed banks. However, the majority of the species protected are not threatened with extinction. Implications/Conclusions: The collation of information on the world's almost 60,000 tree species recognizes their global importance. It gives us an information base to call for a new focus on planning and carrying out biodiversity conservation and ecosystem restoration. The report identifies the regions where further action is needed. It provides recommendations for urgent action and calls for a new coalition to facilitate the action and expertise required. **Keywords:** Tree species, conservation assessments, extinction risk, prioritization, red List, biodiversity

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Progress towards the Red List of Endemic Trees of Venezuela

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The International Union for Conservation of Nature's (IUCN) Red Lists gather key information about the world's biodiversity and the risks it faces, in order to guide evidence-based conservation efforts. Since 2019, Provita and a local team of experts have been working with Botanic Gardens Conservation International (BGCI) on advancing the Venezuelan chapter of the Global Tree Assessment (GTA), which aims to assess the extinction risk of all tree species in the world. Over 1,100 Venezuelan tree species have been assessed by our team so far. Here, we present the preliminary results for the endemic species. All assessments followed IUCN's standards (version 3.1). Most of the assessments were based on criteria B - species distribution. Species records were gathered from GBIF.org, Venezuela's National Herbarium (VEN), and bibliographic sources. A total of 656

Venezuelan endemic tree species from 70 families have been assessed. Seven of these families comprise over 50% of the list, with Fabaceae (90 spp.) and Rubiaceae (69 spp.) occupying the first places. Most of the species grow on wet mountain forests, followed by lowland moist forests. The states with most endemic tree species are Amazonas (281 spp.) and Bolívar (218 spp.), followed by Aragua (80 spp.), Miranda (65 spp.), Distrito Capital and Lara (54 spp. each). Over 91% of the endemic species have only been reported in 1-4 states. Our results indicate that 45% of these species are threatened (CR, EN, and VU), while 25% are Least Concern (LC), and there is not enough information for 27% of them (DD). Fourteen (20%) of the tree families have more than 50% of their assessed endemic species under threat. The most frequently mentioned threats for these trees are small-holder farming, housing, and urban expansion, habitat shifting and alteration (including climate change), and mining.The assessment is still in progress and will be completed over the next few months. A preliminary version of the red list of Venezuelan endemic trees, with 628 species, can be downloaded at GBIF.org (https://doi.org/10.15468/vfkuxf). An updated version will be published later in the year. We hope this information will be useful to guide conservation actions on these species, logging prohibitions, new protected areas, ex situ conservation, and/or reforestation efforts. All assessments are available through IUCN's Red List of Threatened Species portal (https://www.iucnredlist.org/). **Keywords:** tree, endemic, red list assessments, Venezuela

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Planning for Tree Conservation in Colombia: Red List and Conservation Action Plans for Tree Species of Conservation Priority

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Colombia has a very rich tree flora, with almost 6,000 species registered to date. The country also has high tree endemism. As a contribution to the "Global Tree Assessment", we assessed 860 species to complete the red list of the 1,148 endemic trees of Colombia. To categorize the species according to the IUCN red list guidelines, we used geographic occurrences obtained from herbarium-specimens. We carried out detailed analysis of habitat quantity and quality (using forest cover and human footprint maps) and documented anthropogenic threats and conservation actions. Almost half of the endemic trees were categorized as threatened (41% of the assessed, and up to 49% for all species). Most species had small distributions, with an average of 6.2 known populations. Endemic tree occurrences were more common in the Andes and Magdalena regions, which have very high human footprint and consequently a large proportion of threatened species. The major threat to endemic trees was habitat destruction, due mainly to deforestation for livestock and crops. Many endemic trees were present in protected areas (65%), but threatened and non-threatened species had low coverage under protection and many of their populations persist in disturbed habitats. The red list assessments are being used for the difficult task of spatial conservation planning in a megadiverse country, for example by identifying Key Biodiversity Areas and Important Plant Areas. Colombia has hundreds of threatened endemic trees, most of them in global biodiversity hotspots, with very few proactive conservation actions. It is urgent to increase the coverage of endemic tree populations in effectively-managed area-based conservation measures and to complement this with exsitu and other conservation actions. There are conservation action plans for a few timber species in the country, but these efforts need to be supported more widely and extended to other less charismatic groups of trees. **Keywords:** Red List, tree conservation, species conservation

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Conservation of Magnoliaceae in Colombia – a Successful Case Study of National and International Cooperation

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Magnoliaceae was chosen as a priority family in Colombia to implement the National Strategy for plant conservation according to the following principles: a) research, monitoring, and information management, b) conservation in situ and ex situ, c) management and use of plants, d) public awareness and education, e) cooperation among institutions. In 2001, Medellin Botanical Garden, supported by governmental organizations, started to follow the principles of the national strategy at the regional level through the search of trees and populations of Magnolia species in several municipalities from Antioquia province. At the national level, information from herbaria and research institutions of several cities around the country, like Humboldt Institute, National University of Colombia and the institute for the Conservation and Research of Valle del Cauca

province -INCIVA, was gathered. From 2001 to 2005, 14 species were recorded in Antioquia province, including two new species. Since then, several people and national institutions as the Tecnológico de Antioquia and Salvamontes Colombia, have joined to work on Colombian Magnolias. Now, Colombia is the country with the most Magnolia species in South America with over 40 species, some of them in the description process. In addition, private institutions have contributed to the acquisition of land for the establishment of natural reserves for the conservation of magnolias in situ. Lately, several projects have been supported by international organizations such as BGCI and the Franklinia Foundation, enhancing several conservation and research efforts of this highly threatened group. Despite the knowledge gathered so far, it is imperative to keep working on the study and conservation of these species, most of them with very small populations and high level of endemism. That is why institutions such as Medellin Botanical Garden, Salvamontes Colombia and Tecnologico de Antioquia have joined the Global Conservation Consortium of Magnolias. **Keywords:** Magnoliaceae, Conservation, species assessments, endangered species, consotia

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From Assessment to Action: The Morton Arboretum's Efforts to Conserve Oaks in Mesoamerica

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Oaks (genus *Quercus*) are found in forests and shrublands across the Northern Hemisphere that include biodiversity hotspots in tropical and subtropical regions, such as Mexico and Southeast Asia. In these habitats, oaks are often keystone species, shaping ecological relationships and providing multiple ecosystem services and economic benefits. Unfortunately, many oak species are declining and until recently, there was not a complete account of the conservation status of oaks globally. To address this need, staff at The Morton Arboretum partnered with Botanic Gardens Conservation International (BGCI), the IUCN SSC Global Tree Specialist Group, and the Global Tree Assessment (GTA) to conduct IUCN Red List assessments for all the oaks of the world. The resulting *Red List of Oaks 2020* revealed that 50% of the world's oak species (217/430) are of conservation concern, including 112 species assessed as critically endangered, endangered, or vulnerable. What is more, 67 species were assessed as data deficient, highlighting the urgent need for further research, particularly in the tropics. Although oaks are native to 90 countries, the highest species richness for the genus is in Mexico (164 species), China (117), the United States (91), and Vietnam (49). These countries also had the highest number of threatened species at 32, 36, 16, and 20, respectively. Major threats to oaks globally included land use change, a changing climate, and native and non-native pests and diseases. Once armed with the assessment data, staff at Morton were able to prioritize species and regions to develop and conduct *in situ* and *ex situ* conservation projects, such as efforts to study and prevent extinction of the endangered oak *Quercus Brandegeei* in Mexico. This Global Trees Campaign (GTC) project brought together Mexican scientists, international partners, land managers and community members who are working together towards a science-based, stakeholder-inclusive recovery action plan for the species. Although these single-species projects are extremely valuable and provide important case studies, a coordinated, global effort is needed to safeguard the >200 species of oaks at risk. Led by the Morton Arboretum in collaboration with BGCI and dozens of other partners, the Global Conservation Consortium for Oak (GCCO) was launched to translate and amplify the GTA results into action. Members are working collaboratively to develop and implement a comprehensive conservation strategy to prevent the extinction of the world's oaks. **Keywords:** Quercus, oak, GTC, GTA, endangered, assessment, Mexico

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Emerging approaches for biodiversity monitoring in tropical environments

Advances and Prospects of EDNA in Neotropical Rainforests

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Introduction/Background/Justification: The rainforests of the Neotropics shelter a vast diversity of plant, animal and microscopic species that provide critical ecosystem goods and services for both local and worldwide populations. These environments face a major crisis due to increased deforestation, pollution, and climate change, emphasizing the need for more effective conservation efforts. The adequate monitoring of these ecosystems is a complex and time-consuming endeavour. To date, many species remain undiscovered, let alone described, with otherwise limited information regarding known species population distributions and densities. Overcoming these knowledge shortfalls and practical limitations is becoming increasingly possible through techniques based on environmental DNA (eDNA), i.e., DNA that can be obtained from environmental samples (e.g. tissues, soil, sediment, water, etc.). When coupled with high-throughput sequencing, these techniques now enable realistic, cost-effective, and standardisable biodiversity assessments. This opens up enormous opportunities for advancing our understanding of complex and species-rich tropical communities, but also in facilitating large-scale biomonitoring programs in the neotropics. **Objectives**: Provide an introduction to eDNA methods and an overview of their current and potential uses in terrestrial ecosystems of neotropical rainforests. **Methods**: This presentation will rely on different studies making use of DNA metabarcoding and high-throughput sequencing, applied to soil samples that were collected in various forest ecosystems in French Guyana, and for which a variety of genomic markers are studied, hence allowing covering biodiversity in a multi-trophic perspective, from micro-organisms to plants. Natural, urban, or anthropogenically disturbed forests will be considered in order to address a variety of questions, from community assembly processes to human impacts on biodiversity. **Results and Implications:** I will discuss the limits and challenges of eDNA-based methods for our understanding and monitoring of multi-trophic biodiversity in neotropical rainforests, as well as future research and applied perspectives of these techniques for these environments. **Keywords:** eDNA, metabarcoding, environmental genomics, neotropics, rainforests, soil biodiversity, multi-trophic biodiversity

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Soil EDNA Reveals Changes in Biodiversity along Ecological Gradients in Endangered Tropical Ecosystems

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Anthropogenic pressure is unavoidable for tropical ecosystems and the timely information of conservation decisions is a pressing issue in biodiverse, vulnerable, and understudied systems. Soil is a complex living system that both supports and retains the signature of the aboveground diversity. We assessed whether environmental DNA (eDNA) from soil can reveal changes in biodiversity along different ecological conditions in endangered tropical ecosystems to inform conservation policies. In mountain systems, we measured the diversity and

turnover of bacteria, fungi, and eukarya communities along an elevational gradient to determine the transition between cloud forest and paramo ecosystems, being a subject of legal protection the latter one. In tropical dry forest, we measured the diversity and turnover of bacteria, fungi, and insect communities between perturbed and unperturbed localities to reveal how land use change impacts these "hidden" communities. In mountain systems we found a consistent decline of diversity with elevation for all the taxonomic groups, with variable rates of decline across biological groups. Most communities exhibited a marked turnover in composition between 3,400 and 3,500 m.a.s.l. In the case of perturbed/unperturbed dry forest, the alpha diversity of fungi and bacteria did not change with land use but there was a significant change in species composition. In particular, insect diversity decreased in perturbed areas and exhibited the highest turnover in community composition between perturbed/unperturbed areas. These results are a key step for understanding how land use change might impact diversity and overall ecosystem function. eDNA allows us to effectively survey changes in understudied components of biodiversity being a powerful tool for informing conservation planning needed for the persistence of sustainable tropical ecosystems. **Keywords:** Paramo, tropical dry forest, eDNA, elevation, perturbation

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Advances in Freshwater Environmental DNA in Nothern Amazonia Promote the Implementation of Regional and Muti-taxa Ecological Studies

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Neotropical freshwaters and their associated riparian communities are extremely diversified but remain among the most imperilled ecosystems worldwide. Riverine ecosystems are particularly sensitive to anthropisation because hydrologic connectivity transfers disturbances downstream by transporting matters and pollutants over long distances. Hence, catchement-scale disturbances affect local aquatic but also terrestrial biodiversity through the lateral connectivity between rivers and terrestrial habitats resulting from ecological land/water interactions. Characterizing both aquatic and terrestrial assemblages is thus a prerequisite to understanding how anthropogenic disturbances alter biodiversity. However, biodiversity measurements often rely on selective and destructive methods providing incomplete inventories. This applies especially in tropical freshwater ecosystems, where water turbidity, depth, or current velocity impede exhaustive assessment of biodiversity. Over the last decade, however, eDNA metabarcoding has demonstrated an extensive potential to enhance biodiversity monitoring. In line with these advances, we present a summary of methodological studies aiming at improving aquatic eDNA-based inventories in Northern Amazonian freshwaters. We first demonstrate the robustness of the eDNA metabarcoding method, which is highly replicable even with two distinct sampling protocols. We then show that eDNA-based inventories provide realistic pictures of the local fish fauna comparable to inventories obtained with traditional capture-based methods, and demonstrate that eDNA travels over short distances in the water. We finally extend the application of aquatic eDNA metabarcoding to tropical mammal inventories and show that the expected spatial distribution of aquatic and terrestrial mammals can be retrieved from aquatic eDNA samples. Based on these methodological advances, we show how eDNA data can constitute a robust baseline to the design of regional and multi-taxa ecological studies through the case of study of fish and mammal distribution in large rivers of the Guiana Shield. Our results show how human disturbances erode freshwater and terrestrial biodiversity over entire watersheds and call for a closer consideration of the upstream-downstream hydrologic connectivity and the lateral connectivity between rivers and terrestrial habitats in conservation programs. **Keywords:** Community ecology, tropical ecology, Freshwater ecology, environmental DNA, Amazonia

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EDNA of Frogs in Aquatic and Soil Ecosystems

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Global losses of biodiversity are progressively increasing for many taxa during the Anthropocene. However, our ability to monitor biodiversity is reduced when dealing with elusive species, populations with low abundances, or remote locations. The analysis of DNA traces left by the organisms in the environment (eDNA) rose in the last decade as a promising approach to circumvent many of the challenges faced by other methods (e.g., audio-visual encounters and traps) traditionally used for monitoring species difficult to survey. The eDNA has the potential to improve our knowledge about species geographical distribution, population abundance and conservation status. Since 2014, we have applied the eDNA metabarcoding to: 1) test the feasibility of this approach for surveying water and ground dwelling amphibians in the Brazilian Atlantic forest, 2) compare the performance of traditional and eDNA methods for amphibian inventories, 3) search for DNA traces of 44 species reported to be declined or disappeared from the Brazilian Atlantic forest, and 4) identify the possible causes for these disappearances. We amplified around 50bp of 12S rRNA gene of amphibians from freshwater and leaf litter samples. Our results underscore the utility of eDNA metabarcoding as an efficient approach for surveying amphibians associated to tropical water bodies. However, it was not supported as a powerful approach for surveying ground dwelling species using leaf litter samples. The eDNA had a greater capacity of detection per sampling event than rapid field surveys, confirming the presence of species undetected by methods traditionally used. We successfully detected DNA traces of four declined species (*Hylodes ornatus*, *Hylodes regius*, *Crossodactylus timbuhy*, and *Vitreorana eurygnatha*), three locally disappeared (*Boana semiguttata*, *Phasmahyla exilis* and *Phasmahyla guttata*), and two species that have not been seen since 1982 (*Cycloramphus cedrensis*) and 1968 (*Phantasmarana bocainensis*). Our results underscore the efficacy of eDNA metabarcoding to survey species at low population densities and its potential application in conservation biology. **Keywords:** Amphibians, biodiversity monitoring, Brazilian Atlantic forest, conservation, environmental DNA, metabarcoding

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Wanted Not, Wasted Not: Searching for Non-target Taxa in Environmental DNA Metabarcoding By-catch

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Introduction: Metabarcoding of environmental DNA is based on primers that are specific to the target taxa (e.g. bacteria, zooplankton, fishes). However, due to the nature of the commonly used protocols, regardless of the chosen primers, several sequences of non-target species will inevitably be generated, but are usually discarded in commonly used bioinformatics pipelines. These non-target sequences might contain important biological information about the presence of other species in the studied habitats and its potential for ecological studies is still poorly understood. **Objective:** Here, we analyzed the presence of mammal and bird species in aquatic environmental samples that were originally amplified targeting teleost fish species on the fish pass system of the Itaipu dam. **Methods:** Using a fragment of the 12S gene, we characterized richness and community composition based on amplicon sequence variants of fishes, mammals, and birds through environmental DNA metabarcoding of water samples to monitor the impact of both the dam and associated fish pass system in the Paraná River communities. We combined GenBank and in-house data for taxonomic assignment. **Results:** After all cleaning and checking steps, we kept 190 amplicon sequence variants (ASVs) belonging to fishes, 21 to mammals, and ten to birds. For the non-fish sequences, most ASVs were taxonomically assigned to farm/domestic animals, such as cats, cows, and ducks. Yet, we were able to identify a native semi-aquatic mammal, the capybara, in the samples. Four native bird species and a non-native potentially invasive bird (*Corvus* sp.) were also detected. **Implications:** Although the data derived from these samples for mammals and birds are of limited use for diversity analyses, our results show the potential of aquatic samples to characterize non-aquatic birds and highlight the possible presence of a potentially invasive species that had not been recorded before in the region. **Keywords:** Birds, fishes, high throughput sequencing, mammals, Neotropics, vertebrata

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Advances in Near-range Sensing in Tropical Biodiversity Monitoring

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Biodiversity surveys remains labor and cost intensive, and standardization and coordination remain a major obstacle to the implementation of policy and legal frameworks especially in the tropics. Biodiversity monitoring in principle should be objective, repeatable, verifiable, and accessible. Taxonomic training and expertise are crucial to achieving trustable biodiversity surveys, but this expertise is dwindling. A commonly discussed solution to facilitate biodiversity surveys is to integrate new technologies as options or as central elements of such surveys. These technologies require in situ collection by operators, and is therefore referred to as near-range sensing. Environmental DNA methods have made major progress in the last decade, but remain limited by their low capacity to identify taxa at the species level. Approaches based on phenotypic traits (e.g. spectrometric signatures) offer further promise, but have other limitations, which will be discussed. Finally, deep learning techniques could facilitate data analysis, but are still often limited by the availability and reliability of reference databases. I will discuss examples of advances and current frontiers of these methods using tropical tree biodiversity surveys as a case study. One conclusion is that it is essential to develop research projects that integrate multiple technologies within pre-existing protocols. Furthermore, the foundation of biodiversity surveys remains field expertise and collections, and there will be no purely technological solution to biodiversity monitoring. Several ambitious initiatives have been proposed recently, which will be discussed and compared. **Keywords:** Biodiversity, survey, technology

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Emerging uses of large-scale remote sensing in tropical forest monitoring

Applications of Airborne LiDAR and RGB Imagery to Track the Impacts of Climate Change on Forests

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Background: Logged forests cover four million square kilometres of the tropics. Restoration of logged tropical forests is hailed as a nature-based solution to the interlinked climate and biodiversity crises, but there are concerns that recovery may be hampered by increasingly severe El Niño Southern Oscillation (ENSO) droughts. **Hypothesis:** That early successional woodlands would be more heavily impacted by drought than later-successional woodlands, and would be slow to recover once the rains return. Also, that riparian forests, with greater access to soil water, would be less affected by ENSO events. **Method:** We use repeated airborne surveys (LiDAR and photogrammetry) to map canopy height growth and tree mortality over 100 hectares of secondary forest in Indonesia. The timing of the surveys (in 2014, 2017 and 2018) allowed us to assess the impact of a severe ENSO drought (2015-2016) on forest dynamics and subsequent recovery processes, providing insights into forest resilience to climate change. **Results**: Early-successional Forest experienced a ~50 % loss of canopy height and 90 % of established trees appear to have died in response to the drought, but taller canopies showed greater resistance. Riparian forests, with greater access to soil water, were less impacted by the drought than forests further away from the rivers. In the post-drought period, we observed strong recovery in height growth, particularly in the early-successional stands. **Conclusion:** This study shows that the height growth of recovering tropical forests was surprisingly resilient to the severe ENSO event, suggesting the benefits of these nature-based solutions could endure as the climate warms. **Keywords:** Forest, resistance, resilience, ENSO, Lidar, RGB imagery, Indonesia

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Detecting Infrastructure Growth Through High Cadence Satellite Imagery

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Background: Each minute 40 football fields worth of forests are lost to deforestation, usually converted to other land uses, especially commodities production. Roads and other infrastructure surfacing in forested areas are often a precursor to larger deforestation events so detecting these features can be used for early detection of deforestation to follow. Planet manages the largest fleet of earth observation satellites in the world capturing Earth's land mass just about every day at 3–4-meter resolution - a dataset uniquely suited to capturing this development. Objective: Reduce the manual effort required to find areas of new development within the country of Brazil so that deforestation events can be tracked and potentially stopped. Method: First, we trained an image classifier to identify roads and buildings in Planet imagery. Using hand-labeled imagery comprised of 4-band surface reflectance scenes projected to a UTM grid, we were able to train a high performing segmentation model that classified each pixel within the image as a road, building or other. We then applied this model to our near-daily planetscope imagery to extract these features within each published image. By aggregating these results on a weekly basis, we are able to remove most noise within the imagery that may be caused by shadows, clouds or other artifacts to get an accurate representation for that given week. Using these weekly layers, we are able to detect when a pixel changes from one class to another. We require the change to be persistent, meaning the new classification must be present for multiple time periods before

generating a change detection. As a result, change detections show change that occurred 3 weeks prior on average. Each detection includes a "score" percentage indicating how likely it is to be a true positive change so that users can determine their own tolerance for false positives. Results: When filtering for detections with a score greater than 40%, our precision reached 0.75 for roads and 0.58 for buildings within Brazil, enabling users to more easily spot development and narrow the scope of where they needed to focus. We identified a few failure modes to address including agricultural areas, ships in port and coastal areas that surfaced significant numbers of false positives. Conclusions: Planet has shown it is possible to automatically surface areas of human development over enormous areas with a high degree of precision, enabling users to more effectively use their resources to focus on areas that are changing. **Keywords:** Planet, machine learning, computer, vision roads, buildings, rainforest, automated

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Project AMAZECO: Covering the Amazon with an Ecosystem Structure Essential Biodiversity Variables (EBV) Product Combining Satellite and Airborne LIDAR

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The AMAZECO project is about helping governments to make use of LIDAR data for their conservation and sustainable development purposes, and at the same time doing it in a globally harmonized manner, so that all information can also be useful toward monitoring UN 2030 Global Sustainable Goals. We aim to transform the sheer amount of data available through LIDAR surveys into simple information describing ecosystems that can be meaningful and easy to conceptualize by decision and policy-makers. Global information sources may typically be of little help to national governments, because they neglect the specific circumstances of each region. We follow a different approach: our vision is one of a crowdsourced global product fed from local efforts, by creating the tools to facilitate local stakeholders to use these data for their own conservation and sustainable development purposes, empowering local action while enabling a globally-harmonized product. We concentrated in ecosystem vertical profiles (EVPs), which characterize the vertical distribution of sessile biological entities in an ecosystem. In Valbuena et al. (2020) we advocated for a standardization of ecosystem morphological traits – vegetation height, cover, and structural complexity – derived from EVPs characterized by LIDAR. These traits should focus on being relevant to the ecosystem, and not on the means for measuring them. Thus, the objective of the research was in demonstrating that we can deliver platform-independent EVP traits from both satellite and airborne LIDAR sensors and provide the means for a global ecosystem structure LIDAR product that can be crowdsourced through national Biodiversity Observation Networks (BONs). This was enabled by high performance computing (HPC) workflows for common satellite and airborne LIDAR derivation of ecosystem traits, producing and implementing a first prototype product covering the whole of the Brazilian Amazon region with traits produced from combined satellite and airborne LIDAR. The satellite LIDAR was obtained from the currently operational global ecosystem dynamics investigation (GEDI) mission. The airborne LIDAR workflow made use of the extensive dataset of transects from the 'improving biomass estimation methods for the Amazon' (EBA), plus data from the Sustainable Landscapes Brazil (SLB) project. The product consisted of a multilayered raster data product with LIDAR measures of EVP traits, including estimations of their uncertainties and a demonstration of how airborne LIDAR can be used to improve those over a satellite product. The code developed has procedures incorporated in the rGEDI package (Silva et al. 2020), and HPC pipelines to enable replication through **Keywords:** Ecosystem structure, ecosystem vertical profile, LIDAR, laser scanning, global ecosystem

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Novel Approaches to the Assessment of Forest Biodiversity Status through the Use of Remote Sensed Products

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The increasing availability of high-frequency, high-resolution remotely sensed data promises a revolution in our understanding of land-use and land-cover change. We investigate how measures of forest biodiversity and carbon stocks can be derived from these remotely sensed data, how these workflows can be streamlined and how these elements can be made available to support in-country spatial planning and policy-making. Specific workflows include producing measures of biodiversity intactness, from modelling responses to land use change using ecological databases or biodiversity significance based on linking forest data to global species range databases. From remote sensed derived datasets to data integration, our vision is that spatial intelligence for nature and climate be widely available and used to operationalize commitments and targets, frame integrated strategies for nature and climate, and promote transparency and accountability on a global scale. This work has been undertaken as a contribution to the new SPACES (Spatial Intelligence for Climate and Nature) coalition, which aims to mobilize spatial intelligence to support governments, businesses, finance institutions, funders, and investors in implementing the climate and nature agendas. **Keywords:** Remote sensing, biodiversity, carbon, policy, spatial planning, conservation

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Tropical Forest Carbon Dynamics in the 21st Century

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Interannual variability (IAV) of atmospheric CO_2 growth rate (CGR) has shown to be tightly correlated with climate anomalies such as the El Niño Southern Oscillation (ENSO) events. Modeling efforts have also suggested that such correlation is dominated by the responses of tropical land carbon cycle to climate change, which was supported indirectly by the strong coupling between CGR and concurrent tropical land-surface air temperature. However, there has been no direct link between the carbon dynamics of tropical vegetation and CGR largely due to lack of frequent measurements of carbon stocks changes across tropics. Here, we combine spaceborne observations of forest structure from lidar and radar sensors with airborne and ground vegetation inventory, and long-term satellite imagery to develop time series estimates of carbon stocks in tropical vegetation during the 21st century (2000-2018). The products are maps of carbon stocks (above+below) at 10-km spatial resolution and annual time cycles. We find, the first time, a strong correlation (R=0.88) between the CGR IAV and the independently-estimated tropical net carbon fluxes (first-order differences of annual total carbon), with moist forests and dry woodlands contributing equally to the carbon dynamics. Using a mass balance approach for net fluxes, we find emissions from carbon loss due to disturbance (deforestation and fire) contribute little to explaining the CGR IAV, and almost all variations are explained with vegetation carbon recovery in secondary or intact forests. The result indicates that the link between IAV of GCR and climate (temperature or water) is through carbon dynamics of recovering forests in tropics, influencing the future trajectory of CGR and climate evolution globally. Acknowledgements: The research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration. **Keywords:** Tropical Forest, biomass, carbon Dynamics, Amazon, Congo, disturbance, recovery,

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Landsat Data Archive: Global Applications for Natural Resource Management and Conservation

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The implementation of global initiatives towards sustainable development, climate change mitigation, and maintaining biodiversity and ecosystem functions depends on the timely provision of relevant data on land cover and land use change (LCLUC) at global, national, and local scales. The growing and diverse user community requires LCLUC data that is globally consistent yet locally relevant, freely and openly accessible, operationally updated, and has customization capabilities to support a wide range of practical applications. The Landsat data archive is the only tool that enables global multidecadal forest monitoring at medium (30 m) spatial resolution. Recent advances in Landsat data processing into analysis-ready data enhanced our capacity to map LCLUC globally with higher precision and thematic detail. Our team at the Global Land Analysis and Discovery Lab (GLAD) employed the Landsat analysis-ready data to map changes in forest extent and height, intact forest landscapes, cropland, built-up lands, surface water, and perennial snow and ice extent from the year 2000 to 2020 at 30-m spatial resolution. Each thematic product was independently derived using state-of-the-art locally and regionally calibrated machine learning tools. Thematic maps validation using a statistical sample of reference data confirmed their high accuracy (user's and producer's accuracies above 85% for all land cover and land use themes, except for built-up lands). Our global bitemporal maps portray dramatic changes in the Earth's land cover and land use during the first 20 years of the century. The results show the reduction of global tree cover extent and expansion of cropland and settlements. LCLUC dynamics have distinct regional patterns reflecting the expansion and abandonment of intensive land management. Surface water dynamics have pronounced regional variation linked to hydropower projects and depletion of natural lakes in dry climates. The area of perennial snow and ice declined dramatically in a warming climate. The individual datasets and the global LCLUC maps are publicly available from the dedicated web portal https://glad.umd.edu/dataset/GLCLUC2020/ and serve as inputs for the comprehensive global land monitoring system developed by the WRI Land & Carbon Lab. **Keywords:** Landsat, forest, cropland, urbanization, remote sensing, land use, land cover

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Empowerment of IPLCs and Biocultural approaches to wildlife management and conservation: examples from Guyana

People Not Poaching: Lesson Learning from Engaging Communities in Efforts to Tackle Illegal Wildlife Trade

Olivia Wilson-Holt

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International Institute for Environment and Development, London, United Kingdom Background: Illegal wildlife trade (IWT) is a global conservation issue causing declines of many species of fauna and flora and threatening the livelihoods of people who depend on wildlife. Globally, the most common approach to tackling IWT is to enhance law enforcement, such as arming rangers and imposing heavy penalties on poachers. However, critics of this approach argue that efforts to reduce IWT in biodiversity hotspots are likely to fail without the involvement of Indigenous Peoples and local communities (IPLCs). Furthermore, top-down approaches often fail to account for underlying motivations behind poaching and can worsen people-park conflict. A key problem, however, is that there's no blueprint approach to community-based approaches to tackling IWT and therefore a lack of knowledge by project designers and implementers on best practice. **Objective:** The People not Poaching platform sought to address these issues by building the evidence base on the effectiveness of community-based approaches to tackling IWT. By collecting case studies from across the world, including many in the tropics, the purpose of the platform is to understand what does and doesn't work, and why, in these approaches. **Methods:** Using the 116 case studies on the People not Poaching platform, this research aims to analyse information on the effectiveness of community-based approaches to reducing IWT, including the reasons why initiatives have either been a success or a failure, and to pull together a series of lessons learned that illustrate best practice for those funding, designing and implementing future anti-IWT initiatives. **Results:** The case studies offer a diverse insight into what makes a community-based anti-IWT initiative successful and provide many practical examples to illustrate this. Across case studies, common lessons learned include: IPLC rights to manage and benefit from wildlife must be recognized, Partnerships should be multi-level and multistakeholder and include locally led institutions, Projects should respect and incorporate existing IPLC structures and norms rather than introducing new ones, Grassroots approaches are often the most cost-effective, however there is a lack of focus from NGOs on how to identify and support these initiatives. **Implications:** These lessons have implications for funders, designers and implementers of anti-IWT projects - which are often led by international NGOs or government agencies - by providing evidence of the need for IPLCs to be active partners in conservation efforts and to support locally-led approaches for successful outcomes for people and wildlife. **Keywords:** Illegal wildlife trade, IPLC, poaching, livelihoods

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Community Led Turtle Conservation along the Rupununi River, Guyana

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The Yellow-spotted river turtle (*Podocnemis unifilis*) is a species of freshwater turtle found in the Amazon and Orinoco basins of South America and is categorised on the IUCN Red List as Vulnerable. In the Rupununi, Guyana, the species is threatened by numerous issues including wildlife predation, overconsumption by humans and flooding. The consequence of this array of hazards has been the severe decline in the local species population over the past few decades. In response to these threats, community-based initiatives led by two local grassroots NGOs in collaboration with Indigenous communities has sought to reverse the population decline of the Yellow-spotted river turtle through a series of conservation actions. A combination of ex-situ and in-situ methods have been implemented including head starting, translocation, nest monitoring and environmental education. The integration of these approaches has resulted in a noticeable increase in the local population of the Yellow-spotted river turtle although population numbers are still distant from those in previous decades. Evaluation of the projects has revealed that climate change induced flooding will require the continuation of the combined ex-situ and in-situ methods for the long-term future to prevent any further decrease in the turtle population. The projects have also highlighted the importance of environmental education on influencing behaviour change which is a key component to the future sustainable harvesting of the turtle population. The model created by these two projects can be upscaled to conserve a wider area of river in Guyana and to reverse the decline of other threatened populations including the South American river turtle (*Podocnemis expansa*) and the Mata mata (*Chelus fimbriata*). Communities, NGOs and governments can also replicate aspects of the projects to conserve locally threatened freshwater turtle species in their respective regions. **Keywords:** Community-based conservation, translocation, head starting, nest monitoring, environmental education

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North Rupununi District Development Board "Fisheries Management Implementation"

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Fish is an important food resource for the twenty communities of the North Rupununi. In 2011, communities developed the North Rupununi Fisheries Management Plan as a result of a decline in fish resources overtime. In 2018, with assistance from the Sustainable Wildlife Management Programme (SWM)-Guyana, the North Rupununi District Development Board, which is a representative body for the North Rupununi communities, and the Fisheries Department-Ministry of Agriculture, began implementation of this plan. The NRDDB fisheries management plan supports conservation and sustainability of fish resources and promotes co-management of resources. The results of the implementation of this plan will assist communities in identifying areas which needs special protection to manage fish stocks and stem further decline. The specific objectives of this collaboration is to establish guidelines that will ensure careful use of fish resources in the North Rupununi that can be adjusted using information from monitoring, to ensure community members have equal access to fish resources for home use and for selling and support communities' ability to create and enforce resource management by-laws for fish use. The role of partners: The NRDDB and its communities are the implementing body on the ground, integrating the traditional knowledge to a scientific approach in fisheries management which includes river monitoring, coordination of fisheries field research and data collection, data analysis and educational awareness at the local level. In addition, the NRDDB feed information to the Fisheries Department for better decision making. The Fisheries Department is the representative body at the national level in support of NRDDB' Fisheries plan implementation and policy makers. The village councils, Fisheries department and NRDDB staff are the decision makers, planning and implementing the ground work. The implementation process began with awareness and seeking free prior and informed consent of the communities. Scientific and local knowledge are gathered and shared between partners to further develop and implement the management plan. Also, co- management is critical for a better and improve the policy planning, this building a stronger working relationship. However, challenges were encountered in communication between implementing partners, substantial funding and Covid-19 Pandemic locked down to villages. **Keywords:** Sustainability, conservation, management, research, development, knowledge, traditional, environment, fisheries,

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Wapichan Wiizi Wildlife Management Plan in South Rupununi, Guyana: Community Leadership in Biocultural Assessments and Management Planning

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The indigenous peoples of Guyana's South Rupununi share a close bond with their natural environment and surroundings, which has sustained them with all of the resources they needed for millennia. However, fast changes in the socio-economic, cultural, and environmental surroundings are jeopardizing this connection, causing shifts in cultural, traditional, and societal values, and putting the region's abundant natural resources at risk. Wildlife is a crucial resource for the Southern Rupununi indigenous peoples, as it is for other indigenous peoples in Guyana. Wildlife provides a substantial portion of their nutrition, is culturally significant, and helps to maintain environmental equilibrium. The South Rupununi District Council, which represents 21 indigenous communities, has taken the lead in biodiversity management and conservation throughout the region. The Wapichan Wiizi Wildlife Committee (WWWC) was formed in 2019 to organize conversation for the long-term management of wildlife in the Rupununi's south. Since then, several community-led initiatives (steeped in customary laws while acknowledging and applying academic methods), such as the development of wildlife use guidelines in eight villages, a biocultural assessment of the Karaawaimin Taawa mountain chain, and coordination of wildlife management discussions with various rights holders and stakeholders, have all ignited wildlife management discussions, which will eventually culminate in the development of a Wildlife Management Plan. The South Rupununi District Council hopes that this management plan would serve as a road map and strategy for the long-term sustainable use and management of wildlife in the south Rupununi, emphasizing the significance of dialogue and co-management, particularly with the Guyana government. **Keywords:** Indigenous peoples, South Rupununi, Guyana, conservation, wildlife management, co-management

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Spatial Tools for Wildlife Management in Indigenous Territories

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The Amazon basin is the largest and most species-rich tropical forest and river system in the world, playing a pivotal role in global climate regulation and harboring hundreds of traditional and indigenous cultures. More than 10M traditional, peasant and Indigenous people live in rural areas of Amazonia and rely mostly on hunting and fishing to obtain dietary protein and other key nutrients. About 3,5M km^2 of protected natural areas and indigenous lands make up about 45% of Amazonia, officially protecting biodiversity, ecosystem services and livelihoods. Managing these enormous areas is a major challenge. Indeed, scientific tools for supporting management plans, zoning or even the delimitation of protected areas are scarce. By combining a set of collaborative territorial plan, experimental design, camera trap surveys, demographic and spatial hunting monitoring, remote sensing and geographic information systems, we propose here a novel framework on wildlife territorial management. From a long-term collaborative research (2012 to date) with Paumari indigenous people from the Tapauá River, Brazilian Amazonia, we have predicted local wildlife core areas and spatial spread of hunting, in order to assess of hunting sustainability under landscape. Our main goals were building spatially-explicit models on wildlife abundance to predict wildlife core areas throughout the landscape. This context-adaptive and culturally appropriate approach can empower social actors by strengthen local capacity and providing tangible and feasible guidelines to support decision making on wildlife use, local spatial-zoning, local agreements building, and, most strikingly, subsidy the delimitation of indigenous lands and protected areas in Amazonia and worldwide. **Keywords:** Hunting, Amazonia, camera trap, indigenous people, territorial plan

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A Model Building Process for the Participatory Management of Game in the Neotropics

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Guaranteeing wildlife populations' viability is crucial to conserve biodiversity as well as safeguard the food security of forest dwellers. Nevertheless, designing ways of ensuring the sustainability of hunting of game species remains complex. Ecological models can guide conservation actions but require accurate information on population parameters, such as reproductive and mortality rates. Quantifying these rates – especially for tropical forest species is extremely laborious and costly and most models have simplified these aspects. Such sustainability estimations operate under high levels of uncertainty, and although results often point to hunting being unsustainable, many supposedly over-hunted species are still consistently present within hunters' catches. This fallacy can jeopardize the livelihoods of people closely linked to wildlife by limiting their access to a crucial resource. In this study, we outline a model building process aimed at improving hunting sustainability estimations and at narrowing the gap in trust between modelers and managers. We worked on two fronts: 1) we aligned the model and its structure with management objectives and 2) we incorporated complex animal population dynamics based on data collected through a participatory approach with hunters. We used the lowland paca (Cuniculus paca) as model species, one of the most valued species by Amazonian people in terms of both consumption and trade. During past fieldwork in two sites in the Peruvian and Brazilian Amazon, hunters have emphasized the need to improve the management of this game species. In response to this demand, we built an agent-based model using the GAMA platform depicting pacas' population dynamics within the hunting territory of a hypothetical settlement within the Amazon forest. To validate the model, we compared 15 years simulation results with data collected in situ by hunters for 18 years on pacas' reproductive parameters, which are important for proper game management. Our comparison showed that the model was effective to reproduce empirical data on the species' reproductive biology. To improve sustainability estimations we need first of all to improve how game species are represented in our models, as this will dictate how they respond to hunting pressure. Further, if models are to be useful for environmental decision-making, these need to be harmonized with management objectives: their parameters need to reflect system attributes that can be manipulated by managers while outputs need to reflect measurable attributes. Scientists should capitalize on the increasing amount of data available – especially thanks to participation of resource users – and on modelling approaches that can accomodate the complexity and inherent dynamics of game species reproductive biology.
Keywords: Agent-based model, hunting sustainability, Amazon, participatory modelling, animal population dynamics

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Understanding Mammal Species Response to Hunting in Central Africa to Develop Sustainable Hunting Practices and Indicators

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The hunting of wild animals and the consumption of bushmeat constitutes one of the major drivers of animal diversity loss in the tropics, especially in west and central Africa. At the same time, bushmeat remains of extreme importance for the livelihoods and the nutrition of millions of people. Hunting-induced changes in wildlife community structure and composition are detrimental with knock-on impacts that can potentially initiate trophic downgrading of the entire ecosystem and alter its resilience to current and future climatic fluctuations. While limited conservation outcomes have been achieved through conventional international agency-based approaches, a new paradigm in wildlife management has emerged that puts hunters and other stakeholders at the heart of resource management instead of excluding them. However, we still lack practical tools and indices to implement and steward such participatory approaches and management. Here, we propose a conceptual framework to disentangle species and community response to hunting. We tested it along a gradient of hunting pressure in eastern Gabon, ranging from highly hunted areas in the vicinity of villages to almost undisturbed and pristine areas. Using species community composition data from camera traps combined with long-term offtake surveys, we identified the loser and winner species of current hunting regimes. We discuss the application of this framework in the light of the development of sustainable hunting practices and indicators. Finally, we propose recommendations to improve community-led hunting management in Central Africa and pave the way for future research. **Keywords:** Hunting, camera trap, sustainable hunting indicator, wildlife community-led management

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Forest restoration in Colombia to benefit biodiversity and people: who, how and where?

Integrated Economic and Spatial Modelling of Scenarios of Forest Restoration in Colombia: Balancing Biodiversity with Production

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Reversing trends in forest degradation and deforestation is essential for tackling climate change and preventing ecosystem service and biodiversity decline: critical if the Sustainable Development Goals are to be met. Political support for forest restoration at global, regional and national levels is high, but set against a backdrop of continued demand for cultivated land and ongoing deforestation. There is a risk that meeting nationally-determined restoration targets could displace land demand to active deforestation frontiers, generating net biodiversity and carbon losses. Focussing on Colombia, a country that hosts 10% of global biodiversity, we use the spatial partial-equilibrium model GLOBIOM to ask whether national restoration targets (1 million ha by 2030) could be achieved in congruence with increasing demand for agricultural, bioenergy and wood products. We test multiple scenarios of forest restoration linked to specific policies and aims, including focussing on restoring priority ecosystems, or restoring recently deforested land following national policies on the agricultural frontier. We also project future forest cover loss and gain using a probabilistic model based on historic biophysical, demographic, market and non-market drivers of land cover change. Contrasting the results of these models suggests that while there is substantial space for forest restoration to occur on low-yielding pastures without displacing market demand for agriculture to forest frontiers, land use change drivers such as conflict, illicit crops and land speculation that are not captured in market-focussed models might determine success in generating net benefits from restoration. Finally, we discuss the implications of these restoration scenarios and land use futures for biodiversity in Colombia by examining land cover change for different ecosystems and important locations for biodiversity. Opportunities to generate net gains for biodiversity, climate and people from forest restoration are large, but, as shown for the case of Colombia, will require challenging joined-up thinking across multiple disciplines to become reality. **Keywords:** Economic, agriculture, leakage scenarios, forest restoration, regrowth, deforestation

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Scenarios of Forest Restoration Priorities in Colombia

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Restoration of forests and other key ecosystems is a major nature-based solution towards meeting a wide range of global development goals and national priorities, including Sustainable Development Goals, but the stakes are high and financial resources are limited. Country governments, international organizations, and other restoration stakeholders need to identify and prioritize locations suitable for restoration. To be truly effective, and best approximate realistic restoration potential, decision makers require information on not only ecological conditions for tree growth but also restoration's socio-economic impacts: its benefits, costs, and risks. Locations where benefits are high relative to costs and risks are where restoration is more likely to be successful. These locations are also where initiatives are more likely to attract private investment needed to augment government funding and official development assistance. In collaboration with the International Institute for Sustainability Australia, our objective was to find forest restoration priorities in Colombia for six different politically-relevant area targets, based on the maximization of two benefits (i.e. biodiversity conservation and climate change mitigation) and the minimization of the associated costs. Leveraging WePlan Forests, a forest landscape restoration planning framework, we used a combination of global and national-level biophysical and socioeconomic datasets to find spatially-explicit restoration scenarios. These solutions maximize carbon sequestration and reduce the risk of species extinction, while also considering opportunity cost to avoid conflict with agricultural activities and direct establishment cost as well as the potential for natural regeneration. We identified planning solutions that perform well across both benefits simultaneously, despite trade-offs between them. We found that through strategic planning, cost-effective scenarios (i.e. those that balance biodiversity, carbon and cost) can achieve between 85.7% and 87.8% of maximum carbon benefit and between 95.1% and 99.9% of the maximum biodiversity benefit, depending on the restoration target. This translates to 0.34 - 2.68 Gt of carbon sequestration and 17 - 18% of mean reduction in the risk of species extinction. Colombia has tremendous opportunities for restoration as it is one of the most biodiverse countries in the world with also a great potential for carbon sequestration. However, because of the complexities of restoration actions (accounting for multiple biophysical factors) and the social and environmental heterogeneity of Colombian landscape, prioritizing the regions for restoration is not an easy task. These results are a first step that can inform and guide key stakeholders and decision-makers and help the country work towards its ambitious restoration targets. **Keywords:** Restoration, spatial planning, biodiversity, carbon, cost, optimization

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Monitoring Forest Restoration Progress in Colombia: Creating a Database of Public and Private Projects

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Forest restoration has international and national political support, including the UN Decade of Restoration 2021-2030 and the government of Colombia has declared an ambitious target to restore 1 million hectares of forest by 2035. Currently, there is no publicly available coordinated effort to monitor progress towards this target, nor an effort to monitor the success of implemented restoration projects, in Colombia. To address this gap, we initiated a project to collect up-to-date information on restoration projects in Colombia. We initiated the collection of information by reviewing technical reports, books and articles on project implementation, meeting with public and private stakeholders, and generating a public online survey for data collection. We also addressed two major sources of information: the Electronic Public Procurement System (SECOP) and the database of the National Environmental Licensing Authority (ANLA). We also reviewed databases of the Alexander von Humboldt Institute and the Colombian Network of Ecological Restoration where we highlighted the monitoring works that have been published in congresses and symposiums in recent years. More than 500 restoration projects have been entered into the database, 68% from the public sector and 32% from the private sector. Of these projects, only 15% show that they have carried out some type of monitoring. The province with the highest number of projects is Norandina with 60%, followed by Caribe with 15%. The database compilation process highlights multiple challenges in tracking progress towards restoration goals. Some important databases of restoration projects, which should be publicly available, were not accessible even

after repeated requests to the relevant agencies. Another key problem is that many restoration projects do not report their precise location, making it impossible to track project success. The next steps for this database are to add spatial information to as many projects as possible, invite more contributions to the database from relevant agencies, and work to make the database openly available online for public use. The database will provide excellent opportunities for research on land use change and forest restoration success in Colombia. **Keywords:** Management, environmental compensation, goals, evaluation and monitoring

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An Agenda for Forest Landscape Restoration: a Colombian Perspective

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Forest Landscape Restoration - FLR, is a concept that has increased in the recent years, especially with the World commitments related with the targets of decreasing the degradation of soils and a minimum of 15% of lands recovered in the planet. In Colombia, we are not talking only about forest, we have ecosystems with different characteristics and requirements in a socioeconomic complex context. Here we want to present a methodology to evaluate and propose landscape restoration priorities and opportunities at different scales, according with a principle of landscape functionality based on connectivity. We are including a spatial, economic and disturbance identification analysis. The spatial analysis focus on landscape diversity, structure and ecosystem services, to determine those areas preferred to restore and to protect according with the connectivity scenarios. The main objective is related with the types of land production to determine the best and the viable way to start a process of restoration in a local context, considering that the landscape sustainability of the practices is very low. We include a cost benefit analysis of the cost opportunity and current cost of production, especially on types likes agroforestry, forestry and practices related with the restoration implementation (planting, nurseries, seed production, etc). We found that the country faces different levels of degradation that goes from the less degradated areas close to natural areas, to more degradated in areas of ecosystem importance. The benefit of the production and their sustainability is very low, with a high social price that endanger the viability of the ecosystem's services in the long term, that increases with the diversification and enrichment. In the local context, the disturbances need to be analyzed and included to guarantee the success and the inclusion of the limitans like the exotic species, for example. We need to focus on strategies that considers a more integral view, with specific objectives according with the local context, that also encourages people to see the restoration as a benefit for the quality of life from an economic, ecological and wellbeing point of view. The country presents socio ecological scenarios that need to be considered in any restoration process, the security, uncertainty of the land tenure and other ecological aspects need to be prioritized when we are starting restoration process. We need not to only planting trees, we need to include different types of restoration strategies like the enrichment of the forest, productive reconvertion, recovery of the soils, management of the practices and the exotic species, according with the conditions of the specific site. **Keywords:** Landscape restoration, conservation, connectivity, disturbances, spatial planning, socioeconomic context, integral

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Planting 180 Million Trees in Colombia: Meeting the Challenge of a Successful Ecological Restoration through Regional Involvement and Strong Networking

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In the decade of restoration (2021-2030), many global initiatives have emerged associated with ambitious planting trees goals, and Colombia has not been the exception. The Humboldt Institute is an articulating and advisory entity for ecological restoration processes, sought that the plantings be restoration projects with long-term socioeconomic and ecological objectives with the regional support of a network of allies and local communities. The strategy highlight restoration as a value chain with multiple objectives treasuresing from those who know the phenology of trees to collect the seed on time, to those who receive the tree in their territory with a commitment to care for it and use it sustainably. Plantings were carried out under conservation agreement schemes, in strategic ecosystems of the country, such as the tropical dry forest, wetlands and high lands. Priority restoration areas, planting designs with a high diversity of native tree species, support and technical assistance in species propagation, environmental education programs and pilot cases of sustainable value chains with profitability evaluations in community nurseries were considered. Also, the first network of nurseries for native tree species in Colombia was consolidated with more than 200 nurseries, most of them private and community-based. Under this scheme, together with botanical gardens, educational institutions and community associations, 156,824 trees were planted, of 303 species of native tree species of ecological importance for the country, with a total of 212.3 hectares, and 134 planting agreements. A new platform for monitoring active restoration processes with the support of regional alliances and a network of nurseries. **Keywords:** Tree planting, ecosystem restoration, nurseries.

From traits to ecosystems: remote sensing of tropical forest structure and function under environmental change

Architectural Traits of a Costa Rican Dry Forest Tree Community Derived from LiDAR Scanning

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Introduction: Over a decade ago, a general theory of forest structure and dynamics (GTFSD) was proposed to account for power-law patterns of tree size and density scaling across forests (West et al. 2009, Enquist et al. 2009). The GTFSD assumes the origin of power-law scaling in forest ecosystems ultimately lies in the geometry of plant branching networks (West et al. 1999). It appeals to the intuition that forests are groups of trees fluxing energy and matter through branching resource distribution networks, analogous to the way that trees are groups of branches fluxing energy and matter through a single stem--the forest 'is' the tree. This work tests the idea that variation in the size structure of forest populations can be partially explained by the architectural branching traits of vascular networks in tree species. **Objective(s):** i) Extract the branching traits of trees using LiDAR scans and census data to sample individual vascular networks from plot-level 3D scans ii) Given the following hypotheses: -Locally, branching traits vary across species, evaluate the corresponding predictions:Local deviations from the expected size distributions will be explained in terms of deviations from the expected branching geometry across species. **Methods:** We focus on the stem-radius frequency distribution which is the most fundamental representation of forest structure in GTFSD. Taking the expression for the density of individuals of a given mass, and the stem size of an individual of a given mass, we link the radius and length scaling of tree branches to the overall size distribution of individuals in a forest. Size-frequency distributions were estimated from recent census data using standard methods (White et al. 2007). Tree networks were extracted from 3D LiDAR data using spatial coordinates in stem census data and treeseg. Once networks are sampled, processing will consist of fitting cylinders to individual branches to reconstruct the vascular hierarchy and measure branching traits (Raumonen et al. 2013) **Results:** Radius scaling is uniform across tree species due to strong constraints on hydrodynamics in vascular transport. Variation in branch length scaling explained more variability in size structure across species. **Implications/Conclusions:** Reconciling broad theories of organismal form and function with the magnitude of variation and diversity within ecosystems remains one of the central grand challenges in ecology. The relaxed GTFSD framework presented above could allow better predictions of scaling patterns within and across forests by measuring vascular networks. **Keywords:** Terrestrial laser scanning ,tree architecture, metabolic scaling theory ,seasonally dry tropical forest

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Pantropical Plant Functional Traits Dynamics Mapping and Predicting by Integrating Radar and Field Data on the Google Earth Engine Platform

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In the context of global biodiversity loss and the ongoing degradation of ecosystems, it is indisputable that people must take urgent actions on forest management and conservation. As the most biodiverse ecosystem on earth and the largest above-ground carbon reservoir, tropical forests play a vital role in adjusting the global climate and atmosphere, which makes understanding, monitoring, and predicting the spatiotemporal dynamics across this biome and exploring tropical ecosystems composition, structure, and function a high priority for mitigating and halting biodiversity loss. The main goal of this study is to track key plant functional traits (including chemical, morphological, and photosynthetic traits) across the tropics by combining with the high-resolution Sentinel-1 synthetic aperture radar (SAR) imagery, *in-situ* plot vegetation census data collected in six countries covered the four tropical continents, and other ancillary data (e.g. climatic and soil data), on the free-to-use Google Earth Engine cloud platform. Specifically, three vegetation indices and texture features were calculated and derived from SAR imagery. Then the machine learning algorithm Random Forests was applied to map and predict plant functional traits distributions across the tropics. Eventually, we conducted variable importance computation and accuracy assessment to analyse the potentialities of Sentinel-1 SAR data for large-scale biodiversity monitoring and ecosystem conservation. Our study aims to investigate the application of Sentinel-1 SAR imagery for mapping and predicting plant functional traits distributions across the tropical forest biome and to evaluate the potentialities of Sentinel-1 data for biodiversity monitoring and ecosystem conservation. To the best of our knowledge, we are the first to propose the method for mapping and predicting the distributions of plant functional traits using Sentinel-1 SAR imagery and assess the robustness of Sentinel-1 data in ecological applications. Overall, SAR vegetation indices demonstrated a strong correlation with plant functional traits, which proved our method's effectiveness for mapping and predicting plant functional traits patterns across the tropics. **Keywords:** Plant functional traits, radar, tropics, google earth engine, random forest

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The Variation of Canopy Functional Traits across the Tropical Forest Biome

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Tropical forest ecosystems are undergoing rapid transformation as a result of changing environmental conditions and direct human impacts. However, we cannot adequately understand, monitor or simulate tropical ecosystem responses to environmental changes without capturing the high diversity of plant functional characteristics in the species-rich tropics. Failure to do so can oversimplify our understanding of ecosystems responses to environmental disturbances. Innovative methods and data products are needed to track changes in functional trait composition in tropical forest ecosystems through time and space. This study aims to track key functional traits by coupling Sentinel-2 derived variables with a unique data set of precisely located in-situ measurements of canopy functional traits collected from 2434 individual trees across the tropics using a standardised methodology. The functional traits and vegetation censuses were collected from 47 field plots in the countries of Australia, Brazil, Peru, Gabon, Ghana, and Malaysia, which span the four tropical continents. The spatial positions of individual trees above 10 cm diameter at breast height (DBH) were mapped and their canopy size and shape recorded. Using geo-located tree canopy size and shape data, community-level trait values were estimated at the same spatial resolution as Sentinel-2 imagery (i.e. 10 m pixels). We then used Random Forest to model and predict functional traits across the tropical forests at a pantropical extent. We demonstrate that key plant functional traits can be predicted across the tropicsusing the high spatial and spectral resolution of Sentinel-2 imagery in conjunction with climatic and soil information. Image textural parameters were found to be key components of remote sensing information for predicting functional traits across tropical forests and woody savannas. Our approach offers new opportunities for mapping, monitoring and understanding biodiversity and ecosystem change in the most species-rich ecosystems on Earth. **Keywords:** Tropical forest, traits, ecosystem functions, remote sensing, satellite, sentinel-2

Global Mapping of the Photosynthetic Capacity of Tropical Forests Using Sentinel-2A Imagery

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Tropical forests account for one-third of terrestrial productivity but face a multitude of threats from climate change and direct human impacts. Landscape level maps of photosynthetic capacity would help determine pan-tropical drivers of photosynthetic capacity and generate robust projections of regional and global environmental change. We use a unique dataset of photosynthesis, collected from 990 trees using standardised protocols, to map Vcmax25 and Jmax25 across the tropics. Our field sites represent 35 tropical forest plots, cover all tropical continents, and include an elevation, precipitation, and logging gradient. Photosynthetic data was geolocated using LiDAR-mapped tree crowns, and combined with Sentinel-2A imagery and environmental datasets in Google Earth Engine to create Random Forest maps of Vcmax25 and Jmax25 across lowland only and lowland-montane tropical forest. At intercontinental scales, we find that Vcmax25 and Jmax25 are mainly controlled by climate. At the regional level, trait distributions are shaped by soil type. At local levels, trait patterns reflect spectral variation arising from topography and canopy structure. Our approach offers new opportunities to measure and monitor tropical forest productivity and improve the representation of photosynthesis in the next generation of Earth System Models. **Keywords:** Tropical forests, photosynthesis, remote sensing, Sentinel-2A

Integration of Leaf Spectral Reflectance Variability Improves Classification at Different Taxonomic Levels

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The spectral reflectance of leaves is influenced by both the environment and relatedness between species since it is a product of the absorption of light by important structural and functional components of the leaf and other traits shared among closely related species. Through this work we illustrate that the spectral reflectance of leaves is an effective tool for inferring plant taxonomy, but the primary drivers of variability, including time of the year, need to be included in the spectral classification. We collected spectral reflectance, from the visible to the shortwave infrared (500 – 2400nm), of leaves from 42 woody tropical species belonging to six botanical families growing at the Enid Haupt Conservatory at the NYBG during the spring of 2019, summer of 2020, and winter of 2021. Although, these species are not growing in their natural environments, we know that the spectral reflectance varies with the seasons in the tropics as well. To classify leaves to species we ran a partial least square discriminant analysis (PLS-DA) for the spring leaves, and this yielded high accuracy (>90%) at the family and genus levels. Testing for the effect of time of collection in leaf reflectance in the PLS-DA classification, we first use the spring dataset to train the PLS-DA model and used the summer and winter datasets to test the model. In this approach we found that the classifications at the family, genus, and species levels were significantly lower in accuracy (<60%). To account for this uncertainty, we created train/test datasets with a stratified random data partition across species and collection dates, along with k-fold cross-validation. The results for this expanded PLS-DA classification were significantly more robust (>90%). We also calculated the coefficient of variation (CV) to visualize the effects of the collection date on the spectral signature and showed that the areas of highest CV were in the visible and the shortwave infrared (1300-2400nm). We also ran a correlation analysis with functional traits: leaf pigment, water, nitrogen concentrations and leaf mass per area – estimated from spectra by inverting existing PLS models and a Bayesian inversion of the PROSPECT model to see how traits and spectra co-vary over the dates. With these functional traits we run a principal component analysis taking into consideration the phylogenetic relationships of species. We find that accuracy in calculating species richness and the functional space of plants can be maintained if spectral variability is factored in. **Keywords:** Leaf spectral reflectance, taxonomy, leaf functional traits, phylogenetic PCA

Assessing the Link between Spectral Diversity and Functional Diversity

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We are witness to the greatest loss of biodiversity, the rate of biodiversity loss is only comparable to the major extinction events registered in the fossil record. In light of these losses, developing new ways to characterize and monitor biodiversity that takes advantage of remote sensing technologies and products is critical to inform conservation actions and develop effective management strategies to address global change. In this study, I evaluate the strength of the relationships between functional and spectral diversity in the Southeast United States. Specifically, I tested the extent to which plot-based metrics of plant functional diversity and airborne-based spectral diversity metrics are related. The results showed both positive and negative relationships between metrics of plant functional diversity and remote sensing metrics of diversity. Overall, the strength and direction of the relationships vary with metric complexity, where simple metrics showed strong associations between functional with metrics derived from hyperspectral imagery. The results presented here contribute to the development of generalizable approaches for assessing plant biodiversity across multiple spatial and temporal scales. **Keywords:** Bayesian modeling, functional traits, hyperspectral imagery, metrics of biodiversity

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Estimation of Forest Stand Structure in Andean Landscapes Using 3D UAV Remote Sensing

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Background: Satellite remote sensing of vegetation, its structure, functional and physiological properties is essential for studying and monitoring ecosystems. However, optical and multi-temporal satellite data for the tropical Andes is limited by the presence of clouds and requires processing due to the rough topography. Unmanned Aerial Vehicles (UAV), equipped with low cost RGB cameras offer a cheap alternative, since they can provide data of high spatial and temporal resolution, hardly affected by clouds. Using UAV images, 3D models of the vegetation surface can be reconstructed using Structure from Motion (SfM) algorithms. Features extracted from these 3D point clouds can be used to estimate the space-filling by vegetation and can provide additional information on forest structure. **Objective:** Here, we assess the usefulness of 3D features extracted from UAV sensed 3D point clouds to predict vegetation structure. **Methods:** We acquired UAV images of a complex structured Andean landscape along a gradient from monoculture crops of coffee and cacao, over diversified agroforestry systems to conserved Andean Forest of the Yariguíes National Natural Park. We characterized vegetation structure in the midstory and overstory layers over 34 plots using the Point Centered Quarter Method (PCQM) and hemispherical photography. We estimated tree density, height, basal area, leaf area index (LAI), canopy closure and above-ground biomass (AGB). From 3D reconstructions we generated canopy height models (CHM) and derived features based on the height of the points, like maximum height (Hmax), height distributions, skewness, entropy, vertical complexity index (VCI), surface area and volume spanned up by the CHM. Finally, we used different univariate and multivariate models to predict vegetation structure from these 3D features. **Results:** Overall, vegetation structure derived from 3D features allowed to discriminate between agroforestry plantations of coffee, cacao and forest. Using a redundancy analysis, we found that 71% of the variance of vegetation structure can be explained by 3D features. Furthermore, multiple linear models showed significant relationships of predictor features like Hmax, VCI and surface area with on ground variables such as AGB, height in the mid- and overstory, also including density of shade trees. **Conclusion:** 3D point clouds derived from UAV sensing using standard optical sensors are useful to predict stand structure and provide an opportunity to study the horizontal and vertical structure of vegetation. In the future, these 3D features could be contrasted with biophysical characteristics and biological inventories of forests and strengthen biodiversity studies using UAV remote sensing. **Keywords:** UAV, SfM, forest structure, habitat monitoring, biodiversity conservation

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Data Fusion to Hindcast Forest Structural Trajectories during Secondary Succession in Tropical Forests

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The global extent and multi-decadal timespan of Landsat satellite data presents an unprecedented data source for understanding ecological dynamics. Tropical forest succession represents an ecological dynamic that is highly variable across landscapes and regions. Nevertheless, forecasting rates of second-growth forest succession is crucial for restoration planning, including to determine which areas will recover under natural regeneration. The Landsat satellite record represents a potential dataset that can inform historic rates of forest recovery, however, distinguishing between biological variability and measurement error related to remote sensing challenges interpretation of Landsat-derived successional trajectories. We present a Bayesian state-space modeling framework for disentangling biological process from measurement error to model canopy height dynamics in second-growth forests. Our approach enables model-based estimates of canopy height from Landsat imagery via fusion with aerial lidar. We demonstrate our framework in Southwestern Panama, a heterogeneous landscape undergoing variable rates of secondary succession. We found that data fusion using our state space model improved accuracy of hindcasts of forest succession and decreased uncertainty in which sites were undergoing fast vs. slow succession. As a multitude of remote sensing data sources come online, each with their own strengths and limitations, data fusion represents a powerful tool to combine information for inference on ecological dynamics. We conclude with a discussion of how our approach could be upscaled to model forest recovery trajectories across large spatial extents. **Keywords:** Tropical dry forest, lidar, natural regeneration, Azuero Peninsula

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Hydrological Environments, Climate, and Plant Traits Structure Large-scale Amazon Forest Drought Response

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The Amazon rainforest acts as one of the largest terrestrial contributors to global carbon cycling. However, the response of Amazon forests to climate variability and long-term change is highly uncertain. We focus on investigations, encompassing the effects of climate, interacting with hydrologic, edaphic, and geomorphological variations across different forest ecotypes and over multiple events, on ecological responses to drought. Remotely-sensed greening/browning responses to multiple droughts are examined by identifying three regionally-affiliated Amazon Forest ecotypes, defined by fertility, climate, and vegetation traits, with distinct drought responses. We found, in fertile Southern Amazonia, local hydrological environments structured drought response: remotely-sensed drought-associated "green-up" was greater in shallow water table forests (SWTF, whose greater water availability heightened responsiveness to excess sunlight) than those with deep water tables, but diminished with drought duration. In other regions, however, unexpected "green-up" during drought was driven instead by drought-associated relief from extreme wetness (in the Everwet northwest), or by presumed deep-water access of taller more resilient dense-wood trees (in the northeastern Guiana shield). These findings suggest that fertility, climate and community adaptations to local environments jointly determine forest vulnerability. **Keywords:** Amazon Forest, photosynthesis, drought, remote sensing, hydrology

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Using GEDI Tree-height Data to Understand the Large-scale Dynamics of Tropical Mountains Mediated by Landsliding

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Introduction: Landslides contribute to the large-scale dynamics of tropical montane ecosystems, yet compared to other disturbances, they remain largely understudied. The acquisition of vegetation height data by the Global Ecosystem Dynamic Investigation GEDI in combination with Landsat Analysis Ready Data (ARD) may offer the possibility to examine the integrated response of landslides on tropical montane ecosystems at landscape scales. **Objectives:** Focusing on the Sierra de Las Minas of Guatemala (SLM) we 1) develop a regional model linking metrics derived from Landsat data with GEDI's tree height to produce a temporal series of continuous, high-resolution tree height maps and 2) characterize patterns of vegetation re-growth and biomass accumulation in the areas affected by landslides. **Methods**: To address our objectives we combined three broad sets of approaches. First, we built a historical landslide geodatabase using images from the mid 1960s - 2020 that was orthorectified, mosaicked, and classified using ERDAS' Imagine Feature Extraction tools. Second, we used Boosted Tree (BRT) Regressions to model the relationship between GLAD's Landsat ARD Pheno metrics and GEDI's v2 RH95. This model was used to predict RH95 over the SLM for each year included in the Landsat series (2000-2020). Lastly, we examined the temporal variation of tree height in our mapped landslides to understand changes in forest structure and biomass during succession. **Results**: A first BRT revealed a good agreement between the tree height predictions and RH95, and we used the models to produce continuous, tree-height maps. Overall, the maps reflectected broad differences in vegetation types, including disturbance by landslides. Next, we visually inspected the RH95 footprints and predicted heights in well-known areas and found that these variables either sub-estimated the height of tall trees or over-estimated the height of short vegetation. In the SLM where trees may reach up to 50 m, the sub-estimation of tree height may have important consequences for the characterization of forest structure and calculation of biomass. Similarly, the over-estimation of vegetation height of small-stature vegetation - whether natural formations or successional states - may result in vegetation re-growth or biomass accumulation rates taht are not indicative of existing conditons. **Implications/Conclusions**: The use of GLAD's Landsat ARD data with GEDI's tree height data offered the possibility to generate the first, heigh-resolution tree height maps for the SLM. Nevertheless, this effort is a continuous reminder of the challenges involved in the use of remote sensing data in mountainous areas. **Keywords:** GEDI, landsat, landslides, succession, mountains, remote sensing

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Insular habitat fragmentation induced by hydroelectric dams: an emerging threat to biodiversity

Hydropower: An Emerging Driver of Biodiversity Loss, an Established Model for Fragmentation Science

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Introduction/Background/Justification: Expanding human populations, increasing energy demands, and a shift towards low-emissions energy sources have together triggered a rapid rise in hydropower. Much of the expansion of this industry has occurred in developing nations, where hydropower now represents a key driver of habitat loss in tropical forests. Threatened species and entire ecological communities may be imperiled by the growth of hydropower. At the same time, research in hydropower reservoirs has advanced our understanding of fragmentation science, providing insights which can help predict consequences of fragmentation in terrestrial landscapes. **Objective(s)/hypothesis(es):** There are two objectives: (1) to quantify the extent to which hydropower has and will continue to drive threatened species towards extinction, and (2) to assess the contributions of studies based in hydropower reservoirs and the extent to which they have advanced our understanding of fragmentation. For the former, we selected tigers and jaguars as focal species. **Methods:** We compiled information on existing and planned hydropower dams intersecting the current distribution of tigers and jaguars. We then matched the reservoir footprint with published estimates of species densities for tigers/jaguars. We also reviewed studies from hydropower reservoirs and their insights into fragmentation science. **Results:** We identified 164 existing dams overlapping the current range of jaguars and 421 dams intersecting the distributions of tigers. In total, these reservoirs covered 25,397 km^2 in the Neotropics and 13,750 km^2 in the Paleotropics. This habitat loss potentially accounts for the loss of 915 individual jaguars (0.53% of the total population) and 729 individual tigers (20.8-22.8% of the total population). Looking forward, we identified 429 dams planned within the distribution of jaguars and 41 within the distribution of tigers. **Implications/Conclusions:** Our findings suggest that hydropower has already become an important driver of population decline for tigers, and will likely become the same for jaguars in the decades ahead given rampant hydropower development in the Neotropics. However, this energy source has also become vital towards electricity generation in many tropical countries (e.g., >70% for Brazil, which sustains more than half of the global jaguar population). At the same time, hydropower reservoirs have offered insights into fragmentation science, spanning topics including (1) ecosystem disassembly, (2) extinction debt, and (3) evolution. Existing hydropower study sites should remain a key focus for research to provide further insights into the consequences of fragmentation, but the expansion of this industry should be curtailed to avoid further threats to apex predators and tropical forest ecosystems.
Keywords: Apex predators, fragmentation, hydropower, jaguars, renewable energy, tigers

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The Prevalence and Diversity of Avian Haemosporidians in Fragmented Habitats of the Thousand Island Lake, China

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Haemosporidians are one of the most common parasites infecting birds and often negatively affect host fitness. However, how anthropogenic habitat fragmentation may impact the diversity and infection risk of avian parasites remains less described, especially in habitats induced by the construction of hydroelectric dams. Here, we sampled birds on islands and mainland areas of the Thousand Island Lake (TIL) to describe the prevalence and diversity of avian haemosporidian parasites in fragmented habitats. We used molecular-based methods to detect parasites (*Plasmodium*, *Haemoproteus* and *Leucocytozoon*) and to identify the sex of each bird individual. We compared avian haemospordians between islands and mainland areas to investigate the effects of insularity on parasite diversity and disease risk while accounting for bird phylogenetic relationships, morphology traits and functional traits. Overall, we screened 1100 individuals which belongs to 86 bird species. The prevalence was highest for *Leucocytozoon* (18.55%), followed by *Haemophroteus* (14%) and *Plasmodium* (9.55%). We identified 158 lineages of avian haemospordians in the TIL region, with 95 of them (60%) were new records. We found recued prevalence on islands than on the mainland for overall infections, but this pattern persisted only for *Haemophroteus* when separated by different parasite genus. In addition, the prevalence of each genus was associated with different avian functional traits including dispersal ability, flocking tendency and migration status, while individual morphology traits play a minor role. Although we found a slight trend of reduced alpha diversity of avian hameospordians on islands, it was insignificant for either the three genera overall or separately. Collectively, our study reveals that habitat fragmentation can partially influence the parasite pressure for island birds, but it may further depend on the specific genus of parasites and the functional traits of birds. **Keywords:** Bird, diversity, haemosporidian, habitat fragmentation, insularity, prevalence, Thousand Island Lake

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Effects of Habitat Insularization on Amazonian Arthropods and Their Ecological Processes in a 30-year-old Forest Archipelago

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Major hydroelectric dams are among the principal emergent agents of habitat loss and fragmentation in lowland tropical forests. Arthropods play an critical role in maintaining the health and stability of Neotropical forest ecosystems. Here, we investigate how orchid bees, ants, social wasps, harvestmen and dung beetles responded to the effects of forest habitat loss, isolation and forest canopy degradation induced by a vast hydroelectric reservoir in Central Brazilian Amazonia. The Balbina Dam was built in 1986, resulting in an archipelagic landscape containing 3,546 primary forest islands of varying sizes and degrees of isolation, surrounded by 3,129-km2 of freshwater and standing dead trees. Using scent, malaise and pitfall traps and active searches, we sampled 34 islands, 14 open-water matrix sites, and three mainland continuous forests. Local orchid bee species richness was affected by forest patch area but particularly by patch isolation and our models indicate that body size was a decisive predictor of occupancy rates, with most isolated sites occupied only by a few large-bodied bees. Isolation was the single best predictor of dung beetle species richness, followed by the interaction between isolation and island area, and these variables were key determinants of the relict species composition. We found that 61.5% of all islands retained only a single super-tramp dung beetle species. Harvestmen species richness was unaffected by any local, patch and landscape variables while composition was affected by forest cover. Social wasp species richness was affected only by island area, whereas species composition was affected by isolation and tree species richness. Ant species richness was also unaffected by any of the patch and landscape variables but composition was affected by area. Retaining large forest habitat patches surrounded by large areas of forest cover would minimize forest disturbance and enhance the long-term persistence of arthropods species in large hydroelectric dams, and these measures should be considered prior to the environmental licensing of new dams. **Keywords:** Hydroelectric dams, Habitat fragmentation, Island biogeography, reservoir islands, tropical forests

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Invasive Rat Drives Complete Collapse of Native Small Mammal Communities in Insular Forest Fragments

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As tropical forests are becoming increasingly fragmented, understanding the magnitude and timeframe of biodiversity declines is vital towards 21st century sustainability goals. Biological assemblages isolated in forest fragments typically experience a novel hyper-disturbance regime, resulting in drastic shifts in species diversity and community composition through species extinction and turnover. Such changes in species assemblages generally exhibit an 'extinction debt' in which species experience a post-isolation relaxation period over the coming decades. It is therefore important to understand the time frame and extent to which species are lost following fragmentation. Our objectives were to quantify the rate at which native small mammal species richness and abundance changed over time, the rate at which hyper-abundance of a native generalist rodent increased over time and identify the primary drivers impacting the trajectory of small mammal richness and abundance using path analysis. Finally, we discuss the implications of the results for the equilibrium model of island biogeography theory (ETIB) and the rates at which 'extinction debts' are paid. To achieve this, we reconstructed previous work conducted in 1992-94 and 2012-13 who surveyed the same small mammal communities over repeated periods on artificially created island fragments that resulted from the construction of the Chiew Larn reservoir in Thailand. In 2020, we completed a detailed timeline of the decline in species richness and abundance in response to fragmentation spanning 33 years post-isolation. Sampling effort from all time periods amounted to the total capture of 1,789 small mammal individuals from 12 species. A combination of linear modelling and piecewise Structural Equation Modeling (SEM) were used to understand the importance of the Malayan field rat *Rattus tiomanicus,* a hyper-competitive *generalist species,* as an indirect driver of small mammal species richness and abundance decline. We demonstrate a complete collapse of the species-area relationship within 33 years, with no evidence of a re-colonization effect across repeatedly sampled islands. We also reveal a decline in species richness due to island size and isolation time, accelerated by the increasing dominance of *R. tiomanicus*. We conclude that insular forest fragments are highly susceptible to rapid species loss, particularly due to the competitive nature of *Rattus* accelerating the rate at which extinction debts are paid, representing a departure from the main tenets of ETIB. To mitigate these impacts, reducing the extent of habitat degradation, as triggered by fragmentation and exacerbated by isolation time, can help to sustain native biodiversity while averting *Rattus* hyper-abundance. **Keywords:** Extinction debt, forest fragmentation, habitat loss, invasive species, species-area relationship

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Partitioning Extirpation and Colonisation Components of Avian Beta Diversity on Land-bridge Islands

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Temporal β diversity reflects the changes in community composition through time, which usually results from species losses and gains. However, the temporal dynamics of β diversity caused by extinction and colonisation remain unclear. Here, we partitioned the temporal β diversity of bird communities into extinction and colonisation components by using two periods of bird dataset in the Thousand Island Lake, China. We further assessed the effects of island area and isolation on dynamics of avian β diversity. We found that the bird species colonisation increased, but bird extinction decreased the overall avian β diversity on the islands spanning ten years. These results indicate that local extinction results in more homogeneous bird communities while the colonization of new species simultaneously leads to heterogeneous, offsetting each other. We also found that neither differences in area nor inner distance between pairwise islands significantly affected the total temporal changes in β diversity of birds. However, the partitioning indicated that the extirpation-resultant homogenisation and heterogenization were both lower between islands with larger differences in sizes. The further partitioning on temporal changes in avian β diversity via six types of extinction and colonisation processes showed that both loss and gain of different rare species on similar-sized islands decreased β diversity (biotic homogenisation). In contrast, the loss of widespread species on similar-sized islands increased β diversity (biotic heterogenisation). The distance between islands had no significant effects on the temporal changes in β diversity of birds. Our results reveal that the temporal β diversity of birds on fragmented islands was determined by both extinction and colonization, with the heterogenization caused by colonization of rare species being predominated. Thus, to further maintain or increase regional composition variation of birds in fragmented habitats,

we could introduce suitable rare species from the regional pool on different islands. Our results highlight that the extinction-colonisation dynamics behind beta diversity are essential for understanding the spatiotemporal organisation of biodiversity. **Keywords:** Avian communities, β diversity partitioning, colonization, extinction, land-bridge islands, temporal

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A Tale of Savanna Lizards in Artificial Islands in Central Brazil

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Although artificial islands are often formed as a consequence of anthropogenic impacts in ecosystems, they provide opportunities to test some traditional assumptions of the theory of Biogeography of Islands and further effects of habitat fragmentation. Since 1996 we conducted studies focusing on how the formation of small artificial islands affects the ecology of Cerrado lizards. The Serra da Mesa reservoir, formed in October 1996, is the largest in water volume and the fourth in surface area in Brazil. Before reservoir formation, we selected 10 hilltops for long-term monitoring. We conducted samplings from May 1996 to January 1999, from May to September 2001, from July to September 2011, and from June to July 2019. The regional pool was originally composed of 19 lizard species belonging to 10 families. The movement of lizards from valleys to higher areas during flooding caused a noticeable crowding and increased species richness on the hilltops. However, two species disappeared from islands in 1999. In 2001, the richness of islands was smaller compared to plots in reservoir margin but was twice abundant. At this moment, island lizards had a lower body condition than individuals in the margins but were not more asymmetrical. The species that declined or disappeared from islands were the largest and commonest before insularization. Island lizards had similar body condition to lizards in margins in 2011 but were more asymmetrical. In 2019, we found only five species on islands. The more resilient species in islands, the gecko *Gymnodactylus amarali*, presented rapid changes in morphology, ecology, and eventually in its genetics, caused by isolation. Island geckos have larger heads and wider niche breadth compared with margin individuals. They also presented distinct climatic-adapted SNPs compared to populations in near localities. Insularization caused deep changes in the diversity of Serra da Mesa lizards, reducing species richness, impoverishing communities, and affecting individuals' fitness, performance, and survival. It also provoked rapid adaptations in morphology, ecology, and genetics of more resilient species, suggesting that some Cerrado lizards can respond quickly to anthropogenic changes, although we are convinced that we studied a vanishing fauna, in an extinction-debt context. **Keywords:** Cerrado, Insularization, body bondition, fluctuating asymmetry, species loss, rapid changes

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Microhabitat and Island Area Affect the Abundance and Richness of Ants on Fragmented Habitat Islands

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The theory of island biogeography predicts the number of species on islands is balanced by species colonization and extinction through the function of island area and isolation. It indirectly assumes the habitats on islands are homogeneous. However, for some species, especially insects, the microhabitats may be more vital for their survival on islands. Here we assessed the jointed effects of microhabitats (canopy density, depth of leaf-litter, cover of leaf-litter, cover of moss, cover of vegetation and number of seedling) and island attributes (island area and isolation) on ants' species richness and abundance on 33 island fragments in the Thousand Island Lake, China. We placed pitfall traps to capture ants and collected the microhabitats around each pitfall trap. We divided all ants based on diet (predator and omnivore) and used Principal components analysis (PCA) on microhabitats data and extracted the PCA axis as new microhabitats variables. We then used Generalized Linear Mixed Model to test the relationship between species richness (and abundance) and PCA axis and island attributes. The first PCA axis (PC1) represent microhabitats with high light availability, low amount of leaf-litter and high level of understory vegetation, whereas the second PCA axis (PC2) represents site with moderate light availability and lower amount of understory vegetation. We found overall and omnivore species' abundance increase with PC2, indicating that ants with abundant group tend to utilize the microhabitats with more barren or bare ground with a great amount of moss as some omnivore species could directly feed on moss. However, both richness and abundance of predator species increase with island area and decrease with PC1. These results indicated that predator species are more vulnerable of habitat fragmentation, as smaller fragments

support less predator species which in line with tropic theory of island biogeography. Meanwhile, predator also prefer the bare ground but with typical requirements of more canopy cover and less moss cover. Our results indicated that the important of microhabitat of fragmented habitats in determining the ant's species richness and abundance. Additionally, predator species are at higher tropical level and their richness and abundance are essential to the ecosystem health. Thus, conservation effort should focus on those habitats that can support more predator species in fragments. **Keywords:** Ant, habitat fragmentation, predator species, Thousand island lake

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Surviving Island Life: Island Colonisation Leads to Rapid Behavioural and Morphological Change

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Introduction: Islands are biodiversity hotspots. They tend to have high endemism and often function as engines or adaptive radiation. Nevertheless, we lack a deep understanding of the processes that generate phenotypic divergence when populations first colonise islands. **Objectives:** Crucial questions include, 1) Do populations experience niche shifts when they are freed from competition and predation, and how fast do these changes occur? 2) Do shifts in niche occupancy result in phenotypic divergence from mainland populations? **Methods:** To investigate these questions, we transplanted hundreds of slender anole lizards (Anolis apletophallus) from mainland Panama to three islands in the Panama Canal (Lake Gatun) that are species-poor compared to the mainland. **Results:** We found that island lizards changed their behaviour immediately after colonisation, perching on lower and broader surfaces. These behavioural shifts corresponded with selection on a range of traits in the founder population, followed by shifts in the trait means in the second generation. **Conclusions:** Our results reveal that colonising individuals can change their behaviour rapidly to exploit new structural niches, and that substantial shifts in morphology can occur after only a single generation. These changes, which are probably facilitated by ecological release, may represent the first steps in adaptive radiation and show us how species may overcome habitat fragmentation. **Keywords:** Anolis, behavioural drive, bogert effect, experimental evolution, island biogeography

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Are Habitat Loss and Fragmentation Effects on Small Mammals Mediated by Higher Trophic Levels? — Insights from Amazonian Forest Islands

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Under habitat loss and fragmentation, the intensity of local ecological processes involving species interactions changes pervasively, accelerating local species extinctions, and disrupting essential ecosystem functions. We addressed this issue by examining the direct effects of forest area on small mammal (<1kg) assemblages and the indirect drivers as mediated by the persistence of higher trophic levels composed by mammal mesopredators and apex predators. This further allows us to disentangle the relative contribution of top-down vs bottom-up forces regulating assemblages of small mammals. We then considered three alternative hypotheses: (1) only forest area positively affects small mammals, denoting the predominance of bottom-up forces, (2) only predators negatively affect small mammals, suggesting that top-down forces are acting, and (3) both forest area and predator effects are important, suggesting that both forces have a role in ruling mammal assemblages. These three mammal groups composed a tri-trophic foodweb surveyed in 25 forest islands of varying sizes and degrees of isolation within the Balbina Hydroelectric Reservoir in Central Brazilian Amazonia, in addition to three adjacent continuous forest sites. Small mammals (rodents and marsupials) were surveyed using live- and pitfall-trapping and mammal mesopredators and apex predators were surveyed using camera-trapping. As response variables for each mammal group, we selected from one of three options: standardized abundance, biomass and metabolic biomass (biomass$^{0.75}$), according with their explanation of the data. Each of the above-mentioned hypotheses was tested using a piecewise structural equation model (SEM), which fitting was

compared using the Akaike Information Criteria for small sample sizes. Apex predator biomass increased with forest area, as well as the abundance of mesopredators. Metabolic biomass of small mammals, however, was not affected by forest area. From the three hypothesized SEMs, the best explaining the data was the one considering both direct and indirect effects of forest area. According to that, forest area had a positive effect on both apex and mesopredators, whereas mesopredators had an unexpected positive effect on small mammals. As such, although the best model included both direct and indirect effects, the results of that model support the predominance of bottom-up forces regulating this foodweb. This clear prevalence of such mechanisms renders forest islands more susceptible to other major disturbances detrimentally affecting forest dynamics, including timber extraction and the ravages of climate change. Our findings can be used to inform the long-term viability of forest ecosystems affected by hydropower development in lowland Amazonia. **Keywords:** Amazonia, bottom-up forces, habitat loss and fragmentation, island systems, top-down

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Matrix-subsidized Tropical Forest Remnants Retain Threefold More Bird Species than Analogous Islands

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The species-area relationship (SAR) is an essential conservation tool, allowing extinction rates to be predicted based on habitat loss. Naturally formed islands are often used as a baseline when predicting the effects of isolation, age, and matrix type on SARs, but they are anachronistic analogs for remnant habitat "islands" created by land-use change. Here, we contrast forest islands created by damming rivers with forest fragments created by land clearing to examine the effects of the matrix (*i.e.*, land vs. water) on the SAR of birds. We compare 50 SARs based on 1,963 bird species in tropical and subtropical forests, including 1,016 forest remnants. Extinction rates predicted from forest remnants within a terrestrial matrix ($N = 680$) were 14.0% lower than human-made forest islands in an aquatic matrix ($N = 336$). Moreover, matrix effects became more pronounced when examining only 1,506 forest-dependent bird species, whose predicted extinction rate declined by 16.5% and richness nearly tripled (from 7 to 18) in small (˜1 ha) forest remnants in a terrestrial matrix compared to human-made forest islands. We found no support that variables linked with metapopulation dynamics (regional forest cover), extinction debt (isolation time), and global biogeography (elevation, latitude, and regional species pool) explained the observed variation among SARs. Our analysis provides a fundamental test of one of the theoretical foundations of conservation biology. It demonstrates that forest fragments smaller than 10,000 ha, which represent one of the most threatened and numerically abundant tropical and subtropical forest habitats on left Earth, host substantially more forest-dependent bird species than predicted by the biogeography of naturally formed islands. Our findings highlight the potential role of human-modified habitats in curbing extinctions. **Keywords:** Countryside biogeography, extirpation rates, fragmentation, island biogeography, working lands

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Extending Species-area Relationships to the Realm of Eco-acoustics: the Island Soundscape-area Relationship

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Species-area relationships (SARs) are one of the oldest, best documented, and most ubiquitous patterns in ecology, raising its status to ecological law. However, unlike species richness, little is known about the spatial scaling of alternate dimensions of diversity. Among these other diversity types, the quantification of soundscape diversity, or the spectro-temporal diversity of all sounds produced in the landscape, has seen rapid growth in recent years. Soundscape diversity metrics have successfully been used as descriptors of landscape configuration, habitat identity, ecosystem health, diel and seasonal dynamics, proxies for taxonomic diversity, and more. Still, the effects of island size on the soundscape richness remain unknown. In this study, we examined the relationship between the soundscape richness and island size for a set of Amazonian land-bridge islands in the Balbina Hydroelectric Reservoir. We collected long-duration acoustic recordings for 40 plots on 21 islands ranging from 12 – 668 ha. For each island, we calculated the island-wide soundscape richness (gamma) and assessed its relationship with island size. Furthermore, to disentangle the ecological mechanisms underlying the observed pattern, we decomposed the soundscape richness into its alpha and beta components and evaluated

their relationship with island size. Finally, to assess when and where sound is lost from the acoustic trait space, we quantified the soundscape richness-area relationship for various frequency subsets (above or below 11,025 Hz) and diel phases (day, night, dawn, dusk). For the first time, we demonstrate strong Island SoundScape-Area Relationships (ISSARs), with slopes of comparable magnitude to those previously described in island SAR-studies. We observed a positive relationship between the plot-scale soundscape richness (alpha) and island size, indicative of an area per se effect on the soundscape richness. As the relationship between the beta soundscape richness and island size was negligible, habitat heterogeneity effects were likely not driving the observed ISSAR. Finally, we found that the ISSAR-slope was twice as steep for sounds above 11,025 Hz, indicating that organisms that produce sounds at higher frequencies, such as orthopterans and cicadas, are more vulnerable to the effects of island size. Subsetting the acoustic trait space into various diel phase subsets had a minimal impact on the observed slope values. These findings suggest that soundscape richness metrics can effectively capture fundamental ecological patterns and provide novel insights into the mechanisms driving biodiversity change in complex systems such as rainforests, highlighting their use as a tool for ecological monitoring and conservation biogeography. **Keywords:** Soundscape ecology, eco-acoustics, passive acoustic monitoring, species-area relationships

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Biodiversity-hydropower Tradeoffs of Existing and Planned Dam Infrastructure in Lowland Amazonia

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Tropical countries are experiencing a hydropower development boom, yet environmental assessments of mega-dams fail to properly estimate their ecological impacts. We quantified the amount of forest and biodiversity loss associated with 49 existing (ED) and planned dams (PD) in Brazilian Amazonia, and assessed their biodiversity-hydropower tradeoffs. We projected the archipelagic configuration likely to be created by each PD and estimated local extinction rates for 96 vertebrate species based on species-area relationships from a large hydroelectric reservoir we studied. Once built, these dams will inundate ~1.3 Mha of forests, creating 12,457 islands which are expected to lose 89.9% of their vertebrate populations. Although forest loss within and around the reservoirs is higher in EDs, PDs will on average result in greater biodiversity loss and lower hydropower installation capacity. We call for decisive rethinking by policy-makers and energy strategists about the detrimental impacts of future hydroelectric infrastructure in lowland tropical forests worldwide. Tropical countries are experiencing a hydropower development boom, yet environmental assessments of mega-dams fail to properly estimate their ecological impacts. We quantified the amount of forest and biodiversity loss associated with 49 existing (ED) and planned dams (PD) in Brazilian Amazonia, and assessed their biodiversity-hydropower tradeoffs. We projected the archipelagic configuration likely to be created by each PD and estimated local extinction rates for 96 vertebrate species based on species-area relationships from a large hydroelectric reservoir we studied. Once built, these dams will inundate ~1.3 Mha of forests, creating 12,457 islands which are expected to lose 89.9% of their vertebrate populations. Although forest loss within and around the reservoirs is higher in EDs, PDs will on average result in greater biodiversity loss and lower hydropower installation capacity. We call for decisive rethinking by policy-makers and energy strategists about the detrimental impacts of future hydroelectric infrastructure in lowland tropical forests worldwide. **Keywords:** Hydropower, infrastructure, local extinctions, biodiversity-energy tradeoffs, tropical forests

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Integrating seed dispersal and forest restoration, from animal movement to species interactions

The Contribution of Frugivores to Forest Restoration in Fragmented Tropical Landscapes

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Introduction*:* Forest restoration is a priority strategy for limiting biodiversity loss and mitigating climate change. Increasing forest cover through passive natural regeneration has the potential to sequester significant amounts of atmospheric carbon. Frugivorous birds are good allies to promote forest recovery because they can bring seeds from forests to open areas while moving between forest fragments. However, the contribution of birds to forest regeneration will vary depending on the tree species they interact with and the configuration of the landscape. *Objective*: We evaluate how potential forest recovery and composition vary according to birds' dietary and movement preferences along a fragmentation gradient. **Methods:** To simulate forest restoration potential in open areas within fragmented landscapes, we combined datasets that describe the seed dispersal process: frugivory interactions, bird movements, and gut passage time. Using data from the Southeast Atlantic Forest of Brazil, we fitted three hierarchical models with 1) 346 frugivore interactions between 30 bird species and 41 plant species, 2) bird movement tracks recorded across six fragmented landscapes, and 3) gut passage time of 30 species. We used traits from plants and birds as exploratory variables and bird phylogeny to account for phylogenetic relationships. Using species coefficients from the models, we simulated feeding, movement, and seed deposition events for 1400 birds in ten landscapes (1800 m2) that follow a fragmentation gradient. For each pixel, we evaluated the potential forest composition and carbon stock resulting from avian frugivore mediated seed deposition. **Results***:* We found that the contribution of frugivorous birds to forest recovery varied along the fragmentation gradient and was related to bird species' functional traits. Potential forest restoration decreased drastically in landscapes with less than 30% of forest cover and low connectivity (>100 m between fragments). Moreover, small birds with weak fruit preference were more important for restoration in highly fragmented landscapes, but regenerating forests had lower carbon storage capacity. While large birds, with a strong dependence on fruits, increased the probability of restoring forests with a high carbon stock, but only in landscapes with low levels of fragmentation. **Conclusions***:* Our results suggest that both the frugivore community and landscape configuration interact to determine natural regeneration of tropical forests. From our simulations, forests with high carbon storage potential can regenerate naturally in landscapes with > 30% forest cover. However, in highly degraded landscapes (< 30% forest cover) and those with impoverished frugivore communities, restoration interventions may be needed to regrow carbon-dense forests. **Keywords:** Forest restoration, birds movements, fragmentation gradient, seed dispersal, carbon stock

Habitat Use and Seed Dispersal Effectiveness by Oilbirds (*Steatornis caripensis*) in the Southern Andes of Colombia

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The behavior of frugivorous animals (e.g. movement patterns) usually influence plant populations through processes of seed dispersal, however, there are still systems that need to be described and analyzed. This study analyzed information on the habitat use and seed dispersal effectiveness for a population of oilbirds (*Stearornis caripensis*) in the southern Andes of Colombia. To determine what structural and floristic factors influence habitat choice (such as fragmentation, forest cover, and elevation) we analyzed the frequency of use of different land covers by three oilbirds with GPS devices attached. We also used data from 25 vegetation plots (0.1 ha) to characterized the most frequent sites visited by oilbirds. In addition, geographic information systems were used to evaluate the degree of fragmentation and forest cover in the region, and compare it with the sites frequently used by oilbirds. Seed dispersal effectiveness was assessed from the quantity of dispersed seeds dispersed at the main roosting cave, the estimated number of seeds reaching adequate habitats for establishment, germination rates of dispersed seeds, and estimates of seed and seedling survival (from literature review). Oilbirds prefer to visit dense forests, avoid high altitudes and visit both continuous and disturbed forests. The most frequently visited sites have a high proportion of plants known to be consumed by oilbirds. No relationship was found between seed dispersal effectiveness (SDE) and the mean elevation range of the plant species, but SDE was higher when oilbirds were out of the nesting period. The results suggest that the degradation of oilbird populations may confer negative conservation implications on plants (especially large seeded species). Although oilbirds visit secondary forests infrequently ($< 10\%$), they perform a unique ecological role in dispersing seeds to remote locations, including dense forests, as well as degraded and fragmented environments. Oilbirds may be incorporated in ecological restoration programs that aim to sustainably manage biodiversity. **Keywords:** Moving patterns, PNN Cueva Guácharos, seed dispersal effectiveness, vegetation plots

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Impact of Habitat Loss on Frugivore Assemblages and Seed Dispersal Process in Human-modified Landscapes of Atlantic Forest

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Introduction / Background / Justification: Habitat loss is one the greatest threat to biodiversity with pervasive effects on species diversity, which may generate cascading effects on ecological processes, such as seed dispersal. Thus, understanding how habitat loss affects seed dispersal is fundamental for the conservation and recovery of human-modified landscapes. **Objective(s)/Hypothesis(es):** We gathered a robust database of frugivorous birds and mammals across the Brazilian Atlantic Forest to evaluate the effects of landscape-scale forest loss on richness and occurrence of both groups. We also used a database of 25 bird-seed dispersal networks distributed across the whole Brazilian Atlantic Forest to understand how landscape-scale habitat loss shapes network structure. Finally, we performed removal experiments to evaluate the role of mammals on seed dispersal. Results: We found negative effects of forest loss on frugivorous birds and mammal richness and occurrence. Particularly, forest loss has pervasive effects on network structure decreasing the number of links, the number of interactions, and the connectance. In contrast, nestedness increases with habitat loss. Habitat loss also promotes changes in species interaction, shifting the species playing central roles in network organization or contributing to indirect effects. Lastly, the seed removal was directly affected by forest loss but not by changes in mammal assemblage. **Implications/Conclusions:** Our results unveil the widespread effect of habitat loss on frugivore assemblages. However, we add evidence that the pervasive effects on biodiversity also proliferate on a key ecological process – seed dispersal. Thus, we suggest that increasing the amount of landscape-scale forest cover in the Atlantic Forest is of paramount importance to sustain frugivorous birds and mammals, but also the ecological process they perform. Our approach enables the identification of multiple drivers influencing seed dispersal with several implications for the regeneration and restoration of human-modified landscapes. **Keywords:** Frugivory, frugivorous birds, forest loss, fragmentation, mutualistic networks, seed dispersal

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Seed Dispersal by Animals Recovers Quickly during Passive Restoration

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Introduction: Seed dispersal by animals is key for forest regeneration and passive restoration of tropical forests because it maintains plant diversity and accelerates community turnover. We propose that the assessment of seed dispersal by animals should be included in the management of secondary forests because it provides evidence of the reestablishment of species interactions and ecosystem functioning. **Objectives & predictions:** In this study we examined shifts in the importance of different seed dispersal modes during regeneration by modeling the proportion of trees dispersed by bats, small birds, large birds, non-volant mammals and abiotic means as a function of forest age. Moreover, we predicted that the likelihood of a single plant species being dispersed by multiple dispersal modes (i.e., redundancy) increased over time as non-volant mammals and large birds become more important during regeneration. **Methods:** We used data from saplings and trees collected on a chronosequence that spans >100 years of regeneration in the Barro Colorado Nature Monument. We assigned one or more dispersal modes to each species according to a large data set collected in the last decades at the same site. Moreover, we generated a dispersal redundancy index where higher values indicated that a greater proportion of modes dispersed each species. **Results:** Contrary to expectations, tree species dispersed by non-volant mammals dominated from early stages of regeneration, and recovered to old growth levels after 40 years post-abandonment. Seed dispersal by small birds declined over time during regeneration, while bat dispersal played a relatively minor role in structuring the tree community. Redundancy of dispersal modes across species of saplings and trees significantly increased with forest age, but the change in magnitude was small. **Implications/Conclusions:** Our results suggest that proximity to old growth forests coupled with low hunting, explained the quick recovery of seed dispersal by animals in the Barro Colorado Nature Monument, and especially dispersal by non-volant mammals. We suggest that aspects of seed dispersal should be monitored when managing secondary forests (e.g., while employing an Adaptive Management Cycle). **Keywords:** Natural regeneration, ecological succession, functional redundancy, dispersal modes

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Frugivore Composition Influences Seedling Community Composition and the Trajectory of Forest Regeneration

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Background: Seedling community assembly after disturbance sets the trajectory for future forest composition. Seedling recruitment depends on seeds reaching a given area and then successfully navigating the gauntlet of abiotic and biotic challenges in that spot. The importance of the dispersal step in this process is often under-appreciated, perhaps because the vast majority of seeds that reach an area are unable to establish. **Hypothesis:** Seed dispersers are an important biotic filter affecting plant community assembly, therefore the composition of frugivores in a forest community influences seedling recruitment patterns and ultimately sets the trajectory for future forest composition. **Methods:** To assess the influence of dispersers on forest regeneration, we compared seedling regeneration across three islands that vary in their frugivore communities. Guam has lost nearly all frugivores due to predation by a non-native snake, leaving only feral pigs for dispersal. The nearby island of Rota has a depauperate bird community but still has fruit bats, and the island of Saipan has a relatively intact bird community, but no bats or pigs. We performed belt transect censuses of the understory and adult trees across highly degraded, regenerating, and intact forest on all three islands. For each belt transect, we recorded the abundance of seedlings, saplings, and adults. To understand if seeds were likely dispersed from a nearby adult via gravity or from afar through animal-mediated seed dispersal, we determined whether each seedling and sapling had an adult conspecific within 2 meters. **Results:** The disperser community on each island is reflected in the seedling community composition. First, there are few seedlings in the intact forest away from conspecific adults on Guam, compared to other islands. This is problematic for the trajectory of intact forest on Guam, as the future is likely to be less diverse. The opposite pattern is seen in the highly degraded forest, where there are more dispersed seedlings on Guam than on nearby islands, likely due to the pervasive impacts of pigs. However, many of these dispersed seedlings are from non-native species, foretelling a future forest dominated by non-natives. Rota, which is the only island with a significant bat population, shows a clear signal of bats with increased richness and seedling abundance of bat-dispersed species in intact forest. **Implications:** This accidental experiment highlights the importance of dispersal as the first step of community assembly and demonstrates the critical importance of considering the frugivore community composition in passive forest

restoration projects. **Keywords:** Seed dispersal, community assembly, islands, seedling recruitment, frugivore, forest

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Restoration of Plant-animal Interactions in Terrestrial Ecosystems

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Introduction: Ecosystem restoration is one of the most promising strategies to mitigate biodiversity loss. Plant-animal interactions are critical to biodiversity maintenance and ecosystem functioning and consequently are essential to the success of restoration strategies. However, systematic assessments of how restoration efforts consider such interactions are lacking. **Objectives / Hypothesis:** We synthesized available knowledge on restoration of plant-animal interactions by focusing on four specific questions: (1) to what extent are interactions recovered in restored sites compared to degraded and reference sites? (2) which management practices enhance interaction restoration? (3) which interactions and animal taxa are most frequently studied? (4) is interaction restoration being studied in areas deemed critical for conservation? **Methods:** We reviewed 127 articles that studied plant-animal interactions in habitat restoration and trophic rewilding. These articles focused on either of four key plant-animal interactions: seed dispersal, herbivory, pollination, and seed predation. To assess whether these interactions have been restored, we conducted a meta-analysis using a subset of 56 studies that compared restored systems vs. degraded or undisturbed (i.e., reference) systems. **Results:** Seed dispersal was the most studied interaction, followed by herbivory, pollination, and seed predation. Mammals were the most studied group, followed by birds, insects, and reptiles. Seed dispersal and pollination were recovered in restored sites as compared to degraded sites, but not in comparison to reference sites. While several studies were conducted in critical conservation sites, some biodiversity hotspots, particularly in Southeast Asia, have been understudied. **Conclusions:** Habitat restoration and trophic rewilding seem to be effective in bringing seed dispersal and pollination to a better state than in degraded areas. The evidence for herbivory and seed predation is inconclusive. Interaction restoration research and implementation represent critical, pending agendas, particularly in some tropical regions. **Keywords:** Frugivory, herbivory, pollination, seed dispersal, seed predation, reintroduction, restoration, rewilding.

Large-scale tropical biodiversity change: measurement, implications, and spatial scaling

Resurveying Colombia's Birds: 100 Years after Chapman

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Introduction: Understanding the impact of unprecedented environmental change on the ecological and evolutionary functionality of ecosystems is a global challenge. Fundamental to addressing this challenge are broad-scale, high-resolution, historical baseline biodiversity data. Although rare, when such datasets are combined with comparable modern data they provide unparalleled insight into the varied ways biodiversity responds to environmental change and the processes governing these responses. A century ago, the American Museum of Natural History (AMNH) conducted a series of pioneering ornithological expeditions in Colombia. Our team, the Colombia Resurvey Project, recently collected modern survey and specimen data from six historical AMNH localities strategically selected to represent the broad spectrum of elevations and land-use dynamics of the tropics. **Objectives:** Quantify changes in bird communities and their functional diversity over a century, quantify changes in the human footprint over a century and establish the relationship between changes in the human footprint and changes in avian species richness and functional diversity over a century. **Methods:** We used specimens and bird census data for historical and modern expeditions to document changes in the bird communities a century apart (controlling for sampling bias). We graphed functional diversity space for all six communities in the two time periods, and calculated functional diversity indices (richness, evenness, and divergence). We compared the human footprint values at different buffers around a site (500m, 1km, 10km, 100km) and used those the values as explanatory variables in a Generalized Linear Mixed Effect Model with species richness and functional diversity indices as response variables. **Results:** Changes in avian species richness and functional diversity were context-dependent. Overall, sites had declines in functional diversity but species richness either increased or decreased. Functional groups driving this change were large frugivorous birds (extirpated) and small seed-eating birds (colonizers) in different sites. Sites with significant human footprint increase had more significant decreases in functional diversity. Sites with little change in the human footprint had stable bird community composition and functional diversity. Changes in human footprint were more meaningful at local and landscape scales. **Implications:** We show how bird community composition and functional diversity varied over a century of landscape change. The insights gained by comparing these historical and modern biodiversity data are essential to building and improving forecasting models of the impacts of environmental change on biodiversity at multiple temporal scales, preventing extinction, guiding conservation actions, and informing sustainable management. **Keywords:** Expeditions, human footprint, functional diversity, landscape change, species richness,Colombia

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Unpacking the Spatial Scaling of Biodiversity Loss across Colombia

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Introduction: Estimates of biodiversity loss from land-use change overwhelmingly derive from local-scale studies, but disturbance often spans vast spatial scales transcending abiotic gradients and biogeographic barriers. Because land-use change might differentially impacts range-restricted versus widespread species, a key challenge for large-scale conservation interventions is to understand how large-scale biodiversity change is related to local-scale impacts. **Objectives:** We aimed to quantify biodiversity change across the forest/pasture transition in Colombia at scales ranging from local to near national, and then to tease apart the key abiotic gradients that structure the spatial scaling of biodiversity loss. **Methods:** We assembled an unprecedented avian point-count dataset in forests and pastures across Colombia, recording 969 bird species across the Amazon, Llanos, Magdalena, Santa Marta, and all three Andean Cordilleras. We then applied a novel addition to the community occupancy model to derive detailed trait-based predictions of occupancy for more than 1600 bird species in forest and pasture across Colombia and assess the scaling relationships apparent in the results. Finally, we applied generalized dissimilarity models to the forest and pasture data separately in order to understand how abiotic gradients in elevation and precipitation, together with biogeographic barriers imposed by mountains and valley's structure turnover in forest and pasture separately. **Results:** Regional-scale biodiversity losses exceed mean local-scale losses by up to 75 percent. Excess regional biodiversity losses accumulate rapidly with a region's spatial extent, but they are even more closely related to the region's compositional heterogeneity, and Whittaker's beta-diveristy (expressed as a multiplicative partition) yields an approximately scale-free predictor of excess regional-over-local losses. Elevation gradients play a paramount role in structuring turnover biotic homogenization in the system. **Conclusions:** Effect sizes measured at local scales severely underestimate the large-scale biodiversity impacts of land-use change in heterogeneous regions, and particularly on tropical mountains. **Keywords:** Colombia, birds, Andes, Amazon, beta diversity, homogenization, land-use change

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Indicators of Intact Vocalizing Biodiversity across Different Scales in Tropical Forests

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Introduction: Conservation and sustainable management projects need to be able to monitor their progress – or lack thereof – in a timely and rigorous way that is scalable: increasing biodiversity with reforestation in Indonesia should be possible to measure with the same indicator as reforestation in Myanmar. Soundscape monitoring can capture vocalizing diversity over time and across sites, and is being increasingly tested as a tool for conservation monitoring. A major obstacle towards this is the lack of knowledge of how natural and human modified soundscapes change across scales. **Objective**: In this talk, I will describe how soundscapes change at three different scales – local, regional, and intercontinental, and how we can use these insights for tracking conservation progress. **Methods**: We recorded the soundscapes at >400 sites in 5 countries in Southeast Asia, Africa, and Central America, under different degrees of forest disturbance. We quantified how saturated with animal sounds each minute of the soundscape is, using the acoustic index Soundscape Saturation, and calculated Soundscape Synchrony. Results: We found that two peaks in Soundscape Saturation are indicative of undisturbed forest regardless of geographic location. Disturbed forests' soundscapes became homogenized and yet less synchronized throughout the day and over space. Disturbed forests also have a higher nocturnal insect sound activity. Implications: We propose three easily measured soundscape indicators that the conservation and sustainable forest management could eventually use to track the loss of forest fauna intactness, or progress towards faunal recovery. Through this talk we wish to invite other ATBC scientists to test these indicators in their systems, to come up with a globally robust set of indicators, maximally useful to conservation. **Keywords:** bioacoustics, soundscapes, tropical forests, forest degradation, conservation effectiveness, biodiversity

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100-year Resurvey Shows Differential Impact of Climate Change and Landcover Alteration on Populations of Mexican Birds

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The indelible footprint of the Anthropocene interacts with diversity in ways that are often idiosyncratic to individual species and ecosystems. When viewed across ecoregions, separate mechanisms like habitat destruction and climate change may interact as a "double-edged sword" for avian diversity, but these mechanisms likely affect lowland birds and montane birds differentially. Particularly, montane avifaunas have been shown to be driven upslope by a warming climate while lowland birds may suffer substantially from habitat degradation. However, the overall effect may be to homogenize bird communities through promotion of populations of generalist and commensal species, with knock-on extinction and extirpation of specialized birds and regional endemics. In this study, we aim to understand how and why avian communities have changed in Mexico over the past 100 years. Using occupancy models to appropriately compare presence-only specimen data to systematic survey data and community science data, we are beginning to understand how bird species and communities have been affected by human impacts since the 1930s across all of Mexico. Here, we present preliminary results from this Mexican Bird Resurvey Project (MBRP), and discuss implications and future directions. **Keywords:** Climae Change, Occupancy Modelling, Mexico, Neotropical Birds, LandCover, deforestation

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Human-modified Landscapes Reduce Mountainous Biodiversity

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Knowledge of habitat use by biodiversity communities is essential to support conservation actions, but the complex effects of conversion of natural–to-agricultural landscapes in mountainous systems remain poorly understood. We quantified changes in orchids' species richness and total abundance due to land-use change in the richest orchid hotspot using spatial regression with Random Forest. We found 340 species and 15872 individuals across 180 out of 344 sampled plots. Species richness and abundance are modulated by elevation, peaking at mid-elevations. However once the forest is converted into pastureland, the likelihood to find orchids is reduced from 92% to 47%, whilst species richness and individuals are reduced six and four times respectively, across elevations. The main driver of forest species richness is geographical distance, whilst tree DBH at local scale, and forest cover at the landscape scale postively impact orchid richness in pasturelands. Our research provides strong evidence of the damaging effects of forest and paramo conversion to pasturelands. However, improving forest structure (increase trees with large DBH) and forests cover in the landscapes are conservation strategies with great potential to benefit orchid biodiversity. **Keywords:**

Learning together: opportunities and challenges of local communities, scientists and decision makers in conservation education

Building Knowledge Together: towards an Intercultural Environmental Education in the Cocha Cashu Biological Station, Manu National Park, Peru

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Introduction: For more than 50 years, Cocha Cashu Biologic Station (CCBS) has hosted researchers from all around the world, turning into one of the most science-productive tropical areas. It is placed in Manu National Park (MNP), at the peruvian southest. It is a place that protects a great biodiversityfrom Andean-amazonian landscapes, but it is also indigenous territory:Matsigenka and Mashco piro etnias live at the core of the park and Harakbut, Yine, Yora and Quechua etnias live on the periphery. School education has become a priority for EBCC. Our educational proposal contemplates the educative service needs in the place and it is based on the educational national curricula, opting for an Intercultural Environmental Education (IEA). **Objective**: We look to strengthen educational processes within the different comunities at MNP, in order to educate intercultural citizens, citizens whith environmental awareness, scientific interest and pro-activity towards nature conservation and "buen vivir". **Methods:** IEA proposal is build upon educational visits, teaching programs and internships. Educational visits consist on a 3-day scholar camp, they take place all year long at the CCBS, its control and security placements and within the comunity. Educational activities are developed on the basis of both scientific research and local traditional knowledge. Teachers, parents, local experts, reserachers and rangers work together on it. At the beginning of each scholar year, together with partner NGOs and governmental institutions, we organize training workshops for teachers that work in the MNP area, including an internship directed to the undergraduate indigenous youth. **Results:** Since 2017, 40 groups and more than 500 students have been able to participate in these educational visits. We have already performed 5 teachers training. Manu Rural Educational Network was created aiming to support and help the teachers. Three in-situ learning projects have already been implemented, together with 4 virtual projects. These projects have been created in cooperation with other partner NGOs. All of them were contextualized on Manu territory. For the first time in CCBS history, 6 matsigenkas undergraduate students have received their training here. **Conclusions:** Protected natural areas and research centers must become focal points for education. Environmental education must be contextualized and intercultural. The challenge of continuing educational activities requires the involvement of governmental and non-governmental actors at different levels. It is very important to continue showing the impact of education in the management of the protected natural area, integrating young indigenous university students in educational projects. **Keywords:** Intercultural environmental education, indigenous communities, Manu National Park, Cocha Cashu

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Engaging with Indigenous Amazonian Communities to Promote Coexistence with Wildlife and Sustainable Harvest of Natural Resources

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Introduction: From 2017 until early 2020, San Diego Zoo Wildlife Alliance (SDZWA) collaborated closely with an NGO in Norther Bolivia to support conservation efforts within indigenous communities. The Bolivian Association for the Conservation of Andean & Amazonian Ecosystems (ACEAA) has extensive history with the people of the Tacana II Indigenous Territory, and sought expertise in engaging students and teachers in their conservation goals. We collaboratively developed a series of activities and curriculum-based projects that would be locally relevant and simple for teachers to implement in remote regions. **Objective:** One of our primary goals was to increase students' knowledge about wildlife in order to reduce common misconceptions about forest species and resource use. The connectivity and interdependence of forest species was also a strong point of emphasis through our activities. **Methods:** Guided walks with ACEAA biologists were a significant element of this program because they built on students' existing cultural knowledge of the forest while providing an expert guide to deliver factual information. In addition, activities focused on the concept of a food web gave new significance to animals or plants that are often perceived as only having value for human consumption. For instance, species commonly hunted by humans are also prey for jaguar, and may be seed dispersers for important trees. They also worked on design projects and interviewed members of the community about historical changes in biodiversity. As a summation of their experiences of the curriculum and activities, students created community fairs to share messaging with friends and neighbors. **Results:** All four schools fully participated in and followed through on the various activity elements selected for their part of the program. In addition, the wider communities participated in the learning process and were very receptive to the project. It was incredible to see the diverse representations of nature presented through the end of the year fairs–from wildlife dramas to art projects, from speeches to original songs. Each student was encouraged to showcase their nature connection experiences in a way that was personally meaningful. Conclusions: The activities caused reflection and discussion around the sustainability of their use of natural resources, mainly fishing and hunting. Common practices, such as throwing trash on the ground instead of disposing of it, have been challenged by students who want to see their communities become healthier. Students are also finding unique ways to reuse the waste around their homes and repurpose it for positive uses. **Keywords:** Indigenous, Amazon, coexist, sustainable, resources, biodiversity, knowledge, traditional, community, activity

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Environmental Action Civics: Connecting the Community to the Classroom

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The goal of environmental education is to engage people in the protection of nature thus making informed decisions about their environmental behavior. This strategy of sharing knowledge and facts about the environment has not been enough to change people's willingness to take action. Therefore, including civic action into environmental education becomes essential to foster engaged environmental citizens. We refer to this combination of civic action and environmental education as environmental action civics. This multidisciplinary approach asks participants to explore their local communities, identify issues based on their own experiences, develop plans to improve their community and put those plans into action with the support of local stakeholders. Youth are knowledgeable about the environmental issues that affect our world today, but it is important to prepare them in building the skills to solve those issues. As mentioned by Levinson (2014), when young people learn to use tools of civic engagement it becomes their method of choice for advocacy and engagement as adults. Responding to this need, Earth Force has created a living model for community action and problem-solving processes that allows youth to build on their skills and citizenry thus allowing them to address the environmental challenges we face today. Our research-based model is a six step process that allow youth to collect information about their local communities (step 1), participate in democratic decision making processes that allows the group to select the issue (step 2), research about the policies and practices that perpetuate their identified issue (step 3), democratically decide on the strategies to target their issue (step 4), work with community members to implement their solutions using civic action means (step 5), and finally to reflect on actions taken and plan for the future (step 6). Our model prioritizes youth-adult partnership, project-based learning, inquiry, civic engagement and has been put into practice over 25 years in different social, science, math and engineering classes as well as in different organizational settings. Our results are stories from youth making local changes in their local communities, from changing local practices to the creation of policies

to improve their environment. For environmental education to have an impact on the long term, it is key to transition from traditional practices that focus on providing knowledge and outdoor activities, and move into approaches that focus on supporting youth in solving local environmental issues that are meaningful and relevant to them and their communities. **Keywords:** Environmental action civics, youth as active citizens, project based learning

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The Potential of Citizen Science to Promote Conservation in the Amazon: An Analysis of the Use of the ICTIO Application

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The study reports the experience of Citizen Science, considering the use of the "ICTIO" application by fishermen (developed by the Wildlife Conservation Society - WCS e Cornell Lab of Ornithology and the partners of Citizen Science for Amazonia) in the Madeira basin as a tool to help fill data gaps on small scale fisheries in the Amazon, and to support the fish conservation. In the Madeira basin (Rondônia) was developed by ECOPORÉ ONG with the Laboratory of Ichthyology and Fishing (Federal University of Rondônia) at fishing communities and Porto Velho Fishing Market, Rondônia. The project was initially presented and discussed how ICTIO could answer fishermen and researcher questions, training for the use of the application and continuous monitoring. The data collected from 2018 to 2021, were compared with historical data from the basin, to see patterns in catches of commercial fish, especially migratory fish. The results allowed to answer some of the fisher questions, validating ICTIO as a powerful tool in obtaining information on fisheries changes that can support fisheries conservation and management. In addition, is an important opportunity to create and share knowledge between traditional scientists and citizen scientists. **Keywords:** Smartphone, hydropower, participative monitoring, fisheries, Amazon

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Evaluating the Impact of Environmental Education around Ranomafana National Park: Opportunities and Challenges

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Ninety-four percent of lemur species are currently threatened with extinction and more than seventeen species of giant lemur are already extinct. In order to prevent the extinction of Madagascar's remaining lemurs, Centre ValBio (CVB) research station, located just outside of Ranomafana National Park in southeastern Madagascar, began conservation programs in the 1990s. CVB believes in the 'One Health' approach to understanding the relationship between humans and the environment, and one of their core principles is that effective conservation is science based. CVB's approach is based around an integrated program to improve the health, education, and economies of communities surrounding the forests of Ranomafana. This approach combines active learning, skill building, career development, and community engagement to promote conservation. CVB's environmental education programs (discussed herein) began with after-school classes in two villages. The programs have since expanded to include twenty remote primary schools. The all-Malagasy team consists of long-term conservation educators as well as young intern teachers, who together address the issues of valuing lemurs and the forests that they require to survive. In this paper, we will describe three of CVB's environmental education programs and evaluate their impact. We show that these programs (1) are popular, (2) produce concrete outputs that can change rural villages, and (3) improve local knowledge on the importance of biodiversity and sustainable development. **Keywords:** Ranomafana, environmental education, Madagascar, schools, rural villages, biodiversity, conservation

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Protected Areas in Brazil: Socioenvironmental and Educational Landscapes

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In Brazil, for a long time, protected areas were considered separate from their social contexts, generating many conflicts. Gradually, categories and/or management models are being created that increasingly involve the different socio-environmental actors in the management of their territories. In this sense, environmental education has become an important tool for processes of critical and transformative education, which considers emancipation, identity, belonging and solidarity as instruments to promote necessary changes. Our research has been based on an analysis of the current problems of protected areas in Brazil and the role that environmental education can play. The research is contextualized within the currents of symbolic interactionism theory and participatory-action-research. Methodological designs were elaborated using environmental education and perception-interpretation of landscape as basic pedagogical instruments to generate psychosocial and educational processes. In this sense, it was observed that environmental education was fundamental as the basis of the training processes that stimulated the participation capacities of socio-environmental actors to involve them in shared management. Furthermore, it promoted the creation of processes so that people could know, understand, develop sense of belonging and manage the landscapes of their lives. Thus, it was observed that the use of landscape as a pedagogical instrument for the identification of socio-environmental cartographies acquired a strategic value in the perception and interpretation of protected areas, allowing new meanings to be assigned to these landscapes as a "common place". Research has shown, based on the results and discussions, the way to the elaboration of methodological proposals with the intention of contributing to a participatory management of protected areas in Brazil. In this sense, a proposal for action itinerary has been prepared that contains possible guidelines to promote "to do research-to educate-to take action" in protected areas. These are proposals for methodological designs, in which it has been possible to highlight the importance of working on territoriality, identity, the relationship between social representations and public spheres, participation and emancipation, among others. With these proposals, it is intended that protected areas become common places and of public domain with clear educational components. To do this, this research proposes methodological strategies that promote the processes of knowing, understanding, belonging and managing these territories. Research finally allowed us to observe that it is possible to transform protected areas into more socio-environmental and educational landscapes. **Keywords:**

Lesser-known Avian Migration Systems in South America

Surprises from the South: What We've Learned about Migration in South America from Satellite Tracking

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Introduction: Since 2008 our teams have worked at 6 sites across Amazonia and adjacent habitats to track sandbank-dependent waterbirds, most notably the Orinoco Goose (Neochen jubata) and the Black Skimmer (Rynchops niger). **Objectives:** To document intra-tropical migration strategies used by sandbank-dependent waterbirds in Amazonia, to understand stopover ecology and critical conservation implications in a context of high pressure for development including dams. Methods: We have used several technologies with varying degrees of success, including tracking with satellite transmitters, GSM collars, remotely downloaded antennae systems, and ICARUS tags that communicate with the International Space Station. RESULTS: Satellite tracking tag systems have outperformed other methods considerably in our remote fieldsites, so are ultimately worth the high purchase costs to deploy. New migration systems have been uncovered for both the Orinoco Goose and the Black Skimmer. High fidelity to both nesting grounds and certain stopover locations are observed in both species, offering opportunities to contribute to conservation needs. Orinoco Geese differ in their migration strategies regionally, likely as a result of cavity nest site limitation in more open savanna and grassland regions. They have a critical need for safe moulting grounds and are already adapting to many human-dominated landscapes including cattle production areas and ricefields, which may be altering their movement ecology in certain areas. Black Skimmers undertake long-distance migrations in which they may move considerable distances in both latitude and longitude. Individuals from the same breeding populations show highly variable strategies in where to spend the non-breeding season. Implications: We consider the highly concentrated seasonal concentrations of Orinoco Goose in rice fields to be a potential concern for the conservation of this Near-Threatened bird, as persecution in rice fields is common for other waterbirds with which they associate, and disease transmission may be a growing risk. Global skimmer populations have declined in areas of dam construction, so we also discuss conservation concerns with the proposed the Bem Querer dam on the Rio Branco, Brazil to affect the integrity of this uniquely diverse river system, which we have recently observed to be an important north-south flyway for not only our target study species but also for many other species of waterbirds. **Keywords:** Animal migration, waterbirds, Amazonia, movement ecology, flood pulse ecology, rivers

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Avian Migration Studies in Barba Azul Nature Reserve, Bolivia: The Flight of the the Blue-Throated Macaw

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Background: The Bolivian endemic Blue-throated Macaw (*Ara glaucogularis*) with less than 455 individuals left in the wild, is Critically Endangered and is only found in the Beni Savanna ecosystem. This macaw occurs in three isolated subpopulations and only in 2007 did Asociación Armonía discover Blue-throated Macaws west of the Mamore River. There, Armonía created the 11,000 ha (27,000 ac) Barba Azul Nature Reserve protecting Motacu palm forests, the key habitat for foraging and roosting Blue-throated Macaws. Very little was known about their breeding behavior and habitat during the Bolivian rainy season (November to March) as nearly all individuals leave Barba Azul to breed at previously unknown locations. During this period most of the Beni savanna is flooded making accessibility extremely difficult. **Objective:** To better protect the Blue-throated Macaw throughout its range we set out to learn the sites where these birds breed using satellite telemetry. We hypothesized that sites used by the Blue-throated Macaw during the rainy season and outside Barba Azul Nature Reserve are breeding sites and a priority for conservation. Methods: In order to select the best tracking material, we did preliminary tests conducted on captive birds that resulted in choosing Geotrak Parrot Collars, a metal, battery-operated unit that provides data through the Argos satellite system. In September 2019, we tagged three birds in Barba Azul Nature Reserve with Geotrak collars, and received migration data for two birds, until battery depletion in November and December 2019. Results: Our two migrant birds were tracked leaving Barba Azul on the same date (27 September), but departed in divergent directions (approximately 90 degrees in separation). They settled in two sites approximately 50–100 km from Barba Azul. Knowing their likely breeding grounds, Armonía conducted site visits to where the birds were tracked, resulting in the discovery of breeding birds. The work suggests that the Blue-throated Macaws of Barba Azul use breeding sites that are scattered across the Beni Savanna region, although within the recognized boundaries of the northwestern subpopulation. **Conclusions:** We conclude that the use of satellite collars is a feasible option for research with the species and provide important conservation insights. The use of satellite telemetry overcomes accessibility difficulties in flooded savanna ecosystems. It helped Armonía to continue detailed search expeditions to describe the previous unknow breeding habitat. The sites where breeding macaws were found are highlighted for future conservation actions. **Keywords:** Satellite telemetry, critically endangered, psittacidae, preventing extinction, Beni Savanna

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Why the Amazonian Turtles Are Important to Protect Migratory Waterbirds?

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Illegal hunting, habitat loss, and climate change are major threats to migratory waterbirds worldwide. Conservation interventions to prevent populations declines are necessary, especially in tropical developing countries, often immersed in shortages of funding and human resources for conservation. In this talk, I will show a very positive example in Brazilian Amazonia where local communities are effectively protecting migratory waterbirds that breed on seasonal riverine beaches through the protection of nesting sites of Amazonian turtles from the *Podocnemis* genus. We modeled local population responses of four migratory waterbird species on 155 beaches along a ~1,600-km section of a major tributary of the Amazon, as a function of community enforcement, official protection status, human pressure, and landscape features. In general, 21 community-protected beaches within the study area host more than 80% of all sampled birds. Black Skimmers has the most dramatic response, with breeding numbers 135-fold larger in community-protected beaches compared to unprotected sites. Large-Billed and Yellow-Billed Terns showed the same pattern. For the Near Threatened Orinoco Goose, formally protected areas were still the best conservation tool. We demonstrate the value of community-based conservation to protect breeding populations of migratory waterbird species, even the main target being the freshwater turtles. This is a highly effective and low-cost conservation strategy that can be replicated in many other regions of Amazonia. **Keywords:** Community-based conservation, protected Areas, community-based management, participatory conservation, conservation success

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Novel Movement Patterns Documented in Two Species of Amazonian Aquatic Birds in the Rio Branco, Northern Amazon.

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Introduction. Waterbirds that inhabit seasonal environments often perform migratory movements in response to changes in the landscape, usually to optimize the use of food resources or to nest. Most of our knowledge on migratory movements in waterfowl comes from species that inhabit temperate regions. However, ample evidence show that this type of movement also occurs in tropical birds. Seasonal changes in the landscape created by the flood pulse of Amazonian rivers can result in migratory movements, particularly in beach-dwelling species that find their preferred habitats completely flooded for several months each year. **Objective**. In this study, we used GPS transmitters to assess the potential seasonal movements in populations of two bird species, the Orinoco Goose (*Oressochen jubata*) and the Skimmer (*Rynchops niger*) in northern Amazonia. **Methods**. The birds were captured in February 2020 and March 2022 in the lower Rio Branco, in the Brazilian state of Roraima. Skimmers were captured using mist nets and geese by snare traps. We placed transmitters on seven Orinoco geese (4 ARGOS and 3 IBIS) and nine transmitters on Skimmers (4 MTI, 4 Lotek and 1 Ikarus). Geographic locations were transmitted every two hours for geese and on variable schedules for skimmers depending on transmitter model. The data was automatically uploaded to Movebank.org and trajectories analyzed with QGIS. **Results**. The eight transmitters installed in 2020 resulted in between 418 and 710 days of monitoring on the geese and between 2 and 242 days of monitoring on the skimmers (two skimmer individuals provided few days of data in 2020). All monitored individuals left the lower Rio Branco when the beaches were completely flooded (when the fluviometric average was ˜3 m). The geese moved ˜400 km north to spend the flood season in the rice fields in the savannas of Roraima, along the Tacutú and upper Branco rivers. Data collected from six skimmers allowed us to recognize three different migratory routes: four individuals moved north to the coast of Suriname (2 in 2020 and 2 in 2022), one individual went east towards the coast of the Brazilian state of Pará (2020) and preliminary data from a tagged individual in 2022 indicate southeastward movements to the Rio Solimões, probably *en route* to the coast. **Conclusions**. This study revealed novel seasonal movements associated with the fluctuation of the water level of an Amazonian river, suggesting that these kinds of movements are potentially widespread in Amazonian beach-dwelling birds. **Keywords:** Amazon, river beaches, birds, migration.

Orinoco Geese and Conservation of Habitats in Araguaia's Amazonia/Cerrado Ecotone

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Background: The Canguçu Research Station is located on the Javaés River, at the border between Araguaia National Park and the Cantão State Park in the Brazilian state of Tocantins. The habitat is at a diverse ecotone between Amazonian and Cerrado biomes, and is located within a fast-developing region undergoing conversion of natural habitats to planted pastures, rice and soy, in particular. Among other important contributions to the region's biodiversity, the Javaés and Araguaia rivers conserve the largest remaining population of the Threatened Orinoco Goose (*Neochen jubata*) for the Cerrado biome. **Objectives:** We aimed to look at population status and threats to the region's waterbirds, including the threatened Orinoco Goose. **Methods:** We compared past census data along the Araguaia and Javaés Rivers with newer (2017-2019) aerial, boat, and car-based surveys, maintaining a nearly monthly record of seasonal numbers. We also tracked a small number of geese using satellite telemetry. Results: We demonstrate a nearly 50% decline in this important population over the previous decade, but also found large wet-season (non-breeding season) concentrations of Orinoco Geese in rice agrosystems, in associations with other waterbirds. Tracking results demonstrated a regional pattern of movement for the birds we tagged during the dry season breeding period. Tracking helped to locate an unexpected seasonal concentration of geese in nearby rice fields. These dense seasonal concentrations include birds from unknown areas, and are repeated annually, both geographically and seasonally. **Implications:** We consider the potential threats to this Cerrado biome population of Orinoco Geese given these findings, which include habitat alteration, poaching, and spread of diseases. We discuss habitat and conservation needs of threatened species in the region, and recommend actions for local conservation authorities to ensure protection of the unique local habitats and fauna. **Keywords:** Cerrado, Orinoco Geese, population census, movement ecology, disease ecology

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Bird Migration in Lowland Tropical South America, an Overview

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Prior the second half of 20th Century, the migration of South American (SA) breeding birds has not been considered a major research subject (Chesser 1994). Two immigrant ornithologists pioneered SA bird migration studies: Claes C. Olrog - mainly in Argentina, and, Helmut Sick in Brazil. The former made a synthesis of available knowledge for SA in 1968, and Sick was the first to draw attention to the movements of riverine point bars birds when the annual flood arrives in tropical portions of lowland SA (Sick, 1967). Movements were first detected mainly throughout the direct observation of species' seasonal appearance and disappearance, as with the Blue-and-yellow Macaw (Ara ararauna) in lowland Colombia (Collar 1997) and in the Brazilian Pantanal (Carrara et al. 2019). Bird banding from mid 20th century on became the research tool to map them before technological advances made available additional methods. Geolocators, GSM cellular, and satellite trackers have since been used to study different lowland tropical SA birds. Noteworthy migrations became evident throughout the tropical portion of SA. Geolocators found that migrants from Central Brazil´s Lesser Elaenia (Elaenia chiriquensis) population had different migratory paths and strategies (Guaraldo et al, 2021). Geolocators suggested that tropical and temperate Fork-tailed Flycatchers (Tyrannus savana) breeders did not differ much in spring migration strategy despite their large latitudinal range (Jahn et al., 2019). Riverine sandy bars species have been extensively studied through bird-banding and satellite transmitters. Orinoco Goose (Neochen jubata) has important migrations into Llanos del Moxo (Bolivia) wetlands from breeding grounds in Peru (Davenport et al., 2012) and in Juruá River, Brazil (Endo et al., 2013), found through satellite markers. Pantanal´s Black Skimmer (Rynchops niger) moves to Southern Atlantic Coast of Brazil and Argentina as shown by bird-banding (Antas et al., 2016). Satellite transmitters showed Peruvian Black Skimmers moving mostly to Pacific Coast, albeit one moved southeastward into Northern Paraguay before the signal was lost (Davenport et al., 2016). The proper knowledge of these different migratory strategies, sometimes even within the same species, is also very important for their conservation. Huge habitat changes we have been promoting all over SA may be affecting them or shall affect them in near future. For some species, either in upland, wetlands, or aquatic habitats knowing these migrations can be key for their future. We aim to discuss priority groups of species and locations in SA where a better understanding of avian movement **Keywords:** Migration strategies, conservation

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Linking field-oriented ecology and ecologists with land surface models and modelers

Global Calibration of E3SM-FATES Using Ground Data from a Forest Monitoring Network

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Background: Observations from networks of forest plots show important differences in biomass and turnover of forests across continents, and how these dynamics are changing through time. These patterns are not well captured by the current generation of Earth System Models (ESMs). Vegetation demographic models (VDMs) improve the representation of vegetation within ESMs, for instance by accounting for vertical competition for light, and the effects of canopy disturbance on successional dynamics. However, we lack a standardized set of benchmarks with which to assess the ability of VDMs to capture the spatial and temporal trends in forest dynamics that are observed in forest plot data. **Objectives**: We aim to create a standardized set of benchmarks from forest plot data that can be used to assess VDM outputs. We aim to incorporate these benchmarks into the International Land Model Benchmarking Project (ILAMB) and use them for the global calibration of the Energy Exascale Earth System Model - Functionally Assembled Terrestrial Ecosystem Simulator (E3SM-FATES). **Methods:** We used forest plot data from several sites to design a set of benchmarks that capture current forest structure and function at a site, and potential changes through time. Since broad spatial and temporal patterns in forest dynamics emerge from the demographic rates of individual plants, we included demographic metrics such as growth and mortality rates, along with aboveground biomass, forest size structure, and aboveground woody carbon turnover. Dynamics at each site were compared to outputs from E3SM-FATES as a starting point for calibration of demographic rates. We aim to extend the initial set of sites, in order to create benchmarks with global coverage**.** **Implications:** Forests exchange vast amounts of energy, water and carbon with the atmosphere, and in doing so play a critical role in regulating the global climate. To predict future forest dynamics, and their impacts on climate, VDMs must be able to capture trends in forest dynamics, driven by changing demographic rates. By leveraging forest plot data to create a standardised set of model benchmarks, we aim to facilitate global calibration of VDMs and enable more accurate predictions of the role of forests in the biosphere. **Keywords:** Vegetation demographic models, forest plots, global calibration, benchmarking

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Linking Field Observations, Lidar, and Ecosystem Models to Understand the Impact of Amazon Forest Degradation on Water and Carbon Cycles

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Introduction: More than 20% of the Brazilian Amazon has been deforested, and a similar, yet uncertain fraction of the remaining forests have been degraded through selective logging, fires, and fragmentation. Changes in disturbance regime associated with forest degradation cause reductions in carbon stocks, shifts in forest structure and composition, and potentially alter the forest resilience to climate extremes. While critical for understanding processes associated with degradation in detail, field plots are limited to small sampling size and challenges accessing hotspots of degradation. Earth System Models rarely account for the diversity of forest structures that exist within biomes. Objectives: We seek to quantify how forest degradation is affecting the water and carbon cycles, as well as the role of degradation on the forest's sensitivity to droughts, by combining field measurements, remote sensing, and modeling. **Methods:** We integrate forest inventory plots and airborne lidar surveys across the Amazon to provide realistic forest structure conditions at regional scale to the Ecosystem Demography Model (ED2). ED2 is a terrestrial biosphere model that represents the dynamics of vertically structured and horizontally heterogenous forest canopies, and accounts for the variability in forest structure within each grid cell while solving the water, energy and carbon cycles. We carried out a series of $1^{\circ}\times1^{\circ}$ simulations for the Brazilian Amazon initialized with forest structure obtained from airborne lidar surveys and driven with meteorological drivers based on WFDE5 reanalyses (1981–2018). Results: According to the simulations, severe forest degradation (biomass loss $> 50\%$) can reduce evapotranspiration and gross primary productivity by about 35%. Likewise, regional simulations across the Brazilian Amazon indicated that forests near the Brazilian arc of deforestation have high potential of carbon accumulation, but show stronger negative responses of gross primary productivity and evapotranspiration to hot drought conditions than intact forests. Furthermore, simulations under a scenario of expansion of deforestation and degradation suggest that even forests in wetter parts of the Amazon could become more sensitive to droughts if degraded. Implications: These results suggest that the susceptibility of the Amazon rainforest to drought effects are amplified by prior forest disturbance, indicating that reducing or reversing forest degradation could ameliorate effects of climate variability and climate change. **Keywords:** Amazon, forest degradation, data-model integration, climate extremes, remote sensing

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Parameterizing Tropical Forest Diversity: Integrating a Terrestrial Biosphere Model with Remotely Sensed Trait Measurements

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Constraining uncertainty in future model projections of forest dynamics requires adequately capturing biogeographic variation in carbon storage and turnover. Incorporation of edaphic controls on this variation is key, particularly in the tropics. We developed an approach for integrating airborne remote sensing data with a terrestrial biosphere model to constrain heterogeneity in carbon flux dynamics across communities that span topographic-related edaphic gradients, using data from two tropical forests in Malaysian Borneo. Using leaf and plant traits related to structure (height, gap fraction, LAI, and canopy profiles), defense (lignin and phenols), and productivity (SLA, foliar N, and foliar P), derived from Visible-Shortwave Imaging Spectrometer (VSWIR) measurements collected by the Global Airborne Observatory, we characterized community-scale differences in function to define initial conditions for a terrestrial biosphere model (ED2). We then parameterized plant functional types based on remotely sensed community trait distributions (SLA, V_{cmax}, and gap dynamics). Using a simple PCA and cluster analysis, we find that remotely sensed traits alone can be used to distinguish distinct functional communities, explaining nearly 80% of variance across these communities. It also revealed important structural and functional variation within an area characterized as a single forest community based upon field measurements. Plant functional types parameterized with site constrained trait and disturbance values yielded more accurate predictions of canopy demography, forest productivity and above-ground biomass dynamics. Since the main axes of variation in leaf traits correspond to quantities that are measurable from the planned spaceborne imaging spectroscopy missions such as NASA's Surface Biology Geology satellite imaging spectroscopy mission, our approach offers a framework for model-data integration that can be tested and employed across the tropical forest ecosystems at regional and potentially global scales. **Keywords:** Ecosystem demography model, imaging spectroscopy, LiDAR, Borneo, Malaysia, functional ecology

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The Nature of Amazonian Tree Mortality

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Introduction / Background / Justification: Tree mortality is fundamental in determining fluxes and stocks of carbon in a forest. Its stochastic nature hampers our understanding of this process and as a consequence tree death is currently poorly constrained by vegetation models. The rates of tree mortality have increased in Amazonian forests, compromising the capacity of these forests to act as a carbon sink. The increase in the frequency and intensity of the dry season and the rise in atmospheric CO_2 concentration are anticipated to be the main cause of the observed increase in tree death. However, the extent to which each of these drivers contributes to the basin wide increase in tree mortality is still unknown. **Objective(s)/Hypothesis(es):** We evaluate how and why tree death varies across the Amazon basin by assessing the spatial variation of the risk factors tree mortality in different Amazonian regions. Our analysis provides insights on how to better constrain tree death in vegetation models. **Methods:** Using data from over 30 years of forest monitoring across the Amazon, we quantify mortality rates per census and use linear regressions to quantify the trends within each plot. We used a survival analysis approach to quantify the contribution of different risk factors (tree size, growth and species-level traits) on tree death. **Results:** Our results show that species-level growth rate is the best predictor of tree death in Amazonia. Tree-level growth rates were positively related to the probability of death and the bioclimatic affiliation of species was an important risk factor in the Southern fringes of the Amazon. Implications/Conclusions: Our results highlight the importance of combining of species and individual-level variables to model tree tropical tree mortality. Linking mortality in vegetation models to multi-annual mean woody growth rate could result in an improved ability of these models to capture the ongoing changes in Amazon forests. **Keywords:** Survival analyses, tree mortality, global change, demography

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Insights into Tropical Tree Mortality and Damage from a Multi-site Monitoring Program Informing Vegetation Models

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Background: Spatial variation in tropical forest biomass is largely determined by differences in woody residence times and thus tree mortality. Yet, the causes and consequences of tree mortality are not well understood. Tree death involves multiple interrelated factors from drivers (e.g., drought, elevated temperature) through mechanisms (e.g., biotic outbreaks, fire, wind) that ultimately lead to the physiological processes that kill the trees (i.e., carbon starvation, hydraulic failure). Large-scale and frequent monitoring of tree mortality and associated factors will enable more accurate estimates of forest biomass and the mechanistic representation of mortality in vegetation models. **Objective:** Here, we present current advances in tropical tree mortality and damage from a ForestGEO annual monitoring program. We study the relative importance of the tree-level factors involved in tree death and their implications for aboveground biomass (AGB) dynamics. **Methods:** We recorded data on multiple tree-level conditions and assessed the subsequent survival of ˜44,000 trees with DBH1 cm (>2,000 species) across seven tropical forest plots between 2016 and 2022 (29 censuses, 157,241 tree$\times$census observations). Tree-level damage was estimated based on field-based assessments of the proportion of newly broken branches and trunk loss coupled with models describing the accumulation of woody volume with tree height. Damage estimates were then used to compare AGB losses from dead *versus* damaged trees. Results: Across 19 mortality risk factors examined, we found that light limitation and crown/trunk damage were the most impactful risks (i.e., had the two highest 'excess mortality', relative to stand-level mortality). The mortality risks studied co-occurred strongly among trees and, as a result, limited relationships were found between the traditional modes of death (standing, broken, and uprooted) and tree-level conditions/risks. We also found that over one-third of the total AGB losses in these forests were due to damage to living trees (i.e., branch fall, trunk breakage, and/or standing wood decomposition), varying greatly across sites**. Implications:**

Our results show the role of tree-level damage in forest carbon dynamics. While tree-level damage is the most common condition preceding death in tropical trees, non-lethal damage can contribute to significant amounts of AGB losses that are not necessarily captured by studies focused only on tree mortality. Resolving the timing of lethal and non-lethal damage as well as their climatic drivers and physiological consequences should be a priority to better understand woody residence times and improve predictions of the fate of forests in vegetation models. **Keywords:** Climate change, forest dynamics, forest carbon, mortality risk, vegetation models

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Model Hypotheses for Variation in Tree Hydraulic Functional Strategy across Tropical Forests

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Introduction. How tropical forests respond to increasing water stress over the coming decades remains a great unknown. Resolving this requires an understanding of the functional strategies that trees adopt with respect to water use and how these vary across biomes. Strategies are expressed by different combinations of functional traits, which relate to a particular aspect of plant function. Characterising strategies is, however, more challenging than characterising plants by individual functional traits. In principle plants with the same values of one trait may have completely different values of another trait, leading to a very different overall behaviour. As a result, we know relatively little about how plant strategies with respect to water stress vary across space. **Objectives.** We combined trait data and process-based modelling to explore the viability of different tree functional strategies across tropical forests. We aimed to identify the most successful strategies to dealing with water deficit in each location as well as the diversity of strategies that can survive. **Methods.** We compiled a global dataset of tree functional traits related to hydraulic strategy. We analysed these for trade-offs, noting consistency in patterns between tropical and temperate species. We sampled from this trade-off space to create individual tree functional strategy options, which we then applied in a dynamic vegetation model with a novel and detailed representation of plant hydraulics. We ran simulations pan-tropically to assess variation in functional diversity and in successful strategies with respect to productivity and biomass. **Results.** We found a strong relationship between water deficit and functional diversity across the tropics, consistent with that previously reported for species diversity in the Amazon. The western Amazon and South-East Asia stand out as particular hotspots of hydraulic functional diversity. The most successful strategies in these regions in terms of biomass and net primary productivity both tended towards higher risk taking than in drier regions, but with differences in isohydricity. **Conclusions.** Our results provide a set of hypotheses of the spatial variation in successful hydraulic functional strategy which requires testing against field observations. **Keywords:** Functional strategy, functional diversity, tropical forests, plant hydraulics, water stress

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Integrating Hydrology, Tree Demography and Traits Data to Advance Land Surface Model Predictions of Tropical Forest Response to Droughts

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Introduction / Background / Justification: Tropical forests cycle more carbon, water and energy than any other biome, such that any perturbation in its function has repercussions on the global climate. Droughts and extreme wetness are projected to increase in tropical forests depending on region, but how those changes will affect tropical forest composition and function remains uncertain. Next-generation vegetation demography models (VDMs), a component of land surface models, are based-on performance-trait-environment interactions and promise to improve our predictive power, but these interactions are challenging to quantify, especially given limited data for trees' belowground traits and water environments. **Objective(s)/Hypothesis(es):** Evolution and community assembly processes dictate that the extent of trees' response to droughts, or extreme wetness, depends on the perturbation of species' historical hydrological environment and trait-adaptations. Here, I showcase how hydrology, demography and traits datasets can be combined to improve our understanding of plants' drought-response strategies to advance land surface models. **Methods:** For a moist tropical forest in Barro Colorado Island, Panama, we parameterised a next-generation vegetation demography model coupled with a land surface model, ELM-FATES, by leveraging local soil hydraulic properties and by maximizing the

fit between ensemble simulations and observations for multiple hydrological states and fluxes simultaneously. Droughts were identified as anomalies in soil water potential dynamics over the whole soil column spanning three decades of tree demographic censuses. We developed a novel statistical model to estimate species-specific effective rooting depths based on growth records, concurrent soil water-potentials and leaf hydraulic vulnerability curves. Model estimates were calibrated against isotopes-based water-sourcing depths. We also found and leveraged that soft functional traits such as LMA and wood density were effective predictors of leaf vulnerability curves. **Results:** This study revealed that drought response is a function of drought-exposure relative to trait-adaptations at the whole-plant level: deep rooted species were associated with more vulnerable stem hydraulic traits, yet as a result of reduced hydrological drought-exposure they had lower mortality rates than shallow rooted species through several El-Nino droughts. **Implications/Conclusions:** These finding imply that if VDMs are only driven by above-ground hydraulic traits they would kill the wrong trees under droughts by implementing their greater risk of embolism, VDMs must also take rooting depths into account to ascertain if embolism risk is realized via drought-exposure. I will highlight the data required to rapidly advance the capacity of VDMs to predict forest response to droughts across the tropics and beyond. **Keywords:** Hydrological niches, droughts, rooting depths, hydraulic traits, mortality

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The Distribution of EcM Trees in Lowland Tropical Forests

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A lot has recently been written about the global distribution of plant nutrient acquisition strategies related to symbioses between fungi and trees, typically asserting that lowland tropical forests are dominated by plants with AM (arbuscular mycorrhiza) symbioses while EcM (ectomycorrhiza) symbioses are rare or absent. Climatic effects on decomposition rates and local variation in soil quality are considered the main drivers of the global and the local, fine-scale pattern of plant-fungi symbiotic distributions. AM is predicted to dominate at low latitudes and in areas with high soil quality while at high latitudes, and in areas with low soil quality, EcM is predicted to dominate. Using data from a pantropical network of forest dynamics plots, we show that the three major areas of lowland tropical forest differ in their plant-symbiont composition. Most lowland Asian rainforests are dominated by ECM, primarily species of the Dipterocarpaceae. African forests are dominated by mixtures of ectomycorrhizal species, including large expanses of monodominant forests. With the exception of small areas in the Guiana Shield and some white-sand habitats, South American lowland rainforests, including the Amazon Basin, are dominated by AM symbioses and are largely devoid of ECM species. These major differences in plant-symbiosis relationships are unrelated to soil fertility or climate at the pantropical scale. Historical biogeography and unique patterns of diversification within the three regions have resulted in dramatically different forest compositions and putative nutrient-acquisition strategies. Earth System Models treat lowland tropical forests as one biome. Differences in patterns of plant-fungi symbiosis across the lowland tropics have important consequences for carbon uptake and storage in response to global environmental change. **Keywords:** Arbuscular mycorrhiza, ectomycorrhiza, fungi, mycorrhiza, trees, tropics

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Leveraging Multi-source Forest Data to Predict Cyclone Responses in Tropical Forest

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Introduction: Under climate change, altered tropical cyclone regimes could cause long-lasting effects on coastal tropical forest structure, composition, and function. A pantropical meta-analysis of 48 case studies in 24 tropical forests affected by 20 cyclones indicated that total litterfall carbon (C) flux increased from ~1.2 $\pm$ 0.14 to 10.8 $\pm$ 1.44 g C/m^2/day due to cyclones, and reached pre-disturbance levels within one-year post-disturbance. Predicting the large variation in cyclone response across pantropical sites, leveraging site-level ground and remote-sensing observations, is key to predictive modeling of tropical forest response to future cyclones. **Objectives / Hypothesis:** To enable dynamic vegetation model predictions of post-cyclone forest biomass C fluxes, we combined ground and remote-sensing observations in a tropical forest affected by hurricanes Hugo and Maria. We compared ground and remote-sensing observations with simulated litterfall C flux and LAI. We expected that, by assigning different canopy damage and mortality rates to shade-tolerant and light-demanding plant functional types (PFTs), simulated litterfall and LAI data would match observations. **Methods:** We compiled litterfall C flux and MODIS LAI 500-m data from Bisley forest (Puerto Rico) before and over 2 years after Hugo and Maria. We calculated hurricane-induced changes in litterfall C flux and LAI and compared with changes in litterfall C flux and LAI from simulations of the Functionally Assembled Terrestrial Ecosystem Simulator (FATES) coupled with the Energy Exascale Earth System Model (E3SM) land model (ELM-FATES). Following a 300-year spinup with ELM-FATES, we implemented hurricane disturbance with 100% defoliation, 20% structural biomass reduction, and varied mortality rates by referring to Hugo and Maria effects in Bisley. **Results:** By imposing 80% mortality of light-demanding and 50% of shade-tolerant PFTs to simulate the impact of a large hurricane on Bisley, simulated LAI decreased by 55.3%, while remotely-sensed LAI after Maria decreased by 59% relative to pre-hurricane levels. Ground observations suggested a 450-fold increase in total litterfall C flux post-Hugo, representing an instantaneous cyclone-caused input ~1.3 times the average annual litterfall of ~417 g C/m^2/year. Changes in simulated litterfall C flux due to a large hurricane were fifteen times greater than ground observations following Maria, and 2.5 times smaller than observations following Hugo. **Implications / Conclusions:** Ongoing work is focused on benchmarking ELM-FATES predictions against ground and remote-sensing data. To achieve reliable simulations of the effects of altered cyclone regimes on tropical forests, observational data and relationships provide critical benchmarks and inputs. **Keywords:** Dynamic vegetation model, ecosystem function, hurricane, leaf area index, litterfall.

Long-term climate effects on interannual variation in tropical forest reproduction: a global perspective.

Proximate Cues of Flowering in a Subtropical Rain Forest

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Introduction: Plants have evolved mechanisms to track seasonal environmental variation, enabling them to time key life-history events to appropriate seasons. While the proximate cues for flowering initiation are well documented in the temperate areas, it is still unclear what the flowering cues are in the tropics, especially in subtropical regions. **Objective:** In this study, we would like to identify the species-specific proximate cues that initiate flowering in a subtropical rain forest using a 19-year phenological data from the Fushan Forest Dynamics Plot, Taiwan. **Methods*:*** By analyzing 30,800 flower records of 16 species in the Fushan forest, we parameterized phenology models with daily meteorological data. We compared first flowering dates (FFD) predicted by eight possible proximate cues involving photoperiod, solar irradiance, temperature, and rainfall. **Results:** We found considerable interannual variation in the median FFD for most of the study species, ranging from 21 to 101 days. The early-flowering species tended to have greater interannual variation in FFD than the late-flowering species. For 14 out of 16 study species, proximate cues concerning temporal variation in temperature well explained the interannual variation in FFD. The early-flowering species, like *Machilus* and *Castanopsis* spp., might be cued by one to three months of low temperature in the previous fall or winter. In contrast, the late-flowering species might flower after two to four months of consistently warm temperature. The proximate cue concerning irradiance also explained interannual variation in FFD for 11 species but with higher prediction errors than temperature-related cues. The hypothesis related to seasonal variation in rainfall failed to predict the timing of flowering in any species. **Implications:** Our results suggest that future changes in temperature might alter flowering times for most species in subtropical forests, which could lead to changes in ecosystem processes and biosphere feedback to the climate systems. **Keywords:** chill requirement, climate signal, flowering times, heat requirement, phenology, photoperiod, rainfall, solar irradiance

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The Proximate Cues for Flowering in a Tropical Moist Forest

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Introduction: Seasons are an inevitable consequence of Earth's obliquity, and organisms everywhere have evolved mechanisms to time life history events to appropriate seasons. At temperate and boreal latitudes, plants use photoperiod, winter vernalization and growing degree-days as proximate cues to synchronize flowering with favorable environmental conditions. These potential cues are invariant (photoperiod at the equator) or irrelevant in tropical forests where the growing season never ends. We explore alternatives. **Hypotheses:** We evaluate eight environmental signals hypothesized to be proximate cues for flowering in the tropical forest literature. The hypotheses include increasing or decreasing photoperiod, low temperature events, drought punctuated by heavy rainfall or broken by sustained rainfall, and low irradiance punctuated by a brief period of high irradiance or broken by a sustained period of steadily increasing irradiance or high mean irradiance. METHODS: We exploit interannual variation in the timing of flowering and meteorological events to evaluate

the eight hypotheses in a model competition framework. We formulate each hypothesis as a quantitative model to predict the probability of flowering for each day of the year. Model inputs are daily meteorological records. Model parameters include the duration of drought (or low irradiance), the increase in rainfall (or irradiance), the rate or duration of this increase, and a lag between flowering and the date the cue is realized. We evaluate predictions against species-specific flower records from 1,820 weekly censuses (35 years) of 200 passive traps at Barro Colorado Island, Panama. **Results:** Analyses are underway. Preliminary results follow. Photoperiod and low temperature hypotheses are not supported. Irradiance hypotheses are supported for the largest number of species. Rainfall hypotheses are supported for fewer species. None of the eight hypotheses adequately predict flowering times for a substantial number of species. **Conclusions:** We have linked interannual variation in the timing of flowering to interannual variation in the timing of seasonal changes in irradiance in many species. Our models distinguish the aspect of seasonal change – more species respond to sustained periods of high mean irradiance then to sustained increases in irradiance – and quantify critical levels and durations of contrasting low and high levels of irradiance associated with flowering. Cloud cover largely determines irradiance levels on BCI, with irradiance averaging 49% higher in the four-month dry season than in the cloudy, wet season. The behavior of clouds remains one of the greatest uncertainties under global warming, with implications for plant phenologies in humid tropical forests. **Keywords:** Flowering, irradiance, phenology, photoperiod, proximate cue, rainfall, temperature

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Flowering Phenology in a Lowland Mixed Dipterocarp Forest

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Sympatric plant species exhibit various patterns in flowering phenology, from continuous to supra-annual and from periodic to intermittent pulses. This phenological variation is evident in many forests. Hypotheses propose that plant-animal interactions, such as pollination and seed predation, and ancestral signature may be responsible for differential patterns of flowering among sympatric species. In order to investigate the importance of these potential causes for diversification of flowering patterns among sympatric species, we characterize flowering periodicity and synchrony for 148 species with 18-year weekly flower data in the 50-ha Forest Dynamics Plot in Pasoh Forest Reserve, Malaysia. Periodicity is calculated with Fast Fourier Transform. Synchrony is determined by the proportion of flower produced within the flowering time of *Shorea* species, the renowned indicator species for the community level synchronous flowering. We then explore the relation of phenology pattern to dispersal mode and phylogeny. Our results showed that 105 species exhibit supra-annual flowering patterns and 84% of these species participated in GF events. We also found 60% of species flowered sub annually and annually produced substantially more flowers during general flowering events. We found a significant relationship between seed dispersal mode and synchrony types implied the importance of seed predator satiation for intermittent flowering species. No clear relationship was found between flowering periodicity and seed dispersal type. We found no phylogenetic signals for flowering phenology, for both periodicity and synchrony. Regular flowering pattern in this aseasonal forest could not be explained by either cause tested here. The diversification of phenology patterns in aseasonal tropical forests calls for further investigation. **Keywords:** Flowering phenology, synchrony, dipterocarp, seed dispersal, phylogeny

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Inter-annual Changes in Plant Phenology in a Tropical Ever-wet Forest Community of Western Amazonia

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Introduction: There is growing evidence that changes in climate are altering the ecology of tropical forest plant communities around the world. In Western Amazonia, contrary to the more frequent and severe droughts predicted in Eastern and Central Amazonia, climate models predict (along with increasing temperatures) an increase in mean annual rainfall and more prolonged wet periods, which would typically lead to increased cloud cover and so a decrease in solar irradiance. This decrease in available energy may in turn affect species' fitness

through flowering success, as previous evidence has suggested that plant species synchronize their flowering with periods of peak of irradiance. **Objectives & Methods:** Here, we examine how the mean monthly values of six climate variables (irradiance, rainfall, relative air humidity, and minimum, average and maximum air temperature) have changed over a 19-year period (2000-2018) in a 25-ha ever-wet tropical forest plot in Western Amazonia. We analyzed how the inter-annual fluctuations in these variables have influenced flower and fruit production among 248 plant species (recorded in 435 phenology traps), and how species response differs across different guilds (canopy vs. understory trees, climbers, epiphytes) and according to their resource-use traits (wood density, SLA) and dispersal syndrome. **Results:** We found an increase in mean annual air temperatures during the study period, especially in minimum temperature, for which mean annual values varied from 20.8°C to 22.6°C and 45% of the warmest years occurred after 2009. In contrast, mean annual irradiance dropped by ca 10%, with 40% of the lowest-irradiance years occurring after 2009. Mean annual rainfall and relative humidity did not show any clear trend through this period. Nearly 65% of the species responded negatively in terms of flower production to both increasing temperature and decreasing irradiance, even after controlling for the effects of all the other climate variables, which in turn reduced fruit production. The strength and modality (positive or negative association) of species' responses were not associated with any particular trait, guild, or family. **Conclusion:** Our results suggest a negative impact of increasing temperature on flower and fruit production, potentially mediated by higher respiration costs, along with a decrease in the availability of solar energy. These findings provide important insights to better predict shifts in species composition in responses to climate changes in ever-wet forests, which have been poorly investigated so far compared to more seasonal tropical forests. **Keywords:** Flower production, Fruit production, Rainfall, Irradiance, Temperature, Tropical ever-wet forests

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Noah´s Arcs of the Anthropocene: the role of Botanic Gardens in Caribbean plant conservation

The Jardín Botánico Nacional, La Habana, Cuba and Its Role in Conservation of Cuban Botanical Heritage

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The Jardín Botánico Nacional located 25 km southwest of the capital of Cuba, belongs to the University of Havana, it is a recreation, teaching and science center. Among its lines of research, the studies of the flora of Cuba and the conservation of plant biodiversity stand out, consequently it is the headquarters of the Group of Cuban Plant Specialists (GEPC) founded in 2003, attached to the species survival commission (SSC) of the International Union for Conservation of Nature (IUCN). This group, made up of specialists from various institutions in the country, meets to evaluate proposals and assign the categories and criteria of the species. Two red lists have been published from the work of this group: 2005 (1,414 taxa evaluated) and 2016 (4,626 taxa evaluated, 72.86% of the flora). Between both red lists, five rapid categorizations were made (2007, 2008, 2009, 2013, 2014). Special attention has been devoted to endemisms, with 79% of these taxa being evaluated. Cuba is the Caribbean country with the largest number of threatened species: 46.31% of the assessed flora. The main threats to the native flora have been determined, such as: human activities, for example the introduction of invasive exotic species, deforestation, habitat fragmentation, livestock, forestation and agriculture. The JBN also hosts "Planta! Initiative for the conservation of the Cuban flora", organized since 2012 that carries out an active collaboration with university students, in camps, research in nature and environmental education in local communities. The informative work is carried out through the ¨Bissea Bulletin¨: "The Bulletin on Plant Conservation of the National Botanical Garden of Cuba" with four annual issues, television and radio programs and exhibitions. It works in close coordination with the National System of Protected Areas, which houses 73.68% of threatened species. The most urgent conservation needs are monitoring, environmental education and habitat management. Examples of works in this sense have been the studies of species of palms, cacti and magnolias, charismatic groups due to their endemism and beauty. The rescue of species declared extinct or critically endangered has allowed their ex situ cultivation, propitiated by the exchange with provincial gardens through the National Network of Botanical Gardens in Cuba. **Keywords:** Botanical garden, conservation, red list, threaten species, conservation assessment

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Contrasting Efforts in Plant Conservation in Hispaniola

Betsaida Cabrera García

National Botanical Garden of Santo Domingo, Santo Domingo, Dominican Republic

The Hispaniola Island comprises 77,914 km^2 distributed between the Dominican Republic, with 48,442 km^2 and the Republic of Haiti, with 29,472 km^2. Most of the original vegetation on the island has been destroyed as a result of intense human activities from colonial timaes to the present day. This destructive process has caused the floristic richness and the phytogenetic heritage of Hispaniola to suffer a marked deterioration, for which reason efforts are currently being made for its restoration and conservation. In the Dominican Republic, it is estimated that 18 % of the forest cover is primary forest, while in Haiti only 3 % may be considered primary. A high percentage of the Dominican flora is found within protected areas, which cover 25 % of the national

territory. In Haiti, the state of conservation of its interesting and exclusive flora is uncertain, it is assumed that many endemic species are extinct. In the Dominican Republic, the *Jardin Botanico Nacional de Santo Domingo "Dr. Rafael M. Moscoso"*, created in 1976, has been in charge of studying and conserving the flora of the eastern part of the island through numerous national and international projects and agreements, aiming to increase the level of knowledge about the flora and vegetation of priority areas for plant species conservation. According to records made in recent decades, there are some 6,000 species of vascular plants on the island, 5,500 of which grow in the Dominican part. As part of the project "Conservation Status of the Vascular Flora of the Dominican Republic and Application of Threat Categories According to IUCN Criteria" it was possible to evaluate 1,388 species, 831 of which are endemic and 557 native. In Haiti, the *Jardin Botanique des Cayes*, founded in 2003, is working hard to develop the first Red List of threatened plants, which is expected to be published by 2023 with the support of the BCGI. This important consultation tool, together with conservation projects, has made it possible to improve the situation of certain species and prevent their total disappearance.
Keywords: Dominican flora, red list, conservation, Hispaniola

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The Importance of Indigenous Species in the Restoration Project in Haiti

William Cinea

Cayes Botanical Garden, Cayes, Sud, Haiti

Haiti, located in the island of Hispaniola in the Caribbean, is part of one of the most important "hotspots" of biological diversity in the world. Its flora has been studied by several foreign botanists since 1697. More than 5,600 vascular plants have been reported (Acevedo-Rodriguez 2012). Almost all this data is currently deposited in overseas institutions, mainly from Europe and the United States. To date, a few Haitian institutions hold information about its flora. The United Nations has declared the decade from 2021 to 2030 as the Decade on Ecosystem Restoration as a global rallying call to prevent, halt and reverse the degradation of ecosystems worldwide. This call is vital to impulse movements to protect and restore the biodiversity of Haiti. This call is perhaps most important in Haiti. Nearly 96% of all terrestrial ecosystems in Haiti have been highly altered and are in urgent need of biological restoration. Many of the current projects to restore Haiti's ecosystems rely on exotic trees for reforestation. Currently, 90% of the trees used are non-native and even invasive such as Albizia lebbeck, Acacia magnum, and Azadirachta indica. Therefore, these projects might bring more harm than benefits, threatening even more of the country's rich endemic biodiversity and negatively impacting entire ecosystems. Since 2016, the team from Jardin Botanique des Cayes has worked to address these issues by studying and documenting native trees in the wild and promoting their inclusion in restoration efforts nationwide. To study our native flora, we organize scientific field trips to identify indigenous species, photograph plants and ecosystems, take herbarium specimens, and collect seeds to propagate them. We also develop partnerships with local and international institutions to store seeds and to collaborate testing propagation protocols. To support this vital work we are actively looking for financial aid through grants or sponsorships. In the past six years, we have photographed and collected over 1,500 of the more than 5,600 species reported for Haiti. These include seeds from approximately 500 indigenous herbs, shrubs, and trees, which have been selected as potential species for restoration projects. Our nurseries have successfully propagated many native species from seeds, including some of the most threatened taxa reported for the country. The team at the Jardin Botanique des Cayes is working hard to encourage the inclusion of these native trees in all reforestation and restoration projects across the country. **Keywords:** Native plants, ecosystem restauration, blodiversity, hotspot, threatened taxa

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Half a Century of Caribbean Orchid Research and Exploration at Marie Selby Botanical Gardens

Tatiana Arias
Marie Selby Botanical Gardens, Sarasota, FL

This talk aims to communicate main achievements in orchid research in the Caribbean that have taken place at Selby Gardens. I have done a thorough review of the history, research and outreach activities that Selby Gardens orchid research associates have achieved during the past 50 years in this geographic area. I have consulted Selby's databases, herbarium, and spirit collections. I used this information as an opportunity to identify new avenues of research, exploration, and regional collaboration in the Caribbean. Scientists at Selby gardens have amassed one of the world's largest and most important orchid collection and scholarly literature. More than 25 research associates of the gardens have explored countries with coastal areas in the Caribbean, including Costa Rica, Belize, Dominican Republic, Puerto Rico, Guatemala, and the southern part of the state of Florida, USA. Taxonomists like Carl Luer and John Atwood contribute to the identification of many orchid species in the region and the publication of the Orchid Flora of the Greater Antilles. Carl Luer worked extensively in the systematics of the subtribe Pleurothallinidae in the Antilles, including the genera Pleurothallis and Lepanthes, while Bruce Holst and others have made an incredible amount of exploration in Belize, Panama, and Costa Rica. We have also worked with collaborators and research associates from the Caribbean region helping them to develop important research in areas such as conservation, taxonomy, and ecology. More than ten visitors from different countries of the Caribbean have used Selby resources to leverage their research. Selby's impressive live orchid collection houses more than 850 species from 18 countries such as Panama, Belize, and Costa Rica, the three best represented countries in our collection. Herbarium specimens from the Antilles include around 625 specimens, plus more than100 from the southern counties in coastal Florida. In conclusion Selby Gardens have a rich history of orchid research and collaboration in the Caribbean including important germplasm that could be used in conservation projects around the region. In the future we will keep working with local researchers to strengthen their conservation initiatives, and to keep exploring patterns of variation within orchid species in the region and using high throughput sequencing. The region needs further exploration particularly in certain regions of Cuba, Bahamas, and Hispaniola. New species in genera such as Encyclia and Tolumnea are to be described. Much information about orchid morphology, pollination, population biology and blogography is still missing for many species. **Keywords:** Orchidaceae, caribbean, selby gardens

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Conservation of Forgotten and Endangered Caribbean Plants through Domestication for Tropical Landscaping

Maria P. Contreras
Jardín Botánico de Cartagena, Turbaco, Bolívar, Colombia

Plant conservation in urban and semi-urban landscapes has become essential in a climate-change-biodiversity-loss scenario. The integration of native flora into cities contributes to global efforts to conserve plant species and the development of sustainable horticulture (*i.e.,* water-wise gardens). Many large cities have seen the benefits from the introduction of green infrastructure, including community integration, improving health, and reducing carbon emissions. To accomplish this link within urban environments, it is important firstly to study the species. We aim to create technological packages focusing on native plants that were successfully introduced to European horticulture in the XVIII century, nowadays forgotten, and endangered species with ornamental potential of the seasonally dry tropical forest (SDTF). Field trips are regularly made to pristine forest remnants of the Caribbean region of Colombia. Plant collection, seed collection, phenological annotations, plant architecture, and plant ecology are among the primary interests. Plant material is processed at the herbarium of the Cartagena Botanical Garden (CBG) for ID confirmation, at the seed bank for storage and the research nursery for propagation purposes. Trials of light intensity, drought tolerance, different soil types, and irrigation regimens are made to establish species limitations and optimal growing conditions. Considering the area of influence, the SDTF, a highly endangered ecosystem, our work is of great relevance in conserving native plant species and the ecosystem as a whole. We strive to conserve, restore, and enrich ecosystems through long-lasting actions involving the use of native species in urban and semi-urban landscapes. Results will be available at the CBG web portal in order to promote open and accessible data. **Keywords:** Horticulture, landscape, ecology, biodiversity, caribbean, botanical garden

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Decolonizing Botanical Sciences in the West Indies: Hispaniola Case

Yuley Encarnacion Pineyro
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The West Indies are considered one of the top five biodiversity hotspots on the planet, which means they encompass a great diversity of endemic taxa, unique habitats, and vulnerable ecosystems. These hyper-diverse ecosystems have driven the attention of botanical explorers, naturalists, and researchers from all around the world, resulting in historical prolific expeditions, thousands of collections and publications focused on describing the plant diversity in the region. However, botanical sciences in the Caribbean islands have deep roots in colonialism, and there often is a marked disconnect between those actually carrying out the research and the incorporation of local scientists and stakeholders, such as the general public and students being trained in the botanical sciences. Instead, we often find that resulting publications and plant collections have been based on persistent colonial practices and methodologies that exclude local scientists, silently promoting a lack of development and diversity in the sciences in the very countries where the work is carried out, a loss of traditional knowledge, as well as difficult access to information of our genetic resources. The present study aims to assess the incidence of ongoing colonial practices in the botanical sciences, along with promoting decolonization at different scales. By reviewing the literature in the plant sciences, herbarium collections (especially of type specimens), conservation projects, and botanical research approaches/topics on Hispaniolan endemic plants, we present a compilation of historical and ongoing colonial practices and methods that need to be revised and/or changed. Our work underscores the fact that decolonizing science is a complex process that starts with recognizing these practices, while enabling pertinent and responsible conversations, not with the purpose of passing blame, but by engaging stakeholders to seek opportunities and propose solutions for these deeply engrained practices. **Keywords:** Caribbean Islands, colonization, botany, Dominican Republic, Haiti

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Overcoming implicit bias in the tropical science community for better conservation research and practice

Overcoming Implicit Bias in Ecology and Conservation Publishing

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The global scientific community has become increasingly diverse over recent decades. At the leadership and decision-making level, however, field such as ecology, evolution and conservation remain largely dominated by male scientists from the Global North. Through this bias, we are missing key perspectives from most biodiversity hotspots and many other benefits related to diverse communities. Addressing the global biodiversity and climate crises in research and practice requires determining opportunities for diverse leadership and how to overcome challenges in tropical ecology and conservation. In a study of 13 leading journals in ecology, evolution, and conservation, we asked if the increased diversity in global scientific communities is also reflected among top-publishing authors and potential scientific leaders. We investigated the diversity of the 100 top-publishing authors in each journal between 1945 and 2019. In addition, we asked these top-publishing authors whether and how implicit bias affected their publication success and analysed our data set with focus on bias in editorial boards. Out of 1051 individual top-publishing authors in ecology and conservation, only 11% were women. The United States, United Kingdom, Australia, Germany, and Canada account for more than 75% of top-publishing authors, while countries of the Global South were strikingly under-represented. The number of top-publishing authors who are women and/or are from the Global South is slowly increasing over time, and positively correlates with population size and GDP per capita. In a new analysis of this dataset, we also find strong biases of influential editorial boards in these disciplines. Our surveys with top publishing authors indicate that scientific leadership in ecology is less diverse than its community, but also what could be done to promote diversity, equity and inclusion. The results are discussed with special reference to the tropical science community. Many opportunities for increasing representation of women and scientists from the Global South are straightforward and therefore should be implemented immediately in scientific best practice, accompanied by measures that promote awareness and further evaluation of inequality in scientific careers. Despite the presentation of our findings, this presentation will provide a brief introduction into this hybrid symposium "Overcoming implicit bias in the tropical science community for better conservation research and practice". Live-streamed oral presentations and an open final discussion will help to highlight several key challenges and opportunities to promote more inclusive and integrative approaches in tropical biology and conservation. **Keywords:** Diversity, equity, inclusion, publication bias, gender bias, geographic bias, leadership

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Community-based Monitoring and the Inventory of Birds in Colombia: Examples from the Andes to the Amazon

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Bird watching is an enthusiastic activity that could include different participants from academic to non academic background. Given the status of Colombia as a megadiverse country in the tropics, with more bird species than any other country all around the world, encouraging many audiences to explore their nature is a must. Although several efforts to synthesize the inventory of birds in Colombia have demonstrated the importance of the country to maintain such biodiversity, many regions remain understudied and poorly known. I was part of some efforts beginning eight years ago to encourage local leaders to monitor their birds in the Andean and Amazon region of Colombia. After short field and class lectures, some local leaders are still exploring sites that many academic researchers could not visit, they became our eyes and ears in the fields of Colombia. We would present the most remarkable contributions that local birding leaders had given to the Colombian ornithology, namely the inventory of birds in the country, by some examples from two poorly known regions of Colombia: the southern Andes and the Amazon regions. This community-based monitoring by local leaders demonstrates the importance of extending "impact factor" to regional actors, empowering and working together with them, by exploring and reporting their discoveries. Nonetheless, some barriers remain for these local researchers, such as language and paywalls for academic journals. **Keywords:** Amazonas, bird diversity, Caquetá, conservation, local leaders, Putumayo, sustainability

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Conservation in the Tropics: From Ecological Theory to Transdisciplinary Practice

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The vast majority of the global biological diversity is hosted in tropical countries. At the same time, these are the most highly populated countries and suffer instability as a result of their particular socioeconomic and political circumstances. In these contexts, the debate surrounding the expansion of protected areas for biological conservation has been exhausted. It has been proved that the protectionist and colonialist 'pristine' and 'people-free' focuses of protected areas are inoperative. The biodiversity is found in the same territories that are shared by millions of inhabitants, and represents sources of food, medicine and income through raw materials and transformed products. Biodiversity has been used and transformed by thousands of ethnic groups and communities for millennia, generating a valuable heritage of traditional knowledge for its management. However, historically, the traditional disciplines of ecology and conservation science have ignored these contexts and knowledge. This disconnection has generated a considerable gap between the technical knowledge of conservation and the need to develop viable and effective management strategies. The science of conservation requires an evolution towards transdiscipline, within an integrative framework that can accommodate all of the voices and languages of the pertinent stakeholders. Implementation of top-down conservation strategies that only consider purely biological objectives is doomed to failure. Any effort of conservation planning must be constructed in a complete analysis of the local context, where the objectives of conservation must be aligned, as far as possible, with social and economic objectives that will allow landowners and local inhabitants to address their basic needs. I illustrate these issues through several case studies of conservation policies in Mexico related to protected areas management, endangered species management and community land co-management. Alternative solutions for conservation planning that incorporate bottom-up approaches, with plural representation, consensual agreements of collaboration and shared benefits through co-management are presented. **Keywords:** Biodiversity conservation, community-based conservation, sustainability, transdisciplinarity

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Opportunities at the Science-conservation Interface

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It is increasingly clear the need to fill spaces at the interface between science and decision-making. However, there is still a lack of institutional initiatives acting on these interfaces. We argue here that initiatives based on synthesis science can help bridge this gap if they are based on a transdisciplinary and participatory approach. These initiatives or institutions can function as boundary organizations, intermediating the relations between the demands of decision-makers and society, and the different processes of knowledge generation. Understanding the potential of these initiatives may help identify gaps and opportunities for strengthening and improving actions on science and decision-making interface, including capacity building in megadiverse countries. Brazil has been advancing in structuring synthesis initiatives with this perspective of exploring the science-conservation interface. The main objective of this presentation will be to share the lessons learned from two of these initiatives: the Synthesis Center on Biodiversity and Ecosystem Services (SinBiose), implemented as a research program at the Brazilian National Council for Scientific Research (CNPq), and the Biota Synthesis project, a state initiative focused on supporting the state of São Paulo in the development of socio-environmental public policies, considering essentially nature-based solutions. Although recent, these two initiatives show the great potential of synthesis initiatives in filling the implementation gap of socio-environmental public policies in megadiverse countries. **Keywords:** Science-policy interface, synthesis science, transdisciplinarity, environmental policy

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Transdisciplinary Conservation Requires Long Term Collaboration with Patience, Listening and the Pursuit of Justice: Reflections on Jaguar Conservation in Mexico

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Collaboration is required between researchers, biodiversity managers, local businesses, government and indigenous communities to achieve conservation in most tropical regions. However, these different actors can function on different timescales, leading to asynchrony of goals, impeding partnership efforts and limiting the capacity of academic endeavors to fairly represent the diverse ontologies and perspectives. We reflect here on our experience of an on-going collaborative research programme around the Calakmul Biosphere Reserve, Mexico. Our research addressed biodiversity conflicts over jaguar by analyzing relevant local social relations. The intention was to collaborate with local actors to ensure that research processes catalyzed mutual learning, and findings were both accepted and useful. However, since we initiated the research (albeit with 20 years' experience in the region) rather than local request for our input, collaboration had to be fostered. Firstly, we broadly explored people's environmental concerns to understand how jaguar conservation was perceived by local actors. We sought common ground to facilitate collaboration and listened to local issues. These discussions revealed the poor reputation of the scheme that compensated local farmers for livestock depredation by jaguar and we reported this to the administering committee. Secondly, we further evaluated local actors' experiences of this compensation scheme and undertook workshops to improve it, together with a local conservation NGO and the Biosphere Reserve. Thirdly, we explored feelings of injustice regarding conservation. Overall, this research programme encouraged long-term engagement between local and international researchers and many local actors. It led to the co-design and implementation of a training workshop on conflict management. Despite excellent scholarship, the development of sound relationships, and eventual practical impacts, challenges were encountered. Local actors did not always want to engage with 'our' researcher agenda or were distracted e.g. by elections. Some partners did not fulfil prior stated commitments. Local ranchers, whilst friendly, expressed frustration at the lack of tangible short-term benefits. Six years later, the fruits of our persistence are visible: our academic outputs on jaguar conservation are requested by local initiatives and we co-wrote two proposals for practical projects. Our reflections illustrate how the pursuit of common ground and conservation embedded in justice are required to navigate collaborations and reduce our own bias. Despite the urgency of the biodiversity crisis, we need to be willing to listen to different voices, to be patient, and to recognise the different priorities and timescales of others for long-term understanding, action and transformation through transdisciplinary research. **Keywords:** Conservation, collaboration, mutual learning, transdisciplinary research, researcher position, Mexico

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Implementing Transdisciplinary and Sustainability Science for Conservation Research and Practices in the Tropics

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Abstract: Introduction/Background Conservation practices hinges on the collaboration of different actors across disciplines and institutions. Local and traditional communities play a very important role in conservation successes, either due to their vast knowledge of the area, or due to the fact that their support has a huge impact on the implementation in the field. It is thus important to understand the context of the local knowledge of the communities and integrate these knowledge in a new context through transdisciplinary processes. The integration of modern sciences- local knowledge can bring forth new insights into conservation practices that is important for the development of sustainability sciences. The Dangku wildlife reserve is one of the last remaining forest in the lowland tropical rainforest within the Sembilang-Dangku landscape in South Sumatra, Indonesia. In 1990s, the Dangku landscape was an intact lowland rainforest. However, uncontrolled development (including encroachment) coupled with the great forest fires in 2015 have fragmented the landscape into small forest patches, threatening the existence of those endangered species. The interaction of communities, government and the role of civil society in developing a common vision for the area was implemented. **Objectives:** To assess the feasibility of the Dangku landscape as a wildlife corridor through transdisciplinary approach, to study the local context of the community, their knowledge and livelihood practices in the surrounding Dangku landscape. **Methods:** The use of participatory approach in community engagement, focus group discussions, and village mappings. Study on the ethnography of the communities was also conducted. **Results:** There are many issues that need to be addressed first in order to create enabling conditions for the wildlife corridor concept to work on the ground. The challenges of knowledge co-creation for conservation came from each of the stakeholders stemming from their different biases. The communities perceived that the concept of wildlife corridor may hinder their ability to find livelihood. On the other hand some of these communities encroached the areas. Conflicts of land ownership is the norm in the area (between the communities and the state or the private sector and between the communities of different villages). Through many participatory processes and engagement, a conservation partnership was developed together between the government and the local communities. Rehabilitation was actively conducted together. **Conclusions:** We conclude that inclusivity and the changes in paradigm are needed for conservation practices to be implemented. Transdisciplinarity renders the importance of knowledge co-creation in the context of sustainability. **Keywords:** Transdisciplinary, sustainability science, conservation, lowland, tropical, Dangku landscape, South Sumatera

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Challenges to Guaranteeing Inclusion and Equity to Women in Science: An Intercultural Approach with Emphasis on Latin America

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Much has been said over the last few years about the issues faced by women in the STEM fields. Campaigns such as the #MeToo movement have made evident the frequency with which women are subject of sexual harassment and other types of inappropriate behaviours in diverse work environments, academia is, unfortunately one of them. However, these problems are far from being the only ones affecting women's scientific activities. An increasing number of studies have recently shown how women tend to be discriminated against in aspects which appear essential to the academic endeavour, such as participation in research projects, co-authorship in peer-reviewed publications, establishment and maintenance of collaborative networks, representation in expert panels and editorial boards, acknowledgement of previous findings (i.e., citations), attendance to scientific meetings, assessments of ideas and achievements, etc. These worrying trends have been exacerbated due to the COVID-19 pandemic. Here, based on a combination of personal experiences and a literature review, I discuss the ways in which these issues manifest themselves in different regions of the world. I place special emphasis on Latin America, a region whose characteristic cultural patterns make it difficult to implement measures that mitigate the main issues but that, interestingly, does not seem to be in a particular disadvantageous place in certain key aspects. I suggest a series of steps that, if taken, would allow a greater and better participation of Latin American women in scientific activities, and conclude that, in order to attack the roots of the issues affecting women's participation and true inclusion in academia, it is necessary to promote, simultaneously, gradual changes in the cultural aspects inherent to each region. **Keywords:** Latin America, implicit bias, diversity, inclusion, machismo, inclusivity, glass ceiling

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Tropical Biology on Boots: Challenges and Strategies to Promote Inclusion and Equity in Fieldwork

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Fieldwork is an essential and exciting component of tropical biology. Young investigators often fall in love with research once they have experienced data collection, sampling and processing specimens in the field. Fieldwork provides many professional development benefits for participants as they gain valuable and unique experiences. Fieldwork, however, can involve particular challenges associated with providing a safe and welcoming environment for all. In addition, given that fieldwork occurs outside of traditional classroom settings, away from campus, expectations about interactions and performance are often unclear. Lack of transparent and carefully designed strategies to promote inclusion and equity when performing work in the field are of particular concern given the nature of these journeys. Fieldwork often results in unusually close interactions between researchers who share personal spaces and time together beyond standard working schedules. Teams working at foreign locations can be confronted with unknown rules and traditions to the researchers visiting. Some locations can also present particular health and personal challenges for different people in the team. Overall, the complexity of human interactions is accentuated during fieldwork and, unfortunately, those conditions often lead to harassment and discrimination in the face of limited structure to prevent inappropriate behaviors. Researchers from historically under-represented groups in particular, are at high risk of suffering abuse and discrimination during fieldwork. This talk will discuss implementation of codes of conduct for fieldwork and training for research leaders and participants in fieldwork. Specifically, explicit strategies that team leaders can implement when preparing for fieldwork and put into action once in the field will be addressed. By also discussing tactics available for young investigators, we hope to prepare them in the face of the challenges that may come with doing fieldwork. The field of tropical biology will benefit from implementation of clear rules and expectations for personal interactions that promote broad participation at field stations. Conversations around this topic are critical to ensure the success of a diverse, next generation of tropical biologists. **Keywords:** Fieldwork, field safety, inclusion, mentorship

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Consequences of Language Barriers in Ecology and Conservation

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Background: Language barriers—difficulties faced in communicating information when it involves a language other than one's mother tongue—can severely hinder the advance of science and its contribution to tackling global challenges, mainly in three aspects: barriers to: (1) the global synthesis of scientific knowledge scattered across different languages, (2) the application of English-language knowledge to local decision making in countries where English is not widely spoken, and (3) career development in non-native English speakers. **Objectives/Methods:** The translatE project (https://translatesciences.com/) applies scientific approaches to understand and address those three types of language barriers in science with the aim of maximising scientific contribution to global challenges including biodiversity conservation. In this presentation, I will focus on the first two types of language barriers in ecology and conservation, and talk about our latest research, where we investigated the consequences of language barriers in ecological evidence synthesis and use of scientific evidence in local biodiversity assessments. **Results:** Our research shows (i) the number of conservation articles published in non-English languages is increasing over years and (ii) ignoring non-English-language studies can cause severe biases in our understanding of biodiversity and its conservation, however (iii) non-English-language literature is rarely used in global biodiversity assessments. In contrast, in countries where English is not an official language, we also show that (i) non-English-language literature constitutes 65% of the references cited in national biodiversity assessment reports, and is recognised as relevant knowledge sources by 75% of report authors, while (ii) a quarter of the authors acknowledge the struggles of understanding English-language literature. **Implications:** Our findings so far revealed two major consequences of language barriers in achieving global biodiversity targets for the next decade. On the one hand, we uncovered that non-English-language literature can provide important evidence for conservation but is almost entirely ignored at the international level. Future assessments and decision-making at the international level must not dismiss relevant knowledge simply due to the language of its publication. On the other hand, we also revealed that decision-makers face difficulties in using scientific knowledge if relevant knowledge is provided only in English. We must ensure that English-language scientific knowledge is easily accessible, i.e., available also in a relevant language for its users. This will facilitate the use of the best scientific evidence in environmental decisions across all countries, including those where English is not widely spoken and, quite often, biodiversity is threatened the most. **Keywords:** Evidence synthesis, language barriers, biodiversity assessments, research-implementation gap

Patterns and mechanisms of diversity and forest change in the Andes

Environmental Bias of the Colombian Andean Flora

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Introduction: Species records are the primary source of biodiversity research. However, the information available online is geographically and environmentally biased. The tropical Andes is one of the world's hotspots because complex topography and climate variability. The combination of those factors has created a mosaic of ecosystems and species arrangements. Despite the high species diversity of the tropical Andes, the sampling bias in the region are not well understood nor does its impact on the understanding of diversity patterns in the area. **Objectives:** This study aimed to identify spatial and environmental biases in the plant collection pattern of the Colombian Andes flora and study its completeness. **Methods:** All available records of plant species were downloaded from online databases (GBIF, TROPICOS, COL, JBB). We characterized spatial coverage and plant collection density in the Colombian Andes using five cell sizes (e.g, 100 x 100, 50 x 50, 20 x 20, 10 x 10 and 5 x 5 km). In the same grid cells, we performed sampling bias analysis for altitude, precipitation and temperature measuring the magnitude of the sampling bias using the Kadmon index and calculating the completeness by rarefaction. **Results:** Significant bias and gaps were found across environmental, topographic and spatial variables. Spatially, the latitudes 0°– 4°N and 8°–12°N had fewer records than expected, while 4°–8°N had more records than expected. At high altitudes, collection efforts were concentrated in areas above 2000 m, with a temperature regime from 5-15°C and rainfall of 688-1666 mm/year. Scale analysis revealed higher coverage (>90% of the study area) and completeness (60-68%) at high cell sizes (e.g., 100 x 100 km), although, high environmental variability was found in these cells. In contrast, lower coverage (<50%) and sample completeness (22%) were found at a higher spatial resolution, with low environmental variability. Additionally, there is bias around the main Colombian cities (Bogotá, Medellín) and in the high-altitude ecosystems (e.g., páramo). However, low levels of sampling completeness were found even in the best-sampled areas, and there is almost no sampling in the protected areas of the country. **Implications:** The results obtained could have consequences on our understanding of richness patterns in the Colombian Andes. For example, ecosystems representing unique conditions (such as refugia) and flora vegetation limited to small areas could be not represented in the flora record, a problem particularly important in topographical complex areas such as the Colombian Andes. **Keywords:** Northern Andes, sampling completeness, flora, collecting bias, herbarium specimens

The Biogeographic Assembly of a Tropical Montane Biota

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Introduction: Fundamental questions at the interface of biogeography and community ecology are how the evolution and biogeographic history of clades contribute to the assembly of regional biotas, and how these processes feedback with local mechanisms to shape the structure and diversity of natural communities. In the Neotropics, the uplift of the Andes has had an enormous influence on the distribution of both environmental conditions and biodiversity. Indeed, the Tropical Andes represent one of the most species-rich regions in the planet, hosting a disproportionate amount of biological diversity. How the uplift of the Andes (or any other mountain chain) has contributed to the formation of regional and local assemblages remains a topic of intense research. **Objectives:** In this study, we evaluated how the uplift of the Central Andes shaped the assembly of some of the most diverse regional floras in the World. Specifically, we studied patterns in the distribution of species and clades across elevations and biogeographic regions to test two non-mutually exclusive hypotheses: 1. The formation of new environments by mountain uplift promoted adaptive diversification and the colonization of the Andes from environmentally dissimilar regions, and 2. Mountain uplift primarily encouraged the immigration of clades of species that were pre-adapted to new environments at higher elevations. **Methods:** We combined data on the distribution of plant species at two contrasting spatial scales. We used data from the Madidi Project to characterize change in woody plant communities along elevational gradients, while we characterized large-scale plant assemblages across biogeographic regions using data from the Botanical Inventory and Ecology Network. We then evaluated the phylogenetic structure of species assemblages and the evolutionary relationships among constituent species to test predictions made by our two hypotheses. **Results:** Across the Neotropics, we found that most of species in the Central Andes are derived from clades of other temperate regions. Along the elevational gradient, we found that species turnover is primarily the result of high turnover of clades with pre-Andean origins. These results support the idea that the environments created during the uplift of the Central Andes were mainly colonized by clades of pre-adapted species. **Conclusions:** While recent research has highlighted high levels of dispersal among biogeographic regions in the Neotropics, our results suggest that it is generally easier 'to move than to evolve', highlight the importance that niche conservatism has in shaping modern patterns of assembly at regional and local scales. Introduction Fundamental questions at the interface. **Keywords:** Central Andes, madidi project, niche conservatism, adaptive radiation, assembly

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Effects of Local Disturbance and Urban Growth on High-Andean Forests Composition and Cover

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High Andean forests are biodiversity hotspots that also play key roles in the provisioning of vital ecosystem services for neighboring cities. However, they are among the most fragmented and threatened ecosystems in the neotropics. In past centuries, the hinterland of Andean fast-growing cities often experienced a dramatic decline in forested areas, but there are reports that forest cover has been recovering recently. The main aim of this work was to gain a deeper understanding of the forest cover dynamics, together with the effects of anthropogenic perturbations in forest fragments in the Eastern Andean Cordillera of Colombia. Firstly, we analyzed aerial imagery spanning the years 1940 to 2007 from several administrative localities in order to elucidate locality-wide patterns of forest vegetation change. To this aim, we performed image object-based classification by means of texture analysis and image segmentation. We then derived connectivity metrics to investigate whether forest cover trajectories showed an increase or decrease in fragmentation and landscape degradation. Parallelly, we characterized the plant communities of high Andean forest remnants in permament forest plots where we gathered data on both the woody vegetation and the understory compositional and structural parameters and compiled a broad array of variables related to anthropogenic disturbance, ranging from local to landscape-wide metrics. Subsequently, in order to filter variables and to test how environmental and anthropogenic variables are affecting the composition, diversity, and aboveground biomass of these forests a series of statistical procedures (NMDS, pRDA and GLMs) were employed. Lastly, we discussed the observed forest cover trend and the local recent history in relation to the compositional and structural parameters examined in the established plots for each locality. Regarding the vegetation cover reconstruction, we observed a forest cover recovery in all the examined localities, except one. In general, forest recovery was accompanied by an increase in core habitat areas. As to the permanent plots network, we found that the increase of human-related disturbance resulted in less phylogenetic diversity and in the phylogenetic clustering of the woody vegetation and in lower aboveground biomass (AGB) values. This study provides information on the vegetation composition and structure of peri-urban high Andean forests, while unveiling the long-term dynamics of their cover and connectivity, providing valuable information on historical vegetation changes in a highly dynamic landscape. **Keywords:** high-Andean forests, forest cover, forest connectivity, biodiversity, phylogenetic diversity

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Phenology of Woody Plants along a Successional Gradient in a Tropical Andean Mountain Forest

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Background: Cycles of flower and fruit production determine the Spatio-temporal availability of seeds and the patterns of seedling establishment in forests, making them crucial determinants of forest regeneration. The intensity and activity of phenological phases depend on climatic events, such as solar radiation, precipitation patterns, and biotic factors such as plant-animal interaction. Most phenological studies on tropical ecosystems are focused on rainy or dry forests. However, these patterns have hardly been studied in tropical mountain forests, like Andean Tropical Mountain Forests (ATMF), which are considered a biodiversity "hotspot" due to the high levels of endemism with a high level of human activity intervention. However, despite being one of the most threatened ecosystems in the tropics, our understanding of ATMF's ecology is still poor. **Objective:** We studied the phenology of woody plants with flowering and fruiting intensity changes and activity along a successional gradient. **Methods:** We obtained data on fruit and flower production for 68 species during two years (2019-2022). Species were selected from 20 permanent plots located along a successional gradient of ATMFs in the eastern cordillera of Colombia. We monitored 485 individuals and quantified their flowering, fruiting activity, and intensity using visual determination, we attributed a score from 0 to 4 for each plant to estimate each phenological event's intensity. The obtained data was assessed using time-series analyses for evaluating intensity and activity indexes, MANOVA to compare phenology along the successional gradient, and mixed-effect models for climatic variables and phenological activity. **Results and Conclusions:** We found that ATMF tree communities have two peaks of activity in fruiting and flowering during the year. Both peaks occurred during the dry season, the first was from February to March, and the second was from July to August. In addition, we found that the intensity of the different phases (i.e., the strength of phenological events) was significantly higher in early successional forests than in late successional ones. Interestingly, the phenological activity (i.e., number of species flowering and fruiting) did not change in the successional gradient. The larger production of flowers and fruits could have been due to the difference in light availability between early (more open canopy) and late (closer canopy) forests or changes in functional species composition along the successional gradient. These results give us essential ecological knowledge to help decision-makers manage plants and restore the ATMF ecosystem. **Keywords:** Seed disponibility, phenophases, life cycles, fruiting times, succession, Colombian Andes

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Above and Belowground Functional Traits and Their Relation to Andean Species' Performance Planted in Abandoned Pastures

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Ecological restoration has been widely proposed as a tool to promote the recovery of degraded ecosystems. In this context, understanding which functional traits are able to predict tree growth in planting initiatives is a pivotal question. Although the mechanisms that drive plant performance across species have been well documented for aboveground organs, understanding the belowground mechanisms still require detailed measurements. Even more, evidence for coordinated above and belowground trait effects on growth is scarce, and it remains poorly understood how these traits together determine tree growth. We evaluated which traits (leaf, wood, and root) or functional strategies are more important in predicting plant performance. Specifically, we ask: when considered alone, are belowground traits more critical than aboveground traits for predicting plant performance in degraded lands? And, are ecological strategies integrating foliar, wood, and root traits in a multidimensional space able to predict plant growth better than traits alone? We planted 40 individuals of 12 tree species used for forest restoration in the Colombian Andes (480 individuals in total) and measured plant growth and survival for a year. After that time, we harvested 120 individuals and measured two foliar traits, two wood traits, and eight root traits. We related plant performance and trait values through linear mixed models. When evaluated alone, seven of the 12 traits measured significantly affected the species' growth, three of which were related to the root system. Traits related to thin leaves, high stem water content, and a large proportion of secondary roots showed the highest growth rate. In fact, the proportion of secondary roots was the trait that best explained plant growth. These results showed that the performance of species under degraded environments depends on traits associated with the acquisition of limited resources, such as water and nutrients. We found that plant species did not coordinate their above and belowground traits according to plant resource economics, when evaluated together. The species enhanced their growth rates by combining acquisitive traits aboveground with conservative traits belowground, this result emphasizes the call of recent studies for a new, multidimensional trait space that includes these different belowground strategies. **Keywords:** Root diameter, secondary roots, stem water content, functional strategies

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Plant ecophysiology in a changing world: applications for forest management and restoration ecology

Drought Effects on Tree Water Use Are Mediated by Management, but the Effects of Management Can Be Temporary.

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Tropical planted forests have demonstrated that tree plantations can have variable growth and water use patterns in response to drought. Yet research on how specific species will perform during a drought and whether this response can be mediated through forest management is still poorly understood. However, this information is vital as planted forests become more common throughout the tropics, where more extreme droughts are forecasted. We took advantage of a historic El Niño driven drought in 2015-2016 in central Panama to test how native species and a non-native species responded to reduced rainfall (60% less precipitation than average). We installed 96 trees with sap flow sensors that measured continuously for 2.5 years. We also measured meteorological data during the same period (vapor pressure deficit [VPD], temperature, relative humidity, precipitation) as well as the growth of the planted trees, to better understand what factors contributed most to changes in tree water use. In the non-native (*Tectona grandis*) plantation, we also conducted a thinning experiment, thinning half of the plots by 50% to see if thinning may mitigate the effects of drought. While one of the native species (*Dalbergia retusa*) we studied maintained daily transpiration before and during the drought, another native species (*Terminalia amazonia*) and non-native species *T. grandis* showed decreases in daily transpiration during the drought, but significantly higher daily transpiration rates than *D. retusa*. Additionally, we found that thinning had short-term effects on plant water use and growth, with initial increases in water use in thinned stands (versus unthinned stands) during the drought, but that once the drought ended, water use returned back to similar rates as the unthinned treatment. Notably, we found that each species had a unique temperature and VPD threshold, where the sap flow began to decline. While VPD generally led to increases in sap flow, this declined for *D. retusa* at 32°C and >34°C and 28°C for *T. amazonia* and *T. grandis*, respectively. Our results find that *D. retusa* is particularly water-use efficient compared to the other two species and may be an important reforestation species because of this trait. Notably, we also found differential temperature thresholds, where at high VPDs, sap flow began to decline. Of all three species, *T. grandis* had the lowest temperature threshold, which could pose a problem in future climate scenarios, where temperatures are expected to increase. Our results have important implications for reforestation efforts, where accurate tree species selection is critical. **Keywords:** Agua Salud, complementarity, drought, planted forests, productivity, sap flow, transpiration

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Beyond Forest Ecosystems: Using the Trait-based Approach to Understand Restoration Challenges in Brazilian Savannas

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The process of human occupation in the tropics led to the conversion of hyperdiverse native vegetation into degraded states of ecosystems. Species loss leads to changes in the functioning of these ecosystems and consequently affects the provision of services for human beings. To circumvent this situation, there are countless efforts and political incentives to restore these landscapes. Vast areas of former old-growth savannas are currently degraded and need to be restored. The practices and techniques to restore these systems are still limited and the restoration outcomes unpredictable, mainly because of the high because high invasion potential of exotic species and lack of knowledge on species traits that allow survival. Therefore, the studies focusing on species traits might improve restoration outcomes and provide pathways to underpin the ecosystem's resilience. Here, we show how using trait-based approaches might offer insights to deal with the challenges of current restoration practices in the Brazilian savanna ecosystem. We evaluate the functional composition, microbial activity, nutrient cycling, and decomposition rates of early savanna-stage restored by direct seeding of native species and compared to areas dominated by exotic grasses and well-preserved old-growth vegetation. We used multiple leaf traits linking to drought, productivity, and ecological strategies. Additionally, we measured below and above-ground biomass as vegetation parameters. We assessed soil nutrient cycling, comparing the activity of soil enzymes related to carbon and nitrogen and phosphorus cycling, as well as soil microbial biomass and soil fertility properties. Also, we access wood decay by microorganisms using an experiment with woody-blocks decomposition. We found that large-scale techniques for restoring Brazilian savannas did not recover the slow-growth component of old-growth savannas, recovering only a small fraction of the hydraulic diversity and the functional composition. Restored sites are dominated by acquisitive traits such as low belowground biomass and higher aboveground biomass. The soil microbial community and fertility are impacted by burning and plowing before sowing, which leads to low microbial biomass, low microbial enzyme activity, and consequently low microbial wood decay in the restored sites. The low immobilization of nutrients in microbial biomass, low retention of nutrients, and the lack of a belowground biomass pool in restored savannas may threaten long-term restoration success that implies low resilience and invasion resistance. The challenge of future savanna restoration practices is to promote a restoration that uses slow-growth and drought-tolerant species and that considers the soil treatment to restore soil carbon and nutrient cycling processes. **Keywords:** Savannas restoration ecology, functional composition, direct seeding

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Belowground Traits Mediate Tree Survival in a Tropical Dry Forest Restoration

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Reforestation is one of our most promising natural climate solutions, and one that addresses the looming biodiversity crisis. Natural regeneration is often an optimal strategy to promote the reestablishment of native species. Yet, in many degraded landscapes, tree planting can catalyze forest community reassembly where natural regeneration is slow. However, tree survival rates vary remarkably across projects. Building a trait-based framework for tree survival could streamline species selection in a way that generalizes across ecosystems, thereby increasing the effectiveness of the global restoration movement. We investigated how traits mediated seedling survival in a tropical dry forest restoration, and how traits were coordinated across plant structures. We examined growth and survival of 14 tree species for two years and measured six belowground traits and 22 aboveground traits, including a suite of aboveground ecophysiological characteristics. We tested the relative importance of above- vs. belowground traits and examined how interactions between trait combinations mediated seedling survival rates. Ultimately, by taking a broad scope, we aimed to identify a clear hierarchy of traits that should be considered to promote the survival of planted seedlings within tropical dry forest restoration. Species-level survival ranged widely from 7.8-90.1%. Relative growth rate was the strongest single predictor of tree species survival rate, indicating that species with faster initial growth rates typically had higher survival. However, the principal component axes which captured the greatest amount of variation in either

above- or belowground traits were poor predictors of survival on their own. The model that best explained variation in survival including growth rate, belowground traits, and their interaction ($R^2_{adj} = 0.73$). A strong interaction between belowground traits and growth rate indicated that selecting species with fast growth rates can promote establishment, but this effect was most apparent for species that invest in thicker fine roots and deep root structures. In general, belowground root traits were most predictive of seedling survival. However, one ecophysiological trait emerged as an important predictor of restoration outcomes, as seedlings with higher water use efficiency (measured using foliar $\delta^{13}C$) were more likely to survive. Overall, results emphasize the prominent role of belowground traits in determining early restoration outcomes, and highlight minimal above- and belowground trait coordination, providing a path forward for tropical dry forest restoration efforts. As such, our analysis highlights the importance of considering belowground root characteristics, relative to aboveground stem and leaf traits, when predicting early restoration outcomes within these seasonally dry tropical ecosystems.
Keywords: Restoration, tropical dry forest, functional traits, ecophysiology, growth rates

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Using Leaf Functional Traits as an Approach to Species Screening in Restoration Projects in the Amazonia

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The selection of sustainable tree species to be planted in disturbed or degraded areas determines the success or failure of reforestation projects. In general, the selection process is made by trial-and-error method, which takes time and can be unsuccess. Functional traits (morphological, physiological or phenological) affect the performance of trees and have been shown useful to screen sustainable species for restoration projects. However, this approach remains an important gap on the efforts of reforestation using Amazonia Forest species. In addition to the importance of using a large taxonomic diversity of species, the concept of multifunctionality (interspecific variation in the values of functional traits) is relevant to improve the resilience to environmental changes and productivity of plantations. The plant traits related to acquisition, processing, and conservation of resources can be considered 'economic' from a resource analysis perspective. At a leaf level, the resource economics traits are represented by the leaf economics spectrum. The leaf economics spectrum is related to the resource use by plants in a fast-slow continuum: species with a potential for quick returns (i.e., nutrient acquisition associated with fast growth and less durable structures) and species with a slow potential rate of return (i.e., nutrient conservation that results in a slow growth). Specifically, leaf traits representing resource use efficiency as photosynthetic use efficiency of the carbon (net photosynthesis/dark respiration ratio), nitrogen and phosphorus (net photosynthesis/nutrient concentration) explained the interspecific variation on the growth rates of Amazonian trees planted in disturbed areas. Species with high resource use efficiency had high growth rates. Chlorophyll *a* fluorescence parameter obtained from JIP-test congregate fast and non-invasive measurements and indicate the light use efficiency by species. We have found that Amazonian tree species with high nutrient use efficiency also exhibit efficient mechanisms to light trapping and processing. Thus, the best performance of Amazonian species growing in disturbed or degraded areas seems to be more related to species strategies in optimizing the site resources use for carbon assimilation. The design of plantations using species with different resource use strategies (low and high resource demand) is one of the most challenging factors in mixed-species plantations for protection and productive purposes. Therefore, understanding the resource use efficiency of species can help to identify those that can achieve greater establishment and that are more suitable for the composition of successful functional designs. These findings are important to improve reforestation efforts using native tree species to the Amazonia. **Keywords:** Species selection, leaf functional traits, resource, use efficiency, Amazonian tree species

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Using Hydraulic Traits to Predict Species Distribution and to Inform Restoration Strategies in Tropical Ecosystems

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Hydraulic traits underlie niche differentiation and species distribution across environmental gradients in tropical ecosystems. They are also key modulators of multiple ecosystem processes and resilience. Notwithstanding their importance for many aspects of tropical ecosystem functioning, hydraulic traits are rarely used as a criteria to define protocols and inform restoration strategies in degraded tropical areas. Restoration of biodiverse tropical grasslands and savannas is complex and the current success of these projects is low. The reason biodiverse savanna restoration fail remains unknown, although it is likely that plant species being targeted lack suitable functional properties to persist in environments prone to droughts and frequent fires. In this talk, I will present how we are applying knowledge on hydraulic properties of plants to test the importance of functional trait composition to the success rates of ecosystem restoration and the provisioning of key ecosystem services in grasslands and savannas in central Brazil. Our approach provide a road map for future tropical ecosystem restoration practices by suggesting a focus on plant resource-use strategies, and particularly, hydraulic functional traits as a priority to determining ecosystem-scale stability and climate resilience in drought-prone areas. **Keywords:** Savannas, grasslands, Cerrado, Brazil, functional traits, hydraulic traits

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Plant ecophysiology in a changing world: refining ecological theory

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The importance of local habitat in shaping functional tropical tree species' strategies in the context of climate change.

Marion Boisseaux[1], Daniela Krebber[2], Sabrina Coste[1], Geraldine Derroire[2], Claire Fortunel[3], Paul Mischler[4], Christine Scoffoni[5], Angela Casado Garcia[6], Heidy Schimann[7], Clément Stahl[7]

[1]Université de Guyane, Kourou, French Guiana, [2]CNRS, Cirad, Kourou, French Guiana, [3]Institut de Recherche pour le Développement, Montpellier, Hérault, France, [4]LPO, Nancy, France, [5]California State University, Los Angeles, [6]Universidad de La Rioja, Logroño, Spain, [7]INRA, KOUROU, France Understanding the distribution of tree species in relation to abiotic conditions is central to community ecology. Forest habitats are widely recognized to filter trait variation according to their habitat preference, with tree species exhibiting different functional strategies in contrasting habitats. With increasing severity and frequency of drought events caused by climate change, it is crucial to evaluate how tree species from different habitats will respond to drought. We expect tree species specialized in a given habitat to share similar functional strategies that optimize their local performance, while generalist tree species would express a higher intraspecific trait variability (ITV) that reflects their adaptability across environments. To better understand the interplay between habitat and drought, we suggest a fine ecophysiological approach to determine drought vulnerability of tropical tree species depending on habitat preferences. In French Guiana, two main forest habitats co-occur at local scale: terra firme (TF) and seasonally flooded habitats (SFF). They offer contrasting hydrological, topographical and pedological characteristics. We investigated ten leaf functional traits, including water-related traits (water potential at turgor loss point, minimal conductance, saturated water content, stomatal density and venation density) and resource capture traits (leaf area, leaf chemistry) in 279 individuals belonging to 24 neotropical tree species, which included 9 generalist species, 8 SFF specialist species, and 7 TF specialist species. Our preliminary results show that TF specialists tend to have more drought tolerant leaves than SFF specialists. Contrary to our hypothesis, generalist species do not have a higher ITV for water-related traits compared to specialists. Together, our results underline the importance of forest habitat in shaping water use strategies, which can be incorporated into models to better predict tropical tree species' responses to rapidly changing climate.
Keywords: Amazon basin, forests habitats, ecophysiology, drought, tropical trees

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Ecosystem Carbon Fluxes Are Tree Size-dependent in an Amazonian Old-growth Forest

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Large tree individuals in tropical forests store huge amounts of carbon and are thus essential players within the carbon cycle of tropical forests. While many studies have focused on biomass accumulation of tropical forests and their potential to act as a carbon sink, we lack a cohesive study on how different tree sizes contribute to the overall forest carbon flux budget. Here, we use xylem sap flux derived gross primary productivity (GPP) that was modeled with eddy covariance data for an old-growth moist lowland forest in Central Amazon. Additionally, net primary productivity (NPP) was calculated from forest inventory data. We found that GPP was 28.46 Mg C ha^{-2} yr^{-1} at our study site. Emergent canopy trees (diameter >30 cm, average height of 28 m) were responsible for 21.47 Mg C ha^{-2} yr^{-1} of the overall GPP, whereas subcanopy and understory trees contributed 3.95 Mg C ha^{-2} yr^{-1} and 3.04 Mg C ha^{-2} yr^{-1}, respectively. While emergent canopy trees were characterized by low carbon use efficiency (CUE) for only allocating 23% of their photosynthetic products towards growth, these trees were still responsible for more than half of the overall NPP. Subcanopy and understory trees were more efficient by allocating 67% and 59% of their carbon assimilates towards biomass growth, respectively. GPP showed seasonal patterns with a peak during the dry season. GPP of emergent canopy trees doubled in the dry season, whereas understory and subcanopy trees had an almost 60% higher GPP than the wet season. We found evidence that productivity was more limited by the low evaporative demand than by light. This study provides further evidence for the importance of large trees in tropical moist forests and highlights their crucial role in forest carbon cycling. Due to their high drought-related mortality, large trees will make up a critical component of the response of tropical forests to climate change. **Keywords:** Carbon fluxes, gross primary productivity, forest demography

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Resource Acquisition Strategy Modulates Seedling Responses to Experimentally-induced Soil Moisture Manipulation in a Tropical Wet Forest

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Introduction / Background / Justification: Future droughts in the Caribbean are predicted to intensify, which may influence the functional diversity of tropical tree communities. Tree species with traits that buffer the physiological stress of low soil moisture (e.g., deep roots, dense wood) may have a demographic advantage, potentially impacting forest composition and carbon dynamics. **Objective(s)/Hypothesis(es):** We grew seedlings of eight common tree species spanning a range of life history strategies under experimentally manipulated soil moisture conditions in the Luquillo Experimental Forest, Puerto Rico. The objectives were to address: (1) Are species' demographic response to soil moisture variability related to their mean trait values? And (2) Is phenotypic plasticity in seedling functional traits related to soil moisture? **Methods:** Using rain-out shelters (1.2 m x 1.2 m), we created a gradient in average soil moisture conditions, ranging from 9-49%, over an eight-month study period. Rain-out shelters were placed on both experimental and control plots (N=30 ea.). Rainfall was collected from control shelters and placed on the plots following each rain event. We monitored seedling survival weekly and growth (total leaf length) monthly. A final harvest was used to measure total biomass, root, stem, and leaf traits of the surviving individuals. **Results:** Survival of all species responded positively to higher soil moisture. However, species with more conservative strategies (i.e., higher leaf mass per area, and higher stem density) were able to survive even under low soil moisture conditions, compared to species with more-acquisitive strategies which suffered higher mortality under drier conditions. Leaf area growth and survival of species with more conservative functional strategies also tended to be more sensitive to soil moisture, in that their survival and growth increased more rapidly per unit of soil moisture, compared to species with more acquisitive strategies. Intraspecific trait variation was related to soil moisture for most traits and species, suggesting that phenotypic plasticity may play an important role in moderating drought response of seedling populations. Implications/Conclusions: Our results show how drought selects for individual seedlings with traits that confer greater survival and growth at low soil moisture. Over time, individuals more conservative resource acquisition and use strategies may become more common under increasingly frequent and intense droughts in the Caribbean. **Keywords:** Drought, Luquillo, functional traits, roots, leaves, phenotypic plasticity

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Interspecific Variability in Physiological Thresholds during Dehydration Reveals Contrasting Drought-response Strategies and Vulnerability to Hydraulic Failure in Rainforest Tree Saplings

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Background: Several traits, mostly related to stomatal and xylem functioning, represent key mechanisms influencing specie's survival during drought. However, little is known on their coordination, how they shape plant drought-response strategies and how important they are for survival, especially in tropical rainforest trees. Moreover, much focus has been made on hydraulic traits related to the ability of trees to avoid reaching critical levels of xylem embolism, since hydraulic failure is regarded as a ubiquitous process leading to drought-induced

mortality. For this reason, less attention has been drawn to the potential simultaneous role of non-structural carbohydrates (NSC), which could get depleted during drought (i.e., carbon starvation) and help maintain osmoregulation. In fact, no study has satisfactorily investigated the joint response of the loss in xylem hydraulic conductance together with the use and eventual depletion of NSC for tropical rainforest species. **Objectives:** (i) Characterize the diversity of drought-response strategies of 12 coexisting rainforest tree species, (ii) evaluate if species drought-response strategies determine the prevalence of non-structural carbohydrate depletion during drought-induced hydraulic failure, (iii) identify the single or combined effects of traits implicated in species' survival during drought. **Methods:** We studied saplings of 12 species of rainforest tree species in a shadehouse experiment. (i) We measured leaf turgor loss point, leaf and stem xylem vulnerability to embolism, lethal levels of water potentials and associated losses in hydraulic conductance causing mortality, as well as minimum leaf conductance. (ii) We investigated the joint response of the loss in leaf and stem xylem hydraulic conductance together with the response of starch and soluble sugar contents in leaves, stems and roots during a severe drought. (iii) We applied a mechanistic model computing time to hydraulic failure. **Results and Implications:** This talk summarizes the main findings of this study regarding plant functioning during drought, underlining specificities in plant drought-survival across tropical rainforest tree species and discussing the physiological mechanisms potentially involved in changes in tropical rainforest tree communities in a changing climate. **Keywords:** Drought embolism, hydraulic xylem, NSC

Ecophysiological Controls on Water Use Dynamics in Response to Reducing Throughfall and Fog Inputs in a Tropical Cloud Forest

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Introduction: Tropical montane cloud forests (TMCFs) may face increased frequency and magnitude of water stress due to the expected reduction in precipitation and increase in mean cloud altitudes over the coming century. The progressive water stress can negatively feedback with plant-available water inducing significant changes in the TMFCs ecosystem. However, it is still unclear how TCMFs might react to climate change. We may expect that TMCFs will respond most negatively to these changes because the TMCFs trees have not evolved to survive in a more arid regime. **Objective:** Our study aimed to answer two questions: i) How does tree water use, and transpiration responses to vapor pressure deficit (VPD) in cloud forest species respond to decreased water inputs from rainfall and cloud deposition? ii) How is the difference in the magnitude and/or type of tree' water-use responses to reductions in water inputs from rainfall vs. clouds? **Methods:** We performed our study at the Wayqecha Cloud Forest Biological Station in Peru (3000 m elevation), where we reduced fog inputs to one plot using a 30-meter-high curtain intercepting laterally moving low clouds, while in another plot we excluded >90% of throughfall using a roof water exclusion in a 900 m2 area. Both treatment plots were paired with nearby, unmodified control plots. We continuously monitored tree water use in trees on all treatment and control plots from 2018 to 2020 using sap flow sensors. **Results:** The sap flow was reduced by 84% during both the rainy and the dry seasons in the throughfall exclusion plot after more than three years of these treatments. The effects of reducing fog inputs alone were more subtle, with no significant reduction in sap flow. Overall, tree water use starts to decline above 1 kPa VPD independently of the treatment, but the control plot presented higher transpiration for a higher maximum daily VPD than the throughfall exclusion plot. This was a result of strong control of sap flow rates in both morning and afternoon for a similar level of VPD on an hourly basis. **Implications:** Our results highlight the conservative behavior of water use of TMCF trees under water stress. With the expected declines in water inputs associated with climate change, we would expect a strong decline in forest productivity given the relationship between tree water use and tree growth. These results indicate that climate change could drive a strong change in TMCF function. **Keywords:** Climate change, sap flow, drought, cloud forest, tree water use

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The Flow Below: What We Can Learn from Seasonally Variable Root Sap Flow of Three Panamanian Tree Species

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Seasonally dry tropical forests are subjected to highly variable precipitation requiring adaptations to survive prolonged periods of limited water availability. Dry periods and seasonality are expected to be further amplified due to a changing climate, necessitating a mechanistic understanding of plant adaptations to mitigate drought stress. The 2015/16 El Niño–Southern Oscillation (ENSO) event ranks amongst the driest and hottest periods on record in Panama and thus provided an excellent opportunity to study seasonal water relations of common Panamanian tree species. Using heat-ratio sap flow sensors, we measured sap flow of 76 trees between 2015 and 2017 in secondary forests aged approximately 8, 25, and 80 years in the 15 km^2 Agua Salud study area, located in central Panama. Of those trees, 16 individuals representing three common species (*Xylopia frutescens, Vismia macrophylla, Terminalia amazonia*) were instrumented with additional sap flow sensors on three roots each. Raw heat ratio data were logged every 30 minutes and converted to sap velocities and sap flux using physical conversions specific to wood properties of that species. Additional environmental data were provided by in-situ soil moisture sensors and a nearby meteorological station. Sap flow data of individual roots largely followed distinct seasonality of stem sap flow and was primarily driven by a combination of radiation and vapor pressure deficit. However, the roots of some smaller individuals of two species (*Vismia macrophylla* and *Xylopia frutescens*) exhibited inverted sap velocities, as expressed though decreasing flow in one root and simultaneously increasing flow in another root of the same individual. Interestingly, this behavior was only found during the dry season with low soil water content, but was not clearly related to root diameter, and resulted in a total volume of water flux that remained approximately similar throughout periods with inversions. Our results provide evidence for distinct temporal partitioning among roots of trees growing in seasonally dry climates in response to limited soil moisture availability. Future research is needed to address the mechanisms that regulate observed flow inversions: stomatal control in the canopy or water potential limitations root-soil interface as a result of different rooting depths. **Keywords:** Roots, sap flow, drought, el niño, transpiration

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Integrating Ecophysiology and Archeology to Reconstruct Diets of Ancient Civilizations during Drought

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Introduction: Plant ecophysiological approaches are suitable for characterizing plant species based on their drought resistance. However, plant ecophysiology is almost never combined with archaeological or ethnobotanical studies, even though many unresolved questions within the field of anthropology revolve around the collapse of ancient civilizations in the face of drought. **Objective(s)/Hypothesis(es):** To estimate how the availability of food plants varied during different drought intensities, we evaluated the drought resistance of all 497 indigenous food plant species documented in ethnographic, ethnobotanical, and botanical studies as having been used as food by the lowland Maya, and classify the availability of these plant species and their edible components in simulated drought scenarios. Methods: We used the case of the collapse of Classic Maya civilization to implement this approach since the collapse coincided with droughts of strong magnitude, but paleoclimatic data lacks the resolution to determine whether droughts were intense enough to affect food production. Drought resistance was based on well-established plant functional traits. **Results:** Our results show availability of 83% of food plant species in short term drought, 22% in drought up to one year, and 11% during intense drought, lasting several years. These results indicate that short-term or moderate droughts would have caused agricultural disruption, but potential agricultural collapse would have been restricted to intense multi-year droughts only. **Implications/Conclusions:** Overall, our experience suggests that plant ecophysiological techniques are appropriate for archaeological studies and can constrain the availability and utility of plant species under simulated climate scenarios. Further work in the integration of plant ecophysiology and archaeology lie in the quantitative characterization of drought resistance of useful plants of ancient civilizations to construct environmental responses of ethno-floras to past climate anomalies. **Keywords:** Maya, drought, climate, P50 turgor, loss water, potential, ancient diet

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Inter- and Intra-specific Variation among Tree Populations in Their Vulnerability to Drought across a Rainfall Gradient in Puerto Rico

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Climate change is causing shifting rainfall patterns and increases in the duration and frequency of drought events impacting the growth, mortality, and regeneration of tree species and ultimately determining their distribution ranges. Among (interspecific) and within (intraspecific) species, variation in hydraulic traits has important consequences for population-level vulnerability to climate change and determines how individual populations respond to drought. We examined how hydraulic traits linked to drought avoidance (high leaf and stem capacitance) and tolerance (low leaf turgor loss point, high resistance to embolisms, and higher hydraulic safety margins), vary along a pronounced rainfall gradient (1,000–4,000 mm^{-y}) across Puerto Rico to address the following questions. How do these traits vary at the regional level (across the island), site-level (interspecific), and species-level (intraspecific)? At six sites with distinct rainfall (1040, 1660, 1900, 2170, 3070, 3900 mm^{-y}), we measured hydraulic traits associated with drought avoidance—leaf ($C_{ft,leaf}$) and stem ($Cf_{t,stem}$) capacitance —and drought tolerance—turgor loss point (Ψ_{tlp}), embolisms resistance in leaves ($P_{50,leaf}$) and stems ($P_{50,stem}$), and hydraulic safety margins in leaves (HSM_{leaf}) and stems (HSM_{stem}). We measured a total of 283 trees belonging to 20 different species. We measured as many of the 20 species as possible at each of the six sites resulting in 4 to 13 species at each location. Across a declining rainfall gradient, we found an overall decrease in $Cf_{t,stem}$ (R^2=0.14), $P_{50,leaf}$ (R^2=0.22) and $P_{50,stem}$ (R^2=0.17), increase in HSM_{leaf} (R^2=0.19) and HSM_{stem} (R^2=0.12), and no difference in $C_{ft,leaf}$ and Ψ_{tlp}. At the forest-level, we found variation among plots for all traits. Sites with higher rainfall had higher $Cf_{t,stem}$, lower $P_{50,leaf}$ and $P_{50,stem}$ and higher HSM_{leaf} and HSM_{stem} while there was no clear pattern for $C_{ft,leaf}$ and Ψ_{tlp}. For five species, we found evidence of intraspecific hydraulic variation, individuals in the drier sites had more negative P_{50} values and higher HSMs. For example, *Tabebuia heterophylla*, had $P_{50,leaf}$ = -3 MPa in the wetter forests and $P_{50,leaf}$ = -5 MPa in the drier forest. There is an association of higher drought tolerance with a decrease in rainfall and of higher drought avoidance with an increase in rainfall. At the site-level, forests in the drier locations have traits associated with greater drought tolerance and forests at the wetter locations have greater drought avoidance. Intraspecific variation in embolism resistance and HSMs does exist in some species, in particular, the species that grow across forests with the biggest range in rainfall. **Keywords:** Plant ecophysiology, tree hydraulic traits

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Drought Response Traits in Tropical Deciduous Woody Species: Opposite Relation of Turgor Loss Point to Rainfall than in Evergreen Species

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To improve projections of how global-change will affect vegetation, and which species will win or lose under conditions of changing climate and land-use, we urgently need to improve our understanding of the mechanisms underlying plant responses to drought and identify traits that allow us to predict them. The problem is especially acute in the Caatinga, an extensive seasonally dry tropical forest biome in northeastern Brazil, which is threatened by desertification through decreasing rainfall and through anthropogenic disturbance. Turgor-loss point (TLP), the water potential at which leaves lose turgor, has been identified to be a key trait of drought resistance in evergreen woody species, with species with a lower TLP being more drought resistant. In this study we addressed, if TLP is also related to drought resistance in drought deciduous tropical dry forest species. We quantified for 21 deciduous woody species occurring in the Caatinga the turgor loss point, as well as the minimum leaf conductance (g_{min}) and bark conductance (g_{bark}) to water vapor. We then analyzed how the community weighted mean (CWM) of these traits changes across a pronounced rainfall gradient. We hypothesized that the CWM of all three traits increases with rainfall. While we found the expected pattern for g_{min} and g_{bark}, the CWM of TLP decreased with rainfall, i.e. the relation was opposite to the one expected from evergreen species. These results are consistent with a strategy of minimizing water loss through early stomatal closure, which is associated with high TLP, and an effective cuticle and bark. They indicate that avoiding desiccation is an important mechanism for deciduous woody plants in this system. More importantly, these results highlight the need to assess the relation of functional traits to drought resistance in different plant life forms and systems, before using traits to predict plant drought responses. **Keywords:** Functional-traits, community-weighted-trait-mean, rainfall-niche, minimum-leaf-conductance, bark-conductance, tropical-dry-forest, Caatinga

Relationships between Anatomy and Physiology in Tropical Dry Forest Species: Different Traits to Understand Drought Responses in Trees

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Shifts in rainfall patterns and increasing temperatures associated with climate change are predicted for most Neotropical dry forests in the following decades. Under these new scenarios, understanding the mechanisms driving plant drought responses is a priority due to their impact on ecosystem functioning. We measured leaf water potential at turgor loss point (πtlp) as a critical physiological determinant of a plant's tolerance to water stress. We also explored their relationship with 16 leaf and wood anatomy traits related to the leaf economics spectrum and hydraulic safety-efficiency trade-off. Drought tolerance, indexed by πtlp, ranged from -1.3 to -3.1 MPa among species, and was mainly linked to wood anatomy rather than leaf traits. Species with higher drought tolerance (lower πtlp) tended to have traits associated with high hydraulic safety, such as narrow vessels and pits, and low hydraulic efficiency measured as xylem potential hydraulic conductivity. Additionally, more drought-tolerant species showed high tissue investment, such as thick fibers and dense wood. The best model explained more than 50% of the variation in πtlp, and the most important traits were fiber wall thickness and water content. Our results highlight the high variability of woody species' drought responses and the importance of wood anatomy in explaining physiological responses to water deficit in tropical dry forests.
Keywords: Drought tolerance, turgor loss point, wood anatomy traits, leaf traits

Heat Tolerance on Two Extreme Life Stages of the Zingiberales Community of a Tropical Lowland Wet Forest

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Leaf physiological and biochemical parameters change with stages of its ontogeny. Studies in crops determined that heat sensitivity is highly variable across developmental stages. It is likely that heat tolerance varies between different life stages as well, but this has never been tested on tropical plants. Other morphological traits such as leaf thickness and leaf size strongly influence and mitigate heat damage. However, little is known on the extent of how tropical plants deal with leaf thickness and leaf size to reduce heat stress, and even less across life stages. According to previous studies that demonstrate the high plasticity of heat tolerance and many gaps in thermal physiological responses on tropical plants, we aim to test the plastic responses of heat tolerance and other traits related to the temperature at two extreme life sages of plants. This study focuses on species from the order Zingiberales (the ginger and banana-like plants) at La Selva Biological Station, Costa Rica. To test if the performance of photosynthetic systems of Zingiberales species is acclimated to temperature prevalent in their life zone, we estimated the maximum heat tolerance (T_{50}) of the photosystem II. We hypothesize that heat tolerance will vary among life stages because of different leaf sizes across life stages that change their cooling abilities. Specifically, we predict that heat tolerance will be higher in early life stages than late-life stages if early stages are more susceptible to heat damage than late-stage leaves. We determined heat tolerance at two extreme life stages (early and late stage) of 20 species of Zingiberales at La Selva. We also measured traits related to leaf temperatures such as leaf area and leaf thickness. From these traits and the ambient temperature at La Selva, we determined the leaf energy balance by life stage and species. Heat tolerance does vary between the most extreme life stages of Zingiberales. However, contrary to our prediction, early stages have lower heat tolerance than late stages. Given this differentiation in heat tolerance, our study suggests that early-stage leaves are more susceptible to heat damage. Late-stage leaves are older and have larger leaves than early-stage leaves that in return, might obstruct their cooling process. Heat tolerance is an intricated parameter with high plasticity that is strongly related to other factors such as leaf thickness and leaf size. **Keywords:** thermal tolerance, chlorophyll fluorescence, zingiberales, developmental stages, global warming

Divergence of Hydraulic Traits among Tropical Forest Trees across Topographic and Vertical Environment Gradients in Borneo

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Introduction: Fine-scale topographic-edaphic gradients are common in tropical forests and drive spatial turnover in species composition and marked changes in forest structure and function. We evaluate how hydraulic traits of dipterocarp species relate to vertical and horizontal spatial niche specialization along such a gradient. **Objective(s)/Hypothesis(es):** We investigated how hydraulic traits relate to habitat, tree height and their interaction on a topographic-edaphic gradient with uniform climate in Borneo. We tested 1) if forests with higher soil water availability have selected for dipterocarp species with higher water transport efficiency, and lower hydraulic safety than forests on well drained sandier soils, 2) if dipterocarp species adjust their hydraulic traits to become safer and more efficient with increasing size and if this adjustment is different across forest types with different soil conditions, and 3) if topographic-edaphic gradients not only select for specific hydraulic traits, but also change the magnitude of hydraulic trait-trait coordination or trade-offs. Methods: We measured key hydraulic traits in 156 individuals of differing heights in 13 dipterocarp species: embolism resistance, maximum hydraulic conductivity, leaf specific conductivity, leaf-to-sapwood area and wood density. **Results:** We found that embolism resistance increases from forests on more clay to more sandy soil, but did not vary with tree height. In contrast, water transport showed strong increases with tree height. Habitat and height only interact for hydraulic efficiency, with height slope changing from positive to negative from the clayey to the sandier soil. Habitat type influenced trait-trait relationships for all traits except wood density. **Implications/Conclusions**: Our data reveal that variation in the hydraulic traits of dipterocarp trees is driven by a combination of topographic-edaphic conditions, tree height and taxonomic identity. Our work indicates that hydraulic traits play a significant role in shaping the topographic-edaphic and vertical structure and niche specialization of dipterocarp species. **Keywords:** Dipterocarpaceae, hydraulic traits, tropical forest, large trees, niche specialization, tree

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Warming and Drought Lead to Shifts in the Functional Composition of Tropical Forests, a Millennial-scale Analysis

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Old-growth tropical forests are not in a steady state but show changes in productivity, species composition, and functional trait composition. These shifts may have a range of causes, such as climate change and disturbances. Tropical forests can respond to these multiple drivers at instantaneous to millennial time scales, which cannot be disentangled using short-term studies. Moreover, their responses can vary with forest type. For 8 lowland and highland Neotropical Forest landscapes, we assess their long-term responses in functional trait composition to past climate change and (human) disturbances. We link vegetation dynamics from fossil pollen records to functional trait data to assess how shifts in community-mean functional traits can be explained by climate change and disturbance events. We find that tropical forests show clear, predictable responses to environmental changes. Temperature was most important, with warmer climates providing more favorable conditions for taller taxa with soft wood at high elevations and for smaller taxa with soft wood at low elevations. Furthermore, increasing rainfall and decreasing drought favors fast-growing, drought-vulnerable taxa that are tall and have large leaves, whereas increased human disturbances favor more disturbance-adapted species that are short with a fast life cycle and have small leaves to cope with increased heat and insolation in open areas. The predicted future increases in temperature and droughts may cause shifts in tropical forest composition and may reduce their carbon storage and sequestration capacity, thus potentially providing positive feedback on climate change. **Keywords:** human disturbance, fossil pollen, functional traits, fire, climate change

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Plant-Insect interactions in the Anthropocene: patterns, mechanisms and challenges in the Neotropics

Above and Belowground Mutualistic Interactions in *Inga edulis* Are Coordinated by Carbon and Nutrient Demand

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Maintenance of tropical forest biodiversity and its ecosystem services depend on mutualistic relationships between plants and other organisms. These mutualisms may affect the ability of plant species from different functional groups to respond to CO_2 elevation. In tropical forests, phosphorus (P) is one of the main limiting nutrients related to forest productivity, which adds further uncertainty to the role of the Amazon as a carbon sink as atmospheric CO_2 concentration increases. Here, we used a nitrogen-fixing plant species, *Inga edulis,* to investigate if the plant coordination with three types of mutualists (rhizobium, mycorrhizas, and ant bodyguards) are affected by both phosphorus and CO2 factors. We specifically asked 1) if extrafloral nectaries (EFNs) activity is influenced by the presence of rhizobia and mycorrhizas in the roots, 2) if the attraction of ants to extrafloral nectaries is influenced by the presence of rhizobia and mycorrhizas on the roots, and 3) if the phosphorus addition and [eCO_2] affect mutualistic interactions above and belowground. Within the AmazonFACE Program, we used open-top chambers (OTC) with ambient and elevated CO_2 [eCO_2] (˜ +200ppm) (n=4), and carried out a pot experiment where *Inga edulis* seeds were sown in soils with and without phosphorus addition (6 per OTC, n=12 per treatment). After a year and a half of cultivation, the activity of EFNs and ant attendance to the EFN were monitored for five months. After two years of experiment, the seedlings were harvested, and the roots searched for nodules and mycorrhizas. We found that root-rhizobia interactions were the main factor directly influencing the number of activate EFNs and ants attending to EFNs and the relationship were stronger in the P added soils and under [eCO_2]. Mycorrhizas did not affect the EFNs activity, but negatively influenced the number of ants attending to EFNs in P added soils. This pattern is one of the few results revealing responses of CO_2 elevation on plant coordination with multiple mutualistic partners. Under [eCO_2] condition, plant demand for N increases, reducing the carbon cost of nitrogen fixation, favoring plant investment in indirect defense via ant-EFN interactions only if the plant is not nutrient limited. However, plants may allocate carbon to nutrient acquisition via mycorrhizas in P added soils and not for ants-EFN interactions, possibly lowering the biological defense against herbivores. Together, suggest that nutrient limitation regulate carbon allocation under eCO_2 and asymmetric mutualisms can drive complex response of plants within nitrogen-fixing functional group. **Keywords:** climate change, plant biotic defenses, legumes nodulation, plant growth, defense

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Synergistic Effects of Mutualistic Ants on a Neotropical Ant-plant: a Long-term Manipulative Experiment Revisiting the Iconic Cecropia-Azteca System

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Comprehension of the benefits involved in mutualisms is crucial to disentangle the role of interactions in the structure and functioning of populations, communities and ecosystems. The understanding of positive interactions is becoming more important as the planet earth is experiencing a new era – the Anthropocene – where the expansion of human societies is promoting unprecedented biodiversity loss. In ant-plant mutualisms, benefits provided by plants to ants are immediately recognizable, but reverse benefits are less obvious, conditional and accumulate over longer time spans. Here we tested the hypothesis that the ant *Azteca muelleri* simultaneously provides multiple benefits to its host plant (*Cecropia glaziovii*), ultimately increasing plant performance. We planted seedlings and experimentally prevented ant colonization for half of them. Over 4.5 years we quantified the effects of ant presence or absence on plant growth, herbivory levels, fungal infection, fertilization via ant debris and changes in defense strategies. Ant colonization increased plant height by 125% compared to ant-free plants. Such an improvement in plant performance can be explained because plants with ants faced less herbivory, lower prevalence of pathogenic fungi, invested less in foliar trichomes and had more foliar nitrogen. We thus confirmed that ant mutualists provide cumulative benefits including nutritional benefits, effective defense and lower investment into other defenses – which result in increased plant growth. We highlight the importance of long-term experiments that simultaneously evaluate a multiplicity of potential ant effects to better understand their relative contribution to the performance of the mutualistic partner. We recommend that future studies on the association between *Cecropia* and *Azteca* should focus on whether the observed increase in plant growth might translate to an increase in plant reproductive success. **Keywords:** defensive mutualism, herbivory, myrmecophytes, myrmecotrophy, trade-off, trichomes

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Ants Control Herbivory at the Community Level: Large-scale Ant Suppression Reveals a Higher Effect in Forest than in Grassland

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Human activities have a great impact on animal communities and their interactions, and those negative effects are rising fast in the present era – the Anthropocene. However, it is still poorly known how the loss of key animal groups affects ecosystem functions. One well-studied insect- plant interaction is the defence of plants against herbivores by ants. However, this interaction is usually measured on a small scale (plant or branch), focuses on a single plant species and habitat. Therefore, it is still unclear how ants control herbivory at a plant community scale and how the differences in environment modulate this process. Here, we assess the importance of ants in controlling herbivory levels on plant communities of two endangered and contrasting environments, the Atlantic Rain Forest and the *Campo Rupestre* (Rocky Grassland). We set up a factorial experimental design with 16 plots (80 x 80 m), divided into i) forest control, ii) forest ant suppression, iii) grassland control, iv) grassland ant suppression. To precise assess the effect of ant suppression on plant herbivory we used a BACI approach (Before-After-Control-Impact). We randomly choose five individuals (50 cm to 3 m) of the three most abundant plant species in each plot (15 plants per plot). From each plant, we collect and measured the area loss of 50 leaves before and 50 leaves three months after the beginning of ant suppression (24000 leaves in total). We sample a total of 28 plant species (12 in grassland and 16 in the forest). Over three consecutive months, we suppressed nearly 70% of ants, which causes a four-fold increase in herbivory when compared to control. This result was similar for both habitats (forest control = 0.61%, forest ant suppression= 2.21%, grassland control= 0.26%, grassland ant suppression = 1.14%). However, the overall herbivory levels were higher in forests than in grasslands. Here we showed for the first time that through a top-down control ants decrease substantially the herbivory on the whole plant community and this effect could be observed in a short period of time (three months). These effects seem to be more prominent in the forest than in grasslands, where plants usually present a less physical defence. By decreasing herbivory at a community level, ants can improve plant growth and ultimately enhanced carbon uptalking. Therefore, human activities that affect ant communities, especially their abundance, also impair plant community structure and ecosystem functioning,

especially in forests. **Keywords:** Ant exclusion, Formicidae, Ecosystem Service, Ecosystem function, plant defense

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Not Everything Is What It Seems to Be: Interactions among Mistletoes, Host Plants and Insects in a Changing World

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Parasitic plants are important sources of stress and can strongly impact their host plants through direct and indirect associations with other associated organisms such as insect herbivores, ants and pollinators. We investigated the direct and indirect influences of multiple partners involved in interactions between the mistletoe ***Psitachantus robustus*** and its main host tree, **Vochysia thyrsoidea** and herbivore insects, ants, and pollinators. We hypothesized that the presence of the mistletoe could modify the herbivory patterns of its host by altering the diversity of associated insects. Additionally, we hypothesized that associations between fluid-feeding insects and ants should indirectly decrease mistletoe reproduction by repelling pollinators and directly by reducing seed size, germination, and establishment of plants presenting denser herbivore aggregations. We found that the mistletoes' influence on the insect herbivores was related to their feeding guild. In addition, we found a decrease in leaf-chewing insects, but an increase of levels of herbivory damage in parasitized plants. While the mistletoes' presence did not influence the hemipteran sap-sucking insects, this herbivore guild directly responded to the abundance of their associated ants. Meanwhile, the ant's presence on inflorescences did not affect the visitation rates of its main pollinator, the hummingbird **Eupetomena macroura**. Nevertheless, we observed a significant reduction in seed size in those plants hosting larger aggregations of fluid-feeding herbivores. By exposing the distinct effects of the different partners involved, our results shed light on the intricated interactions mediated by parasitic plants and multitrophic interactions, opening the path for new investigations. **Keywords:** Campo rupestre, ants, interspecific interactions, Loranthaceae , pollination, insect ,herbivores

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Revisiting Herbivory and Florivory in Tropical Plants: Patterns and the Importance of Functional Traits

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Antagonistic interactions between plants and insects are widely studied and potentially influence plant survival, distribution, community organization and ecosystem processes. Insect herbivory, although ubiquitous, remains largely undocumented for tropical plants, which are host to more and sometimes more specialized herbivores, which might inflict higher damage.We evaluated leaf herbivory in tropical plants sampled using a standardized protocol and present a conceptual framework to understand the role of florivory on flower evolution of tropical plant species. We also provide the first global estimates of herbivory levels and florivory incidence and floral area removed by florivores across biogeographic regions, taxa and functional groups. In contrast to previous assumptions, our study shows that herbivory levels for 152 tropical plants species sampled along 32 sites are higher than previously reported, reaching 12% of leaf area removed, with higher levels of herbivory for forest plants compared to open vegetation. Our global survey using published and field data collection on florivory (182 species distributed into 64 families from all continents) showed higher florivory in tropical plant species, despite significant geographic and phylogenetic biases. Caterpillars were the most common florivores mainly chewing petals of purple and yellow flowers of shrubby species, removing around 8% of floral area. Owing to the lack of standardization of the metrics used to measure floral damage, we propose standardized protocols to estimate three common metrics of florivory. Herbivory and florivory are central topics within research in the Anthropocene, an epoch characterized by widespread decreases in populations of insects' orders that comprise both herbivores, pollinators and florivores. **Keywords:** Insects, herbivory, leaf damage, floral damage

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Thermal Mismatches between Host Plants and Insect Herbivores along Elevational Gradients: Implications for Global Warming

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Tropical organisms are assumed to be at particular risk of extinction under projected global warming because their physiologies are adapted to constant annual temperatures. Although temperatures in the tropics are constant trough time, they quickly decrease with elevation. One major challenge is to determine how global warming will affect biotic interactions. This study simultaneously explores thermal tolerances of tropical plants in the order Zingiberales (banana-like plants) and their insect herbivores (*Cephaloleia* beetles, Chrysomelidae) along the La Selva-Barva elevational gradient in Costa Rica. The persistence of biotic interactions will depend on the physiological tolerance to novel temperatures by both host plants and associated insect herbivores. The central question of this study is if interacting plant and insect herbivore species display thermal tolerances associated with prevalent temperatures of their habitat. We predict that plants and insects in the lowlands will have higher tolerance to increasing temperatures than species at higher elevations. An alternative hypothesis is that there is a thermal mismatch between plants and insect herbivores. If plants are more tolerant to high temperatures than insects, one possibility is that lowland plant species will experience enemy-free space at warmer temperatures. Photosynthetic thermal tolerance was estimated for 506 individuals from 18 genera, 61 species from the plant families Musaceae, Heliconiaceae, Zingiberaceae, Costaceae, Cannaceae, and Marantaceae. For each individual, we estimated the maximum heat tolerance (T_{50}), the temperature that causes a 50% reduction of initial F_v/F_m (maximum quantum yield of the Photosystem II, PSII). Thermal tolerance was estimated for 733 individuals from 33 species of *Cephaloleia* beetles. For each individual beetle, we estimated the critical thermal maximum, the temperature at which insects lose motor control. Plant species at low elevations are at higher risk of extinction under projected warming than high-elevation species, T50 is higher in plant species at higher elevations. Insect herbivores show the opposite pattern: high elevation species have lower thermal tolerance than species in the lowlands. Our results show that plants and their associated herbivores exhibit thermal mismatches. Plant thermal tolerance increases with increasing elevation but insect thermal tolerance decreases with increasing elevation. The consequences of this thermal mismatch on the resilience of plant-animal interactions to global warming will be further discussed during the oral presentation. **Keywords:** climate change, elevational gradients, Insects, plants, thermal tolerance

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Reconnecting the forest canopy: Lessons from artificial canopy bridge studies in various geographies and habitats

Canopy Bridges: a Necessary Tool towards Sustainable Infrastructure for Arboreal Species

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Increasing global habitat fragmentation is expected to impact arboreal wildlife even more than terrestrial wildlife. While terrestrial wildlife must face the challenge of moving between fragments, arboreal wildlife must do so after descending to the ground, an unfamiliar activity. Species with the behavioral plasticity to cross between fragments over linear infrastructure face the threat of terrestrial predators and collisions with vehicles, while the species that do not cross face the threats of inbreeding depression and resource loss. Given these threats along with the danger of electrocutions when crossing on power lines, it is more important than ever to develop canopy bridge solutions, with both natural and artificial bridges, that provide continued habitat connectivity for arboreal species. The number of canopy bridge projects around the world has grown in recent years. However, results of few projects have been shared in the peer-reviewed literature. For this reason, researchers have had little opportunity to learn from each other to understand such fundamental questions as which bridge designs work for which species with which body sizes and locomotor strategies and which bridge materials work best under different contexts. An up-coming Special Issue of *Folia Primatologica* will feature 25 peer-reviewed papers on canopy bridge studies, effectively doubling the number of studies on this topic and dramatically expanding their geographic scope. We will provide a summary of the review paper that we contributed to the Special Issue on all canopy bridge studies published to date, demonstrating where they have been performed, which species have used bridges, and, most importantly, which bridge designs seem to be most effective. We will also evaluate gaps in the field of canopy bridge research, including species that seem not to use them, with suggestions on possible solutions. With this review of the expanding literature on an important conservation topic, we hope to provide information to guide future studies to scale up the practice of canopy bridges across fragmented habitats globally. **Keywords:** Conservation solutions, fragmentation, connectivity, linear infrastructure, arboreal wildlife

Reconnecting Brazilian Rainforests: Lessons Learned from Canopy Bridges Applied Projects

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Brazilian rainforests are one of the most important tropical regions on Earth with high biodiversity that provide vital ecosystem services. However, these regions are threatened by a rapidly expanding road network, leading to habitat loss and fragmentation, wildlife mortality, and secondary threats such as deforestation and poaching. Roads that bisect habitat fragments reduce the movement of individual animals, leading to reduced gene flow and, eventually, to regional population decline. Smart, cost-effective strategies are urgently needed to reduce the impacts of connectivity loss caused by roads around the world. In the Neotropics, most arboreal species are strictly arboreal, rarely if ever coming down to the ground, making them particularly sensitive to connectivity loss created by gaps in the canopy. We must develop the necessary knowledge about how arboreal mammal species use artificial canopy bridges (ACBs) to safeguard their welfare and conservation, particularly threatened and endangered species in high biodiverse regions. In this presentation, we are going to present five applied case studies of conservation projects on canopy bridges across Brazil: i) the "Reconecta" project in the heart of the Brazilian Amazon, which tests two different types of designs of canopy bridges for different arboreal species, ii) the "Urban Monkeys Project" with canopy bridges for the vulnerable brown howler monkeys (*Alouatta guariba clamitans*) in Southern Brazil, iii) a wooden canopy bridge project for the endangered black lion tamarin (*Leontopithecus chrysopygus*) in São Paulo state and, iv) a citizen science project with homemade canopy bridges in the Cantareira State Park, also in São Paulo state, and v) canopy bridge project for the critically endangered pied tamarin (*Saguinus bicolor*) in the campus of the Federal University of Amazon. Finally, we discuss the lessons learned from these projects, especially concerning how animals with different locomotor strategies might benefit from specific canopy bridges designs. **Keywords:** Canopy-bridges, neotropics, arboreal species, primates, mitigation measure, road mortality, functional connectivity

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Preliminary Results on Arboreal Mammal Use of Three Artificial Canopy Bridge Designs over a Logging Road in Peruvian Amazonia

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Linear infrastructure in the form of roads is a major source of habitat fragmentation and a barrier effect when animals cannot cross from one side to the other. Roads are a significant threat to tropical forest in Amazonia, fragmenting habitat for both terrestrial and arboreal species, with the latter at even more pronounced threat due to their need of canopy connectivity to move. Wildlife crossings structures have gained acceptance as mitigation measures and a few experiments to test use of different designs have been proved due the distinct locomotion in arboreal species. We studied 10 paired canopy bridges of three designs and monitored them with camera traps between August and December 2021 in Tahuamanu, Madre de Dios, Peru. The bridges were 15 -35m$\pm$5. long and installed over a logging road, with two designs being two-dimensional and the third being unidimensional. Cameras were installed in bridges upon installation to register crossings in the canopy and beneath bridges on the ground to register ground crossings of arboreal mammals. In 614 trap nights we logged 49 photo events only in one of the two-dimensional bridge designs and all of them were kinkajou (*Potos flavus*), with the first event being four days after installation. We conservatively estimate that these events represent four different individuals, and interestingly, the animals used only one side of the bridge to cross and crossing speed increased over time. However, on the ground, we recorded 51 photo events of five arboreal species (*Ateles chamek, Sapajus macrocephalus, Saimiri boliviensis, Saguinus fuscicollis, Tamandua tetradactyla*) crossing the road. Other studies in the area suggest that there are an additional ˜ 20 arboreal species in the area. Our results provide valuable preliminary insights into habituation time and design preference for arboreal mammals in tropical forest. As our study continues, we will have more robust data to inform future canopy bridge projects and to contribute to this vital solution for arboreal mammals in a rapidly changing world. **Keywords:** Artificial canopy bridges, arboreal mammals, roads, logging, fragmentation, tropical forest.

Spider Monkeys Do Not Use Artificial Canopy Bridges to Cross Linear Infrastructure

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Arboreal animals need canopy connectivity to move freely across the landscape and access critical resources such as food, shelter, and mates. Deforestation impacts canopy connectivity when landscapes are fragmented due to linear infrastructure, such as roads, transmission lines, pipelines, and railways. Under these circumstances, natural canopy bridges become vital to arboreal animals, especially for animals that are reluctant to use the ground. Natural canopy bridges over linear infrastructure are possible when the linear infrastructure is narrow or regrowth of the canopy can occur after construction. When this is not the case, artificial canopy bridges can be implemented to mitigate the consequences of linear infrastructure. The aim of our study was to evaluate the evidence for the use of artificial canopy bridges by spider monkeys (Ateles spp.) to cross linear infrastructure that interrupts canopy connectivity. We selected spider monkeys as a model taxon because they are highly arboreal, use a highly acrobatic form of locomotion, and are threatened with extinction. After an extensive literature search and sending out over 1,500 emails, we did not find any evidence for any spider monkey species using artificial canopy bridges to cross linear infrastructure. We report details of five cases in which the absence of evidence for spider monkeys using artificial canopy bridges to cross linear infrastructure was based on systematic monitoring. We examined the factors that may constrain spider monkeys' use of artificial canopy bridges and made recommendations for effective artificial canopy bridges for spider monkeys.
Keywords: Deforestation, canopy connectivity, arboreal animals, crossing, linear infrastructure

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Secondary forest succession, theory, synthesis and application

Before Tree Planting: Integrating the Nursery Sector into Restoration Strategies

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Rallying efforts to restore degraded ecosystems and achieve multiple Sustainable Development Goals, such as climate change mitigation and biodiversity conservation, have led nations to commit to ambitious tree planting targets by 2030. Indeed, tree planting has become the most visible benchmark to highlight these efforts. Yet, restoration is a complex process involving manifold actors that need to work in an articulated way. One neglected step in the chain of actions that lead to successful restoration projects is that of the nursery sector, a key part of this process as they are responsible to propagate the suitable species to achieve different restoration goals. Here we evaluate what are the main challenges and opportunities that nursery gardeners are facing in a megabiodiverse country such as Colombia, and how to build on this information to propose new metrics that integrate both ecological (ability to propagate plants) and socio-economic aspects (nurseries as a sustainable activity) for evaluating the potential of restoration success. We ensembled a database with 190 nurseries located across the country. Most of these nurseries are small, private initiatives and likely serve as the basis of livelihood for thousands of families across the country. Preliminary results show that nurseries face important barriers regarding infrastructure, legal issues, and technical problems related with seed conservation and germination. Together, they are propagating over 1900 native tree species. Although this is an astounding number, the supply is dominated by only five species. Thus, it is key to promote diversity of native species in terms of quantity and quality. To evaluate the biological and socio-economic factors that may be limiting the supply, we need to promote capacity building, facilitate the sharing of experiences, and to develop different metrics related with nurseries' capacity to propagate native species. Overall, benchmarks no only focused on quantifying the ecological dimension of restoration initiatives (e.g., tree survival and growth, species diversity) but on other steps of the chain of actions in this complex process may help to transform restoration in a sustainable activity for local people. **Keywords:** Restoration, nursery, metrics, native species

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Restoring Dry Landscapes of Ghana: Key Lessons for up Scaling

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Introduction/Background/Justification: Dry landscapes covering areas in Ghana dominated by dry forests and woodlands are severely degraded and have high poverty levels and acute out-migration. Forest and landscape restoration is regarded as having the potential to increase the resilience of dry landscapes, as well as improve ecological integrity and enhance the wellbeing of local communities. There has been growing efforts to restore degraded dry landscapes in Ghana through the adoption of multiple forest landscape restoration approaches. **Objectives:** The main goal of this study was to provide new insights into field implementation of restoration projects and initiatives, and to capture lessons that could inform future up scaling of restoration to achieve the ultimate goal of restoring multifunctional landscapes. **Methods:** A mixed method approach including literature review and a case study via stakeholder consultations with local communities and other relevant state- and non-actors were used to collect information on predominant restoration approaches and key factors that have led to the success or failure of restoration projects implemented in the dry areas of the country in the last 10-15 years. **Results:** The study showed that different stakeholders including government institutions, NGOs and private sector companies have initiated and implemented various restoration projects

using approaches such as reforestation/afforestation, woodlot establishment, agroforestry and trees-on farm, as well as protection and restoration of riparian buffers. Five overarching lessons learned that are associated with planning, technical and governance aspects of restoration were identified in this study. Key among them is the need to engage and empower local people and land users to participate meaningfully in restoration projects. Furthermore, collaboration and partnership among stakeholders and political support contribute to the sustainability of projects. Incentives generate support from local people, but they should directly or indirectly increase the resilience of farmers and local communities so as to provide a disincentive for further degradation of the environment. Securing land and tree tenure to local land users, especially women, is a critical step to ensuring the success of restoration projects. Bushfires, cattle grazing and flooding pose major threats to the success of restoration activities in dry landscapes. **Implications/Conclusions:** The lessons learned show that restoration goes beyond tree planting and that important technical and governance issues have to be considered when up scaling forest and landscape interventions in drylands. **Keywords:** Drylands, Ghana, forest and landscape restoration, tree tenure, restoration failures

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Indicators to Assess and Monitor Secondary Forest Recovery

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Tropical secondary forests (SFs) cover large extents of human modified landscapes and can help restore ecosystems at low costs and high ecological effectiveness. Recovery rates, however, vary with environmental conditions and are negatively affected by anthropogenic impacts. Hence, to be able to assess and monitor the ecological integrity of SF, it is important to identify indicators that have a consistent response to degradation (are predictable) and can be applied across a region (are generalizable). In this study we aimed (i) to identify the relative importance of environmental conditions and anthropogenic impacts for SF structure, diversity and function, and (ii) to identify the best indicators for assessing and monitoring SF across the Amazon region. We consider as best indicators those which variation is mainly described by anthropogenic impacts and are weakly affected by site and environmental conditions. We used information from 135 vegetation plots from 12 sites across the Brazilian Amazon, with ages ranging from one to 35 years after abandonment. We fitted general linear mixed models to select (based on the lowest AIC) the best models for each indicator of vegetation structure (basal area, maximum DBH, Gini index, and stem density), diversity (Hill numbers q0, q1, q2), and function (aboveground biomass). We assess the fixed effects of the following drivers: land use and cover (forest cover, fire frequency, number of clearances, land use type: pasture, shifting cultivation and "mix"), soil and topography (CEC, CFV, SOC, N, pH, silt, clay, sand, HAND), and climatic conditions (MAP, MAT, CWD, dry season temperature, dry season precipitation). Site was included as a random factor. The selected best models had marginal R2 higher than 0.53 (apart from Hill q0 with R2=0.24), and R2 of the random effects between 0.06 and 0.14. All models were significantly and strongly affected by age (average standardized effect size of 0.63 ± 0.23), followed by anthropogenic impact (0.32 ± 0.10) and environmental factors (0.19 ± 0.08). We ranked the models in descending order of (i) lowest dependency on site location (represented by the variation explained by random effects), (ii) highest effect size of anthropogenic impact variables and (iii) lowest effect size of environmental variables. Accordingly, the most promising indicators were the Gini index of structural heterogeneity and the species diversity hill numbers q1 and q2. Absolute values of these indicators can be derived for each successional stage (initial, intermediate and advanced) and used to assess the ecological integrity of SF across the Amazon region **Keywords:** Natural regeneration, restoration, ecological integrity, resilience, indicators, Amazon

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Estimating Restoration Benefits across Regenerating Tropical Forest Landscapes

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Conserved tropical forests provide multiple benefits to people, but the contributions of forests undergoing restoration are still uncertain, as many restoration areas are found in suboptimal biophysical conditions for ecosystem recovery, being frequently impacted by human-mediated disturbances, and are too young. Quite often, the assessment of restoration benefits is also limited to a few ecosystem functions, limiting a broader understanding of the restoration of forest multifunctionality. Here, we will present the methodological approaches developed by the NewFor project to understand restoration benefits to nature and people. We employed a multi-scale, multi-functional monitoring approach, in which different restoration systems (e.g., restoration plantations, second-growth forests, active and abandoned tree monocultures, agroforests) and reference conditions (degraded and conserved old-growth forests, agro-pastoral land uses) were evaluated in the field, using a multifunctional monitoring protocol, and through different remote sensing techniques (lidar sensors in drone, airplane and satellite). We will describe the application of this monitoring approach to forests of São Paulo state, southeastern Brazil, and explore the potential contributions to decision making. **Keywords:** Forest restoration, restoration plantations, natural regeneration, forest multifunctionality

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A Conceptual Framework of Ecological Succession

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Ecological succession has been traditionally approached as a niche-driven process, where a deterministic shift in species composition is predicted to be driven by changes in environmental conditions as succession unfolds. In the last decades, advances in community ecology have shown how plant community dynamics are affected by a wide range of mechanisms involving local biotic and abiotic interactions but also strongly by dispersal-based processes at the landscape scale. In addition, empirical studies have repeatedly shown that even nearby abandoned fields with the same abiotic conditions do not necessarily follow a single and predictable trajectory, but can follow multiple successional trajectories. Together, this indicates how the re-assembly of plant communities during succession is affected by a myriad of ultimate and proximate factors operating simultaneously across multiple spatial scales and interacting among them. We show that all such mechanisms can be grouped in a relatively limited number of series of 'higher-order' processes that are hierarchically linked, creating minimal causal pathways that each drive predictable successional dynamics of plant communities. Specifically, we identify these "high-order" causal pathways and integrate them in a graphical framework that provides a synthetic understanding of the major underlying causes and mechanisms leading to both predictable successional shifts in species composition and variation in species dynamics at multiple spatial scales. We further identify and discuss, within some of the main causal pathways, examples of specific 'lower-order' mechanisms that affect successional species dynamics at local scales. Until now, studies on tropical forest succession have mostly been pattern-driven, based on observational studies aiming to detect recurring trends to infer a process behind the observed patterns. However, our framework illustrates how the same successional trajectories and dynamics observed in field studies can be explained by alternative causal pathways, or by different lower-order processes within those pathways. We therefore argue that a more process-driven research program is needed to advance our theoretical understanding of ecological succession, and to improve our ability to assist in the design of landscape restoration based on natural regeneration. **Keywords:** Ecological succession, community ecology, species dynamics, conceptual framework, restoration

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Tropical Forest Recovery on Abandoned Lands, Underlying Drivers, and Implications for Restoration

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Tropical forests disappear rapidly because of deforestation, yet they have the potential to regrow naturally on abandoned lands. We analyze how 12 forest attributes recover during secondary succession, and assess the underlying biophysical and social drivers, using 77 chronosequence sites across the Neotropics and West Africa. Tropical forests are highly resilient to low-intensity land use, after 20 years, forest attributes attain 78% (33-100%) of their old-growth values. Recovery to 90% of old-growth values is fastest for soil and plant functioning, intermediate for structure and species diversity, and slowest for biomass and species composition. We show how biophysical drivers (rainfall, temperature, pH) and social drivers (landscape forest cover, previous land use) affect forest recovery and discuss the implications for ecosystem restoration. **Keywords:** Tropical forest, secondary succession, drivers, climate, soil, restoration

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Successional Patterns in Tree Size Distribution along a Rainfall Gradient

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Successional ecology requires general theories for synthesis and forecasting. While site-specific idiosyncrasies have been demonstrated in many recent studies and across-site variation is increasingly being appreciated, we still need to find characteristics of succession that are invariant across sites or that vary predictably along major environmental or anthropogenic gradients (e.g., rainfall and land use history). The metabolic scaling theory, though based on a few assumptions, provides a simple and elegant model that can be used to examine shifts in the size frequency distribution of tree communities after disturbance and compare scaling parameters across multiple sites. The process of competitive (a)symmetry is expected to drive similar successional patterns of tree size variation across a wide range of tropical forests, but the rate at which size distributions become more unequal may depend on the nature of the most limiting resource(s). Using datasets from multiple 2ndFor sites and modifying a modelling framework developed by Niklas et al. (2003), we quantify successional trajectories in term of tree-size structure and show how these trajectories change along a wide rainfall gradient. We also outline key statistical challenges and potential ways forward in terms of data collection and modelling.
Keywords: Forest structure, size distribution, diameter, metabolic scaling theory, 2ndFor, rainfall

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Both Local and Regional Environmental Conditions Contribute to the Natural Restoration Trajectories of West African Forests

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In West Africa, little is known about the restoration trajectories of secondary forests, and even less about the origin of the variability observed in recovery rates. We installed 8 chronosequences on a typical North-South climatic gradient in West Africa and inventoried, for each chronosequence, all trees over 2.5cm DBH on 20 plots aged 0-50 years, including controls. These data allowed us to quantify, and model in a hierarchical Bayesian framework, the recovery trajectories of biodiversity, aboveground biomass and floristic composition. The relative effects of local (plot history and landscape context) and regional (climate and soil) variability on these trajectories were then estimated. The results show that diversity recovers faster than composition, while above-ground biomass is the slowest. Seasonality of rainfall, soil hydromorphism and the number of remnant trees had a major impact on all restoration trajectories, while the duration of the previous agricultural cultivation negatively influenced the speed of recovery of aboveground biomass and diversity. In conclusion, the variability of regional pedoclimatic conditions certainly plays a role in the reconstitution rates of secondary forests, but local conditions linked to the history of the plot and to the landscape context are very important to consider in a decision-making framework for the choice of more or less active restoration techniques. **Keywords:** Secondary forest, Ecosystem trajectories, West africa, Bayesian modelling, Biodiversity, Carbon

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Does One Model Fit All? Shifts in Tree Demographic Strategies across Succession in Wet and Dry Neotropical Forests

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Secondary tropical forests play an increasingly important role in climate change mitigation, biodiversity conservation, and timber provision. We are beginning to understand how community-level metrics, such as biomass, species richness, or functional composition of the tree community recover. However, successional changes in community composition arise from differences in demographic rates of the multiple tree species that comprise local communities. Yet, our mechanistic understanding of and ability to forecast shifts in dominance of different demographic strategies across succession remains limited. We used demographic rates of 787 tree species across two wet and two dry Neotropical forests to identify generalities in demographic trade-offs and patterns of forest succession. We found two consistent trade-offs in wet and dry forests. The first one is the growth-survival trade-off distinguishing species with fast growth and low survival (fast species) from species with slow growth and high survival (slow species). The second one is a trade-off between fast growth and high survival – and hence tall adult stature (long-lived pioneers) – versus high recruitment rates per unit of basal area in the old-growth forest (short-lived breeders). This consistent and data-driven definition of demographic strategies enabled us to explore general patterns in tropical forest succession across the four forests. As expected, early succession was dominated by fast species in three of the four forests. Slow species increased in basal area over succession, but remained at low levels in three of the four forests. In contrast to expectations, long-lived pioneer species dominated not only at intermediate successional stages but also in the old-growth stage in all forests. This calls for a revision of our current definition of the 'old-growth' stage. Instead of relying on the disappearance of long-lived pioneer species from the forest it should incorporate their persistence and (co)dominance. **Keywords:** Conceptual model of succession, demographic strategies, life-history strategies, species classification

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Resprouting: The Neglected Recovery Mechanism in Tropical Secondary Forests

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Resprouting, the ability of plants to regenerate damaged tissues through the production of new shoots, has been posed as a main regenerative mechanism in tropical dry forests (TDF) affected by human activities. Although resprouts are a remarkable feature of early regenerating forests in dry lands, their contribution to the whole process of forest regeneration is poorly documented. Furthermore, we do not understand how resprouting ability relates to other forest regeneration mechanisms like dispersal limitation or niche differentiation. Here, using data from two TDF sites where forest regeneration has been monitored through time, we: 1) assess the effect of resprouting on the structure and species composition of regenerating forests, and 2) evaluate how resprouting ability relates to plant traits related to dispersal limitation (dispersal mode, seed size) and niche differentiation (wood density, specific leaf area, and maximum height). We fitted nonlinear models to assess the relative contribution of resprouts to forest recovery, and a path analysis to test for associations among functional traits. Our results show that resprouts are consistently present across regenerating forest stands, but their abundance decay with time since last disturbance and can be highly variable across sites of the same age. We also found resprouting ability to be partially related to dispersal mode, with wind dispersed species being less prone to be represented by resprouts than species with animal dispersal. Together, or results indicate that although resprouting effectively contributes to biomass and species accumulation during forest regeneration,

its presence is not wide or uniform across regenerating stands. More important, resprouting interacts with other regenerative mechanisms, particularly dispersal limitation, in shaping tree community recovery: it seems to provide a kickstart for those species that may be limited by seed dispersal, therefore accelerating species accumulation and replacement. We propose a model of forest succession that explicitly integrates resprouting as a mechanism of forest regeneration in TDFs, and identify several research priorities in order to advance on our understanding of the integration of resprouting on successional theory. **Keywords:** Resprouts, dispersal limitation, niche differentiation, habitat filtering, regeneration niche

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Forest Successional Stage Affects Survival and Growth of Forest Tree Species Differing in Shade Tolerance

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During the course of succession, the light availability at the forest floor decreases dramatically. As tree species differ in their shade tolerance, it is expected that species differ in their performance through succession. Here, I present the results of a transplant experiment established to study the survival and growth of seedlings of tropical tree species in successional stages differing in age in the Bolivian Amazon. Seedlings of nine tree species, ranging from pioneer to shade tolerant species, were planted in three successional stage (1, 10 and 20 years old). Survival and height growth rate were monitored during two years, after which a destructive harvest was done. Successional stage and species had an effect on almost all variables measured. Survival rate decreased with age of the successional stage, as did height growth rate and relative growth rate. This suggest that all species, regardless of their shade tolerance, perform better early. Results also indicate that different plant traits enhance survival at low light and growth at high light. This study suggests that differences in survival and growth among species at different successional stage play an important role in succession. **Keywords:** Secondary forest, succession, growth analysis,

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Seeing Through the Smoke – fire as a catalyst of Amazonian tipping points

Estimating Fire Emissions in the Amazon and Cerrado Biomes of South America Using Remote Sensing

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Fires in the tropics are driven by climate and land-use change. In the Amazon, fires are linked to post-deforestation biomass burning, agricultural and pasture management fires, and forest fires. Earth system models predict an increase in the intensity of dry seasons in this region in the 21st century. Therefore, carbon emissions from drought-induced forest fires can counteract pledged reductions of deforestation in the following decades, yet they are not included in national carbon emission estimates. Further, air pollution caused by fires has been linked to seasonal upturns in respiratory diseases affecting the population in Brazil's fire-prone areas. Against the backdrop of the COVID-19 pandemic, air pollution can potentially increase the risks of hospitalisations and mortality. Improved assessments of fire impacts, emissions and their impact on air quality are therefore of high importance. Spatially specific estimations of fire emissions are made possible through a range of satellite products that are now available. We develop a remote sensing based approach that makes use of observations of burned area, land-cover change data and new high resolution biomass maps (ESA-CCI). By generating annual reference biomass maps for forests that are continuously updated with deforestation, fire-induced mortality and regrowth and combining these with existing estimates of grassland and crop residue fuel consumption, we derive new estimates of dry matter burned. Based on this methodology we present initial estimates of dry matter burned and trace gas emissions for the entire Amazon basin and the Brazilian Cerrado at monthly intervals and compare our estimates to those of the global fire emissions database (GFED4). This allows us to identify areas of uncertainty in current emission estimates and present alternative workflows for generating improved regional products. These products will further be used to improve greenhouse gas budgets and to study effects on human health, ecosystem services and biodiversity. **Keywords:** Amazon, fires, degradation, carbon emissions, remote sensing, forest, savanna

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Fire in the Larder: Understanding the Impacts of Invasive Fires on Biodiversity and Forest Food for Traditional Communities

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Invasive fires have become both more frequent and severe in tropical forest landscapes. Impacts have been largely understood in terms of carbon emissions, hectares of forest lost, species impacted and further consequences for ecological processes. Yet the rising flammability of tropical forests presents immediate and poorly understood implications for traditional populations. Traditional peoples, including the mixed-descent ribeirinhos of the Brazilian Amazon, integrate forest use and extraction in their daily lives, livelihoods and well-being, drawing heavily on indigenous lifeways. For instance, through the collection of various species that provide nutritional diversity, contribute to family food security, offer medicinal properties, and those used in the construction of homes (e.g. palm thatch and timber) and transport (i.e. canoes) amongst others. The interlinked and place-based nature of traditional peoples and forests, means that these communities are also

first in line when forests are degraded through extensive fires. Further, feedbacks between fire, extraction and the functional ecology of the species impacted, holds considerable implications for the future of forests and the various dependencies that are contingent on them. This study applied mixed methods including household questionnaires to solicit livelihood portfolio data, social perception-based data of species abundance and recovery following fire, geospatial data of fire prevalence and combined it with functional ecology insights to consider these dynamics and feedbacks. We collected household data in two time-steps, in 2010 (n156) across 12 communities, and revisited a sub-sample in two communities in 2019 (n16) living in two fire-affected sustainable use reserves in the Brazilian Amazon. We present our findings, consider their implications in the context of increasing fire prevalence, and reflect on the necessity of just and equitable governance to reduce fire prevalence. **Keywords:** Fire, tropical forests, functional ecology, food security, traditional peoples, justice

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Projections of Future Forest Degradation and CO2 Emissions for the Brazilian Amazon

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In recent years, the area affected by forest degradation in the Brazilian Amazon has frequently been higher than deforestation. From August 2006 to July 2019, the degraded area totalled 194,058 km^2, representing almost two times the 99,630 km^2 deforested in the same period. The impacts of degradation include biodiversity loss and changes in the carbon stocks, affecting the CO_2 balance and future climate changes. This paper aims to explore socio-economic and environmental factors that influence forest degradation, project future scenarios, and assess the impact on the regional carbon balance, combining forest degradation and deforestation-related processes (clear-cut deforestation and secondary vegetation dynamics). We show that, while net CO_2 emissions from 2020 to 2050 are 0.74 Gt CO_2 in the Sustainable scenario, this value reached 22.63 Gt CO_2 in the Fragmentation scenario, an increasingly plausible scenario given the recent trends in the region. **Keywords:** Land-use scenarios, Brazilian Amazon, forest degradation scenarios

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The Fate of Amazonian Forests in an Increasingly Fragmented Fire-prone Landscape

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Introduction: Fire in Amazonia is a human-dependent land management tool used for removing forest cover through multiple degradation events, for consolidating the deforestation process and for clearing managing productive lands. To guaranty the stability of Amazon Forest process aiming to maintain its ecological functions, it is critical to understand and manage the factors that drives fire risk. **Objectives:** We aim to provide a comprehensive overview on how the components of fire risk are changing in Amazonia, including exposure, hazard and vulnerability, exacerbating fire impacts on Amazonian forests. **Results:** Widespread forest fires, hitting Amazonia, especially in drought years are not only a function of climatic conditions, but also a result of extensive changes in landscape configuration that affects local climate and increases the exposure of forests to fire. During drought years, fires can damage areas two to three times larger than current deforestation rates. Reduction in the connectivity of forests due to deforestation can make local climate more favourable to fires. Edge creation exposes a large fraction of forests to the incursion of fires. Forests burned once suffers a reduction of about 25% their biomass, with this impact persisting for decades. Successive fires in the same burned forest, may exacerbate the fire impact, as the lower biomass, combined with an increased density of canopy gaps, changes microclimatic conditions, favouring more intense fires and a greater severity. If continuously affected by multiple fires, forest cover can be completely removed from successive degradation. Carbon emissions from burned forest in Amazonia are at the similar magnitude than emissions from the deforestation process during drought years. The recovery of carbon stocks in burned forests is not trivial as despite an increase in the

net primary productivity in years following the event, the increased rate of tree mortality offsets the gains. The net ecosystem productivity of burned forests in Amazonia reaches a steady state few years after fire, but supporting a biomass which is 75% of that from the original pre-fire forest. Conclusions: If no mitigation strategies are enforced, Amazonia may turn into a highly fragmented landscape, covered by human-modified forests which do not support high biomass and biodiversity. Negative implications on the climatic stability at the continental level are expected, with consequences for the economy and society of Amazonian-dependent countries. Critical understanding of the pathways these forests may take is fundamental for strategically plan actions to implement Amazonia's sustainable development. **Keywords:** Fire, Amazon, carbon cycle, remote sensing, forests, environmental change, climate

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Effect of Drought, Wildfire and Cropland on Soil Moisture in Southeastern Amazon

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Introduction: Soil moisture is one of the main drivers of vegetation dynamics and directly influences climate. Currently in the Amazon, forest fires, drought events, and land use and land cover change (LULCC) are some of the main factors that alter land surface processes, but their direct impact on soil moisture is still poorly understood. **Objective**: We measured the volumetric water content (VWC) by the Gravimetric Water Content (GWC) method between 2010 and 2019 in three treatments: an area burned annually between 2004 and 2010 (50 ha), an unburned Control (50 ha), and a cropland in southeastern Amazon. We used these measurements to test the effect of fire, the 2015-2016 drought event, and the conversion of forest to agricultural land covers on soil moisture. **Methods**: The data collections took place monthly with the aid of an auger at depths of 0.5, 1, 2, 3 and 4 m. For each treatment, two wells were drilled with the auger. And for each depth a soil sample was taken. We used analysis of variance (ANOVA) to test the effects of predictors (fire, drought and cropland) on soil moisture in the R software. Results: Overall, the VWC was significantly higher ($p < 0.001$) in the cropland compared to the burned (30%, 60 mm) and control (20%, 44 mm) plots. The 2015-2016 drought reduced the VWC by 9% in the two forest plots (~19 mm), and by 6% in the cropland (~16 mm), with this effect being more intense in the topsoil. Implications/Conclusions: Our results also highlight a marked seasonal effect of VWC in the forest even in the deep soil — indicating that the trees are absorbing water at this depth, especially in the dry months — while in the cropland, this effect was reduced with increasing depth. The higher VWC in the cropland can be linked to the absence of trees with deep roots that could be pumping water into the atmosphere. The lower VWC in the burned plot may be due to the greater use of water by the vegetation in post-fire recovery. As LULCC and climate change intensify, soil drying by drought events can become more recurrent and intense, exacerbating wildfires, and subsequently endangering the health of the southeastern Amazon transitional forest. **Keywords:** Climate extremes, wildfires, soil moisture recharge, forest transition ecosystems

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Why Research Needs to Understand the Complex Causes of Amazonia's Present-day Fire Crisis.

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The last decade has seen a rapid growth in research in Amazonian fires, stimulated by the prominence of fire events during El Nino years and other climate anomalies, and the ongoing use of fire as a tool in land speculation and deforestation. This talk will synthesize some of the key findings from fire research, examining how this has accompanied the recent history of fire in the Amazon, from the first research in the 1980s to the present day. It will demonstrate the importance of understanding what is burning for quantifying impact and developing solutions. Finally, it will examine some research priorities, focusing on the knowledge gaps that are hindering the development of better fire management. **Keywords:** Fire, deforestation, agriculture, climate extremes, drought, knowledge gaps

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Ecological Insights from a 12-year Burn Experiment in a Transitional Amazonian Forest

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Background: Compounding disturbances events associated with drought, fire, windstorms, and forest fragmentation have interacted to degrade tropical forests. As climate and land-use change, these events are expected to become more frequent, widespread, and intense. An important scientific practical question is whether tropical forests' recovery will outpace forest degradation associated with novel disturbance regimes. Despite a high resilience, tropical forests may not recover when disturbances are too intense and severe. **Objective:** To provide a synthesis of multi-year measurements of vegetation dynamics and function (fluxes of CO_2 and H_2O) in forests recovering from 12 years of controlled burns, followed by two wind disturbance events. The study's hypothesis was that in the experimentally burned areas, differences in forest structure and functioning would decrease over time between burned and unburned areas, although recovery would be slower along the forest edges and in the treatment burned every three years, where fire and wind damage were more severe. **Methods:** The experimental study area was in Mato Grosso state, 30 km north of the southern boundary of the Amazon rainforest in Brazil and consisted of three 50-ha plots burned annually, triennially, or not at all from 2004 to 2010 (with exception of 2008). In burned plots areas, fire lines were ignited using drip torches along transects spaced 50 m apart during the peak of dry season, in between July and early September. To evaluate post-fire forest recovery of CO_2 and H_2O fluxes, we used tow eddy covariance systems, one located in an unburned forest and another in the burned plots. We also conducted pre- and post-fire inventories across the three treatment plots, and measured canopy dynamics different methods. **Results:** During the first seven years of post-fire recovery, tree survivorship and biomass continued to decline and species composition to change, especially along forest edges, where the disturbances were more severe. However, more recent vegetation regrowth triggered partial recovery of vegetation structure and fluxes due to higher light-use efficiency and water by plants growing in the burned plots, compared to the control. **Implications/Conclusions:** While the effects of interacting compounding disturbance events on biomass and species composition can persist over many years, a rapid recovery of carbon and water fluxes can help stabilize some local climatic conditions. **Keywords:** Amazonia, wildfires, forest, tree mortality, carbon emissions, forest edge, disturbance

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Assessing Functional Shifts in Human-modified Amazonian Forests

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The impacts of fires in Amazonian forests are varied – from changes in the forest structure and microclimate to shifts in the taxonomic composition of both fauna and flora. Much less understood is how forest fires affect the distribution of functional traits of the affected forests – i.e. given the elevated mortality of trees in burned forests and the recruitment of pioneer species, is there a shift in plant functional traits? Here we evaluate how forests affected by fire and logging differ from undisturbed ones in 11 morphological and chemical traits of the dominant tree species. We sampled >1,000 individuals distributed across 20 forest plots and calculated the community weighed mean of each of the 11 sampled traits. Surprisingly, we found no significant difference in the community weighed means of the 11 sampled traits. We then compared the community weighed means of the sampled traits between large (>10cm DBH) and small (2-10cm DBH) trees in each forest plot. We found that the community of smaller trees is more functionally different from that of the larger trees in forests affected by both selective logging and forest fires than in undisturbed forests, highlighting a possible future functional shift in forests. This is of great concern as future forests might not perform the same set of functions and, therefore, not deliver the same set of services of current forests, with possible profound impacts on key forests processes such as nutrient cycling and carbon assimilation. **Keywords:** Fire, Amazon, degradation, functional traits, logging, forest, climate change, community

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A Novel Approach for Assessing the Long-term CO2 Balance of Burned Amazonian Forests

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Amazonian forest wildfires are likely to become more frequent under a hotter and drier climate and could contribute significantly to Brazilian CO2 emissions. Currently, the annual estimates of CO2 emissions and removals from LULUCF in Brazil are estimated following IPCC guidelines by the environment ministry system (SIRENE). However, the SIRENE platform covering national and subnational emissions, does not include emissions from wildfires. This is a potentially important omission as previous studies have pointed to the non-recovery of carbon stocks of burned forests within 30 years in the Brazilian Amazon. Quantifying these emissions is not simple - computing changes in carbon stock from live and dead pools require a dynamic system modelling and repeated measurements from forest plots. Here we assessed the long-term carbon balance of burned forests and developed an approach considering that part of the carbon lost from fire is immediately emitted to the atmosphere, and another part is transferred to dead organic matter, being emitted slowly through decomposition. We developed a dynamic spatial-temporal model in Google Earth Engine that integrates biome-specific parameters, such as maps of carbon stocks, dead wood and litter combustion factors, tree mortality, decomposition and turnover rates to quantify net CO2 at a year-to-year basis with high spatial resolution burned area maps. Our model brings novelty for integrating two unique datasets — before-and-after fire censuses of 40 permanent forest plots in the Brazilian Amazon, and a high resolution burned area map (Mapbiomas Fire) ranging from 1990 to 2020. We estimated that in 30 years, burned forests in the Brazilian Amazon have emitted 1,274 Tg of CO2. These emissions stem only from fires in forests that remained up to 2020, e.g., it does not include burned forests that were deforested. Since 2009, forest wildfires emissions are equivalent to 41% of deforestation emissions. Our analysis indicates more burned forests are likely to remain in future years under a scenario of controlled deforestation — during the most recent period in our analysis (2012-2020), 47% of burned forests were not deforested but acted as a carbon source. Until now, there has been no spatially explicit method of incorporating forest fire emissions into Brazil's carbon accounting from LULUCF and assigning those emissions to specific years. While our proposed approach is preliminary and requires refinement, we were able to apply it to the whole Amazon basin, revealing for the first time how fire emissions progress over time across across forest stands and fire regimes. **Keywords:** Forest wildfires, emissions, carbon, dynamic modelling, google earth engine

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The Effects of Fragmentation on Fire in the Amazonia Biome

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The Brazilian Amazonia is increasingly exposed to fires due to the association of human activity and climate change. Human activities, such as landscape fragmentation and land-use management, have introduced fire into the Amazonian Forest with negative impacts on its biodiversity and carbon cycle. Although advances have been made to understand the impact of fragmentation on forest edges, there is still limited mapping of the relationship between landscape fragmentation on fire occurrence within forest fragments in the Brazilian Amazon. The aim of this study was to: (i) map the trends and status of landscape fragmentation, (ii) test the general relationship between burned area, landscape fragmentation, and agricultural land in the Brazilian Amazonia. To estimate the trends and status of landscape fragmentation a Forest Area Density (FAD) index was calculated based on the MapBiomas land cover dataset. Burned area (BA) fraction derived from the Moderate Resolution Imaging Spectroradiometer burned area dataset was analysed within native vegetation against the FAD and agricultural land fraction from MapBiomas. Our results show an increase in landscape fragmentation across Amazonia in the last two decades with a higher concentration in the Arc of Deforestation. The BA fraction within forest fragments is higher in the highly fragmented FAD categories and decreases towards the highly connected categories. During drought years this relationship is maintained, yet we found a higher BA fraction within forest fragments. In summary, landscape fragmentation and agricultural fraction play a key role in increasing burned area fraction within forest fragments and it can be exacerbated during drought years. With the predicted increase in frequency and extent of droughts in South America due to global climate change, the

integrity of intact forests of Amazonia is at risk of fire spread caused by human activity. This will compromise the forest structure and composition, negatively impacting the carbon cycle and its future ecosystem service provision. **Keywords:** Landscape fragmentation, fire, Amazonia, remote sensing

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Unravelling the Complexity of Amazonian Tipping Points

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Introduction: The Amazon forest could reach a tipping point of large-scale dieback in the coming decades. Understanding the actual likelihood of this tragedy requires addressing the various factors shaping Amazonian resilience. The region is undergoing a major regime shift. Ancient stabilizing feedbacks are now weakening and being replaced by novel ones that increase the risk of abrupt shifts. **Objectives:** Grounded on the theory of complex dynamical systems, we assess existing evidence for tipping points in the Amazon Forest system, as well as the most probable trajectories following ecosystem shifts. **Methods:** We review the scientific literature and compile evidence of tipping points from paleo-ecological studies, current observations and modelling. We discuss how the inherent complexity of the system may add uncertainties about the risk of tipping points, but also reveal opportunities for action. **Results:** We identify four potential large-scale tipping points in the Amazon Forest system involving temperature, rainfall and deforestation as external drivers. We also identify three common ecosystem trajectories associated with distinct disturbances and stabilizing feedbacks. Most likely, ongoing deforestation may cause large parts of the Amazon to shift into an open-canopy degraded state, trapped by fires. Such local ecosystem shifts may become contagious and cause a large-scale forest dieback, but this depends on a combination of mechanisms. In particular, spatial heterogeneity and connectivity play important roles in shaping forest resilience by affecting whether the system will collapse abruptly or gradually, i.e. whether tipping points in fact exist. Conclusions: We conclude that the very same mechanisms that kept Amazonian forests resilient for millennia are now disappearing, heterogeneities that reduce disturbance contagiousness, ancient connectivities that promote forest recovery, and the biological and cultural diversities that increase forest adaptability. Now, these pillars of Amazonian resilience are being lost. Existing evidence indicates that the most important actions to avoid tipping points are ending deforestation and forest degradation. Nonetheless, climate change will continue to intensify, implying that keeping the Amazon resilient may depend on our capacity to control global greenhouse gas emissions. Decisions regarding the future of this iconic system must involve local and global actors, bridging the ancient ecological knowledge of indigenous and local peoples with updated science to promote its social-ecological resilience to upcoming events. **Keywords:** Climate change, deforestation, feedback, fire, resilience, social-ecological systems, tropical forest

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Amazon Tipping Points: an Earth System Modelling Perspective

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Amazonian forests face intensifying threats from climate change and human disturbance, and the prospect of near-future large-scale forest 'dieback', i.e. the rapid collapse in above-ground biomass and/or a loss in the capacity of forests to recover, as the Amazon forest approaches a climate tipping point. Such a dieback would limit the world's ability to mitigate climate change, conserve biodiversity and support sustainable development. The objective of this presentation is to review the evidence for such a tipping point from an Earth System Modelling perspective. I will first give an overview of modelling methodologies, giving a historical perspective on advances in modelling capabilities and their projections for the Amazon Forest from the original works from the turn of the century to the current state-of-the-art results as reported in the IPCC six assessment report. Here I show how model capability has improved to include forest demography, plant hydraulics and mechanistic representations of fire disturbance, air pollution impacts, and consider land-use change. I will finish by highlighting remaining uncertainties and propose how these can be addressed with integrated and targeted data-model efforts. **Keywords:** Tipping point, climate change, earth system models, Amazon dieback

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Status of biodiversity in the Amazon

Introduction

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Introduction: Preserving Amazonian biodiversity critically depends on documenting patterns of species richness, geographic distributions at large spatial scales and across many branches of the Tree of Life. The Science Panel for the Amazon (SPA) assessment report highlights that the actual species richness of the Amazon is vastly underestimated, partially because of the difficulty of sampling in this vast region and also because many groups are understudied. Existing spatial and taxonomic biases in biodiversity data in the Amazon affect our capacity to understand the true patterns of biodiversity in the region and indicate solutions for conservation. Although the IUCN Red List (RL) provides the highest quality conservation assessments for individual species using multiple and rigorous criteria, it requires substantial time and information such that many species remain classified as "data deficient". Meanwhile the rate and scale of Amazon deforestation and habitat destruction challenges the conservation community to develop expedited methods for risk assessment. **Objectives**: This symposium motivated by the gaps highlighted in the SPA report and also by the opportunity to join effort of scientists to fill them. The symposium will match taxonomic experts with GIS specialists to estimate the conservation status of all the species in a clade, including those classified as "data deficient". **Methods**: The symposium will present case studies from multiple Neotropical plant and animal groups of organisms, showing how specimen collection data obtained from museum and publication records can be used rapidly estimate species extinction risk. Estimating species ranges for conservation assessment requires compiling, organizing, and proofing a comprehensive database with thousands of geographic coordinates. We will demonstrate the use the R package ConR (Dauby et al., 2017) to estimate Extent of Occurrence (EOO), providing preliminary conservation assessments of species for which extinction risks have not been assigned by the IUCN–RL. **Results**: A study of Neotropical freshwater fishes shows greater extinction risk in species with smaller geographic ranges. Conclusions: We will demonstrate how estimates of EOO can be used to help prioritize regions and taxa in upcoming IUCN-RL assessments of Neotropcial species conservation risk. **Keywords:** Biodiversity, conservation status, extent of occurrence, IUCN red list.

Red Listing of Amazonian Plant Species

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Introduction: Amazonian forests and their plants are under increasing pressure from deforestation, anthropogenic fire, forest resources extraction and climate change. As with the other taxa examined in this symposium, no comprehensive assessment has yet been made to report the threat level for Amazonian plant species based on a complete set of IUCN Red List criteria. Earlier attempts have been made for c. 5,000 tree species based on population changes driven by deforestation, and c. 10,000 tree species combining effects of both deforestation and climate change. These studies also estimated population sizes and area loss by 2050 based on two deforestation scenarios, with one study including two climate change scenarios. These studies concluded that currently 25% of all Amazonian trees may be threatened according to a limited set of IUCN criteria, but that this number may increase to 57% from ongoing deforestation and over 50% may be threatened due to climate change. **Objectives/Hypothesis:** The Global Tree Specialist Group has made several advances in IUCN assessments using a broad range of available scientific data types. Here we compare information related to geographic and taxonomic datasets for tree and non-tree vascular plant species. In this way, we determine the species with the greatest threat and the least attention. **Methods***:* Using recently developed algorithms to extract museum collection data from large online repositories and the scientific literature, to clean, validate and analyze these data against a near-complete set of RL criteria, we estimate the current threat level of over 16,178 Amazonian plants including tree and non vascular species. **Implications/Conclusions:** The bioinformatic workflow presented here allows rapid assessments of potential conservation threat for thousands of plant species, even in a region as large and biologically complex as the Amazon. These assessments allow investigators to quickly identify species that share similar levels of conservation threat, and group species based on similar geographic range sizes or exposure to similar anthropogenic drivers of conservation threat. These assessments will facilitate conservation planning based on species with similar taxonomic, physiographic or geographic properties, similar geographic or ecological range sizes, or similar degree of spatial fragmentation or drivers of conservation threat (e.g. land-use change, climate change, pollution). **Keywords:** Amazon redlisting evaluation, trees, non vascular plants, threats, conservation

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Conservation Status of Potentially Threatened Amazonian Fishes

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The rate and scale of habitat changes has challenged the conservation community to quickly generate species risk assessments using readily accessible environmental variables as proxies and expedited methods. This study generates preliminary conservation assessments for the Amazonian Fish Species (AFS) that are currently awaiting IUCN assessment, and investigates relationships between extinction risks and ranges, elevations, and species publication date. Ours findings indicate that AFS are still preserved in many areas throughout the Amazon region, with the exception of those possessing narrow geographic ranges located outside formally protected areas. Additionally, our findings indicate that newly described species with smaller geographic ranges that inhabit upland rivers are more vulnerable to extinction. The AFS will benefit from conservation status by prioritizing geographic areas with the highest concentration of coexisting and threatened species. Thus, conservation efforts directed towards Amazonian ichthyofauna must prioritize upland habitats, particularly in the Brazilian and Guianas shields, which are home to the majority of the potentially threatened AFS. **Keywords:** Biodiversity, ichthyology, conservation assessments, potentially threatened species.

Evaluating IUCN Conservation Status of Amazonian Birds

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Across Amazonia, apart from pre-Colombian agricultural practices and sparse modern urban areas, native habitats remained mostly intact up until 1970's. In the last 50 years, large infrastructure projects such as highways and river dams were the venue for increasing deforestation and habitat conversion rates in the countries comprising the Amazon region. The fast pace of environmental change in Amazonia affects animal and plant species. Although the IUCN Red List already provides detailed threat assessments for most bird species, new studies re-evaluating the taxonomic status of Neotropical birds show that many lineages currently treated as subspecies of Amazonian birds should be recognized as full species. IUCN threat assessments do not follow closely the constant changes in taxonomy, and this may be signalling a false scenario for the conservation status of Amazonian birds. To assess the IUCN conservation status of all Amazonian bird taxa (species and subspecies) based on their range size (IUCN criterium B), we built a point locality database with c.620,000 records where we identified each record at the subspecies level for 3,320 taxa. We built custom extent of occurrence range maps for all the 3,320 taxa based on their point localities and on expert scientific knowledge. We used the point locality records from each taxon to generate environmental niche models, projecting suitable habitats within their extent of occurrence (EOO) maps in present and future climate scenarios, also incorporating current and future projected deforestation information. Our results show that at least 27% (901 of 3,320) of Amazonian bird taxa should be classified within one of IUCN's threat statuses, and that within future climatic and deforestation conditions, up to 47% (1,559 of 3,320) of Amazonian bird taxa should be considered threatened. Among these, 60% (939 of 1,559) are either from montane evergreen forests from the eastern Andean slopes, or from the lowland evergreen forest (terra-firme) of the southeast portion of Amazonia. Our study reveals the importance

of evaluating threat status of Amazonian birds at the infraspecific level and calls for immediate conservation effort to protect animal communities which are still poorly understood in the most bird diverse region of our planet. **Keywords:** Avian, distribution, neotropic, IUCN, conservation, GIS, niche, modelling

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Synergize Project: Building Ecological Knowledge on Amazonian Insects through Collaboration

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Integration of existing knowledge is critical to better understanding and managing our planet's biological resources. Research networks that integrate, synthesize and embed scientific knowledge into decision-making and policy are vital to tackling the current biodiversity crisis. Insects are the major stockholders of global biodiversity and key contributors to ecosystem functioning and human wellbeing. However, the data available on this important group is spatially limited and largely lacking for the tropics. This is particularly important for Amazonian forests and freshwater ecosystems, which house an extremely diverse, but mostly unknown, entomofauna. Here, we aim to [a] introduce the Synergize project – a new collaborative network for Amazonian biodiversity, [b] demonstrate the spatio-temporal distribution of ecological knowledge on terrestrial and freshwater insects, and [c] identify the magnitude of the taxonomic shortfall within published and unpublished community data for ants, dung beetles, and freshwater caddisflies, damselflies, dragonflies, and stoneflies surveyed across the Brazilian Amazon. We included datasets that meet four criteria: (1) provide multi-species abundances/frequencies within a single or multiple land uses, (2) have geographical coordinates and standardised sampling methods for each site and/or temporal survey, (3) have taxa identity resolved to at least genus level, and (4) surveys within the Brazilian Amazon. To standardise species nomenclature across multiple datasets, we worked with expert taxonomists to validate IDs and build up-to-date lists of species for the Brazilian Amazon. Thanks to the generosity of >90 scientists, we collated 91 insect community datasets surveyed within >4,900 forest and freshwater sites. In summary, the Synergize network includes data on over 432k dung beetles, 168k ant records and 58k freshwater insects from 1296, 4118 and 717 (morpho)species, respectively. When assessing the differences between the fully described and unknown species, we found that 48%, 55% and 59% of our individuals/records were associated with known species of dung beetles (n = 216), freshwater insects (n = 402) and ants (n =625), respectively. Our collaborative research network addresses three shortfalls in the ecological knowledge of Amazonian insects: lack of taxonomic information (Linnean), data scarcity on species distribution (Wallacean), and data absence on species abundances across space and time (Prestonian). To our knowledge, this is the most comprehensive ecological database collated to date in the Amazon, which will be useful to researchers and decision-makers aiming to understand the status of biodiversity in tropical forests and freshwater. Future efforts aim to include partners and study sites in other Amazonian countries. **Keywords:** Tropical insects, Amazonia, Forest, Freshwater, Entomofauna, Research Synthesis.

Sustainable Land-Use Systems to foster simultaneously climate change mitigation, forest conservation, and Colombian peacebuilding goals

Measuring the Contribution of Sustainable Land Use Systems (SLUS) to Climate Mitigation and Peacebuilding

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Land access and use are common drivers of (violent) conflict, sources of GHG emissions and one of the most important natural resources in post-war contexts. Some climate mitigation and peacebuilding strategies have targeted the land use sector and delivered sustainable land-use systems (SLUS) to affected communities as an entry point to integrate land based-climate action and peacebuilding objectives. SLUS are practices within agricultural and livestock production systems that meet sustainability principles (environmental, social and economic). Nevertheless, there is a lack of programming and evaluation frameworks, including explicit theories of change and indicators that integrate these two objectives. This study aims to fill this gap by developing an impact pathway analysis and its operationalization through a theory of change and indicators to follow the precise mechanisms that specific SLUS activities use to affect different GHG emissions and conflict drivers. To do so, we used a mixed-methods approach, first, two in-person and two virtual workshops, and semi-structured interviews to conduct a participatory context analysis for understanding the drivers of conflict targeted by the SLUS's implementations. Second, through a household survey (n=929), we illustrated the impact pathways of SLUS in peacebuilding at the household level. Results show that SLUS such as agroforestry contribute to climate change mitigation and impact co-benefits in three core factors, (i) socio-economic inclusion by creating jobs and elevating sustainable livelihoods, (ii) dialogue and conflict transformation by allowing negotiations and participatory design of farms that include conservation agreements, (iii) natural resource management, governance and institutions by preventing conflicts around natural resources such as land and water and promoting social cohesion and cooperation. **Keywords:** Climate change, REDD+ co-benefits, environmental peacebuilding Indicators, monitoring and evaluation,

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Assessing Contributions to Land-based Climate Action and Peacebuilding from Interventions in Sustainable Agriculture in Conflict Affected Areas

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Colombia is facing two crises: the effects of climate change, which has been intensified by deforestation. As well, the effects of the armed conflict, which weakens the social fabric and influences land-use changes. In Colombia and other territories affected by climate change and conflict, various farm-level agricultural interventions are being implemented to reduce deforestation for climate change mitigation, increase agricultural production, and contribute to peacebuilding. Some of these interventions include promoting sustainable land-use systems such as agroforestry systems, building peace, and reducing pressure on forests for climate action

and biodiversity conservation. However, the effects of such interventions on climate change and peace are not yet fully understood. This research aims at assessing contributions to climate action and peacebuilding from agricultural interventions through an assessment framework. Specifically, we take two case studies of cocoa smallholders in priority areas for landscape restoration and carbon sequestration located in territories affected by the armed conflict in Colombia. We analyze if the implementation of cocoa cultivation in agroforestry systems reduces land-based greenhouse gas emissions while delivering peacebuilding. We classified a sample of 922 smallholders according to the complexity of their farming system along a gradient from a baseline system that does not incorporate agroforestry arrangements to an advanced agroforestry system with many timber and non-timber trees and a focus on organic fertilization and commercial practices. Economic results are compatible with ecological balance since more advanced systems also have a more significant potential for carbon sequestration, greater tree species diversity, and a high propensity for forest conservation. It is also noted that producers with advanced sustainable production systems feel that they have increased spaces for dialogue and cooperation and have reduced conflict over the use of and access to natural resources. To generate mobility of producers classified at the basic and intermediate levels to an advanced level it is necessary to strengthen the use of organic fertilizers and the implementation of better post-harvest practices. It is also necessary to generate incentives to establish conservation zones and plant shade trees. **Keywords:** Assessment framework, peacebuilding, land-based climate action, agroforestry, armed conflict

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Best Management Practices in Sustainable Land-use Systems to Reduce GHG Emission of Cocoa Cropping Production in Colombia

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The main challenge in the agricultural sector in Colombia is how to generate opportunities for sustainable development towards the reduction of land-based greenhouse gases emissions, conserving forest, and restoring degraded areas in Colombia. Agroforestry systems improve climate change adaptation and mitigation by promoting agricultural crop diversification and land restoration, increasing water availability in the soil, and increasing carbon sequestration. While the environmental benefits of cocoa in agroforestry systems in terms of diversification and productivity are well documented, the relation between cocoa land-use change and the GHG mitigation potential is unclear. The objective of this study is to identify the main hotspots of GHG emissions in cocoa cropping systems in agricultural frontier areas and determine the role of organic cocoa cropping system as an alternative to reduce GHG emissions and press on forest in agricultural frontier areas in Colombia. For this, the present study aims to quantify the GHG emission in the cocoa cropping systems in two departments in Colombia, Caqueta, and Cesar, being contrasting in environmental and socio-economic conditions. The GHG inventory includes the evaluation of two critical emission sources, land-use change and use of fertilizers in different farm typologies, including traditional, organic, and intensive cropping systems. Using remote sensing was identified the relation between cocoa establishment and deforestation, therefore GHG emissions for land-use change. Using the static chamber methodology were quantified the GHG emissions from the application of synthetic and organic fertilizers from the soil. In the framework of the Life Cycle Assessment, the carbon footprint of the system was evaluated using data collected in 950 farms in both departments obtaining a detailed quantification of all activities, processes, as well as input and output flows of both production systems. Our preliminary results show that in some areas of Caquetá there are encroachment cropping systems in which, the primary or secondary forest is intervened for the implementation of new cocoa areas. Preliminary results show the mitigation potential of organic fertilization, reducing the emissions of N2O. Based on our results, we do not discourage cocoa production in the agricultural frontier, but raise questions on adequate land planning in agricultural frontier areas, as well as on the need for tying production to zero-deforestation commitments and compensating the aggregate environmental and social benefits when promoting more sustainable cacao production systems. **Keywords:** Carbon footprint, land-use change, organic agriculture, mitigation potential

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A Rapid Approach for Informing the Prioritization of Degraded Agricultural Lands for Ecological Recovery: A Case Study for Colombia

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Turning national restoration commitments into action involves systematic spatial planning and prioritization of areas for investment, which can be aided by the development of accessible methodologies used for identifying areas for intervention. To achieve restoration at the landscape level, efforts must focus on ecological recovery, where productivity and ecosystem services are recovered on degraded agricultural lands, to meet not only environmental objectives but socioeconomic objectives as well. This can be accomplished through the establishment of sustainable land-use systems (SLUS). As financial resources for restoration are limited, identifying areas where resources can be used efficiently to achieve particular restoration objectives is critical. This study presents a rapid approach to identifying and prioritizing degraded agricultural lands for low-cost ecological recovery using geospatial tools and publicly available remote sensing datasets. We apply the proposed methodology to Colombia, where we identify opportunities for cost-effective interventions on productive lands with light to moderate degradation based on biophysical indicators of soil degradation. In tandem, we identify areas experiencing underutilization, where SLUS can be used to sustainably intensify production, and overutilization, where SLUS can be used to mitigate soil degradation. We identify and map over 10.3 million ha of land with potential for ecological recovery. We find that the Caribbean region proportionally has a high prevalence of moderately degraded agricultural and agroforestry soils, while the Andean region has a high proportion of moderately degraded production forestry soils. Our results aid in the identification and prioritization of areas where multifunctional SLUS, such as agroforestry, agroecology or climate-smart agriculture, can be developed to restore productivity and ecosystem services to degraded agricultural lands. **Keywords:** Agroecological restoration, sustainable land-use systems, land degradation, GIS

The Cocoa Sustainable Business Model for Fostering Climate Change Mitigation and Peacebuilding in Colombia

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Biodiversity, land degradation, and erosion continue to escalate all around the world, but especially in countries with significant importance in post-conflict regions, such as the Colombian case. This alarming trend leads to environmental, social, and economic risks that need to be analyzed for fostering climate change mitigation and peacebuilding processes. In that vein, assessing promising sustainable business models is crucial to co-creating of profits, social and environmental benefits and for the identification of land-use interventions challenges to achieve peacebuilding and environmental conservation in rural areas of Colombia. Responding to this need, we used a two-phase mixed methods design. First, we present a quantitative baseline on six sustainability indicators: income, costs, yields, associativity, knowledge generation, soil improvement, biodiversity, and robustness and stability in cocoa sales in two contrasting regions with degraded landscapes: Caquetá and Cesar. Second, through a qualitative approach with cacao growers, we assessed the effectiveness of the potential business model in terms of sustainability indicators. Preliminary results show that for producers, better quality cocoa, i.e., fermented and dried on the farm, with organic practices and sold associatively, is the way to achieve positive and significant changes in income, costs, yields, biodiversity, soils, etc. This framework maps and assesses the potential linkages between land use interventions and business models for cacao growers for alleviating poverty, building resilience to climate shocks, and promoting peacebuilding in Colombia. **Keywords:** Sustainability indicators, peacebuilding, business model, land use interventions.

Exploring the Linkages between Sustainable Land-use Systems and Knowledge Networks: the Case of Cacao Agroforestry Systems in Two Colombian Regions

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Land management strategies such as agroforestry systems (AFS) have been recognized as vehicles to support the socioecological transitions toward sustainability, but they are knowledge-intensive innovations. Different approaches to scale their benefits have mainly promoted a restricted set of technological packages, which have often not spread successfully beyond some farms or plots because they fail to consider fine-scale variation in the local circumstances within which AFS needs to be adapted. This is the case of cacao agroforestry systems (CAFS), which have the potential to be adapted to different biophysical conditions and socio-economic needs by developing different management options with varying permanent or temporary crops and shade trees. However, the detailed data for adapting CAFS to different local conditions are usually lacking. Therefore, CAFS scaling requires crafting usable knowledge and developing innovative strategies to produce, reproduce, and adapt CAFS knowledge that considers the varying biophysical conditions of sites, the specific socio-economic needs, and the local knowledge and perceptions. Under this background, the objective of this study is twofold: (1) to examine how actors from different levels and sectors are interacting to support CAFS across two regions, and (2) to represent local knowledge about CAFS management in one municipality in each region. Data collection was based on semi-structured interviews with cacao-related actors at the regional level and in-depth interviews with cacao smallholder farmers at the local level in Cesar and Caquetá, Colombia. Data analysis included a social network analysis to disentangle the relationships between cacao actors in terms of knowledge and information flows. It also employed cognitive mapping to assess the adapted CAFS local knowledge of smallholder farmers. Social network analysis showed: (1) highly-centralized networks that connect multiple actors by a low amount of mostly non-reciprocal ties, (2) the predominance of bridging over bonding ties, and (3) a set of key actors that varies substantially from one region to the other. Cognitive mapping revealed the lack of homogenization of the cacao post-harvest management practices, but it also evidenced farmers' use of ecological processes to optimize cacao management practices considering their resource limitations and local conditions, such as the identification of a particular cover crop to reduce weed control. This comparative approach helps to generalize insights on the role of knowledge networks and local knowledge in scaling knowledge-intensive innovations like CAFS in regions with highly diverse landscapes. **Keywords:** Agroforestry systems, cacao production, social networks, knowledge governance, local knowledge

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The High Frontier revealed: Arboreal camera trapping's potential to unlock the canopy's mysteries

Climbing to New Conclusions: Innovating Remote Camera Technologies and Approaches for the Advanced Study of Nocturnal Pollination in the Canopy

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The structural complexity of tropical forests supports and contributes to myriad ecological interactions. However, multiple barriers have long hindered the human observer's ability to adequately witness and document nocturnal animal behaviors in the canopy where an impressive proportion of biodiversity resides. With the advancement of tree climbing techniques, concurrent with that of remote camera trapping technologies, it is now feasible to engineer and deploy equipment for extended periods of time to capture precise images and videos of rare occurences or behaviors by small, fast-moving organisms high in the treetops at night. These breakthroughs can shed light on arboreal plant-animal interactions, specifically pollination. For example, in tropical forests, approximately 80% of orchids are epiphytic, yet considering the immense diversity of species, detailed species-level understandings of orchid natural history remain limited, and oftentimes pollination syndromes are the only hypotheses available from which to predict candidate species or guilds of potential pollinators. Specialized arboreal camera traps can be designed to enhance our comprehension of rare and endangered species to support their conservation. Here, I will: (1) Present a case study on the methodologies innovated for documenting elusive pollinators of Florida's endangered ghost orchid (*Dendrophylax lindenii*) in the cypress canopy of the Everglades Basin, (2) Describe the need to replicate and scale these approaches across populations and species, and (3) Provide recommendations for the adaptation and integration of novel technologies for remote and autonomous biodiversity monitoring in the challenging environment of this high frontier. **Keywords:** Arboreal, orchid, pollination, canopy, technology, innovation, biodiversity, conservation

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Arboreal Camera Trap Reveals the Frequent Occurrence of a Frugivore-carnivore in Neotropical Nutmeg Trees

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Introduction / Background / Justification: Arboreal and flying frugivorous animals represent primary dispersers in the Neotropics. Studies suggest a possible compensation for the loss of large species by smaller ones with expanding rampant anthropogenic pressures and declining populations of larger frugivores. However, studies on seed dispersal by frugivores vertebrates generally focus on the diurnal, terrestrial, canopy, and flying species, with the nocturnal canopy ones being less studied. **Objective(s)/Hypothesis(es):** This study aimed at filling the gap of knowledge in the latter category. We hypothesized that foraging and seed dispersal by smaller ($<$ 5kg) nocturnal vertebrates may compensate for the loss of other large arboreal seed-dispersing frugivores. **Methods:** We set up camera traps over 30 m high in the crowns of two nutmeg tree species (*Virola kwatae* and V. *michelii, Myristicaceae*) during the fruit peak period. We used the CamtrapR® package on Rstudio® Version 1.1.463 and Digikam® software to extract, organize, and tag images, respectively. In addition, we compared the diversity of fruit consumed and the size of seeds listed in the literature among the

main frugivores known to disperse the study nutmeg trees. Results: The analysis of 162,885 images recorded during 55 survey days on 11 fruiting trees produced 587 independent events (separated by at least 30 minutes) of nine main frugivores. The nocturnal kinkajou (Potos flavus (Schreber, 1747) (Order Carnivora, Procyonidae) represented 48 percent of the records. The overall distribution of average seed size dispersed by the observed frugivores shows similar patterns among animal species and groups. The careful examination of images revealed that primates could pick, open, and peel the entire ripe fruit during the day before the kinkajou had access to dehiscent ripe fruit at night. Toucans and other birds only have access to dehiscent fruit during daily hours. **Implications/Conclusions:** Our finding suggests that kinkajou could play a significant role as a disperser of the study nutmeg trees and other plant species at the plant community level. Arboreal camera traps also allow for visualization of niche partitioning between the observed canopy species and how they behave, highlighting the advantage of primates over kinkajou. Such information is vital for conservation because small frugivores' compensation for seed dispersal is crucial in increasing anthropogenic stressors. Extending the remote camera trap protocol to other fruiting trees appears fruitful to measure the impact of disturbances on the functioning of tropical forests and better to evaluate the role of all canopy frugivores animals. **Keywords:** Kinkajou, French Guiana, rainforest, nutmeg, virola, seed, frugivory,

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Experiences in the Implementation of the Orion Camera System

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In recent times, camera traps have revolutionized the study of wildlife, mainly mammals. Due to the data obtained with this tool, it has been possible to document the richness of species in geographical areas of special interest, in addition to providing valuable information regarding the occupation and abundance of species that are usually the object of study in several conservation processes. Camera traps are usually installed at ground level in the hope of capturing species with terrestrial habits, however, the possibility of using the camera trap method to evaluate tree systems has been opened. In this context, some studies have been reported in which researchers have climbed trees to install the cameras, and others in which they have been able to install the cameras in the canopy, from the ground. The Orion Camera System (SCO) (Méndez-Carvajal, 2014) allows cameras to be installed in the medium-high stratum of the canopy without the need to climb the trees, being a practical method that does not imply prior training to climb the trees and eliminate the risk to the researcher. In addition, the costs for such a demonstrator using such a method may be lower compared to a professional climbing team. In order to evaluate the effectiveness of the SCO, two pilots were carried out in two zones in Colombia. The first was carried out in the department of Antioquia, it presented 10 photo-trapping stations, 8 in the canopy and 2 on the ground, completing 462 traps-night and recording 21 species of mammals and 10 birds, With the cameras located in the canopy, the 5 species of primates that inhabit the area were recorded. In the second, carried out in the department of Putumayo, 10 photo-trapping stations were followed, completing 2762 traps-night, registering 10 species of mammals and 1 of birds. In both studies, species of arboreal mammals were recorded, which were rarely recorded in photo-trapping and biological characterization works. It is concluded that this method is practical for implementation in the field and can complement the information in biodiversity inventories and can even be used in monitoring and behavior studies, with an adequate design.
Keywords: Mammals, arboreal species, biological characterizations

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From the Ground to the Tree: How Arboreal Cameras Can Increase Our Understanding of Primate Distribution

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Camera traps have commonly been used to document the presence of medium to large-sized mammals in tropical forest ecosystems, as they are non-invasive and sample continuously with little human interference. These camera traps have traditionally been placed at ground level, however, more recently arboreal camera traps have been deployed to document arboreal and semi-arboreal species, such as primates, in these same systems. Despite this, the amount of additional information learned from arboreal cameras in terms of distribution of species has not yet been explicitly studied. Therefore, using camera traps deployed at 3 heights, ground-level, mid-canopy, and high-canopy we sought to quantify the amount of information collected by each camera across

a landscape for primate species. We used data collected in a 2019 study from Bwindi Impenetrable Forest National Park, Uganda. Our results showed that for the 9 primate species found in the park, 5 were detected at ground-level, 8 were detected in mid-canopy, and 8 were detected in high canopy. Only one species, the mountain gorilla, was only detected at ground-level, while 4 species, were only detected in mid- and high-canopy. All species detected by arboreal cameras were detected by both mid- and high- canopy cameras. In terms of distribution, by including arboreal cameras, primate species were detected on average at 25% more sites than detected by ground cameras alone, with a range from 0% to 75% more sites per species. When taking into account detection probability, the increase in occupancy when arboreal cameras were used in addition to ground cameras was on average 0.280, with a range from -0.049 to 0.816. Our study shows the importance of including arboreal camera traps in addition to ground camera traps when surveying primates in a tropical forest. Without the addition of these cameras, occupancy and distribution is underestimated in most species, which can lead to erroneous conclusions about the health of the populations. **Keywords:** Arboreal camera traps, primates, species distribution, canopy

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The Potential and Practice of Arboreal Camera Trapping: A 2022 Update

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Arboreal camera trapping is a technique that allows exploration of a largely understudied domain: the forest canopy. The number of studies using this technique has increased in recent years, however, collating best practices and making them available to the scientific community will make data collection more efficient and effective. Our review paper "The potential and practice of arboreal camera trapping," published in early 2021, summarized the scope of arboreal camera trapping research globally to date, including the systems and research questions to which the method can be successfully applied. Our study also provided guidance to manage the challenges of arboreal camera trapping. Numerous studies have been completed since the publication of our study. We have since updated our literature review through June 2022 on work that reports the use of arboreal camera traps. This includes the country and year of publication as well as the study objective, focal taxa and habitat monitored with arboreal camera traps. We continued to find one of the most common challenges of arboreal camera trapping to be camera placement and camera site access. We have produced a series of mini-guides to overcome these and other challenges, such as selecting the right camera mount, methods for placing cameras without climbing, climbing protocols and safety when placing cameras, and managing interference with cameras by animals in the treetops. We have also created a repository for arboreal camera trapping references on Research Gate to provide a resource as the field grows. We expect this information to be useful for future research that incorporates this method. **Keywords:** Canopy ecology, camera traps, wildlife monitoring, conservation

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Conservation in the Canopy: Using Passive Recording Devices to Investigate Habitat Associations of Two Threatened Primates

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The Chocó rainforest in the Pacific Forest of Ecuador is an internationally recognized biodiversity hotspot that has been more than 95% deforested for agricultural purposes, which has reduced wildlife habitat and isolated remaining habitat patches. In response to rapid deforestation, the Capuchin Corridor was established to promote connectivity among local reserves. As managers from these reserves plan to acquire land to expand the Capuchin Corridor, a better understanding of threatened species' habitat associations, such as two native threatened primates: the Ecuadorian capuchin (*Cebus aequatorialis*) and the Ecuadorian mantled howler (*Alouatta palliata aequatorialis*), is required to inform management and acquisition decisions. We recorded activity and distribution of both primate species using twenty trail cameras and acoustic monitoring devices deployed in the forest canopy across the Capuchin Corridor. We compared primate detections using cameras and acoustic recorders. We assessed the influence of habitat type (agriculture and 3 forest types [cloud, dry, and wet]), vegetation structure, and landscape composition on occupancy and activity using single-season occupancy models. We also mapped total detections of both primate species to identify areas of frequent use.

Models that included covariates were compared to null models using AICc and goodness-of-fit-tests. Although the 90% confidence intervals overlapped '0', the model that included a positive relationship with station height was the best model for Ecuadorian mantled howlers and the model that included a positive relationship with distance from habitat edge created by human activities was the best model for Ecuadorian capuchins. The lack of significance likely was due to small sample sizes, a common issue when studying threatened species. Maps indicated that cloud forest on the northeastern edge of the Capuchin Corridor were frequently used by both species. We suggest preserving intact forests with tall trees to aid in both species' conservation. These results are being used to support active and future land acquisition and restoration efforts for the Capuchin Corridor.
Keywords:

The other side of drought: Why shallow water-table forests may be resilient to climate change-linked-droughts

Introduction to the Water Table: Why Does It Matter for Plants and How It Varies across Geomorphology and Soils

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Introduction: Groundwater is a key source for plants when the depth to the water table (WT) or the capillary fringe is within the reach of roots (i.e. in shallow water table sites), but this source has been neglected in ecological studies. The depth of the water table and its temporal fluctuation, both seasonally and inter-annually, may be key to understanding the responses of vegetation to climate variations. However, forests on shallow WT are under-sampled in the Amazon basin, what may bias the conclusions about forest responses to climate change. To guide a research program that explicitly considers this water source and its relationships with climate affecting forests, it is necessary to understand the spatial and temporal patterns of variation of WT. **Objective:** Describe WT patterns as a function of climatic and terrain properties across the Amazon. We assume that most of the time, groundwater at high depths is not accessible to roots, and thus focus on shallow WT ($<$ 5m depth). Following classical hydrology principles, we expect that variation of shallow WT depth is modulated by the interaction of precipitation, topography and soils. **Methods:** Here we compile WT depth data from literature (9 sites) and new sources (PPBio network, 14 sites) and analyze the spatial and temporal patterns as function of geology, geomorphology, topography and climatic water deficit. **Results:** The WT varies from $<$ 1 to 40–65 m across the Amazon basin, and 50% of the Amazon area has shallow water tables. Shallow WT are found extensively across the young Neogene-Quaternary formations in the western to central portion of the basin, while on the old Archean/Proterozoic highly weathered Guiana and Brazilian Shields shallow water tables are less extensive, mostly confined to the bottom of topographic profiles. In the old-dissected land formations, the seasonal fluctuation (difference between dry and wet months) of shallow WT levels is very small (0.5–1.5 m) in less seasonal climates (1–3 dry season months), but increases with seasonality (2.5–4 m where dry season $>$6 months). Younger and flatter formations experience much higher seasonal variation in WT (up to 8 m) with the amplitude less coupled to local climate seasonality. **Conclusions/Implications:** Amazonia has a mosaic of WT depth variation in space and time that needs to be taken into account in the efforts to understand climate change. Several combinations of WT depth/climate/geomorphology are not yet included in coupled vegetation/hydrological monitoring programs and should be prioritized. **Keywords:** Hydrology, Amazonia, soil moisture, forest function, tropical forest

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The Filtering Effect of Water Table Depth on Plant Functional Traits

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Introduction : Water table depth (WTD) is an overlooked component of local hydrological conditions that impacts soil water availability to plants in tropical forests. The extremes of a WTD gradient may impose soil water deficit or excess to plants, and little is known about how plant traits interact with the groundwater and how this impacts plant strategies and distribution. **Hypothesis:** We hypothesize that WTD acts as a filter of plant traits, determining ecological strategies, species distribution patterns and intraspecific variation across tropical forest landscapes. **Methods:** We summarized the knowledge accumulated over the past 10 years of our sampling efforts of morphological (leaf, wood) and physiological traits in 102 tree and 115 liana species, at local scale and across the Amazon basin. These species occur along the WTD gradient, either along the whole gradient or on its extremes, growing in non-flooded (terra-firme) forests. **Results:** We found that tree species occurring strictly in the extremes of the WTD gradient differ in their hydraulic architecture traits and resistance to embolism. Tree species occurring in shallow WTD forests have higher specific leaf area (SLA), and preliminary results suggest higher photosynthetic capacity. These species have lower wood density, wider xylem vessels and lower embolism resistance compared to deep water table forests. Low resistance to embolism in shallow WTD holds when considering intraspecific variation. Across the Amazon, the combination of shallow WTD and high soil fertility results in a risky hydraulic strategy with a high vulnerability to embolism in sites with high productivity. Some lianas' trait changes along the WTD gradient differ from trees, e.g. higher SLA in shallow WTD, but others go in the similar direction (larger stomatal size and lower WD). **Conclusions/Implications:** Our results indicate WTD is an important filter of plant traits explaining ecological strategies, species distribution and intraspecific variation across Amazon forest landscapes. Shallow WTD tends to select traits that maximize water transportation and resource acquisition and minimize drought resistance in trees. Lianas seem to have different strategies to deal with WTD conditions and data on resistance to embolism may help to unravel mechanisms behind these differences. Understanding species distribution patterns through their trait interactions with soil water availability is essential to predict tolerance/resistance capacity of tropical species against climate change. **Keywords:** Amazon, hydraulic traits, plant strategies, infraspecific variability, species distribution.

The Spatial Patterns of Amazonian Forest Composition and Structure as Determined by Water Table Depth

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Introduction: The Amazon rainforest has long been recognized as a heterogeneous vegetation mosaic including flooded and unflooded (*terra-firme*) forests. More recently, it was recognized that about 50% of *terra-firme* forests grow on shallow water tables (WT) connecting those two main forest types through a more subtle waterlogging gradient. Previous studies from our group have shown that WT has important effects on forest structure and composition in the Amazon basin at local scales, selecting resource-acquisitive and hydraulically vulnerable tree species, and being associated with higher compositional turnover. But how those local patterns translate to spatial patterns of forest structure and composition across scales is unknown. **Hypothesis:** We hypothesize that shallow water table forests are less diverse, shorter, thinner, and stock less biomass as a result of seasonal waterlogging and limited growth season. **Methods:** We collect/compile forest structure and composition data for over 500 forest plots distributed across the entire Amazon basin. WT depth measures for each plot were obtained from field measurements or estimated from large-scale hydrological models or remote-sensing products. Forest structure was analyzed using regressions and structural equations modeling. Composition analyses were performed using multivariate analysis. **Results:** At the whole Amazon basin scale, tree richness decreases in shallow WT forests within wet climates. Shallow WT forests store 18% less biomass than deep WT forests, even when under drier climates. The influence of WT on species composition was less clear and only observable in two of four Amazonian biogeographical regions. Within these same regions, species turnover increases in shallow WT depths. Controlling by climate and floristic composition, shallow WT forests are shorter and thinner. **Conclusions:** Amazonian forest composition and structure are related to water table depth across scales. Shallow water tables act as a strong environmental filter with impacts to tree diversity and growth. Shallow water table forests may buffer forests against droughts, but at the cost of tree diversity, growth, and carbon sequestration under average historical climatic conditions. Future research should focus on unravelling the context-specific response of forest diversity and composition to local WT depth fluctuation and exploring the causes of the high species turnover within shallow water table forests. In both contexts (shallow and deep WT), functional biogeography studies can be promising but are currently limited by the availability of trait data on shallow water table forests and species, something we hope to change in the next years. **Keywords:** Groundwater, waterlogging, environmental gradients, biodiversity, species turnover, richness, biomass, height

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A Remote Sensing Perspective on the Effects of Water Table Depth on Forest Structure and Functioning

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Introduction: About 50% of the Amazon basin comprises forests growing on shallow water tables (WT). These regions are severely undersampled in forest plot networks as compared to deep WT forests and yet may exhibit distinct responses to drought. Specifically, droughts have been shown to have deleterious effects on deep WT forests while shallow WT areas may benefit from some level of drying, which reduces anoxia and extends the growing season. Here, we explore the influence of water table depth (a proxy for local soil water availability) on spatial and seasonal patterns of forest structure in the Amazon including through case studies by our group. Forest structure is the physical manifestation of tree demographic processes and is mechanistically linked to key ecosystem functions. Therefore, understanding spatial and temporal patterns and drivers of forest structural variation may provide valuable insights into mechanisms of forest responses to climatic changes. **Hypotheses:** We examine the hypothesis that shallow rooting depths and (unstable) waterlogged soils of shallow WT regions give rise to higher tree turnover rates and forest structures characterized by higher stem densities, lower canopy heights, and higher gap fractions. We hypothesize that the seasonality of vertical leaf area distributions in deep WT forests opposes that of shallow WT forests since the period most favorable for growth (growth window) is during the rainy and dry seasons for deep and shallow WT forests, respectively. **Methods:** We measured the canopy structure of ~300 Amazon Forest plots distributed across large-scale climate and WT gradients using tree inventories and ground-based profiling canopy lidar (PCL). We made seasonal forest structure PCL measurements at deep and shallow WT sites. **Results:** Stem density and leaf area index (LAI) increased and canopy height decreased with increasing soil water availability (decreasing WT). The seasonality of forest structure at a deep WT forest was dependent on canopy height as well as light environments. Specifically, lower canopy leaf area in the sun and shade exhibited opposite seasonal patterns, likely due to differential air and soil water availabilities. **Implications / Conclusions:** We review the implications of these case studies for Amazon forest function and drought responses, and present a research agenda for furthering understanding of the influence of soil water on forest structure and function. This includes unprecedented opportunities offered by linking a new shallow WT forest plot network, led by members of our group, to existing and recently launched lidar and spectral remote sensing platforms. **Keywords:** Water table depth, forest structure, remote sensing, lidar

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Forest Dynamics and Responses to Drought Modulated by the Water Table Depth

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Introduction: Understanding forests' response to drought allows a better prediction of how resilient they will be in an accelerated climate change scenario. There seems to be a consensus that decreasing tree growth and survival are major and pervasive drought negative impacts in forests. In Amazonia, almost 50% of forest grows on shallow water tables (WT), which could act as a direct water source for plants during droughts, modulating the whole ecosystem dynamics and responses. However, Amazonian drought reports come mainly from deep WT forests, implying that our knowledge of how the Amazon responds to drought is incomplete. **Hypotheses:** We hypothesize that shallow WT acts as a buffer of drought negative effects commonly reported in deep WT areas, modulating Amazonian Forest dynamics and responses to drought. **Methods:** We calculated tree mortality and recruitment rates and variation in tree diameter increment and aboveground biomass (productivity) based on long-term inventory plots distributed across Amazonia, covering major drought events in last decades and comprising a high range of soil-hydrological conditions (from shallow to deep WT forests). WT depths for each plot were obtained from field measurements or estimated from large-scale hydrological models or remote-sensing products. **Results:** While in non-drought periods shallow WT forests show higher mortality rates and ˜18% lower aboveground biomass productivity than deep WT forests, this pattern was reversed during droughts. Increased drought severity over the last two decades did not lead to decreasing tree growth nor increasing mortality over shallow WT forests. On the other hand, in deep WT forests trees decreased growth up to half and increased mortality up to six times when compared to non-drought periods. Evaluating forest responses to the severe 2015–2016 drought, shallow WT forests did not show changes in mortality rates neither lose biomass, but tree recruitment rates increased by half compared to pre-drought rates. Moreover, using monthly growth rate observations, trees in shallow WT forests maintained more constant growth during drought than trees in deeper WT forests, which had 53.9% reduction of monthly increment and 66.5% reduction of the annual stem increment during that drought period. **Conclusions:** Groundwater in shallow WT counteracts drought negative effects on forest dynamics and productivity. These findings highlight the need of better understanding shallow WT forest responses to drought, with the large portion of the Amazon covered by shallow WT indicating a large potential hydrological refugia and implying that previous projections of drought impacts may be overestimated. **Keywords:** Amazonia, Biomass, drought, forest dynamics, hydrological refugia, productivity, water table

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A Synthesis and Theoretical Perspective Linking Hydrological Regimes with Functional Responses to Understand the Potential Resilience of Waterlogged Amazon Forests

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Introduction: Understanding how the historical environment and tree functional traits impact tropical forest stress responses is important for predicting climate change feedbacks. The impacts of water availability on tree performance are determined by vascular and other tree functional traits. The long-term pattern of soil water and water table depth—the hydrological regime—influences this functional composition, with more varied regimes likely supporting more functional trait variation. The coupling between traits and long-term hydrological regimes, however, and how this coupling influences forest functions like production under rapidly shifting regimes, remain little-understood. **Objectives:** We develop a theory that first links long-term tropical forest hydrological regimes with tree trait composition, specifically of traits that influence water-related stress tolerance. Traits are then linked to forest functional responses over hydrological conditions to predict the impacts of regime shifts. We apply this framework to the question of Amazon Forest variation over long-term water regimes, from frequent drought to waterlogging, to understand the full spectrum of forest responses to climate change. **Methods:** We develop a flexible quantitative framework that assumes (*i*) that a community functional response—we focus on canopy production responding to soil water—is directly coupled to the frequency of environmental conditions (regime), however, with (*ii*) limitations to function imposed by physiologically stressful conditions such as soil water excess (anoxia), or water deficits. We simulate scenarios for community production responses to hydrological regime shifts, and compare with Amazon Forest case studies. **Results:** The addition of drought and waterlogging stress limitations offset community functional response curves from hydrological regime curves, this introduces nonlinear responses to regime shifts that can be both positive and negative depending on the degree of shift. For example, moderate drying in a very waterlogged regime decreases the stress limitation of function, predicting enhanced production, agreeing with growing Amazon field evidence. However, further drying would produce strong production losses. Our theory makes symmetrical predictions when very dry regimes become wetter. Ecological and biogeographical factors controlling the coupling of the long-term regimes and trait-determined functional responses strongly influence climate impacts. Implications: Large waterlogged shallow water table depth forest regions may provide a source of Amazon resilience to moderate climate change. However, our findings also point to a high degree of nonlinearity, including the potential for forest collapse. Growing remote and field network data provide opportunities to fit, refine, and evaluate this theory, offering new predictive insight into the roles of environmental regimes, functional traits, and their variations, in forest climate responses. **Keywords:** Amazon Forest, climate change, hydrology, functional response, traits, waterlogged soils

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The role of biotic interactions in shaping tropical forest diversity

The Role of Plant-insect Interactions in Community Assembly at Local and Regional Scales

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Introduction: The outstanding diversity of Amazonian forests is predicted to be the result of several processes. We argue that at a regional level, lineages have dispersed across the Amazon repeatedly. Whereas, interactions between plant and insects could be a principal mechanism structuring community assembly at a local scale. **Methods:** Using metabolomic and phylogenetic approaches, we are investigating the patterns of historical assembly of plant communities across South America using the Neotropical genus of trees *Inga* (Leguminosae) at four, widely separated sites. **Results:** Our results show a lack of phylogenetic and chemical structure at a regional scale suggesting that the metacommunity for any regional community in the Amazon is the entire Amazon basin. Local communities are assembled by ecological processes, with the suite of *Inga* at a given site more divergent in chemical defenses than expected by chance Implications/Conclusions: Our results suggest that *Inga* species have dispersed freely across the Amazon. Nevertheless, what seems to determine which species are allowed to coexist within a single community are natural enemies. Thus, interactions between plants and herbivores are a major factor shaping community composition at local scale in tropical rain forests.
Keywords: Amazon, chemical defenses, community assembly, local scale, metabolomics, Inga, plant-herbivore

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Exploring the Phytochemical Landscape in Space and Time: Implications for the Evolution of Tropical Trees and Species Coexistence

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Introduction: Ecological theory predicts that the high local diversity observed in tropical forests is maintained by negative density-dependent interactions within and between closely related plant species. **Methods:** Using long-term data on tree growth and survival for coexisting *Inga* (Fabaceae, Mimosoideae) congeners, we tested two mechanisms thought to underlie negative density dependence (NDD): competition for resources and attack by herbivores. We quantified the similarity of neighbors in terms of key ecological traits that mediate these interactions, as well as the similarity of herbivore communities. **Results:** We show that phytochemical similarity and shared herbivore communities are associated with decreased growth and survival at the sapling stage, a key bottleneck in the life cycle of tropical trees. None of the traits associated with resource acquisition affect plant performance. Implications/Conclusions: These results suggest that herbivore pressure is the primary mechanism driving NDD at the sapling stage. They also support the hypothesis that biotic interactions, facilitate high levels of coexistence and species diversity in tropical rainforests. **Keywords:** Amazon, chemical defenses, negative density-dependence Janzen-Connell, metabolomics, Inga, plant-herbivore

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Pests and Pathogens in Tropical Disturbed Habitats: Heliconias as a Model System

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In the Neotropics, species from the genus *Heliconia* (Heliconiaceae) are an important component of the forest understory in conserved and human modified habitats. Because the use of heliconias as ornamental plants and their economic value, their pests, pathogens and pollinators are relatively well known. Therefore, *Heliconia* species provide an excellent model system for understanding the impact of anthropogenic disturbance on biotic interactions. All plant structures of heliconias interact with a variety of organisms in different relationships including the following trophic guilds: parasites, saprophytes, herbivores, omnivores and predators. Using community ecology metrics and ecological networks we have determined that habitat modification affects the biotic interactions between heliconias and other organisms. In general, we found that habitat disturbance increased the level of leaf damage by herbivores and fungal pathogens and the abundance of parasitic nematodes of heliconias. In contrast, disturbance decreases floral visitors. Habitat disturbance changed the community structure of heliconias natural enemies and potential pollinators. The ecological networks showed that pathogen-heliconia networks were more specialized and compartmentalized than herbivore-heliconia networks probably because the high intimacy that pathogens have with their host plants as compared to the more generalized feeding modes of herbivores. Because heliconias provide food and habitat for the associated fauna and several microhabitats for colonization, species of the genus could be used as habitat elements for animal conservation in human impacted landscapes. **Keywords:** Heliconiaceae, habitat disturbance, biotic interactions, pests, plant diseases, habitat elements

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Latitudinal Gradients in Tritrophic Interaction Diversity

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High diversity of tropical communities is partly due to chemically mediated interactions between plants and insect herbivores. Using large scale transplant experiments and observational studies conducted at neotropical sites from Southern Mexico to Southern Brazil, we documented relationships between plant chemistry, taxonomic diversity, and network complexity, with a focus on the tropical pepper genus, *Piper* (Piperaceae). We found that attributes that vary with latitude, particularly precipitation, temperature, and biodiversity had strong effects on chemically mediated plant-herbivore interactions. For example, experimental changes in plant diversity had strong but unpredictable effects on herbivore diversity and responses to experimental droughts or floods. Our results clearly support the idea that simple Tilman-style diversity experiments will not yield similar results in complex tropical communities, and that network complexity requires more contextual data on plant traits, land use history, and natural history of herbivores. **Keywords:** Herbivory, phytochemistry, diversity, latitudinal gradients, climate change, networks

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Multi-host Pathogens and the Maintenance of Forest Diversity

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Spatio-temporal analyses of plant community dynamics suggest pathogens play a central role in the maintenance of local forest diversity by conspecific negative density- and/or distance-dependent mortality (CNDD). However, such analyses cannot determine whether observed patterns are caused by pathogens with relatively narrow or broad host ranges. To assess the host ranges of fungal pathogens attacking seedlings, I: (i) isolated fungi from diseased seedlings of 26 tree species, (ii) identified and assigned the axenic isolates to operational taxonomic units (OTUs) based on 99% ITS sequence similarity, (iii) documented the host(s) from which a given OTU was isolated (host associations), and (iv) experimentally assessed the pathogenicity and specificity of isolates with greenhouse-based inoculations. However, the ITS region provides limited taxonomic resolution and there is no single sequence similarity threshold that appropriately captures lineage-specific variability across fungal genera. Thus, for a subset of genera, I am delineating species based on multi-gene phylogenetic analyses and re-evaluating initial ITS-based conclusions about host associations. The ITS-based description of fungal host associations and experimental assessments of specificity suggest that pathogens with host ranges spanning plant families and orders are common in Panama, with one pathogenic *Mycoleptodiscus* isolate causing significant

disease when inoculated onto tree species in three orders. Preliminary multi-locus analyses leave some ITS-based OTUs intact and split or collapse other ITS-based OTUs, depending on the fungal genus. For example, a single *Calonectria* "species" based on the ITS region is split into four different species complexes when additional loci are used. Two of the four putative *Calonectria* species were isolated from heterofamilial tree species, while two putative species appear host-specialized. While these preliminary multi-gene analyses lend some support to past conclusions of host generalism being common among fungal pathogens of seedlings, they also demonstrate that specialized pathogens may go unobserved when fungal species discrimination is based on the ITS region alone. ITS-based species delineations are likely to over- and underestimate the host ranges of plant-associated fungi, impacting conclusions about plant-pathogen interactions and the mechanisms by which pathogens contribute to the maintenance of forest diversity. Undoubtedly, generalist and specialist pathogens both play an important role in diversity maintenance. Generalist pathogens can unevenly affect seedling recruitment across host species through host-specific coinfections, host affinities, and host- and age-specific impacts. Experimental tests of these potential mechanisms are pivotal future directions for understanding the processes maintaining tropical forest diversity and such tests depend on an investment in culture-based research. **Keywords:** Seedling pathogens, host specificity, forest diversity, multi-host pathogens, multi-locus, ITS

Seed Infecting Fungi, an Understudied Component of Plant-microbial Interactions, Show Strong Host-specific Effects on Seed Survival and Germination

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Natural enemies have emerged as important mediators of species diversity in tropical forests through density-dependent regulation of plant populations. In response, plants have evolved an array of chemical defenses. While much attention has been given to the allocation of these defenses in protecting leaf tissues from invertebrate herbivores, many classes of defense compounds that repel herbivores also show anti-microbial activity. Seeds are among the most highly defended plant tissues and are susceptible to both pre- and post-dispersal seed predators and pathogens in the soil. Defenses that have evolved to protect against seed predators or herbivores may therefore play a role in determining susceptibility to pathogens and vice-versa. In this study, we examined whether the seeds of congeneric tree species differ in their susceptibility to seed-infecting fungi consistent with the level of host-specificity required to generate density-dependent effects. Surface-sterilized seeds of *Cecropia insignis*, *C. longipes*, *C. peltata*, and *Jacaranda copaia* were buried in mesh bags in five common gardens in the understory of lowland forest on Barro Colorado Island, Panama, and retrieved at intervals of 1 to 30 months. We assessed viability of seeds and then isolated and characterized seed-infecting fungi via DNA barcoding. We found that a large fraction of seeds were infected by fungi after burial. Rather than burial duration or burial site, tree species identity was the strongest determinant of fungal community composition. Germination assays showed that fungi often had host-specific impacts on seed germination and viability. Evidence of strong host-dependent differentiation of fungal communities among species buried at the same sites, coupled with functional specificity of these fungi in their impacts on seeds of different tree species, supports pathogen-mediated coexistence of related tree species at the seed stage, preceding the demographic stages (seedlings, saplings) most often studied by tropical ecologists. A next step is to determine how seed chemistry associated with susceptibility to fungal infection relates to the chemistry and anti-herbivore defenses of above-ground plant tissues. **Keywords:** Seed, seed-infecting fungi, pathogen, seed bank, Cecropia, host-specificity, density-dependent.

Extending Janzen-Connell to Seeds: Spatial Structure of Survival, Germination, and Seed-associated Fungi in a Lowland Tropical Forest

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Mechanisms responsible for maintaining high diversity of tree species in tropical forests constitute a central question in community ecology. The Janzen-Connell (JC) hypothesis has been invoked for decades to explain the coexistence of large numbers of plant species in natural ecosystems. Briefly, by selectively reducing survival rates of conspecifics occurring near parental trees, natural enemies promote the recruitment of heterospecifics, ultimately increasing species richness at the community level. In Neotropical forests, transplant experiments in which seedlings were grown in soils conditioned by conspecific plant species have shown widespread negative feedback effects and revealed that fungal antagonists of plants might shape population dynamics and promote local biodiversity. While most studies confirming JC effects and looking at plant-fungal interactions have focused primarily on seedlings, seed-infecting fungi that are important candidates for producing strong JC effects are often neglected. To understand how seed survival and germination vary as a function of fungal communities associated with conspecific vs. heterospecific trees, we buried fresh seeds of four species of pioneer trees (*Cecropia insignis*, *C. peltata*, *C. longipes*, *Jacaranda copaia*) under and away from the crown of 8 adult trees of *C. insignis* and 4 adult trees of *J. copaia* at Barro Colorado Island, Panama, and retrieved them after 3 and 12 months of burial. Fresh (not buried) and buried seeds were tested for viability. After surface-sterilization, total genomic DNA was extracted from seeds and sequenced for fungal metabarcoding on the Illumina MiSeq platform. Although the proportion of germinable seeds decreased over time for all species, seed survival varied significantly among species and burial sites. Seed mortality was higher under the crown of conspecifics for *J. copaia* and *C. insignis* but did not vary when buried under or away crowns of heterospecifics. We found that all the species differ in their seed-associated fungal communities when exposed to the same soilborne fungi, however, fungal diversity was lower when seeds were buried under the crown of conspecific trees. Our results highlight the importance of seed-fungal interactions and their consequences as driving factors that promote and maintain biodiversity by selectively modulating seed survival. **Keywords:** Seeds, plant-fungal interactions, diversity, seed-associated fungi, pioneer trees

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The role of functional traits in shaping species coexistence at local and landscape scales.

Pantropical Tree Growth Response to Climate and the Mediation Effect of Species Functional Traits

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Introduction: Tropical forests represent key terrestrial ecosystems for carbon stocks and biodiversity. The dynamics of carbon storage in forests are primarily driven by tree performance in terms of mortality and growth. But climate change is altering tree performance, with important consequences for carbon cycle, climate regulation and biodiversity. Yet, we are still lacking accurate predictions of the response of tropical forest in terms of their composition, dynamics, and functions to altered climate. While demographic approaches have traditionally focused on how individual performance vary with ontogeny or size, trait-based approaches have focused on how morphological or physiological properties of individuals (traits) change with abiotic and biotic factors and links to performance. Though the link between traits and performance influences population dynamics and subsequent community structure and ecosystem functions, we still understand little about the drivers shaping the trait-performance relationship, and in the context of climate change, about how species traits may mediate differential growth sensitivities to average climate conditions or climate anomalies. **Methods**: Here, we use a set of complementary Bayesian multilevel models to understand the effects of average climate conditions and climate anomalies on decades of multi-annual tree growth data encompassing multiple environmental gradients distributed across the tropical continents. We use morphological, chemical and physiological functional traits of over 700 tropical tree species distributed across our plots to test whether interspecific differences in growth sensitivity to climate can be accounted for by species traits known to affect growth in certain environmental contexts. **Results**: We show that tropical tree growth responds negatively to increasing anomalies in temperature and atmospheric evaporative demand (VPD), but growth sensitivity to these and other climatic drivers vary widely across species. These interspecific differences in average growth rate and growth sensitivity are partly accounted for by functional traits related to acquisition resource strategies. We also highlight a range of trade-offs in species positive and negative responses to average climatic conditions and climate anomalies, suggesting eco-evolutionary constraints related to local climatic variations and species biogeography and niche. **Implications**: Our work shows that both average climate conditions and climate anomalies shape tree growth in tropical forests across continents, and that species traits can help to understand the mechanisms underlying the variability of demographic responses to climate change. We also show that considering region-specific growth responses to climate is important for accurate predictions. This approach offers a promising way forward to forecast tropical forest dynamics under different climate trajectories. **Keywords:** Tree growth, demography, functional traits, climate change, tropical forests, Bayesian, multilevel models photosynthesis, vapour pressure, deficit population dynamics

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Importance of Species Abundances Representativeness and Trait Variability for a Functional Trait Community Characterization in Tropical Dry Forests

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The community functional trait characterization in species-rich ecosystems faces sampling trade-offs on species abundances representativeness and trait variability. Overall, sampling designs for dominant species have received broad attention by using community-weighted mean (CWM) to indicate locally optimal phenotypes. CWM, as a descriptor of optimal phenotypes, does not consider trait variability, failing in to explain the mechanisms behind of community trait composition. In particular, when viable co-existing strategies promote divergence, or at fine scales where ecosystems have similar filtering pulses, as is expected in Tropical Dry Forests. We compared different trait sampling designs, vary the species abundance representativeness and trait variability, to evaluate differences in the level of trait community characterization and the trait-environment and trait-biomass relationships in TDF. Following and abundance-weighted trait sampling design, we intensively sampled 15 functional traits in 321 species of ten 1-ha permanent plots in TDF. We sampled a least one individual per species per plot (in the case of 'rarer' species) up to 12 individuals when abundant (N=1391 tree individuals). We also monitored stem biomass growth for 19,740 trees for the sampled species, between 2013 and 2017. To evaluate the abundance representativeness, we ran linear correlations between the total species abundances per community and those for the abundance-weighted trait sampling and dominant ones. To assess the main sources of trait variability, we performed a nested variance partitioning with individuals, populations, species, and communities as the ecological scales. We performed linear and linear mixed-effects models for the sampling designs to test the trait-environment and trait-biomass relationships. We found that (i) sampling designs considering only dominant species did not adequately reflect the species abundance representativeness in TDF. (ii) Differences within communities explained a higher proportion of total trait variability than among them. (iii) Trait-environment and trait-biomass had consistently stronger relationships when samplings improve the species abundances representativeness and trait variability. Our results indicate that abundance-weighted trait sampling designs may be useful to reconciling the trade-offs between species abundances representativeness and trait variability in samplings characterizing community trait composition, and to detect trait-environment and trait-biomass relationships in TDF. **Keywords:** Abundance-weighted sampling design, community weighted mean, trait variability, sampling effort

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Variation in Plant Ecophysiological Traits along a Tropical Aridity Gradient Explained with Optimality Theory

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The 'pure' effect of aridity on photosynthetic and water-transport strategies is not easy to discern because of large-scale correlations between precipitation and temperature. We analyse traits collected along an aridity gradient in Ghana, West Africa, that shows very little temperature variation, in an attempt to disentangle thermal and hydraulic influences on plant traits. Theoretical predictions of the variation of key plant traits along the gradient are tested with field measurements. Most photosynthetic traits show trends consistent with theoretical predictions, including higher photosynthetic rates in the drier sites, and an association of higher photosynthetic rates with greater respiration rates and greater water transport. Hydraulic and leaf-economic traits show less consistency with previous theories, however. In particular the relationship between the sapwood-to-leaf-area ratio (AS/AL) and potential specific hydraulic conductance (Kp) is found to differ from that shown in a global dataset. Nonetheless, the link between photosynthesis and water transport holds: species with both higher AS/AL and Kp (implying greater water transport) (predominantly deciduous species found in drier sites) tend to have both higher photosynthetic capacity, and lower leaf-internal CO_2, than others. These results indicate that aridity is a primary driver of the spatial pattern of photosynthetic traits, while plants show

a greater diversity of water-transport strategies to support higher photosynthetic rate in arid environments.
Keywords: Optimality theory, aridity gradients, plant photosynthesis, water transportation, functional traits

The socio-ecological dynamics of tropical silvopastoral systems

Public Policies and Silvopastoral Systems in Colombia, Argentina, and Costa Rica: A Comparative Analysis

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Projected increases in global food demand highlight the importance of Latin America as one of the major future food suppliers, particularly regarding animal-source foods such as beef or milk. Despite the importance of the cattle sector for the region, its negative environmental impacts are numerous and the shift towards sustainability is perceived as slow and uncoordinated. This study aims to identify achievements and difficulties in the implementation of public policies for a sustainable cattle sector in Colombia, Argentina, and Costa Rica, for which policies focused on the use of silvopastoral systems are prioritized. Based on the review of scientific articles, government reports, and publications of international organizations, a comparative qualitative analysis was carried out, documenting the policy developments between 2010-2020. For the three countries, the findings highlight a large number of public policies focused on the implementation of silvopastoral systems, both at the local and national levels. At the same time, the efforts of the governments to include such strategies in the National Development Plans and stimulate legislative advances are evident. However, they also coincide in difficulties, such as the disconnection and lack of continuity between policies, unclear budgets for their financing, and little socialization within the communities. Another obstacle to the success of public policies is the way in which they are perceived by producers, who on many occasions refuse to make the transition from conventional to sustainable methods, considering that it implies the availability of economic resources, knowledge, and training that are difficult to access. The results also indicate that, despite the initiatives developed over the last ten years, problems such as deforestation and increasing greenhouse gas emissions persist in the three countries, although to different extents and at different levels. It is concluded that the policy efforts for the implementation of silvopastoral systems should be seen as initial steps in a long-term process towards achieving a sustainable cattle sector. Recommendations are provided that could help increase the success of these and new policies at different stages, from the identification of the problem to their evaluation, particularly given the difficulties of financing, disconnection, and participation of citizens and producers. **Keywords:** Public policies, sustainable intensification, cattle, silvopastoral systems, climate change

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Mixed Methodologies to Understand Livestock Farmers' Participation in Agri-environmental Projects: Dialogues about the Social in Interdisciplinary Research

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This presentation will showcase the contribution of social sciences to biodiversity and environmental conservation research and policies through a case-study in three Amazonian departments in Colombia: Caquetá, Guaviare and Putumayo. Our project combined qualitative and quantitative methodologies in Human Geography, Sociology and Economics to understand farmers' uptake of agri-environmental projects, including in-depth semi-structured interviews and a telephone quantitative survey. The presentation will start by making evident some misunderstandings about what social sciences are, do and can contribute and argue that dispelling them is crucial if true interdisciplinarity is going to help halt environmental degradation and support communities

in their territories. In other words, this section will attempt to better define the terms of interdisciplinarity between the social and the a-social sciences. But there are also misunderstandings and tensions between us social scientists: the quantitative-qualitative debate permeates us too. The second part of the presentation will show the value of mixed methodologies by contrasting the results of our interviews and survey and pondering the conclusions they would lead to if we did not have both sets of tools and findings. Aside from what our findings suggest for the specific case of halting deforestation, protecting biodiversity and supporting communities in Colombia's Amazonian region, their implications are applicable too for other research areas where the complexity of issues call for truly interdisciplinary approaches. **Keywords:** Interdisciplinarity Mixed-methodologies Amazon Colombia Silvo-pastoral farming Agri-environmental projects

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Sustainable Beef Labeling in Latin America: Initiatives Based on Silvopastoral Systems

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Scientific research is increasingly convincing regarding the environmental impacts of food production, and this situation coincides with a greater consumer awareness. Under these premises, the development sustainability labels arises, for example for beef, which offer a guarantee that the production is carried out according to the principles of environmental responsibility and sustainability. Due to the lack of research in this regard, the objective of this article is to identify and analyze existing sustainability labels for beef and on-going initiatives in this regard in Latin America and the Caribbean (i.e., Mexico, Bolivia, Brazil, Argentina, Colombia, and Uruguay), particularly in relation to silvopastoral systems. For this, a qualitative-descriptive study was carried out based on primary (expert interviews) and secondary information (e.g., scientific articles, documents from international organizations such as FAO, IICA, ECLAC, and others, and publications of entities involved in sustainability labelling). The results show as a success the consolidation of labels based on these production models in countries such as Brazil (labels: Carbon Neutral Brazilian Beef, Sustainable Angus), Uruguay (label: Carbon Neutral Meat), and Colombia (labels: Aval Ganso, Colombian Beef Grass-Fed CO, Sustainable Cattle Label, Environmental Label for the Cattle Sector). Colombia stands out for the diversity of recently emerged labels, which, although still under development, expose it as a benchmark at the regional (Latin American) level. However, difficulties are also recognized in the multiple contexts addressed, such as the aversion of producers to implement silvopastoral systems, considering that this implies the availability of economic resources, knowledge, and training that are difficult to access. Another difficulty is the low demand for the certified end-product due to the additional cost that it may represent, much more so considering an international pandemic scenario that continues to affect employment and incomes and, therefore, consumer decisions. On the other hand, the case of Argentina stands out, which, despite its advances in public policies and legislation for the development of a sustainable cattle sector, has not made considerable progress in the development and use of sustainability labels for meat. The situation in Central American countries is also worrying, where no initiative of this type have been identified. It is concluded that the development of sustainability labels for the cattle sector that consider silvopastoral production models is an important step in the transition towards an environmentally responsible cattle sector, but this process must be articulated with other types of strategies and actions of various actors. **Keywords:** Sustainability labeling, sustainable intensification, sustainable cattle farming, animal welfare, carbon

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The Use of *Arachis pintoi* in Cattle Systems in Colombia's Orinoquía Region as a First Step towards Silvopastoral Systems

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Cattle production is an important contributor to human nutrition, income generation, and culture, but causes significant negative environmental impacts and is among the most vulnerable sectors to climate change. Silvopastoral systems (SPS), which include trees, shrubs, and grasses, are sustainable alternatives to improve efficiency in cattle production and reduce its environmental footprint. In many circumstances, however, their adoption is linked to high initial investments. In this way, the gradual introduction of legumes as a first step towards the transformation of grass-monoculture grazing systems can already result in important economic and

environmental benefits that can then support the subsequent addition of trees. In this study, we analyze such a scenario for the case of cattle production on poorly drained soils in the foothills of the Colombian Orinoquía region. The region is dominated by extensive grazing systems with *Brachiaira humidicola* cv. Humidicola (Humidicola), a highly adaptable grass under temporary waterlogging conditions with low nutritional quality. As a result, feed scarcity is a serious limitation for the Orinoquían cattle systems, especially during the dry season. According to climate estimates, annual precipitation and maximum temperatures are expected to further increase in the region, reducing the quantity and quality of forages and increasing the risk of waterlogging. In response to this, the legume *Arachis pintoi* CIAT 22160 (Arachis) was selected by AGROSAVIA as a possible alternative for cattle production due to its nutritional content, durability, and compatibility with grasses like Humidicola. Based on this, our study assesses milk profitability in the Colombian Orinoquía foothills from an economic perspective, through the evaluation of two different production systems: T1, the Arachis – Humidicola association, and T2, a Humidicola monoculture (traditional system). To estimate economic indicators, we employed a cashflow model and risk assessment. The projections consider expected changes in forage performance for both treatments, resulting from variations in the projected climatic variables under different climate change scenarios for the region RCP (2.6 & 8.5). Milk production was simulated using the LIFE-SIM model. Results show that T1 increments animal productivity by 11% and shows better grass persistence due to higher soil-nitrogen (N) levels resulting from the association with the legume, among others. The legume also provides positive impacts on soil structure and composition, which helps improving the adaptation capacity of the system. Finally, producer incomes increase because of a lower vulnerability to (climate) risks and reduced production costs (due to lower N fertilizer use). **Keywords:** Climate change, forage legumes, adoption, risk analysis, land-use change

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Fast Tracking Silvopastoral Systems by Using Local Tree Knowledge in the Amazon Region of Colombia

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The inclusion of tress within pastures (i.e., silvopastoral systems) is a nature-positive action to adapt and mitigate climate change, while boosting cattle production and ecosystem services in the Amazon region of Colombia. Deployment of silvopastoral systems often relies on tree species that are commercially available (locally or elsewhere). However, these tree species might not be optimally adapted to local environments. Furthermore, local communities might not be familiar with the use and management of such tree species. These are among factors that threaten the long-term success of silvopastoral systems in the Amazon region. Currently, a project funded by the European Union aims to implement silvopastoral systems in the Amazon region. One component of the project is to deploy silvopastoral systems based on locally collected species. Furthermore, the project aims to co-design silvopastoral systems that are tailored to the farmers' needs and local context—taking into consideration gender and youth—to ensure large scale deployment and long-term sustainability of such systems. The objective of this presentation is to provide insights of how local knowledge is being used for the deployment of silvopastoral systems in the Amazon region of Colombia. **Keywords:** Agroforestry, smallholders, species recommendations,

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Ficus Thonningii Silvopastures for Reducing Drought Related Risks Disasters in the Drylands of Northern Ethiopia

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Smallholder silvopastoral systems in Africa provide multipurpose benefits including animal fodder, soil and water conservation, non-timber products, and services. Northern Ethiopia has historically been affected by recurrent drought, soil erosion, and concomitant poverty and malnutrition. Farmers in northern Ethiopia have, for decades, used *Ficus thonningii* in smallholder silvopasture. A decade-long study on the uses, characteristics and impacts of a traditional *F. thonningii* silvopasture and its role in adapting and coping to drought and climate variability revealed that this unique silvopastoral system helps drought-prone communities adapt to drought in many different ways. The foliage improves livestock productivity and can replace commercial concentrates up to 50%. Moreover, while being easy to propagate, drought-tolerant, and multipurpose, the species produces about 500% fodder biomass per ha year-round compared to other mainstream fodder trees

and shrubs. The foliage on farmlands improves soil fertility while increasing the water holding capacity of the soil. A steady increase in *F. thinning* silvopastoral plantations has resulted in the improved ability of local farmers to escape the ills of recurrent drought (climate change) and also resulted in observable changes in environmental resilience, such as the re-emergence of locally extinct wildlife (e.g., the endangered White-billed starling). *Ficus thonningii* can be propagated to similar drylands for enhancement of local capacity to adapt and cope with climate-related disasters. Results from the study have been synthesized into a protocol for the establishment of *Ficus thonningii* silvopasture. The application of these protocols has enabled the adoption of *Ficus thonningii* silvopasture by tens of thousands of farmers in northern Ethiopia **Keywords:** *Ficus thonningii*, Northern Ethiopia, Silvopasture, Climate change adaptation and mitigation

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The Potential of Silvopastoral Systems in the Brazilian Amazon's 'arc of Deforestation'

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Background: Deforestation in Amazonia is most severe in the "arc of deforestation" across the states of Mato Grosso and Pará, driven by intensive soybean and cattle farming. Agroforestry and silvopastoral systems (SPS) offer a more sustainable land use that slow this deforestation, benefits small farmers via increased food security and incomes, whilst simultaneously increasing biodiversity and carbon storage. **Objective:** To employ a multi-disciplinary approach to develop improved native tree-based agroforestry/SPS and to overcome social and gender bias in their implementation. **Methods:** Use of next-generation DNA sequencing, plus local knowledge, to identify relatives of cultivated species of the nitrogen-fixing legume genus *Inga* and to test their performance in a field trial to see which are best suited for planting in the highly seasonal forests of southern Amazonia. To develop small-scale SPS using native trees and to encourage their uptake via provision of innovative technical support and microcredit. To understand the current roles, strengths, and barriers to developing women's social and economic autonomy and to increase the socio-economic impact of agroforestry and SPS income-generating initiatives. Results: We identified seven *Inga* species for our field trial. We showed that species never or seldom used in cultivation (e.g., *I. huberi*, *I. macrophylla*) outperform widely used species such as *I. edulis* in both growth rates and survival. We planted 20x c.3ha demonstration SPS in 4 communities in northern Mato Grosso. These used lines of trees of mixed species separating areas of grazing. Species were chosen to provide benefits (ecological and economic) at different stages of the SPS life cycle. To encourage uptake, we have developed simple printed guides plus an innovative mobile phone application, AmazonPasto. We focused on two women's agroforestry groups, working with "pequi" (the nutritious fruit of the tree *Caryocar brasiliense*) and the Female Fibre Artisans Network, who produce handicrafts from forest products. Our findings show how important it is to connect people with the forest at different levels, integrating various aspects of livelihoods with sustainable harvesting of trees, seeds and non-timber forest products. **Implications/Conclusions:** The Instituto Ouro Verde (IOV) has supported the implementation of more than 2,000 hectares of agroforestry and SPS in northern Mato Grosso. The success of IOV's programme is built on an interdisciplinary scientific approach. Its uptake depends upon consultative dialogue with communities to create systems that take into account the objectives of individual farmers reinforced by innovative use of technology and provision of microcredit. **Keywords:** Agroforestry, Silvopastoral Systems, Legumes, Gender, Amazonia, Sustainability, Livelihoods

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Potential Economic Benefits of Integrating Silvopastoral Arrangements in Latin American Beef Cattle Fattening Systems

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The environmental impacts caused by cattle are undeniable, and, in addition to the expansion of land, comprise problems related to biodiversity loss, deforestation, and greenhouse gas (GHG) emissions, the latter making the sector a main contributor to climate change. Given the social and economic importance of cattle, it is crucial to implement strategies that can both mitigate environmental impacts and allow productivity increases. Silvopastoral systems (SPS) constitute a valuable strategy for this purpose, since they generate environmental benefits, related to the reduction of GHG emissions, increased nitrogen fixation, and nutrient cycling, as well as economic benefits, such as increased production efficiency, reduced production costs, and the generation of additional income. This study evaluates the implementation of a SPS in beef cattle fattening (treatment 1, T1) in Colombia from an economic perspective and contrasts the results with a traditional grazing system under grass monoculture (treatment 2, T2). The information was collected in trials at the campus of the Alliance of Bioversity International and CIAT in Palmira, Colombia, during 2021 and 2022. The grass varieties used in both treatments were *Brachiaria brizantha* cv. Toledo and the *Brachiaria* hybrid cv. IATTC BR02/1752. The legume *Leucaena leucocephala* was integrated in the SPS (T1). We applied a discounted cash flow model, that allowed for the estimation of profitability indicators, and a risk analysis. According to the results, the Net Present Value was positive for both treatments. The probability that this indicator takes negative values is, however, with 21% higher for T2 than for T1 (0%). The Internal Rate of Return is 21% for T2 and 69% for T1. The Benefit-Cost Ratio indicates that for every US $ spent on the investment, US $ 1.5 are being obtained as benefit in T2 and US $ 2.7 in T1. The results suggest that the integration of *Leucaena leucocephala* is an economically and financially viable endeavor for the cattle producer that surpasses the traditional system by far. In addition, it leads to higher efficiency that allows increasing the annual income of the producer. The adoption of this SPS, in addition to its economic benefits, also contributes to conservation, resource-use efficiency, and mitigating GHG emissions. This study is a valuable input for actors involved in the adoption processes of SPS in Latin America, such as producers, extension agents, financial institutions, and public policy makers, since it provides an overview of what can be obtained from investing in SPS. **Keywords:** Cattle, beef, mitigation, climate change, silvopastoral system, sustainable intensification

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Silvopastoral Systems: Contributions to the Environment and Local Livelihoods in the Colombian Amazon

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The Amazon is one of the world's richest regions in biodiversity, yet fast changes in land use have led to the degradation of important ecosystem services. The small-scale deforestation in Colombia represents around 80%. The largest driver of primary forest depletion are pastureland growth, illicit crop production, and land grabbing. The main challenge in the Amazon landscape is how to generate opportunities for sustainable development that contribute to food security and wellbeing, while safeguarding the natural capital that is required to sustainably manage deforested landscapes. Silvopastoral systems (SPSs) are presented as agroecological solutions that synergistically enhance livestock productivity, improve local farmers' livelihoods and hold the potential to reduce pressure on forest conversion. In the framework of the Sustainable Amazonian Landscape Project, SPS were codesigned with farmers, combining scientific and local knowledge, and farmers' assets, needs and preferences. SPS improve resilience by promoting agricultural crop diversification using local crop and forage varieties and increasing water availability at the regional level, which contributes to reducing vulnerability to eventual extreme climatic events. SPS has proven to improve socioeconomic indicators at the farm level by increasing milk production by up to 20%, resulting in a 1 to 1.31 increase in the cost-benefit ratio compared to traditional grazing. Even with moderate tree planting densities, the carbon sequestration potential of SPS was estimated at 5.8 Mg CO2 ha-1 yr-1 which, in addition to the reduction of enteric methane emissions, can mitigate GHG emissions by 2.6 Mg CO2e ha1 yr1 compared to current practices. By validating SPS on the ground and assessing the potential of SPS to deliver multiple benefits, the findings of these studies have contributed to public and international cooperation initiatives (e.g. NAMA, NAPA, NDC, Sustainable Bovine Livestock Policy) aimed at enhancing the sustainable use of deforested areas in the Amazon while

reducing pressure on forests, GHG emissions and improving smallholder resilience and livelihoods. **Keywords:** Alternative land use, codesign, mitigation and adaptation, climate change

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Can Silvopasture Support Biodiversity in Amazonian Farmlands?

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Faced with the challenge of balancing the needs of an ever-increasing global population with the pressure to mitigate against the impacts of climate change and protect biodiversity, we seek methods of sustainable intensification of food production. Silvopasture, where trees, shrubs and forage plants are integrated into pastureland is often proposed as an agri-environmental solution that can yield both environmental and social benefits. These benefits range from reducing the need for irrigation and chemical additives, improving welfare of livestock, increasing carbon sequestration and diversifying income streams for farmers. Yet the impacts of this type of farming on biodiversity remain relatively understudied. We aimed to contribute to this knowledge gap by investigating the effects of silvopasture on key components of biodiversity, both plants and invertebrates. In 2020, we visited 16 farms in Caquetá, a department in the Colombian Amazon. At each farm, we performed a biodiversity assessment by surveying both invertebrates and plants in different habitat types, small forest remnants, silvopasture and traditional pasture. Two methods were employed to sample insects and spiders in each habitat, malaise traps which were left in place for seven day, and three 50 m sweep transects along which a sweep of the vegetation was taken every metre. Plants were identified in five quadrats along the same transects as the sweep samples. Identification was carried out locally, in the field or by experts at the Universidad de la Amazonia. Both the botanical and entomological results indicate that forests, even small remnant forests on farmlands are host to unique communities with highest levels of diversity. 75% of total plant diversity was accounted for by tree species sampled in forest patches. Similarly, invertebrate community composition differed significantly between forest and traditional pasture, with silvopasture found intermediate to these two habitats. This suggests that silvopasture can support invertebrate forest species. We found higher native plant diversity in silvopasture enriched by *Brachiaria* compared to traditional pasture, which contradicts previous research that found that *Brachiaria* species can suppress and outcompete native plants. Our results support the hypothesis that silvopasture may constitute a method of farming that is less damaging to biodiversity, in terms of both plants and invertebrates. This has implications for farm management practices and is of particular relevance with rising interest in nature-based solutions. However, our results also show that forest remnants should be a conservation priority and be preserved within farmlands. **Keywords:** Silvopasture, biodiversity, plants, invertebrates, sustainable intensification, forest remants

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Ficus thonningii Silvopastures for Livelihood Improvement, Climate Change Adaptation and Environmental Resilience

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Smallholder silvopastoral systems in Africa provide multipurpose benefits including animal fodder, soil and water conservation, non-timber products and services. Northern Ethiopia has historically been affected by recurrent drought, soil erosion, and concomitant poverty and malnutrition. Farmers in northern Ethiopia have, for decades, used *Ficus thonningii* in smallholder silvopasture. A decade-long study on the uses, characteristics, and impacts of a traditional *F. thonningii* silvopasture and its role in adapting and coping to drought and climate variability revealed that this unique silvopastoral system helps drought-prone communities adapt to drought in many different ways. The foliage improves livestock productivity and can replace commercial concentrates up to 50%. Moreover, while being easy to propagate, drought-tolerant, and multipurpose, the species produces about 500% fodder biomass per ha year-round compared to other mainstream fodder trees and shrubs. The foliage on farmlands improves soil fertility, while increasing the water holding capacity of the soil. A steady increase in *F. thonningii* silvopastoral plantations has resulted in the improved ability of local farmers to escape the ills of recurrent drought (climate change) and also resulted in observable changes in environmental resilience, such as the re-emergence of locally extinct wildlife (e.g., the endangered White-billed starling). *Ficus thonningii* can be propagated to similar drylands for enhancement of local capacity to adapt and cope with

climate related disasters. Results from the study have been synthesized into a protocol for the establishment of *Ficus thonningii* silvopastures. The application of these protocols has enabled the adoption of *Ficus thonningii* silvopastures by tens of thousands of farmers in northern Ethiopia. **Keywords:** *Ficus thonningii*, Northern Ethiopia, silvopasture, climate change adaptation, mitigation

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Silvopastoral Systems, Working with Communities in the Department of Caquetá

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Silvopastoral systems (i.e., pastures with trees) are a nature-based solution to mitigate the negative impacts of cattle production. Silvopastoral systems most often show increased animal productivity per unit area, soil health remediation, greater animal comfort, reduction of greenhouse gas emissions and improved family economy than traditional pastures (monocultures of grass). As such, there is a great interest for the wider implementation of silvopastoral systems in cattle production systems in Colombia. However, the implementation of silvopastoral system is not straightforward and requires different management from cattle farming. Currently, the RUTAS PDET Program, financed by the European Union and co-implemented by the Bioversity International - CIAT Alliance, is encouraging the adoption of sustainable livestock systems with improved pastures (including silvopastoral systems). Among the objectives of the program is the co-design and implementation with local communities of sustainable livestock systems (including silvopastoral systems) in 370 livestock farms (560 hectares) located in the department of Caqueta, Colombia. This program will run for four years, during which time the co-design of the livestock systems will be built hand in hand with the producer, ensuring that the needs of the livestock family are heard and addressed through the complementarity of the technical staff of the Bioversity-CIAT Alliance. Likewise, training will be provided to the community in good livestock practices, pasture management and farm planning, and it is expected that at the end of the project, milk/cow/day production will increase by 20% and 950 protected hectares will be obtained under the conservation agreements.
Keywords: Forage, livestock, productivity, silvopastol sistems

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Silvopastoral Systems to Promote Pollinator Friendly Cattle Production Systems

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Worldwide losses of pollinators threaten human food supplies and ecosystem functions. Pastures used to feed cattle are important drivers of insect pollinator declines in Tropical Latin America. Plants of the legume family (*fabaceae*) are mostly pollinated by insects, in particular by bees. The inclusion of legumes in pastures (grass-legume system), or as forage banks or the development of silvo-pastoral systems (SPS) with tree legumes, has been widely promoted to improve livestock production and soil fertility, but not to enhance ecosystem services from pollinators. The objective of this work is to provide an overview of forage legumes and SPS, their interplay with pollinators, and the ecological and socio-economic benefits of pollinator–forage legume interactions. We further discuss the challenges and opportunities of scaling sustainably SPS with principles of pollinator ecology and native beekeeping. **Keywords:** Agroforestry, sustainable cattle production, insects

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The Wildmeat and Health nexus: use and trade in times of COVID 19

Impacts of COVID-19 on Wildlife Conservation

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The COVID-19 pandemic has had a tremendous impact on almost all aspects of human life worldwide and, consequently, in the lives of all animals with which humans interact direct and indirectly. Conservation concerns raised by the myriad effects caused by COVID-19 on human-animal interactions range from species to ecosystem levels. Here I will discuss both sides of those effects on the wildlife, focusing on major activities involving humans and animals, such as hunting, fishing and trade, among others. COVID-19 has been undeniably tragic, but the positive and negative consequences observed in this pandemic period can give us a unique opportunity to re-evaluate our relationship with natural ecosystems and their resources. **Keywords:** Coronavirus pandemic, wildlife exploitation, wildlife conservation

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Effects of the COVID-19 Pandemic on the Use of Wildlife as Food in Ethnic Communities in South America

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The COVID-19 pandemic has had diverse effects on the environment and particularly on wildlife, through diverse and sometimes contradicting impact pathways. In this study, based on data collected in indigenous and local communities from South America (Peru, Colombia, Guyana, Ecuador), we investigated changes in the use of wildlife resources for food during the first months of the COVID-19 pandemic. Our study generates unique ground data collected just after the COVID outbreak collected among 756 households in 60 communities, mostly from indigenous backgrounds. We show that wildlife had a role to play as a safety net during the crisis. However, this role was conditioned by the availability of wildlife, the maintenance of traditional knowledge and skills for hunting and fishing, and by secured access to the resource. Also, while wildlife was considered as a short-term and immediate solution during the first months of the crisis, longer term strategies were prioritised at the household and involved diversifying food sources through domestic meat and crop production. We caution that relying on natural resources as a safety net may constitute a poverty trap in cases where the resource is limited and access to common resources is insecure. Although the trends observed and impact pathways differ according to each local context, our study generates some general patterns at the household level that allow to draw some lessons learnt about the value of wildlife in rural livelihoods in times of crisis. We also draw some important recommendations about the need for health response policies to consider more inclusive processes in decision making for this and other pandemics. **Keywords:** COVID-19, wildlife use, food security, IPLCs, adaptation strategies, South America

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Possible Impacts of Wildmeat Trade Bans on Indigenous and Local Communities

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Many have greeted China's lampdown on wild animal hunting and consumption with enthusiasm. A similar response to the capture and consumption of wild meat occurred during the Ebola outbreak, which originated in an animal-human interaction and raged in West Africa from 2014 to 2016. At that time, some even suggested the disease was good for wildlife because people would not be eating wild animals as a result. However, the solution to the problem of zoonoses must be more nuanced than outright global bans. Where no other protein is available, eating wild meat is a necessity, but it should be banned where there are alternatives and where profiteering from wildlife is the motive. The interrelationship between wild meat consumption, food security and poverty alleviation must be explored simultaneously when making decisions without relying on an outdated colonial discourse of conservation that favors wildlife over people. Rural and Indigenous communities who harvest wild meat sustainably as a source of dietary protein already face growing competition from deforestation, biodiversity loss, legal and illegal trade. We should not add to these increased risks of malnutrition or hunger.
Keywords: Wildmeat, zoonoses, local communities, trade ban

The Vulnerability and Resilience of Wild Meat Value Chains during the COVID-19 Pandemic

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This article examines the impacts of the COVID-19 pandemic on wild meat value chains. Based on questionnaires carried out with wild meat hunters, traders, vendors and consumers across case study sites in Democratic Republic of Congo, Cameroon, Guyana and Colombia, three key impacts are observed. First, wild meat value chains were disrupted by interventions used to reduce the spread of the virus, such as social distancing and travel restrictions, with impacts experienced most acutely by urban traders and consumers. Second, concerns about the public health implications of consuming wild meat were slightly heightened during the pandemic, which had further implications for wild meat value chains. Third, there were many instances where people returned to rural areas and turned to subsistence hunting as a useful pastime and means of coping with value chain disruptions caused by the pandemic. Our results point to differences in how the COVID-19 pandemic disrupted wild meat value chains with urban consumers and vendors more acutely affected than hunters and rural consumers, who were generally better able to cope. We suggest that this was at least partly because those in rural areas are able to fall back on subsistence hunting as an environmental coping strategy in the midst of crises. Our findings highlight the need for greater attention to be paid to how different actors along wild meat value chains are likely to be impacted by shocks and stressors affecting the sector, as well as new policies and interventions to regulate the sector. Our findings also stress the importance of preserving subsistence hunting as an environmental coping strategy as it has proven to provide rural actors with a means of pivoting away from markets in times of crisis to ensure their own food security, income and wellbeing. **Keywords:** Wild meat, vulnerability, environmental coping strategies, value chains, COVID 19, Africa, Latin America

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Human Behavioral Change and the Wild Meat Trade after Ebola and COVID-19 in West Africa

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Introduction: The flow of wild meat from habitat source areas to urban centers is perceived as the main driver of wild meat overutilization in the tropics and subtropics. To achieve change on the scale that is required to reduce the unsustainable exploitation of wildlife for food and the emergence of zoonotic disease, behavioral change interventions are needed to reduce wild meat consumption in large cities. The emergence of the Ebola epidemics and the COVID-19 pandemic have had consequences on the use of wild meat either

directly through government bans or indirectly through people voluntarily deciding not to eat this type of meat. **Objective:** Quantify whether zoonotic diseases have an impact on the purchasing behavior of consumers for animal groups likely to be implicated in the transmission of animal pathogens. **Methods:** We present surveillance data of wild meat purchases and consumer attitudes in Nigerian wild meat markets (2010-2021) and review a number of West African studies quantifying the effect of Ebola and COVID-19 on trade and consumption of wild meat. **Results:** Analyzing urban wild meat markets in Nigeria we have shown a marked decline of sales of animal species associated with Ebola after the first Ebola case in 2014. Interviews revealed strong rural versus urban and age-specific differences regarding wild meat consumption and attitudes. Most people worried about Ebola and more than half of interviewees agreed that wild meat poses a transmission risk. Except urban males, over-60-year-olds were least informed about the risk of wild meat, indicating that any future behavioral change campaign should focus on the younger age classes. The declining sales show that changes in purchasing behavior and national education campaigns were effective in reducing the trade of bats and primates, animal groups likely to be implicated in Ebola transmission. Similarly, significant declining trends of sales of many species were observed after the first Nigerian cases COVID-19 cases in March 2020. However, a Sierra Leone study didn´t show a decline after COVID-19. **Discussion:** Published data show that behavioral change was not uniform in West Africa. There was a decline of wild meat trade after Ebola and COVID-19 in Nigeria as well as after Ebola in Liberia. However, no such changes were observed in Togo after Ebola and Sierra Leone after COVID-19. Such differences between countries are essential to consider since the social-psychological drivers shaping consumption of wild meat may differ significantly between nations due to historical and educational factors. **Keywords:** Zoonotic disease, wild meat, ebola, Covid-19, West Africa, human health

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Behaviors and Food Safety Practices That Shape Exposure to Zoonotic Diseases along the Wild Meat Trade Chain

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The rise of zoonotic diseases that cause public health crises has sparked calls for policy action, including calls to close wildlife markets. Yet, these calls reflect limited understanding of where, precisely, exposure to risk occurs along wild meat trade chains and threaten to negatively impact food security and livelihoods. This article uses ethnographic methods to examine potential exposure to viral pathogens – as well as bacteria and parasites – across a wild meat trade chain in the Democratic Republic of Congo. Focusing on hunting, village-level consumption, transportation, markets, and urban consumption, we reveal specific activities that may expose different actors involved in the trade chain to health risks. Based on these findings, this article discusses interventions aside from market closures could help prevent and mitigate zoonotic disease risks associated with wild meat trade chains. The article concludes by discussing how ethnographic methods help fill gaps in knowledge about zoonotic diseases. **Keywords:** Food safety practices, wild meat, supply chains, zoonosis,

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Tropical forest response to temperature: a pantropical synthesis of elevation gradients, and leaf thermoregulation studies

Using Transplant Experiments to Understand the Effects of Climate Change on Trees and Crops in the Tropical Andes

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Introduction: A predicted response of many plant species to global warming is migration to higher elevations. Likewise, rising temperatures may force small-scale farmers to shift their cultivation of specific crops to higher, cooler elevations. However, in both cases these migrations may not be required if plants can tolerate higher temperatures, or migrations may be prevented if there are other factors such as changes in soil conditions that make the upslope areas unsuitable. **Objectives and Methods:** We conducted two sets of experimental transplant studies along elevation gradients in the Peruvian Andes to explicitly simulate the potential contrasting responses of natural vegetation (*Weinmania bangii* – a dominant Andean forest tree species) and subsistence crops (several traditionally grown varieties of potato and maize) to global warming: (a) 'upward migration', in which case plants were grown at their current elevation/temperature but in soils transplanted from higher, cooler elevations, and (b) 'no migration', in which case plants were transplanted downslope along with their home soils into warmer areas. For *W. bangii*, we replicated the transplant experiments with populations from the upper/leading edge, middle and lower/trailing edges of the species' elevational/thermal range to assess the influence of local adaptation on responses to changes in temperature and soil. **Results:** In the case of the crops, maize production declined markedly in response to new soil conditions and production of maize and potatoes declined by ca 90% when plants were grown under hotter temperatures, mainly because of the greater incidence of novel pests. In the case of natural vegetation, we found that seedling survival and growth of *W. bangii* were not affected by changes in soil conditions, regardless of the origin population. However, warming did result in decreased seedling survival, specifically, a simulated warming of 1°C caused a significant reduction in the survival of *W. bangii* seedlings transplanted from the mid-range population, and 2°C warming caused a severe decrease in the survival of seedlings transplanted from both the mid-range and lower-edge populations. **Implications:** These findings reveal that climate change is a real and imminent threat to natural Andean ecosystems, as well as to local small-scale agriculture and food security. There is a pressing need to develop effective management strategies to mitigate the effects of global warming to help prevent the loss of native tree species and reduce agricultural yield losses. **Keywords:** Tropical Andes, cloudforest, global warming, local adaptation, species migration

Andean Dominant Tree Species Respond Differently to Global Warming: Insights from Field Experiments

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The tropical Andean forest are reported to be going through compositional changes. Data from the Colombian Andes demonstrates compositional changes in juvenile and adult trees which are driven by mortality of highland-affiliated species in the warm extreme of their thermal ranges and increased abundance of lowland-affiliated species, with evidence suggesting that it is warming and not low precipitation that is the main cause. However specific mechanisms behind such changes remain unknow. Here we use a 2-year field transplant experiment on an elevation gradient in the Colombian Andes to study the impact of warming on growth of dominant Andean tree species. Specifically, we exposed the study species to a range of temperatures within their thermal niches (14°C, 22°C, 26°C), with the trees growing in a common irrigated soil. We planted 24 x 2 year old saplings of 15 of the most dominant tree species of intermediate succession from the Colombian Andes. The plants included one lowland affiliated (*Inga*), and seven highland affiliated (*Clusia*, *Clethra*, *Guatteria*, *Ilex*, *Miconia*, *Tibouchina* and *Weinmannia*) genera. We hypothesised that there would be differential responses of lowland affiliated and highland affiliated species. Tree growth and leaf foliar traits were monitored on a quarterly basis for three years. We used (i) logistic regression to assess survival probability as a function of temperature and species identity, (ii) two-way ANOVA to evaluate sapling growth and leaf trait differences between temperature treatments and species. We found sapling survival and growth rate decreased with warming in all highland affiliated species but increased in all lowland affiliated species. Ten of the studied species grew best at 14°C but did survive and grow at + 22°C, albeit at a lower rate. In addition, some species that showed reduced growth and survival with warming invested in leaf traits, showing an increased number of leaves or leaf mass per area at warmer locations. Our findings suggest the high survival of lowland affiliated species across the studied temperature range. However, highland affiliated species were unable to grow and survive at the extreme of their current thermal ranges. **Keywords:** Andean forest, highland-affiliated, thermal ranges, transplant experiment, survival and growth

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Water-use Strategies under Heat Stress and Their Impact on Growth and Mortality of Rwandan Tropical Trees

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African tropical rainforests are commonly found at higher altitudes than tropical forests in South America and Asia. Lower temperatures in these African forests have been suggested to explain why their carbon sink is more resilient to climate change. However, higher-altitude tree communities may be subjected to changes in species composition when temperatures increase, in turn affecting both carbon storage and biodiversity. Namely, lower-altitude and early successional species with faster growth and shorter life cycles may be at an advantage against higher-altitude and late successional species, leading to thermophilisation of tree communities. We suggest that tree water-use strategies control how growth and survival of different species respond to heat and drought and that hydraulic traits can be used to characterize these strategies. We studied young plants of 20 tropical forest tree species grown at three different altitudes in Rwanda differing in temperature and precipitation. The tree species were chosen to represent common montane and transitional rainforest species with different successional strategies. We studied the following hydraulic traits: stomatal conductance (g_s), minimum conductance of leaves (g_{min}), plant hydraulic conductance (K_{plant}), leaf osmolality and defoliation during drought. We also related these traits to growth and mortality data. We found contrasting water-use responses of early and late successional tree species to high temperature and drought. Late successional species with low photosynthesis, g_s and g_{min} were at a higher risk for mortality at the warmer sites. This may be due to low transpiration causing high leaf temperatures and pronounced photosynthetic heat stress in these species. On the other hand, early successional species were more likely to shed leaves at the occurrence of a drought stress, preventing excessive loss of water. This strategy lead to lower mortality and more pronounced growth enhancement at warm sites in our study, but may be disadvantageous for larger trees or when droughts are longer or more severe. We show that African tropical tree species follow distinctly different strategies to deal with heat and drought. Late successional species experience more heat stress and may be at a disadvantage when temperatures increase, though this may be different for older and larger trees. Early successional species may be better suited for a warmer climate as long as defoliation can bridge drought periods. The relative

decline in late successional species in a warmer climate observed here may lead to biodiversity loss of plant and animal species associated with the affected tree species. **Keywords:** Climate change, defoliation, hydraulic conductance, minimum conductance, osmolality, stomatal conductance

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Photosynthetic Thermal Acclimation Capacity of Tropical Montane Rainforest Trees in Rwanda and in the Colombian Andes

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Tropical montane forests are among the most productive ecosystems within the tropical region and store a significant amount of carbon in live biomass. With ongoing global climate warming, tropical climates are also getting warmer. The productivity and climate feedbacks of future tropical montane forests depend on the ability of trees to acclimate their photosynthetic metabolism to these new, warmer conditions. However, knowledge of acclimation ability of photosynthesis and its underlying biochemical processes to warming in trees grown under natural field conditions is currently limited due to data scarcity. To reduce this knowledge gap, we used two separate field experiments located in Colombia (with 15 species) and Rwanda (16 species), and for each experiment, tree species were grown at three different sites along an elevation gradient differing in ambient air temperature. At all three sites, we measured the responses of net CO_2 assimilation at different CO_2 concentration (50 to 2000 ppm) and at different leaf temperatures (15 to 40 °C) in 3 years old trees. We used these data to derive key photosynthetic biochemical parameters (maximum Rubisco carboxylation capacity - V_{cmax} and maximum electron transport rate - J_{max}) and their temperature sensitivity, as well as the thermal optimum of net photosynthesis (T_{optA}). We show that tropical montane tree species from the two continents are generally able to acclimate their T_{optA} by increasing in trees grown in warmer conditions, but the magnitude of change in T_{optA} differs among species from different successional groups (early- versus late succession) and climate of origin (lowland versus montane). Shifts in T_{optA} are largely driven by concomitant changes in thermal sensitivity parameters of underlying biochemical processes of photosynthesis (V_{cmax} and J_{max}) with warming. We also show that, at a standard temperature of 25 °C, V_{cmax} is largely constant, while J_{max} decreases with warming. Our findings indicate tropical montane tree species from Latin America and Africa can thermally acclimate their photosynthetic physiology, but that this thermal acclimation ability is related to species successional group and their climate of origin. **Keywords:** Photosynthesis, thermal acclimation, tropical forests, montane, Africa, Andes

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Physiological Acclimation and Leaf Temperature Proximities to Thermal Thresholds across a Puerto Rican Forest

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Tropical forest upper canopies cycle a disproportion amout of carbon compared to middle and lower canopy leaves. There is a growing body of evidence suggesting that tropical forest upper canopies are approaching temperature thresholds, where climate warming could reduce upper canopy carbon uptake. Even so, we know little about how a forest canopy might acclimate across the gradient from the shaded understory to the sunlit upper canopy. We investigated this tropical forest canopy gradient acclimation potential on two tropical canopy trees, *Guarea guidonia* and *Ocotea sentenisii*, in a Puerto Rican Forest located at the Tropical Responses to Altered Climate Experiment (TRACE) site. We measured photosynthetic and respiratory responses to temperature after one month of experimental, leaf-level warming. Overall, we found limited evidence for physiological acclimation to experimental warming. Only *Guarea* showed respiratory acclimation through lowered temperature sensitivity (Q_{10}). Despite the high stress conditions of the upper canopy, net photosynthesis did not acclimate for either species. However, *Ocotea* understory leaves acclimated toward higher rates of electron transport with experimental warming. Neither species photosynthetic temperature sensitivity, or thermal niche, acclimated or varied throughout the canopy height gradient. Surprisingly, the optimum temperature for photosynthesis

(T_{opt}) decreased as canopy height increased, due to the greater stomatal sensitivity to high temperatures in the middle and upper canopies. Declined T_{opt} in the mid and upper canopies contributed to these leaves operating beyond their T_{opt} greater than 50% of the time during daylight hours in the upper canopy and greater than 20% of the time in the mid canopy. Leaf area did not vary across the canopy height gradient and stomatal conductance was low at high temperatures for the upper canopy leaves, suggesting that these leaves did not have high rates of transpiration and experienced little to no thermoregulation in the upper canopy. The lack of T_{opt} acclimation and frequent exposures to temperatures above T_{opt} put these upper canopy leaves at a high risk of reduced carbon uptake under climate warming. **Keywords:** Forest canopy, photosynthesis, respiration, thermoregulation, height gradient, temperature response

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Diurnal Variation of Photosynthetic Rate on Tropical Montane Tree Species

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Introduction: Understanding the response of photosynthesis to climatic variation is needed to predict the forest response to future climate. Commonly, coupled leaf photosynthesis and stomatal conductance models, such as the FvCB model, integrate physiological data from leaf-gas exchange and local environmental conditions to understand plant responses to climate under controlled conditions (e.g., CO_2, temperature and light). However, only a few studies explore the variation of the photosynthetic rate under natural conditions. Here, we use field data to parameterise the FvCB photosynthetic model using a separate data set of diurnal cycles of photosynthesis we then evaluate the model. We further explore the variability of photosynthetic rate under natural conditions on an elevation gradient in the Colombian Andes. **Hypotheses:** To explore the variability of photosynthetic rate under natural conditions, we used three working hypotheses: i) intra-specific variation of photosynthesis capacity parameters (PCP) affect the model performance, ii) under optimality theory, the photosynthetic rate tends to be close to the optima most of the time along the diurnal cycle, and iii) high photosynthetic rate accumulated along time lead to high tree growth. **Method:** We used saplings of seven tropical montane tree species that grow in three sites with different elevations (600, 1300, 2400m asl) . For each species, the FvCB model was parameterized using A-Ci curves under 25ºC for multiple individuals. Then, we used PCP to predict the photosynthetic rate under local climatic conditions employing local meteorological data. We compared: i) models that include average PCP values per species and models that account for intra-specific variability of PCP, ii) compare the variability of the estimated photosynthetic rate along diurnal cycles with optima estimated from A-Ci curves, and iii) estimated accumulated photosynthetic rate for one year and compare with the tree growth rate. **Results:** We found that including intra-specific variability increases the goodness of fit of models than using the average PCP value per species. Also, we found that species tend to be close to the optima, at least in some portion of the day. These results highlight the difficulty of modeling photosynthetic rates on tropical montane tree species under natural conditions because different parameters commonly modeled as leaf temperature or average PCP value at community level affect the performance and estimation of photosynthetic rate. Also, tree growth rate is coupled to accumulated photosynthetic rate and is a useful to forecast the response of tropical montane tree species to climate change. **Keywords:** Photosynthesis, diurnal climate variation, tropical montane tree

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Leaf Thermoregulation in the World's Hottest Tropical Rainforest

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Some studies suggest that tropical forests operate near a leaf temperature threshold, above which reduced photosynthesis will cause dieback and conversion to new biomes. Other studies show a homeostasis of leaf temperatures, suggesting plants may be buffered against temperature increases. Assessing the global generality of these results is challenging, however, because we lack methods for measuring physiologically-relevant leaf temperatures across macroecological scales of time and space. One promising approach uses a cellulosic δ^{18}O model with data for climate and δ^{18}O for plant cellulose and source water to yield a time-integrated estimate of the average temperature at which photosynthesis is most productive. The approach suggests most photosynthesis occurs at ~21 °C across latitude from subtropical to boreal forests, but has been debated for its treatment of post-photosynthesis oxygen exchange processes. Here we re-evaluate the approach. First, we quantify effects of oxygen exchange on temperature estimates using data for branches and leaves of 8 tree species spanning a 11 °C temperature gradient in Biosphere 2, the world's hottest tropical rainforest. Second, we examine the macroecological implications of oxygen exchange using data for trees spanning a latitudinal gradient from Panama to Oregon. In Biosphere 2, we observed substantial differences between temperatures estimated using leaf and branch δ^{18}O. Temperatures estimated from branch data were invariant with air temperature, while those from leaf data varied more but were still buffered relative to air. Similar results were obtained for the Panama-to-Oregon gradient. Thus, leaf cellulose is more suitable than wood cellulose for δ^{18}O estimates of photosynthesis temperature. Together, these results suggest the earlier global value of 21 °C for photosynthesis reflects not only a relative homeostasis of plant temperatures, but also post-photosynthesis oxygen exchange that makes wood cellulose δ^{18}O more similar to source water. This general decoupling of plant and air temperatures is consistent with the homeostasis hypothesis and may constitute a thermal refuge in the face of a changing climate. **Keywords:** Temperature, photosynthesis, climate change, thermoregulation

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Long-term Drought Effects on the Thermal Sensitivity of Amazon Forest Trees

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The continued functioning of tropical forests under climate change depends on their joint resilience to drought and heat. However, there is little understanding of how tropical forests will respond to a combination of these stresses, and no field studies to date have explicitly evaluated whether sustained drought alters their sensitivity to temperature. In this study, we measured the temperature response of net photosynthesis, foliar respiration and the maximum quantum efficiency of photosystem II (F_v/F_m) of eight hyper-dominant Amazonian tree species at a 17-year tropical forest rainfall exclusion experiment, to investigate the effect of long-term reduction in soil water availability on forest thermal sensitivity. Additionally, we compared thermal traits across tree species that had previously been classified as drought-tolerant or intolerant, based on their mortality response after exposure to the same experimental drought, testing whether the direction and magnitude of thermal trait adjustment in response to sustained soil moisture deficit is influenced by drought tolerance, and if there is co-ordination, independent of treatment, between drought and thermal sensitivity. Despite 0.5 – 2 C higher canopy air temperatures in the drought plot compared to the control, no change in average thermal sensitivity of net photosynthesis or respiration was observed. However, photosystem II tolerance to extreme-heat damage (T_{50}) was reduced from 50 ± 0.3 C to 48.5 ± 0.3 C under drought. Surprisingly, drought-induced thermotolerance declines were stronger in drought-tolerant species compared to drought-intolerant. However, drought-tolerant species were further characterised by a wider thermal breadth of photosynthesis (T_{span}), conferring a greater photosynthetic stability to moderate rise in temperature, and were more able to maintain high stomatal conductance rates at high leaf temperatures (higher g_{sTL46} and lower g_{sdiff}) compared to drought-intolerant species, making them less likely to experience critically high leaf temperatures. Our results suggest that long-term reductions in precipitation, as projected across much of Amazonia by climate models, are unlikely to greatly alter the response of tropical forest communities to rising mean temperatures but may increase the risk of leaf thermal damage during heatwaves. **Keywords:** Drought, heat-stress, photosynthesis, respiration, thermotolerance, fluorescence, thermal sensitivity, tropical trees

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Investigating the Effects of Higher Temperatures on Cerrado Tree Reproduction

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The Cerrado (South American savannah) is a complex mixture of grassland and tree and shrub woodland, it is a hotspot for biodiversity conservation and provides essential ecosystem services. However, this important ecosystem has been historically undervalued and understudied, and is under immediate threat from land use change and climate change. Some areas are already experiencing rapid warming and climate models predict temperature increases of between 1 and 5°C across the Cerrado biome by the end of this century, potentially affecting many aspects of plant growth and function. Crop research has revealed that sexual reproduction, particularly pollen (male gametophyte) development, is one of the most sensitive stages of flowering plant development to temperature, with higher-than-average temperatures repeatedly shown to reduce pollen viability and fruit and seed production. In the Cerrado, a reduction in the quantity or quality of pollen, fruits, or seeds produced by native species could not only affect their reproductive ability and therefore the future community structure of the Cerrado, but also the survival of insects and animals (and sometimes humans) who rely on these products. However, our understanding of the impacts of high temperatures on reproduction in non-crop species is very limited, and even more so in larger, woody species. In order to investigate how higher temperatures predicted for the Cerrado will impact sexual reproduction in native woody species, we carried out direct heating experiments on adult individuals of common tree species *Byrsonima pachyphylla* and *Davilla elliptica*. We developed novel passive heating methodologies to warm both individual inflorescences and whole trees *in situ* during floral bud and fruit development, and analysed the effects of higher daytime temperatures on pollen viability (through pollen staining and germination) and fruit production (following hand pollination). Surprisingly, our results show some indication that higher daytime temperatures may increase pollen viability in these two species. However, we also present evidence that for *B. pachyphylla* higher temperatures could reduce the proportion of pollinated flowers that develop into mature fruit, which could have implications for species persistence and community structure in the future. To the best of our knowledge these are the first warming experiments to be carried out *in situ* on Cerrado vegetation, and although only on a small scale, they provide an initial insight into the effects that climate change could have on the continued reproductive success of Cerrado species. **Keywords:** Cerrado, trees, reproduction, heating experiment, pollen viability, fruit set, climate change

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Photosynthetic Thermal Optima Controlled by Stomatal Conductance in Six Subtropical Species and Do Not Acclimate across an Urban Thermal Gradient.

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Introduction: Modeling the global response of photosynthesis to climate change is limited by our understanding of the major component processes of net photosynthesis (Anet) and their temperature responses within and among species. While the mechanisms underpinning the temperature responses of RuBP carboxylation and regeneration and stomatal conductance (gs) are relatively well understood at temperate latitudes, more work is needed to characterize these patterns within lower latitude species. **Objectives:** We addressed two research questions: (1) Do subtropical trees acclimate their optimum temperature of Anet (ToptA) and Anet at Topt (Aopt) to elevated growth temperatures? And (2) What limits Aopt in subtropical trees? **Methods:** We measured the acclimation of Anet within six commonly planted tree species across steep (~5°C) urban thermal gradients in Miami, Florida (USA), taking advantage of an underutilized "natural experiment" for testing species responses to potential future conditions. We performed nested temperature-CO2 response curves of Anet for 20 individuals each of each species, measuring Anet, maximum RuBP carboxylation, maximum RuBP regeneration, and gs, and modeling the Topt and maximum process rate of each parameter. **Results:** Contrary to most other studies of intraspecific acclimation of photosynthesis, we did not find acclimation of ToptA, Aopt, Anet, or any of the underlying photosynthetic parameters to growth temperature in any of our six tree species across the thermal gradient. There was significant involvement of all three underlying parameters in limiting photosynthetic performance across all species, but model selection for the best single-predictor model of Anet revealed that almost all trees across our study species were best predicted by gs. **Implications/Conclusions:**

The lack of observed acclimation of ToptA was surprising given the relatively large range of growth temperatures captured. Also surprising was the fact that Anet did not decline in any of the study species as a result of the lack of ToptA acclimation. While it is possible that our expected results were obscured by microsite variations in growth temperature that we did not capture, our results suggest that Anet in some tree species may be resilient to long-term changes in temperature (i.e., over the lifetime of a tree) even if ToptA is static. We also found that gs usually limited Anet in all six species, evidence that controls on Anet in the subtropics may be more similar to those in the tropics than those in more temperate zones and highlighting the need for continued investigation of the environmental controls to gs. **Keywords:** Photosynthesis, thermal optima, Vcmax, Jmax, stomatal conductance, thermal gradient, acclimation

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The Importance of Tree Species Traits for Leaf Temperature Regulation – Observations from Three Forest Types in China

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Leaf temperature is a key variable governing plant physiological processes, such as photosynthesis and respiration. Further, very high temperatures can lead to leaf necrosis. Increasing warming of the atmosphere and occurrence of heatwaves means that understanding physical and physiological processes of leaf temperature is of increasing importance. Despite this, there is little data on leaf temperatures, particularly addressing different thermoregulation strategies of tree species. Both microclimate (radiation, air temperature, vapour pressure deficit and wind speed) and species traits (leaf structure and stomatal conductance) are necessary to model leaf temperatures. Both leaf structure and the response of stomatal conductance to the microclimate varies between species. Hence, even given the same microclimate, leaf temperatures can differ between species. The objective of this study was to explore the thermal behaviour of canopy dominant species under a range of climates in order to assess the extent of variation in leaf temperatures within and between sites, and to understand the microclimatic and species traits underlying this variation. We monitored temperatures of transpiring and non-transpiring leaves, and microclimate conditions, and measured leaf traits, for four dominant tree species in a tropical seasonal forest, a sub-tropical montane forest, and a savannah in Yunnan Province, China. Leaf temperatures were measured using thermocouples on exposed canopy branches at one minute temporal resolution. Microclimate was monitored both at site and branch level using a weather station, and measuring air temperature and light environment of the branch. We measured diurnal cycles of leaf gas exchange and leaf structural traits. Exploration of continuous datasets such as these is challenging. Data were analysed using a range of approaches to determine differences in thermoregulation between species and sites, and how these are linked to species strategy. Our data show differences between sites with the warm sites having leaves cooler than the ambient air, and the cooler site having leaves warmer than the ambient air. There were significant differences in leaf temperatures between species within all sites. In general, trees at the warmer site displayed both greater transpirational cooling and sensible heat losses. However, there was a variety of strategies shown within sites linked to differences in water use and the extent to which leaf temperature changes with radiation load. This study allows greater understanding of tree thermoregulation strategies through extensive measurements and analysis. This can improve our understanding of the species and ecosystems that may be at greater risk from climate change. **Keywords:** Leaf temperature, thermal ecology, microclimate, China, stomatal conductance, functional traits

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Tropical forest responses to large-scale experiment nutrient additions across scales

Ecological Responses to 12 Years of Fertilization in a Lowland Wet Forest in Costa Rica

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Nutrients influence key processes of the tropical carbon cycle, such as primary production and soil microbial activity. Long-term, large-scale field experimental nutrient addition trials are the most direct way to test the role of nutrients on ecosystem processes. The EARTH Forest Fertilization Experiment (EFFEX) is the second oldest running tropical fertilization experiment in the world. Here we present results on tree growth, decomposition, soil carbon dioxide (CO2) fluxes, as well as soil properties after 12 years of continuous fertilization with nitrogen (N) and phosphorus (P). At the community level, there was no effect of fertilization on stem basal area, although there were species-specific effects. Several understory plants increased foliar N concentration with N addition, but this effect disappeared when N and P were added together. Leaf litter decay rate (k) and P immobilization were significantly greater in plots that received P (+P, +NP) than in plots that did not (+ N, controls). Nitrogen addition did not significantly affect litter decomposition, but caused a transient increase in soil CO2 flux that disappeared after three days A laboratory incubation using different forms of N and P fertilizer produced the same result. Nitrogen addition also lowered the activity of sulfatase enzymes and increased the activity of enzymes involved in carbon (C) decomposition. In terms of soil properties, N addition decreased pH by 0.2 units, while P addition doubled Ca concentration (the fertilizer contains Ca). Phosphorus addition increased labile inorganic phosphate concentration by 15-fold, doubled soil P saturation, and increased microbial P. However, P addition had little impact on organic P fractions, suggesting that P mineralization rates have not changed due to stoichiometric imbalances. Total C and N were unchanged by fertilization. Base cations at this site are some of the lowest reported for the Neotropics, and (other than Ca) were unchanged by fertilization. Overall, observations of the tree community at EFFEX suggest that, at this site, stochastic events, such as wind blowdowns and lightning may be more important drivers of aboveground biomass stocks and cycling than changes in nutrients, at least at the decadal timescale. In soils, there was a modest biogeochemical response to fertilization despite large changes in soil nutrient concentrations, perhaps related to base cation limitation or the duration of the experiment. Given the apparently context-dependent nature of fertilizer effects in the tropics and elsewhere, collaboration across regions and biomes is crucial to unravel the role of nutrients in carbon cycling. **Keywords:** nutrients, phosphorus, nitrogen, tree growth, decomposition,enzymes

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Nitrogen and Potassium Regulate Ecosystem Net Primary Production in a Ugandan Tropical Forest

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Nutrient limitations play a critical role in regulating tree growth and net primary production (NPP). To understand how nutrient availability constrains ecosystem processes on highly weathered soils in tropical forests in Africa, we established a large-scale nutrient manipulation experiment (NME) in a highly diverse semi-deciduous tropical forest in northwestern Uganda. Specifically, our objective was to investigate the roles of nitrogen (N), phosphorus (P), potassium (K) and their interactions on ecosystem processes. The NME was set up using a factorial experimental design including seven nutrient addition treatments (+N, +P, +K, and in combination as N+P, N+K, P+K, and N+P+K) plus a control plot, each replicated four times. At each of the thirty-two 40 x 40 m plots, we measured the effects of the nutrient additions on above- and belowground NPP. Aboveground NPP was assessed by measuring tree diameter growth increments using dendrometer bands (monthly) and census techniques (bi-yearly), and litterfall using litter-trap technique (bi-weekly). Belowground NPP was assessed by measuring root biomass (yearly) and root productivity with ingrowth cores and sequential coring approaches. Rainfall measurements were made daily. Measurements reported here were made in the first two years of the NME. In this experiment, we determined that multiple nutrients (co)regulate different ecosystem processes. While there were no community-wide tree growth responses to nutrient addition, we found that tree growth (and their limitations) varied depending on (1) tree species, where a few dominant species grew significantly larger in N addition plots, and semi-deciduous trees responded positively to K addition during dry periods, and (2) tree size, where medium-sized trees (10-30 cm diameter at breast height (DBH)) grew significantly faster in all N addition treatments in the second year of the experiment. Next, although tree growth among poles and saplings (1-10 cm DBH) was not influenced by any nutrient additions, P addition reduced tree mortality of saplings (1-5 cm DBH). Regarding the belowground components, the addition of N reduced fine root biomass (FRB) by 35 % in the first year of the experiment. This rapid and large reduction in FRB highlights that maintaining a large fine root network is an energy and resource-intensive process and that trees will scale back their root network when they have adequate nutrients (and other limiting resources) available. The findings of this study provide further evidence that NPP in highly diverse tropical forests is constrained by different nutrients, dependent on tree species, tree size, and moisture conditions. **Keywords:** Uganda, nutrient manipulation experiment, tropical forest, net primary production limitations

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Changes in Tree Functional Composition and Diameter Growth as a Response to Long-term Nutrient Addition in the Ecuadorian Andes (NUMEX)

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Introduction: Tropical montane rainforests in the Andes are threatened by a vast number of human activities including climate change and increasing nutrient. Increased nutrient availability in inherently nitrogen (N) and phosphorus (P) limited montane forests can change functional community composition and ultimately ecosystem functioning. **Objectives:** This study investigated how community functional composition and tree diameter growth in highly diverse tropical montane rainforests changed under altered nutrient availability over a period of 12 years. A particular focus was on the contribution of demographic components (growth, recruitment, mortality) to functional shifts and on evaluating the tree growth response using species functional traits. Methods This study took advantage of the NUMEX (Ecuadorian nutrient manipulation experiment) project conducted in South Ecuadorian old-growth montane rainforests, which aimed to investigate the effect of long-term nutrient addition in this highly diverse ecosystem. The experiment was conducted in forests along an altitudinal gradient with study sites at 1000, 2000 and 3000 m. Starting in 2008, moderate amounts of N (50 kg h-1 yr-1), P (10 kg ha-1 yr-1) and a combination of both were applied to treatment plots of 400 m2 of size. Ten leaf and stem functional traits were used to characterize the tree communities in 2008 and changes until 2020. Diameter growth of $>$ 2000 individual trees was monitored over the study period and related to tree functional properties. Results: The assessment of tree communities prior to the first fertilization revealed a pronounced gradient from functionally rich communities exhibiting more acquisitive resource use strategies (fast nutrient uptake and high growth rates) at low elevation towards rather resource conservative communities at high elevation. After 12 years of N and N+P fertilization, analysis of demographic components

(recruitment, growth and mortality) contribution to changes in abundance-weighted mean trait values revealed a shift towards tree communities exhibiting more acquisitive resource use strategies. Tree growth differed across elevation sites, but overall N+P addition performed best when looking at trait level growth as well as ecosystem productivity inside plots, suggesting that co-limitation of N and P varies with elevation. Acquisitive species showed increased growth as a response to nutrient addition. Species-specific response was diverse but no negative responses to nutrient addition were observed. In general, individual species responded most positively to N+P addition. Conclusions: Our results confirm the importance of nutrient availability in these highly diverse and still poorly understood tropical montane forests, highlighting that potential community shifts are likely to occur **Keywords:** Tropical Andes, nutrient manupulation, NUMEX, Ecuador

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Differential Nutrient Limitation of Early Growth in N-fixing Legumes and Non-Legumes in Tropical Dry Forest

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The availability of different nutrients such as nitrogen (N) and phosphorous (P) in soil affects the plant community differentially depending on the plant's ontogenic stage, species, or functional type. In this sense, the nutrient limitation can play an essential role in the composition observed in a tropical forest. For example, P addition can increase root nodule production in nitrogen (N)-fixing legumes adult trees in the tropical dry forest. While legumes are the dominant family in tropical dry forests, we know little about their establishment and early growth and whether nutrient limitation plays a role. To understand if N-fixing legumes are limited by nutrient availability in their early stages, we planted seedlings of N fixing legumes and non-legumes into the understory of an existing, large-scale, fully factorial N and P fertilization experiment in Guanacaste, Costa Rica. The experiment consists of four different fertilization levels: (1) control (no nutrient addition), (2) N addition (150 kg N ha^{-1} yr^{-1}, as urea), (3) P addition (45 kg P ha^{-1} yr^{-1}, as phosphoric acid), (4) N:P (at the rates mentioned above). We grew seedlings from ten native tree species (five N-fixing legumes and five non-legumes). When the seedlings were about seven weeks old, we transplanted them into the experiment. Of each species, four individuals were planted per plot, for 40 individuals per plot. Censuses of survivorship, growth, and leaf number were carried out approximately every three months. Additionally, soil samples were taken to confirm the effect of the treatments on P. The soil samples confirmed that P addition increased soil P availability. In general, the plots with P addition have higher seedling growth rates compared to the control and the other treatments. N-fixer legumes have a higher growths rate than non-legumes in all treatments, except for N addition. Plants in the N and N:P treatments had fewer leaves than the control and the addition of P. Interestingly, the non-legumes had, on average, a higher number of leaves than the N-fixer legumes in all treatments. The mortality rate was higher in treatments with nutrient addition than in control plots. So far, our results support the hypothesis that, in general, the addition of P favors plant growth in its early stages, with only slight differences between legumes and non-legumes. Additional censuses are needed to determine if these patterns persist and whether there is differential survivorship over the dry season. **Keywords:** fertilization, nitrogen, nutrient limitation, phosphorus, seedlings, tropical dry forest, Legumes

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Phosphorus Additions Increase Microbial Phosphorus Accumulation and Carbon Turnover in Tropical Soils in French Guiana

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Many regions in the Amazon Basin are characterized by highly weathered soils (Ultisols and Oxisols) with high nitrogen (N), but low rock-derived phosphorus (P) (and base cations) availability, which may be (co-)limiting plant productivity. However, much less is known how low P availability influences the activity, physiology and resource acquisition strategies of heterotrophic soil microbial communities, and thereby affects organic matter decomposition, nutrient mineralization and long-term carbon (C) sequestration in tropical soils. To tackle this gap, we studied various properties of soil microbial communities in tropical lowland forest soils located in the

north-eastern Amazon in French Guiana, near Paracou and Nouragues field station, as well as their response to several years of N and P additions as part of the Imbalance-P project. We determined microbial biomass, stoichiometry, respiration rates, and estimated soil microbial growth using a substrate-independent method based on the incorporation of ^{18}O labelled water into microbial DNA, as well as their extracellular enzyme activity potential. Our results showed that at the studied sites the soil microbial communities slightly increased their biomass C and N contents in response to N, but not P additions. In contrast, P additions increased microbial P (and decreased C:P ratios), which suggests that microbes are an active sink for P. However, P additions also increased total and available soil P pools, indicating that the P demand of both plant and microbial communities, adapted to naturally low P conditions, potentially became saturated after multiple years nutrient additions. Albeit weak, we found a slightly stronger effect of P than of N additions on both microbial biomass-normalized respiration- and growth-rates, while overall the C use efficiency of the communities remained unaffected. This suggests a higher turnover of C by soil microbial communities under alleviated nutrient limitation. In addition, we found that in particular P additions decreased the investment in extracellular enzymes targeting P mining. Our results highlight that in tropical forests soil microbial communities have a crucial role in soil C, N and P cycling and might act as potential strong sinks for available P in such highly weathered soils. While microbial C and N dynamics are more tightly coupled, our data demonstrate the potential for non-homoeostatic stoichiometric behavior of soil microbial communities in terms of P cycling, which is important to consider in soil and ecosystem models relying on strict stoichiometric relationships. **Keywords:** Nutrient manipulation, limitation, soil, microbial dynamics

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Experimental Evidence for Nutrient Limitation on Autotrophic and Heterotrophic Respiration in a Central Amazon Forest

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Tropical forests are more productive terrestrial ecosystems compared to other biomes on Earth, but to fully understand their contribution to global carbon (C) balance, it is necessary to determine respiratory fluxes in these ecosystems. Autotrophic (leaf, stem and roots) and heterotrophic respiration (soil microbes) return CO_2 from the ecosystem to the atmosphere and is affected by soil nutrient availability. However, such carbon-nutrient interactions remain a major uncertainty in tropical forest ecology. Since the majority of forests in Amazonia grow in soils with very low availability of rock-derived nutrients (e.g: phosphorus (P), cations), we hypothesise that both autotrophic and heterotrophic respiration would be affected by soil nutrient manipulation in a Central Amazonia Forest. To explore how ecosystem respiration changed with soil fertilisation, we used a randomly blocked, fully factorial nitrogen (N), P, and cation addition experiment (the Amazon Fertilisation Experiment (AFEX), with 8 treatments x 4 blocks in 50 x 50 m plots) in an old growth forest near Manaus, Brazil. Canopy leaf and stem respiration were measured using a portable photosynthesis system (LI-6400) in October 2018 and an infrared gas analyser (EGM-04) in October 2019, respectively. Soil authotrophic and heterotrophic respiration were measured using a portable respiration system (LI-8100A) in monthly surveys from September 2017 to August 2018. Leaf respiration decreased with the combined addition of P and cations (P:CATIONS: $F_{1,25}=4.09$, $p= 0.05$). Stem respiration decreased by 12% with P addition (+P) compared to without P addition (-P) (- P: 1.26 ± 0.05 versus +P: 1.11 ± 0.05 μmol m-2 s-1, $F_{1,30}=4.1$, $p= 0.05$), and was driven by trees within the 35-45 cm diameter size class. Soil heterotrophic respiration increased 13% with added P (-P: 4.51 ± 0.18 versus +P: 5.10 ± 0.23 μmol m^{-2} s^{-1}, $F_{1,24} = 5.21$, $p=0.03$). However, soil autotrophic respiration decreased when N was added without cations compared to other N * cation combinations (N:CATIONS: $F_{1,28}=6.05$, $p= 0.02$). Overall, we found stronger soil than aboveground respiration responses to nutrient additions. However, a previous study at our site showed stronger above and below ground productivity responses to added nutrients compared to the respiration responses reported here. Therefore, it appears that the rapid producitivty responses did not come with a high respiration cost, at least in the short-term. Together, initial responses from the AFEX project indicate that nutrient limitation needs to be accounted for to better understand ecosystem level carbon dynamics in Amazonian tropical forests. **Keywords:** CO2 efflux, phosphorus, cations, nitrogen, tropical forest

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Canopy Treelets Are More Sensible to Nutrient Addition than Understory Specialists Species in the Understory of a Tropical Heath Forest.

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The growth of tropical rain forests' trees is limited by soil nutrients, particularly tropical heath forests that have among the least fertile and most acidic tropical soil. Trees smaller than 10 cm DBH are often ignored by forestry and ecological studies. This cohort includes forest understory specialists, that reproduce without receiving direct sunlight, and saplings of non-understory species. Here, we propose that the response of tropical heath forest trees to nutrient addition might differ across life history strategies. For example, nutrient addition increased growth of canopy species, but understory specialists' growth rate decreased after long term N and P addition in a sub-tropical Chinese forest. Furthermore, allometric equations are widely used to calculate forest biomass but the response of trees' allometry to nutrient addition is unknown, and nutrient deposition is increasing throughout the tropics. In 2016 we started a factorial Nitrogen and Calcium Carbonate fertilization experiment in a tropical heath forest in Sabah, Malaysian Borneo. We tested the impact of nitrogen deposition and change in soil pH on tree growth rate between understory specialist species and overstory species by measuring the DBH of 3200 stems under the four different treatments and tree allometry for 1600 trees throughout three years. Understory specialists species made up only 16 % of the total species number, but they represented 49 % of stem density in this forest understory. The saplings of overstory species significantly increased their DBH growth rate after N addition and significantly increased their crown volume growth rate after Nitrogen and Calcium Carbonate addition, highlighting a greater crown structural plasticity of overstory species in comparison to understory specialists. After the treatments, there was no significant difference in the allometric relationship between tree diameter and height across both understory specialists and overstory treelets. This highlights that height – diameter allometric relationships appear stable in a framework of increased nutrient availability. The allometric relationship between tree diameter and crown volume, instead, show clear differences across life history strategies, with understory specialists having a wider crown, but with a similar crown volume, than overstory treelets for a given DBH across all the treatments. We speculate that future nutrient deposition by anthropic pollution may increase growth rate of topical heath forests and favour treelets of canopy species. This might decrease overall species diversity through the loss of understory specialist plant species. Nonetheless, biomass estimates relying on current allometric equations will remain reliable even under increased nutrient deposition. **Keywords:** Allometry, crown dimensions, fertilisation, forest dynamics, liming, nutrient deposition

Tropical forest restoration: Role of soil biota-root symbioses (mycorrhizae and N-fixing bacteria)

Afrotropical Forest Succession: from Nitrogen to Calcium Limitation

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Secondary forests constitute an increasingly important component of tropical forests worldwide. Although cycling of essential nutrients affects recovery trajectories of secondary forests, the effect of nutrient limitation on forest regrowth is poorly constrained. We used space-for-time chronosequences of secondary tropical forest succession to assess potential nutrient limitation along forest succession in central Africa. Using several approaches, we show that atmospheric phosphorus supply exceeds demand along forest succession, whereas forests rely on soil stocks to meet their base cation demands. Soil nutrient metrics indicate that available phosphorus increases along the succession, whereas available cations decrease. Fine root, foliar, and litter stoichiometry show that tissue calcium concentrations decline relative to those of nitrogen and phosphorus during succession. And finally, biological nitrogen fixation is downregulated along succession, with no more fixation taking place in older secondary forests, while the overall N cycle is shifting from conservative N cycling to a largely open N cycle along succession. Taken together, these observations suggest that calcium becomes an increasingly scarce resource in central African forests in later secondary succession. Furthermore, ecosystem cation – and calcium in specific- storage shifts from soil to woody biomass over succession, making it a vulnerable nutrient in the wake of land-use change scenarios that involve woody biomass export. Our results thus call for a broadened focus on elements other than nitrogen and phosphorus regarding tropical forest biogeochemical cycles and identify calcium as a scarce and potentially limiting nutrient in an increasingly disturbed and dynamic tropical forest landscape. The understanding of these underlying nutrient dynamics in secondary succession will be vital to come up with optimal management guidelines for restoring central African forests after disturbance.
Keywords: Secondary forests, nutrient limitation, chronosequences, biogeochemical cycles

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Microbial Plant-soil Feedbacks Affect Secondary Succession of Tropical Rainforests

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Plant-soil feedbacks (PSF), i.e., the reciprocal effects between a plant and the microbiome of the soil it grows in, can alter tree performance and thus species' local abundance and diversity. PSF have been shown to affect grassland succession, yet their role in the recovery of tropical rainforest remains unknown. PSF could drive a directional tree species turnover if they affect fast-growing, less well-defended species that are associated with early stages of succession more negatively than better-defended, late-successional species. Host-specific pathogens could moreover favor the recruitment of phylogenetically unrelated successor species and drive diversification. The rate of turnover could be affected by two opposing processes. Increasing microbial diversity could dilute the effect of individual microbial species and reduce the overall community-level strength of PSF with successional time, while decreasing light levels may create temperature and moisture conditions that favour microbial growth in late-successional soils. In a two-phase greenhouse experiment in Panama, we assessed the interactive effects of successional age of the soil (0, 15, 25 and 115 years of forest recovery) and light level (high vs low) on PSF effects on germination, survival, and biomass of seven tree species that

vary in their association from early- to late-successional forests. Subsequently, we inoculated seedlings of three successor species with the soils conditioned in phase one. We compared conspecific vs heterospecific PSF and quantified PSF variation with phylogenetic distance between conditioning and successor species. We found positive, negative, and neutral PSF. PSF strength and direction varied strongly among species with late-successional species being least susceptible. Overall, species experienced more positive PSF in soils from forests of successional ages that they naturally occur in. Light level strongly, yet inconsistently, modulated PSF. Negative PSF on successor species decreased with phylogenetic distance to conditioning species. Our results suggest that PSF affect most tree species during secondary succession. Lower susceptibility in late-successional species indicates declining community-level importance of PSF with succession. Positive, species- and soil-age-specific, PSF indicate a higher specificity of mutualistic microbes than historically assumed. This may promote establishment of certain tree species at their associated successional stage and thereby contribute to plant niche differentiation. PSF favoring phylogenetically unrelated successors suggest that PSF can accelerate tree species turnover and diversification. We present evidence that microbial-mediated PSF have a pervasive influence on secondary succession of tropical rainforests by enhancing tree species' niche differentiation and favoring phylogenetic diversification over time. **Keywords:** Fungi, mycorrhizae, forest regeneration, community assembly, tree species turnover

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Integrating Mycorrhizal Associations with Nutrient Acquisition Strategies in Southeast Asian Dipterocarp Forests

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Plants utilise various combinations of root morphological and architectural traits, root exudates and symbiosis with mycorrhizal fungi to acquire nutrients. These trait combinations and trade-offs have been well-documented in temperate and Neotropical forests but are understudied in major biodiversity hotspots in the Paleotropics. In Southeast (SE) Asia, dipterocarp forest communities are predominantly associated with ectomycorrhizal (EM), unlike the more common arbuscular mycorrhizal (AM) symbiosis in Neotropical systems. This EM association, coupled with root enzymatic activity, may provide dipterocarp trees with an enhanced capacity to access organic nutrient forms in the soil. However, it remains unclear how such mycorrhizal associations integrate with other root trait trade-offs and nutrient acquisition strategies within an organic nutrient economy underlying SE Asian dipterocarp forests. In this study, we test the hypothesis that SE Asian dipterocarp forest species experience similar trade-offs incurred during phosphorus acquisition and thus align with root trait trade-offs observed in other forest communities worldwide. We quantified root morphology, architecture, root enzymatic activity and mycorrhizal status of 33 species in an old-growth and secondary forest in Bukit Timah Nature Reserve, Singapore. Subsequently, we examined root trait coordination and trade-offs among species from both forest types and mycorrhizal associations. In agreement with previous studies, our preliminary results found evidence for two primary axes of principal component analysis explained by traits pertaining to fungal collaboration (PC1 = 53.0% of total variance) and resource conservation (PC2 = 28.4% of total variance). Due to the highly contrasting nutrient uptake mechanisms between AM and EM fungi, AM and EM tree species exhibited significantly different trait syndromes, where EM trees exhibit greater root enzymatic activity ($F_{1,38} = 9.71$, $P = 0.003$) and root tissue density ($F_{1,39} = 4.81$, $P = 0.034$) but lower root diameter ($F_{1,39} = 4.56$, $P = 0.039$). Overall, while we found similar root trait trade-offs among the collaboration and conservation axes as other forests worldwide, we also provide evidence for distinct nutrient acquisition strategies between AM and EM tropical species and how mycorrhizal associations may be linked with other nutrient acquisition strategies across species. These findings suggest that with the inclusion of mycorrhizal associations, the viable trait space for nutrient acquisition available to plants may be much larger than previously imagined in nutrient-limited tropical environments, warranting further investigation into how plants overcome nutrient limitation worldwide.
Keywords: Root traits, phosphatase, mycorrhizal, phosphorus, nutrient acquisition

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Advantages of Being a N-fixing Plant When Restoring Tropical Dry Forests

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Tropical dry forests are critically endangered, as 97% of their area is threatened by human disturbances. The soils of these forests are highly degraded and tend to have low phosphorus available impacting plant performance. Therefore, the lack of precipitation and soil nutrient depletion make necessary the implementation of active interventions including large-scale planting of native seedlings and management strategies such as phosphorus fertilizers and irrigation. To test the efficacy of these management practices and determine how different N-fixer and non-fixer species respond to them, we established a large-scale experiment in south-western Colombia on abandoned pastures where we planted 3,794 seedlings of 11 native species that belong to these functional groups. Our plantings were coupled with two treatments: water and phosphorus + water to determine: 1) if N-fixing seedlings have faster growth and higher survival rates compare to non-N-fixing seedlings, and 2) if N-fixing and non-N-fixing seedlings respond differently to watering and phosphorus addition. The 11 species planted are all able to associate with arbuscular mycorrhizae, but only four them can access atmospheric N thanks to their associations with N-fixing bacteria. We monitored the survival, growth, and resprouting rates of our 3,794 seedlings for two years. After 2 years of monitoring our plots, N-fixing seedlings had 87% survival rate across our treatments, while non-N fixers had 67% survival rate. Growth rates were similar for both N-fixing and non-N-fixing seedlings. Seedlings that received extra water when planted had higher survival rates. Finally, seedling's growth rates were similar across the two treatments, suggesting that phosphorus is not the only nutrient limiting plant growth. Our data show that overall N-fixing seedlings had higher survival rates, but growth rates of both N-fixers and non-N-fixers were similar. Water was key for early seedling establishment but fertilization with phosphorus did not increase seedlings growth more than watering after seedlings were established. These results suggest that planting a mix of both N-fixers and non-N-fixers is necessary to ensure the success of restoration projects, and that extra management practices like phosphorus addition are not always critical for seedlings establishment and growth. **Keywords:** Tropical dry forest, N-fixing-seedlings, phosphorus, watering, growth, survival, restoration

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The Role of Symbiotic Nitrogen Fixation and Arbuscular Mycorrhizae during Secondary Forest Recovery in the Neotropics

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Introduction: Neotropical forests are increasingly threatened by fire and clearing for pastures and croplands, but also have the potential to recover rapidly through both unmanaged and active reforestation. There is growing awareness that microbes which can form symbioses with plants—such as nitrogen-fixing bacteria and arbuscular mycorrhizae—may be critical for nutrient cycling and forest recovery. However, it is unclear how active the management of plant species and their symbionts must be for successful restoration. **Objective:** What can we learn about plant-microbe symbioses from unmanaged recovery of Neotropical secondary forests to inform how critical they are for active restoration? More specifically, do symbiotic nitrogen fixation and mycorrhizal colonization consistently increase early in succession to aid in forest recovery? **Methods:** First, we quantified changes in plant-microbe symbioses during forest recovery in two tropical forests: 1) In the south-eastern Amazon, we studied the dynamics of nitrogen-fixing trees and symbiotic nitrogen fixation in a forest that was recovering from prescribed fires, 2) In the Panama, we examined how mycorrhizal colonization, used to represent plant investment in mycorrhizae, changed across secondary succession from clearcutting. **Results:** In the southeastern Amazon, the basal area of putative nitrogen-fixing trees increased from about 1% to about 10% seven years after the last fire disturbance. However, symbiotic nitrogen fixation rates did not increase to the same extent, from negligible rates to ˜0.5 kg N ha^{-1} yr^{-1}, much lower than other Neotropical secondary forests. In Panama, total arbuscular mycorrhizal colonization did not increase or decrease across forest age, although components of mycorrhizal colonization did (such as the presence of arbuscules alone). **Conclusions:** The low rates of symbiotic nitrogen fixation in the southeastern Amazon are likely due to a combination of high nitrogen availability and the species composition of nitrogen-fixing trees. The lack of a strong change in mycorrhizal colonization across forest age in Panama may be due to a high investment in mycorrhizae, the methodology of measuring plant investment in mycorrhizae, or because mycorrhizae themselves can range from symbiotic to parasitic. Although symbioses can change dynamically during unmanaged forest succession, they likely vary depending on baseline soil nutrient availability and other factors that are still unknown, implying a lack of a “one-size-fits-all” approach to restoration. Ultimately, our findings suggest that the need for active management of plant-microbe symbioses may instead depend on how disturbed the seed bank and microbial communities are after forest clearing events. **Keywords:** Nitrogen fixation, arbuscular mycorrhizae, nutrient strategies, belowground function

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Tropical montane ecosystems: biodiversity, carbon and climate change

The Effect of Biogeographic Legacy on Tropical Andean Forests

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Introduction: The common expectation that aboveground biomass (AGB) decreases along elevational gradients due to temperature reduction is challenged for some recent studies showing that tropical montane forests in Africa, South America, and Southeast Asia contain similar AGB values their lowland counterparts. One possible driver of high AGB on tropical montane forests is biogeographic history. If temperate originated tree species colonize highlands after mountain uplift and are pre-adapted to coldness, these tree species can maintain larger size and AGB on mountain forests. **Hypothesis:** The size of tropical originated tree species decreases with elevation, while the size of temperate originated species is higher in highlands. **Methods:** We used herbarium records from tropical tree species distributed in tropical Andes obtained from BIEN database. Then, we generated a tree community matrix across the tropical Andes, cutting in latitude each degree and separating elevational bands each 500m. Then, we classified each species in tropical and temperate originated species based on the current distribution of each botanical family that these belong. Also, we obtained maximum tree diameter and maximum tree height from TRY database from each species. We used the genus or family average if one species is not reported in the database. Finally, we estimated if tree size decreases with elevation and expected and the effect of biogeographic origin on this relationship. **Results:** We found that tree size tends to decrease with elevation, and this relationship is stronger using tropical trees alone. The size of temperate originated species does not change along elevation, supporting the idea that these species maintain larger tree size on tropical highlands and affect the variation of AGB on tropical elevational gradients. In contrast, the size of tropical trees decreases with elevation as expected if coldness influences the performance of large trees. Then, we suggest that temperate tree species that migrate to tropical mountains can influence the current structure of tropical montane forests. **Implications/Conclusions:**The evolutionary history is a driver of the montane forest structure and can be useful to understand the response of these forests to climate change. **Keywords:** Andean biogeography, tropical-temperate mixing, tree size

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Temporal Shifts in Functional Composition of Andean Forests at Different Elevations Are Driven by Climate Change

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Andean forests are a global biodiversity hotspot harboring many species living within narrow climate ranges. These ecosystems also harbor high functional diversity of plants, but it is still unclear how species and their functional attributes will respond to the ongoing climate change along environmental gradients and through time. In this study, we aim to investigate whether Andean forests are changing their functional composition over time along the elevational gradient by assessing temporal changes in species composition and abundance and representativeness of their functional traits. If climate change is leaving a fingerprint in functional composition, traits associated with temperature would be the ones that should show the most detectable changes with

increases in temperature. For example, warmer temperatures exacerbate the reduction of both leaf area (LA) and specific leaf area (SLA), leading plant communities towards more conservative strategies over time. We used temporal forest dynamic of nine 1-ha permanent plots along 2.800 m in elevation in the north of Colombian Andean Forest, and in situ functional characterizations of seven morphological traits of 1,104 species. Using the Trait Driver Theory, we tested whether directional shifts exist in the functional composition of Andean forests in response to climate change and species dynamics. We quantified the shift in functional composition by calculating the central moments of trait distribution and their rate of change. We assessed the response of species and functional composition to changes in climate and demography by assessing the covariation between changes in traits distribution moments and changes in climatic variables, mortality, and recruitment. Our results show a directional change in the functional composition. The trends move toward more conservative strategies over time along elevation. Changes in most traits were explained by historical increases in minimum temperature and individual mortality. Changes in climatic conditions and the demographic response of species are leading to an increase in the dominance of more stress and heat-tolerant species within Andean communities. These changes are reflected in temporal decreases in traits such as specific leaf area along elevation and demonstrate the adaptation capacity of Andean species to new environments. **Keywords:** Andean Forests, climate change, elevational gradient, functional turnover, forest plots,

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Using Space-for-time Substitutions to Infer the Long-term Climate Sensitivity of Tropical Forests

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Introduction: Predictions of how tropical forests respond to climate change are needed over timescales of decades and centuries. However, our ability to assess changes over long timescales is limited by the amount of time we have been able to observe systems. Relating spatial variation in ecological variables to environmental gradients provides a space-for-time substitution potentially providing insights into these longer-term responses. **Methods:** The aboveground carbon stocks, rate of aboveground wood production and carbon residence time was assessed in 590 forest plots located across the tropical rainforest biome. Spatial variation in these variables was related to environmental variation. **Results:** Carbon stocks declined with increasing daytime temperature, with the rate of decline steepening in the hottest forests. Carbon stocks also increased with dry season precipitation. Thus, carbon stocks were lowest in the hottest and driest forests. **Implications:** Our estimate thermal sensitivity of tropical forests is lower than some studies using inter-annual variation, but lies within the range of temperature sensitivities of CMIP5 models. Many areas of South American forest are expected to reduce in carbon stocks under moderate future warming, even after accounting for CO2 fertilization.
Keywords: Climate change, carbon stock, forest dynamics

Tree Diversity Patterns in African Tropical Montane Forests

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Understanding the patterns of biodiversity distribution and what influences them is a fundamental pre-requisite for effective conservation and sustainable utilisation of biodiversity. In this study we identified large-scale variation in tree species composition across tropical mountain forests in Africa (wet and moist, defined as $>$ 800m asl). We used plot data from 23 sites in 12 countries in Africa (72,336 stems). As number of stems sampled per site was not even, we used Hill numbers. Elevation and climatic variables were extracted from BIOCLIM. We found relatively low alpha diversity (except in Nguti, Bakossi, Kahuzi, Itombwe and Udzungwa) but high beta diversity. A mean hierarchical classification, based Bray-Curtis distance ($n = 10{,}000$ replications), did not sperate geographical regions (west-central-east Africa), wetter from drier sites, nor large vs small mountains. Historical factors (forest refugia, not considered in this study) likely explain some of the patterns observed. Increased botanical exploration in some mountains could help better disentangle patterns observed. **Keywords:** Tropical mountain forests, plant diversity

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Tropical South American Peatlands: distribution, impacts of disturbance and knowledge gaps

What Do We Know about Peruvian Peatlands? Ecosystem Services, Threats, and Regulatory Framework

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Peatlands are wetlands where oxygen deficiency resulting from a high water table allows slow decomposition of dead vegetation and peat formation. Peru is one of the richest countries in the tropics in peatlands, it has them in its three regions, with a marked preponderance in the Amazon. These ecosystems provide important ecosystem services, such as the storage of immense amounts of carbon, the fixation of carbon dioxide, a unique biodiversity, local and regional water regulation, and the provision of livelihoods and cultural values for local populations. Unfortunately, they are being deteriorated by anthropogenic activities including infrastructure development and resource extraction (e.g., oil, minerals), and unsustainable uses or practices of varying intensity (eg, overgrazing, peat extraction). , felling of palm trees, overhunting) that threaten them and increase their vulnerability. Similarly, climatic changes compromise its stability. Given this, policies are being proposed to encourage their sustainable use and thus ensure their conservation, including international initiatives that serve as a fundamental baseline in the regulatory framework that Peru has been updating, where peatlands are included to achieve mitigation goals. and adaptation to climate change. The Peruvian regulatory framework includes norms and instruments for the sustainable management of wetlands, and to date progress has been made with the development of specific policies, such as the most recent Supreme Decree No. 006-2021 MINAM, where the general provisions for the multisectoral and decentralized management of wetlands, where the importance of peatlands is highlighted. However, their explicit inclusion in policies related to climate change, such as REDD+ and Nationally Determined Contributions (NDCs), is still awaited. Greater scientific research on Peruvian peatlands is a pending challenge. In particular, it is necessary to map them, inventory them and characterize their ecological properties and their economic and social values, as well as identify and reassess the knowledge that indigenous communities put into practice to manage them sustainably. The presentation seeks to synthesizecurrent knowledge about Peruvian peatlands, emphasizing knowing the ecosystem services they provide, the threats that put their conservation at risk, and the current regulatory framework. **Keywords:** Tropical peatlands, regulatory framework, ecosystem services, climate change, Peru

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Elevation and Temperature Are Strong Predictors of Long-term Carbon Accumulation across Tropical Andean Mountain Peatlands

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Introduction: Mountain peatlands are understudied globally, especially in tropical regions such as the Andes. Their high abundance across the landscape and thick carbon (C) rich soils establish them as nationally important C reservoirs. However, they are at high risk of degradation due to unsustainable land use and climate change. Mitigation of these threats requires detailed inventories of C stocks present and improved understanding of the major drivers of long-term C accumulation in these ecosystems. **Objectives:** 1) What is the belowground C storage per unit area for Andean peatlands? 2) Are there differences in C storage between peatlands in the northern and southern climatic ecozones (páramo and puna) of the tropical Andes? 3) Which environmental variables (elevation, temperature, precipitation, solar radiation) best predict longer-term C accumulation rates in tropical Andean peatlands? **Methods:** We cored 24 peatlands located between 3,000 and 4,800 m elevation across Colombia, Ecuador, Peru, and Bolivia, calculated C storage and long-term- and recent apparent rate of C accumulation (LARCA & RARCA, respectively), and tested their relationships to environmental variables (elevation, temperature, precipitation, and solar radiation). **Results:** The peatlands had a mean thickness of 4.7 m (range, 0.7 m–11.25 m). The mean age of peatland was 7,918 yrs B.P., with a range from 490–20,000 yrs B.P. The mean C stock was 1743 Mg ha^{-1} and did not significantly vary by climatic region or basal age but did increase with elevation. LARCA was best predicted by age and elevation, while RARCA was negatively related to mean annual temperature. **Conclusions:** These findings indicate that peatlands in the tropical Andes store thick deposits of soil C that are likely influenced by temperature, making them vulnerable to changes in climate. To inform climate policy, there is a need for science that will determine the potential for adaptation and mitigation treatments to increase the resilience of these C rich ecosystems to climate change. **Keywords:** Mountain peatlands, carbon, peat, Andes, accumulation rate

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Methane and Carbon Dioxide Fluxes in Drained and Undrained Tropical Mountain Peatlands in Colombia

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Tropical Andean peatlands are home to a unique biodiversity and store large amounts of carbon. Mountain peatlands are frequent in the northern Andes and can cover up to 17% of the landscape. Although many mountain peatlands are small, covering one or few hectares, some can be large on unique geomorphic settings such as old lakes and abandoned volcanic craters. Peatlands develop in relatively flat areas, many of which have been transformed to agricultural fields after draining. Peatland drainage exposes organic matter to oxygen, increasing decomposition and C emissions. Methane emissions are controlled by vegetation, quality of the organic matter, temperature, and water table depth that affects degree of peat anoxia. They tend to be lower in mountain peatlands than lowlands, but few data exist. Our research focused on understanding the patterns of greenhouse gas fluxes on a large peatland in the central part of the Colombian Andes, including the variation on the main microtopographic features: hummocks, hollows and ditches. Half of the site was drained over 60 years ago, and a complex pattern of vegetation change, subsidence and flooding developed. We monitored carbon dioxide and methane fluxes for one year on the disturbed and undisturbed areas. Our results showed a higher rate of ecosystem respiration on disturbed (1.5 µmol m^{-2} s^{-1}) than on undisturbed sites (0.6 µmol m^{-2} s^{-1}) with higher rates of emission from hummocks lacking vegetation in the disturbed area. Methane emissions were influenced by soil temperature and depth to the water table, with higher emissions on disturbed sites with high water table than undisturbed sites. Overall species composition was different between the two areas with shrub and large herbaceous plants encroaching on the disturbed area. Our results highlight the negative climatic impacts of human activities on Andean mountain peatlands and suggest restoration pathways that can reduce GHG emissions and help to protect valuable species. **Keywords:** Tropical Andes, peatlands, carbon cycle, methane disturbance

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Using Remote Sensing to Map Degraded Mountain Peatlands with High Climate Mitigation Potential in the Wet Tropical Andes

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Peatlands are a unique wetland class that sequesters soil carbon for millennia. Peatland carbon stocks are known to be some of the largest in the world. However, little is known about the distribution of peatlands in tropical areas, especially small mountain peatlands found in the tropics due to poor precision of current maps. The climate mitigation potential of peatlands relies on the protection of threatened areas or the restoration of degraded sites. Identification of the regional potential of climate change mitigation requires knowledge of peatland distribution, regional patterns of disturbance and land use change, and patterns of GHG emissions and absorptions. Remote sensing of peatlands in tropical mountains have many challenges: incorrect returns from radar on rough landscapes, permanent cloud cover, seasonality, differences between flooding and soil saturation from high precipitation, confusion between land cover types, and lack of relevant ground truthing points. Here, we focused on understanding the distribution and diversity of peat accumulating ecosystems on a subregion of the central Andes of Colombia using a remote sensing approach. Our analysis strategy included an intensive field campaign with over 500 field points and a multiplatform-multisensor remote sensing mapping strategy. Ground truthed points were randomly assigned and data on land cover, land use, and soil carbon down to 40 cm was collected. Remote sensing analysis was based on a combination of C and L radar bands (Alos Palsar 1 and 2, Sentinel 1), optical imagery (Landsat and Sentinel 2), and high-resolution topography. We discriminated the different land cover classes using a random forest algorithm. We identified 11 land cover classes with four different peatland classes: graminoid, shrub, cushion plants, and pasture peatlands. The overall precision was above 85% with the lowest precision differentiating between pasture peatlands and pastures on mineral soils. The region's 429,000 ha were dominated by forest (40%) and shrub vegetation (28%). Peatlands covered nearly 10% of the area whereas disturbed areas covered nearly 12% of the region. Peat soils under intensive pasture represented 0.1%. Carbon content was similar in natural peatlands. Our results prove the accuracy of the mapping technique used and highlights the extension and relevance of these ecosystems in the Central Cordillera in Colombia. These results will be of paramount importance for future studies of climate change mitigation and a tool to help developing countries in achieving their targeted GHG emission reductions. **Keywords:** Peatlands, Colombia, disturbance, NDC, Tropical Andes, climate mitigation

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Differing Depth-mediated Shifts in Methanogen and Methanotroph Communities among Tropical Andean Mountain Peatlands

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Mountain peatlands of the tropical and subtropical Andes are numerous and play a key role in carbon cycling because they contain large stocks of carbon stored as peat and can sequester and emit greenhouse gases, especially carbon dioxide and methane (CH_4). Whether a peatland is a source or sink of CH_4 depends on the balance between methanogens and methanotrophs. These CH_4 related microbial communities are affected by the redox potential and substrate availability and quality. Tropical Andean mountain peatlands are characterised by cushion and graminoid plants. Sparse data suggest these peatlands have low methane fluxes, although these plants possess aerenchyma which can transport CH_4, perhaps because they supress CH_4 emissions by transporting oxygen into peat. The dominant plant functional type and alterations caused by disturbances such as grazing can impact the soil microbial communities, altering the balance of methanogens and methanotrophs. Our objective was to assess the differences and potential drivers of the methanogens and methanotrophs microbial communities across a gradient of Andean tropical peatlands. We collected peat cores from seven mountain peatlands from Colombia, Ecuador and Peru and used high throughput sequencing of the small subunit ribosomal DNA (SSU rDNA) to determine bacterial and archaeal community composition in soils. Methanogens and methanotrophs represented less than 5% of the relative read abundance of the studied sites. With increasing soil depth, the abundance of methanogens and methanogen:methanotroph ratios increased except in one heavily grazed site where methanogens were abundant near the surface. We also found changes in the community composition of methanogens and methanotrophs amongsites and with soil depth. The dominant methanogen class observed in the surface varied among sites and were Methanomicrobia or Methanobacteria. However, the community on the surface of the heavily grazed site formed a cluster separated from the other

studied sites and depths, perhaps driven by enteric microbes or labile inputs from cattle. Previous studies on CH_4 fluxes carried in the heavily grazed site and and in a non-grazed site, showed low CH_4 emissions (8.1 mg CH_4 m^{-2} d^{-1}) in the non-grazed site and high CH_4 emissions (132.3 mg CH_4 m^{-2} d^{-1}) in the heavily grazed. The high grazing could be the driver of the changes in the methanogen and methanotroph community that we observed and matches the previously described high CH_4 fluxes measured at this site. Further co-analyses of microbial communities and CH_4 fluxes will test the generality of these ptterns. **Keywords:** Mountain tropical peatlands, methane, methanogens, methanotrophs, microbial community composition

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Major CO_2 Losses from Degradation of *Mauritia flexuosa* Peat Swamp Forests in Western Amazonia

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Tropical peat swamp forests are major global carbon (C) stores that are particularly vulnerable to human intervention. In Peruvian Amazonia they have been severely degraded through recurrent cutting of *Mauritia flexuosa* palms for fruit harvesting. This has potentially transformed them from a CO_2 sink into a significant source. To estimate emissions associated with degradation, we combined C stock changes in aboveground biomass with peat C losses along a gradient comprising undegraded (Intact), moderately degraded (mDeg) and heavily degraded (hDeg) palm swamps. Temporal and spatial dynamics of the main components of the peat C budget (heterotrophic soil respiration (Rh) and litterfall) were measured (bi)monthly over three years, while annual site-specific root C inputs and default dissolved organic C exports were taken from the literature. Variables measured at tree or microtopographic level were site-scaled considering forest structural changes from degradation. Site-scale litterfall (Mg C ha^1 $year^1$) at the hDeg site (2.3 $\pm$ 0.5) was less than half the rate at the Intact and mDeg sites (5.2 $\pm$ 0.9 and 6.0 $\pm$ 1.6, respectively). Conversely, site-scale Rh (Mg C ha^1 $year^1$) was higher at the hDeg site (9.6 $\pm$ 0.6) than at the Intact and mDeg sites (7.5 $\pm$ 1.1 and 6.1 $\pm$ 0.5, respectively). The peat carbon budget (Mg C ha^1 $year^1$) indicated that medium degradation reduced the sink capacity of the soil (from -1.8 $\pm$ 1.8 at the Intact site to -0.3 $\pm$ 0.7 at the mDeg site) while high degradation turned the soil into a high C source (6.0 $\pm$ 0.6 at the hDeg site). The large total C stock loss rates of 23.5 $\pm$ 14.3 and 57.7 $\pm$ 14.3 Mg CO_2 ha^1 $year^1$ at the mDeg and hDeg sites, respectively, which originated 94 and 77% from aboveground biomass changes clearly highlight the need for sustainable management of these peatlands.
Keywords: Carbon budget, CO2 emissions, litterfall, heterotrophic respiration, palm swamp peatlands,

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Vascular epiphytes: current knowledge and future challenges

"Epiphytes Sensu Lato" : Biological Variation Vs. Terminological Chaos

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Background - Many plants use others for structural support. These are typically assigned to different categories such as epiphyte, hemiepiphyte, climber, or mistletoe, which is based on sites of germination, growth and nutritional independence from the host. Unfortunately, such a seemingly unambiguous categorization is not consistently applied in individual studies, and intraspecific biological variation, which actually precludes a neat categorization in many cases, is typically ignored. This has led to a rather confusing situation, in which it is even doubtful whether one form, "secondary hemiepiphytes", exists at all. I present several analyses of the literature and results from field studies that highlight the problem. Objective - There are many ways to be a structurally dependent plant. The current scheme of grouping and the use of terminology does not appropriately reflect biological reality and needs to be revised. **Methods** - As a first step we can analyze what information is already available, e.g. by compiling life form information from the literature (floras, annotated species lists, vouchers). Unfortunately, data are not necessarily reliable and different sources often provide inconsistent information. Thus, there is no way around field studies that document intra- and interspecific variation and in the best of cases, understand the underlying mechanisms. **Results** - 1) Terminological chaos: I present data documenting that many researchers have developed an idiosyncratic terminology, which obviously impedes unambiguous communication. 2) Biological variation: I present data from both literature studies and field studies that document that the neat assignment of plant species to either the group of "epiphytes", "climbers", "lithophytes" or "terrestrials" is frequently not justified. The magnitude of the problem is unclear because there are few reliable data. **Conclusions** - The way we categorize biological variation shapes our perception of reality. Emphasizing clear-cut categories (= discontinuity) instead of gradients (transitions and continuity) may easily lead to erroneous conclusions and misunderstandings of biological processes. For example, many studies in the fields of ecology, evolution and physiology compare "epiphytes" with "terrestrials" without acknowledging intraspecific variation in this trait. Thus, many of the patterns we identified are possibly incorrect. There is clear need for pertinent studies and for the creation of awareness in the research community – we need an unambiguous use of terminology. The goal is clear: we want to understand biological variation and must avoid terminological chaos. **Keywords:** Epiphytes biodiversity, hemiepiphytes, climbers mistletoes, facultative_epiphytes, nomadic_vines variation

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Vascular Epiphyte Life History Responses to Anthropogenic Change: An Experimental Approach

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The diverse vascular epiphyte community in tropical rainforests is at the interface between the atmosphere and the forest floor and dependent on rainfall, cloud water, and sparse canopy soil for nutrients and water. As such, predicted anthropogenic changes in nutrient deposition (pollution) and water availability will have profound effects on epiphyte ecology. We conducted a 24 month, ex situ, experiment to determine the impacts of predicted increases in pollution (+nitrogen, +nitrogen & phosphorus, + phosphorus) and reduced water availability (-30%) on life history in five cosmopolitan epiphyte species in 3 general (*Guzmania* (Bromeliaceae), *Anthurium*

(Araceae), *Elaphoglossum* (Elaphoglossaceae)) in a lowland rainforest in Costa Rica. These taxa obtain nutrients and water differently: Guzmania absorbs nutrients and water through the tank surface, *Elaphloglossum* uses canopy soil roots, Anthurium uses aerial roots and canopy soil roots. Not surprisingly, we found significant variation across life history in response to experimental treatments and species, namely leaf production, leaf longevity, and reproduction. For example, *Elaphoglossum* leaf longevity was significantly longer under nitrogen addition (11.0 +/- 1.1 months) compared to control and other treatments ($<$ 8 months), whereas Anthurium leaf longevity was not significantly impacted by nutrient addition (10.7 +/- 0.2). Contrary to expectation, nutrient addition had no significant effect on reproduction in *Elaphoglossum* or *Anthurium* and had a negative effect on reproduction in *Guzmania.* Nutrient addition reduced the likelihood of bromeliad sexual reproduction compared to the control treatments. As inflorescence production precedes sexual reproduction, nutrient addition may indirectly influence asexual reproduction and thus spatial expansion in the canopy through rhizome extension with asexual pups. Interestingly, tracking leaf gain and loss in bromeliads, we found that bromeliad leaf replacement varied broadly with bromeliads that produced pups having low leaf replacement rates while bromeliads with no asexual reproduction having high leaf replacement (2x original leaf number) over 23 months, regardless of treatment. The ability to alter life history and functional traits under various conditions is critical to success in the liminal canopy space, interestingly, these epiphyte functional groups respond differently, and often in opposite ways, highlighting niche partitioning. These shifts in life history and leaf functional traits inform our understanding of how the canopy community will respond to global change. These data are part of a larger experimental study examining both ex situ and in situ vascular epiphyte responses to changing nutrient and water regimes. **Keywords:** Epiphyte, canopy, life history, demography

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Putting Vascular Epiphytes on the Traits Map

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Introduction: Plant functional traits impact a plant's fitness and constrain its environmental niche. Epiphytes are a prominent life form in humid tropical forests and many adaptations have been described as characteristic. We question if the many case studies indeed reflect "typical" adaptations of epiphytes, but generalizations are limited by a lack of comparable and unbiased data on functional traits. **Objectives:** We aim to broaden the data on functional traits available for epiphytes. Using these, we formulate hypotheses how functional traits should reflect adaptations to specific constraints of the epiphytic habitat to cope with type, availability and stability of the substrate, and the availability of light, water and nutrients. **Methods:** These hypotheses were tested by collecting an unprecedented dataset of $>$ 100 000 trait observations from 2601 species of epiphytes and comparing these with traits of ground-rooted herbs and trees. We test if epiphytes differ in individual traits, whether they occupy a distinct region in the global trait space and whether their trait network differs from ground-rooted plants. In addition, we distinguish orchids, bromeliads and ferns, the three most species-rich groups of epiphytes. Results : Epiphytes differ from ground-rooted plants mainly in traits related to water relations, but surprisingly do not have lower leaf nutrient concentrations, except for nitrogen. Mean rates of photosynthesis are much lower than in ground-rooted plants and lower than expected from the nitrogen concentrations. The combination of traits clearly distinguishes epiphytes from trees and also from most herbs. Orchids differ from bromeliads and ferns mainly by having smaller and more numerous stomata and ferns differ from bromeliads by having thinner leaves, higher nutrient concentrations, and lower water content and water use efficiency. In epiphytes, herbs and trees, the central nodes in the trait network are represented by specific leaf area, mass-based photosynthesis together with nitrogen concentration. In epiphytes, traits related to plant water relations have stronger connections and cations have weaker connections to the remainder of the trait network. **Conclusions:** Although this work substantially adds to the available traits for epiphytes, currently mainly leaf traits have been collected. Important gaps are root, shoot and whole plant traits, demographic traits and gas exchange traits and we suggest how future research might use available data and fill data gaps to advance our understanding of epiphyte ecology. This will also help to characterize the ecological niches occupied by the numerous species of epiphytes and understand their responses to environmental changes.
Keywords: Epiphytes, growth form leaf traits plant, functional traits, trait network

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Vascular Epiphyte Diversity at the Local Scale: State-of-the-art and Outlook

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Vascular epiphytes are a striking feature from tropical forests and they are most diverse in the Neotropics. As a structurally dependent group, they rely on their host for support. Although epiphyte diversity is insufficiently studied, it is predominantly explored at the tree and the site scales. The first evaluation of vertical epiphyte distribution determinants on a tree dates to 1925, forty years later, variables determining local diversity were assessed across forest types for the first time. Studies at these scales characterize the body of literature on epiphyte research, but new approaches have emerged in the last years. Still, we lack a current synthesis to address knowledge gaps and new research directions. We summarize the current knowledge of epiphyte diversity at the tree and local scale based on scientific literature and our shared experience and understanding, focused mainly on the last ten years. This review uses two modern tools: the ResearchRabbit app, a novel way to search for papers and authors and visualize research landscapes, and a combined text mining approach with a joint cluster-ordination to categorize the current literature into relevant literature research clusters. We focus on the last ten years and elaborate on the most critical research axes of epiphyte diversity at the tree and local scales. There are known patterns at the tree and local scale, and the effects of tree and site on epiphyte diversity are intertwined. With this comparative overview of current studies, we want to show the development in the field and point to future research directions. **Keywords:** Tree scale, local scale, vascular epiphyte, diversity, Neotropics, outlook

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Identification of Large-scale Vascular Epiphyte Biodiversity Patterns

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Justification: Vascular epiphytes contribute substantially to local plant diversity in tropical forests. However, does this trend hold true at larger spatial scales? **Objectives:** We give an overview on the current state of the art in epiphyte research at the regional to global scale, with the objectives of understanding a) the general trends and contribution of epiphytes to large-scale gradients of vascular plant diversity, and b) the drivers responsible for constraining their regional and global distribution. **Methods:** We draw inferences from epiphyte biodiversity studies spanning regional and elevational gradients to global-level biogeographical analyses. **Results:** Epiphytes substantially contribute to both regional and global centres of vascular plant diversity, with clear hotspots in the Neotropics and tropical Asia. These hotspots are attributed to extensive tropical forests and mountain ecosystems, both of which offer optimal conditions (e.g., high humidity) for epiphyte growth and survival. Across elevational gradients, epiphytes generally peak in species richness at mid-elevations, highlighting their comparatively narrow climatic tolerances compared to terrestrial plants. Implications: Our talk highlights the importance of epiphytes as contributors of biodiversity beyond local scales, and that their striking regional differences have resulted from historical and evolutionary processes, such as the radiation of large endemic angiosperm groups in some regions (e.g., *Pleurothallis* spp, and Bromeliaceae in the Neotropics). **Keywords:** Vascular epiphytes, regional, global, elevational gradients, Neotropics, tropical forests

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Identification of Responses to Anthropogenic Disturbances and Climate Change on Vascular Epiphytes

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Epiphytes, plants that germinate and root non-parasitically on other plants at all stages of their life, constitute one of the most prominent life forms in the canopy of the tropical forests on Earth. Epiphytes, have been considered particularly vulnerable to climate change and forest loss because of their existence at the interface of vegetation and atmosphere. In humid tropical forests, one of the biomes where an increase in extreme temperatures is expected for long periods of time (heat waves), vascular epiphytes (e.g.,orchids, bromeliads, and ferns) can represent up to 50% of the diversity of local vascular flora, while globally they constitute about 10% of plant diversity. In the Neotropics, for example, in the forests of Ecuador, vascular epiphytes represent up to 39% of the flora, while in Brazil, Colombia, Costa Rica and Panama, they contribute with 23-26% of the plant species diversity. In general, epiphytes are highly dependent on tree structure and environmental quality, drastically reducing their abundance and diversity in disturbed ecosystems. Land-use change has dramatically impacted tropical forests resulting in degraded landscapes with fragmented forests in different states of conservation, and embedded in a mosaic of agricultural and livestock patches. This condition impacts the dispersal and natural regeneration processes of plant communities. For many epiphyte species, it reduces dispersal opportunities since they require well-established tree communities to survive. Here, we present advances on the conservation status of epiphytes according to The International Union for Conservation of Nature (IUCN) for species in Brazil, Colombia, and Mexico. In addition, for selected species we evaluated the impact of deforestation on species distribution and habitat loss due to increasing temperature. Given that many epiphyte species are endemic, and many are represented by only few records, considerably more studies are needed to assess the conservation status of more species and –if possible– vascular epiphytes as a group. Our knowledge of diversity and ecology of epiphytes is still incipient, and data on epiphyte species distribution in degraded forests are extremely scarce. Our results indicate that deforestation represents the greatest impact on epiphyte diversity due to habitat loss, followed by ecosystem degradation and conversion of forests to agricultural systems. However, even if epiphyte species richness loss is imminent, the diversification of epiphyte phylogenetic diversity may imply high resistance to environmental filters produced by climate change and landscape transformation. **Keywords:** Vascular epiphyte, tropical forest, climate change, diversity, species distribution, disturbances

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XPRIZE Rainforest: Revolutionizing Tropical Ecology and Conservation with Technological Innovations

XPRIZE Rainforest: Revolutionizing Tropical Ecology and Conservation with Technological Innovations

Peter Houlihan

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Rainforests are the most diverse, complex, and imperiled terrestrial ecosystems on Earth. Despite their critical importance to the livelihoods of Indigenous Peoples and local communities, harboring immense biodiversity, regulating climate, and being the origin of many modern medicines, rainforests are undervalued, understudied, and overexploited. Time is running out. Although not yet fully documented and quantified scientifically, an integral value of rainforests is their biodiversity. Remote sensing and in situ methodologies traditionally used to identify and catalogue biodiversity are labor and time intensive, often requiring lengthy field expeditions and subsequent analyses, impeding efforts to urgently gather timely data necessary to understand and protect the full ecosystem wealth of rainforests before they are lost forever. XPRIZE Rainforest is a global, five-year competition challenging innovators to develop novel technologies to rapidly and comprehensively survey rainforest biodiversity and use data to deliver new insights in near real-time that promote the health and conservation of this vital ecosystem. In alignment with the Convention on Biological Diversity, successful technologies developed in the competition will demonstrate capabilities that include improved survey speed, autonomous operations, the ability to survey multiple stories of rainforest, innovative detection methodologies, and rapid data integration to provide new insights in unprecedented detail. Insights may include, but are not limited to, new ecological dependencies, biodiversity and climate connectivity, undiscovered threats, anthropological findings, or sustainable societal interactions with the rainforest. An improved understanding of these ecosystems will support the sustainable use and well-being of standing rainforests and its inhabitants, leading to new scientific discoveries, technological innovations, and to just and sustainable bioeconomies. XPRIZE Rainforest currently has 36 teams from 18 countries composed of tech innovators, ecologists, biologists, data scientists, engineers, and those working in AI, drones and robotics and other important sectors coming together to help document, understand, and preserve rainforests around the world. In Summer 2022, XPRIZE Rainforest will announce the 25 teams selected to advance to the Semifinals Testing of the competition taking place in 2023, followed by Finals Testing in 2024. The individuals assembled here are members of the XPRIZE Rainforest Advisory Board, Judging Panel, and broader prize ecosystem. The audience will learn how emerging technology from the competition can be harnessed to protect and conserve rainforests, in partnership with Indigenous Peoples and local communities, and how together, improved understandings of biodiversity can lead to a more equitable and sustainable future. **Keywords:** Biodiversity, technology, drones, machine learning, artificial intelligence,

Interactive Tools Can Drive Evidence-informed Decisions in Conservation: Insights from Camera Trap Surveys in the Amazon

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Addressing global challenges facing natural ecosystems and human societies will require dynamic and adaptive solutions based on best-available science. Currently, we are in an unprecedented time in the history of scientific research where the pace of knowledge generation and data gathering is exponentially rising. This explosion is aided, in part, by technological advances (e.g., remote sensing, camera trapping, acoustic recorders, eDNA tech) that allow us to collect fine-scale data over broad spatial and temporal ranges, the advent of digital repositories, portals and platforms housing these data (refs) and the increased popularity of data papers. Despite the potential wealth of information available, there is widespread recognition that a significant gap remains between the generation of knowledge and its ultimate use in informing decisions and actions in conservation practice. In this talk we address one aspect of the science-action boundary, specifically, the delivery of information for decision-making. One way of bridging the knowledge-action boundary is to make the data more accessible through visual tools (e.g., dashboards, visualizations, data portals, infographics). We describe a new framework for active approaches to data visualization: Interactive Data Visualization for Empowerment and Action (IDEA). We believe IDEA can empower decision makers more effectively to take action because they have actively participated in the generation of the information, a crucial component of learning. Second, we illustrate this concept with an interactive dashboard that allows non-technical users to explore and gain insights from camera trap survey data collected in three protected areas and one community conservation corridor. We describe the insights gained by the users of the tool that resulted in specific conservation actions. **Keywords:** Camera traps, visualization, conservation, corridors, mammals

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Smithsonian Tropical Research Institute: A Global Scientific Platform

Oris I. Sanjur

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The earth’s landscapes and seascapes are undergoing a transformation at an unprecedented rate, threatening biodiversity and the maintenance of ecosystem services. These concerns are especially pressing in the tropics, where 80% of the world's biodiversity is found, where most humans live, and where current models predict the greatest climate induced environmental change. Our ability to understand, predict, and manage how organisms, communities, and ecosystems respond to environmental changes will determine the sustainability of diversity on our planet. The Smithsonian Tropical Research Institute (STRI) is among the leading tropical research institutes in the world. It was founded to increase and share knowledge about the past, present and future of tropical ecosystems and their relevance to human welfare. This work began in Panama in 1910 when the Smithsonian led one of the world’s first major environmental impact studies to survey and catalog the flora and fauna of lowland tropical forests that would be flooded for the creation of the Panama Canal. A century later STRI is the standard-setting global platform for research on the astounding biodiversity of tropical forests and marine ecosystems, and the cultural diversity of the peoples that make use of them. As a research institute in the tropics, STRI is uniquely positioned to advance basic and applied research, with an emphasis on field studies, to understand tropical organisms and communities and their role in the biology of our planet as a whole. Its research is not only shared widely within the global scientific community, but also reaches policymakers, receives international media attention and is the foundation of an outreach and training program for hundreds of teachers and tens of thousands of schoolchildren. STRI is also a world-class education, training, and outreach organization for the Latin American region and beyond. Every year, STRI hosts approximately 1,200 young scholars from undergraduates to Ph.D. students in field courses as well as interns with staff scientists and fellows pursuing their own research questions. They join one of the largest and most diverse communities of early-career academics anywhere in the tropics. STRI also has four public outreach sites that yearly host more than 100,000 students and day visitors who discover the amazing plants and animals of the tropical rainforest, experience hands-on science, enjoy recreational spaces and learn about science that reveals the many wonders of tropical nature. We will share an overview of STRI ‘s scientific work, and its role as global research platform.

Part II

Oral Sessions

Agriculture, Forestry and sustainable alternatives I

Harvest Simulations on *Chamaedorea linearis* and *C. pinnatifrons* to Promote Its Conservation through Use

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Introduction: Conservation through use is a widely a used strategy to protect species, of which wild populations are harvested and could be facing threats. This is the case of *Chamaedorea*, one of the most commercialized genera of ornamental palms. Their ornamental uses involve the entire palms sold as indoor plants, leaves for floral arrangements, and fruits for propagation. The species *C. linearis* and *C. pinnatifrons* have high potential as ornamentals but are considered as "near threatened" and "least concern", respectively. Some populations of *C. pinnatifrons* in Colombia are considered "vulnerable". The conservation and protection of these species can be promoted through their use by developing management plans allowing for their sustainable harvest by local people. Nonetheless, questions remain about the harvest rates that populations can tolerate without risking their permanence. **Objective:** Determine the population demography and construct different simulations to explore the impacts of entire individuals-, leaves-, and fruit-harvest. **Methods:** During 2019–2021, both species were sampled in seven 10x10 m plots located in Cundinamarca, Colombia. We recorded the population's vital rates of survival, growth and fecundity. To understand the populations' dynamics, we developed Integral Projection Models (IPM) based on their vital rates information. To simulate harvest, we modified the IPM with different rates of extraction. We estimated the harvest's sustainability through effects on population growth rate and population size over the next 20 years. **Results:** The population of *C. linearis* is decreasing, while the population of *C. pinnatifrons* is increasing. The harvest of entire individuals- and of a percentage of leaves -decreased the population growth rates and population sizes in comparison to the no harvest scenario. This is explained by a reduction in the growth of juveniles and adults (harvested sizes) which were, according to elasticity analyses, the demographic process and sizes that most contributed to growth rates of both populations. In contrast, fruits-harvest simulations had similar tendencies than those without harvest, probably due to the low elasticity of the number of racemes. Conclusions: Conservation strategies should focus on protecting juveniles and adults in *C. linearis*, since it seems that they cannot tolerate any harvest practices and their population is decreasing. In *C. pinnatifrons*, the propagation of individuals through the harvest of fruits can be promoted as a sustainable use strategy to ensure the supply of materials and the populations' conservation. *The Vicerrectoria de Investigaciones de la Universidad Militar Nueva Granada, INV-CIAS-3410, ATBC Seed-research grants and Colombia Biodiversa fund financed this research.* **Keywords:** IPM, Chamaedorea, harvest simulations, understory, ornamental, wild populations

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Birds as Fungal Dispersers between Coffee Plantations and Forests

Elena Prado-Ragan

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North Dakota State University, Fargo, Spain Birds overlap with fungi in nearly every biome, yet their role in facilitating fungal dispersal has been overlooked. To determine if birds carry fungi from agriculture to forests, birds were mist-netted at eight sites where coffee plantations bordered forest fragments in Coto Brus, Costa Rica. Bird captures were analyzed to determine which species could be facilitating the movement of fungi, due to their frequent activity in both coffee and adjacent forest. Coffee plantations in Coto Brus neighbor La Amistad, the largest intact forest in Central America. Bird capture data was also analyzed to determine if the number of bird captures or species recorded is influenced by site distance from La Amistad. Of the 111 bird species captured, Rufous-tailed hummingbirds, Swainson's thrushes and Ochre-bellied flycatchers made up 31% of all captures. These species were also captured in coffee and forest, as well as made up 20% of all forest captures. Birds mist-netted in forests represented 56% of capture data and 57% of all recorded species. Of the species captured in forests, 37% of birds were also recorded at least 1x in coffee. To determine the effect of site distance from La Amistad on species composition and bird activity, bird captures were compared from the most proximate to furthest site from La Amistad. With proximity to La Amistad, the number of bird species and captures in coffee increases, whereas the number of bird species and captures in forests decreases. The increase in bird species and number of captures in coffee with proximity to La Amistad, suggests that coffee sites closer to large, intact forest borders have a greater potential for fungal spillover into forests. **Keywords:** Birds, fungal spillover, La Amistad, coffee

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Continuous Forest at Higher Altitudes Plays a Key Role in Maintaining Biodiversity across a Mid-elevation Coffee Landscape in the Western Andes of Colombia

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Shade coffee is one of the most widespread and economically important crops in montane tropical regions. This coffee system provides structurally complex vegetation and canopy cover and, for some species, may serve as a more hospitable landscape matrix than non-shaded crops. However, substantial knowledge gaps remain regarding species use of coffee landscapes as research to date has centered principally on small-bodied species and species able to use the canopy. At the same time, challenges associated with climate change lend urgency to understanding biodiversity in montane shade coffee systems at a landscape scale. With climate change, coffee production is predicted to move upslope, and in many montane regions, well-conserved forest only remains at higher elevations. Our research focused on ground-dwelling birds and medium-large mammals in a shade-coffee landscape of the Western Andes of Colombia. We asked the following questions: 1) How do occupancy, richness, and community composition of birds and mammals change from continuous forest at higher elevations to forest fragments and shade coffee at mid-elevations? 2) Do birds and mammals differ in their response to shade coffee? 2) Do forests at higher altitudes contribute to maintaining biodiversity in mid-elevation shade coffee? This information is important for understanding the conservation value of shade coffee, impacts of further forest conversion at mid-elevation, and potential effects of forest loss at higher elevation on biodiversity within shade coffee and mid-elevation forest fragments. Over two years, we sampled ground-dwelling birds and mammals (31 and 29 species, respectively) with camera traps in shade coffee plantations and forest fragments at mid-elevation and continuous forest upslope. We used a multi-species occupancy model to correct for detection and to estimate occupancy, richness, and community composition. Shade coffee lacked ~50% of the species found in continuous forest, primarily large-bodied and insectivorous birds and forest-specialist and large-bodied mammals. Forest fragments had species richness more similar to shade coffee than to continuous forest, but species composition differed between coffee and both forest assemblages. Birds in coffee plantations were generally a unique subset of disturbance-adapted specialists, whereas mammals in coffee were mostly generalists encountered across land uses. Distance from continuous forest was the most important landscape-level predictor of occupancy for both taxa, suggesting that this forest plays a key role in maintaining biodiversity across the coffee landscape. Conservation of biodiversity in shade coffee landscapes, therefore, will be ineffective unless linked to larger landscape-level conservation initiatives that conserve higher elevation forest. **Keywords:** Andean forest ground-dwelling birds, human disturbance, large mammals, multi-species occupancy

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Biodiversity and Human Well-being in Productive Landscapes: The Case of Coffee Agroecosystems in the Central Colombian Andes

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The contradictory historical management between agricultural production and biodiversity conservation has contributed to strengthening the main driver of global biodiversity loss: habitat loss. It is therefore required that these two activities be reconciled in spaces that have the potential to promote ecological and human well-being simultaneously. We present an analysis of the contribution of coffee agroforestry systems to the conservation of local biodiversity and the human well-being of its small farmers, through a comparative study of three systems located in the Colombian coffee region in central Andes: coffee agroforestry systems (CAS), coffee monocultures (CM) and conserved areas (CA). Initially, we evaluate the main agroecological structure (MAS) of the productive systems (CAS and CM), through its structure and plant diversity, its management practices and connectivity with its surrounding landscape. Secondly, we compare the biodiversity of the three systems (CA, CAS, and CM) through the evaluation of their acoustic activity and the characterization of their soundscapes. Third, to approach human well-being of the coffee farmers, we asked them about their own conceptions of well-being and their economic and logistical capacities, their social relationships, and their access to technical assistance. After contrasting the agroecosystems studied, we found that the CAS have a more developed MAS than the CM, mainly due to their plant diversification and their management practices. In addition, the CAS and the CA did not present significant differences in their acoustic activity, while they did differ from the CM. The proportions of the identified sound sources were similar between CAS and CM, although different when compared to CA, particularly in terms of anthrophony, wind, running water, and amphibian detection. Finally, we found that the most important elements of human well-being for the farmers provided by their farms were tranquility, being able to live in harmony with a healthy environment and economic well-being, although in this last aspect they recognize that they face various difficulties. Overall, it is essential to study ecological and human well-being simultaneously, especially in spaces that have the potential to provide both, such as CAS. The viability and persistence of these spaces depend on both types of well-being, and with this, the possibility of generating opportunities for reconciling use and conservation in highly transformed spaces. **Keywords:** Conservation in productive landscapes, soundscape ecology, human well-being, agroforestry

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Agriculture, Forestry and sustainable alternatives II

Improving Pollination Deficits of Native Cacao Varieties from Peru for Enhanced Smallholder Benefits

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Even though the chocolate tree is a tropical smallholder crop species and pollination of the crop tree has been a research topic for decades, yields are still strongly limited by pollination. The knowledge gaps surrounding the cacao pollination deficits are detrimental to the many smallholders' livelihoods that rely on cacao yields. Because the crop depends on insects for cross-pollination, pollination deficits might be due to a lack of flower visitors that deposit enough pollen that is compatible. To counteract pollination deficits, manual pollen supplementation has been proposed to improve yield, but its success in native cacao varieties has not been assessed so far. In native cacao, self-incompatibility, i.e., the inability to fertilize flowers with pollen from similar genetic origin, may limit hand pollination benefits severely. To increase our understanding of fruit set limitations of native cacao, we surveyed flower visitors, assessed pollen deposition in and conducted hand-pollination experiments with five genotypes of Peruvian native cacao. We monitored fruit set of manually self-pollinated and cross-pollinated flowers and compared quality of manually and naturally pollinated fruits, by assessing fruit weight, seed number and weight, and premium seeds per harvested fruit. We found that under natural conditions, flower visitation was mainly by herbivores (38-65%), and that flying midges, the alleged cacao pollinators, only rarely visited cacao flowers (7%). Moreover, average pollen deposition on flowers was low (˜30 grains), as well as fruit set success (0.8%). Natural pollination might thus be limited by the number of effective pollinators that visit flowers. Manual pollination, compared to natural and self-pollination increased average pollination success, but gains depended on the genotype of the pollen donor. Mean cross-pollination success ranged from 1.8% to 4.1% and self-pollination success was 0.5%, indicating that fruit set success in native cacao systems is constrained by compatibility among genotypes. Lastly, fruit quality improved when cross-pollinating manually: Seed weight and proportion of premium beans was higher after manual pollen supplementation. Increases fruit quantity and quality due to hand pollination might lead to native variety fruits being sold at higher market prices, which can increase socio-economic benefits of cultivating native white cacao. However, hand pollination is associated with high labour costs. Instead, plantation designs that maximize pollen exchange among compatible genotypes to improve yield quantity and quality, could be more cost-efficient. Lastly, we discuss farmers´ considerations concerning manual and natural pollination strategies in native cacao. **Keywords:** Flower visitors, Theobroma cacao, cross-pollination, pollination deficits, incompatibility, farmers´ considerations

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Above-ground Biomass Storage Potential in Primary Rain Forests Managed for Production in Costa Rica

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Tropical forests play a fundamental role in mitigating climate change (CC) through storage of carbon in above-ground biomass. However, greenhouse gas emissions through tropical deforestation or forest degradation are sizeable. To mitigate degradation caused by conventional logging various techniques seek to reduce biomass loss in production forests. However, little knowledge exists about the potential of sustainable management for maintaining and restoring the CC mitigation capacity of tropical forests. Our research contributes to knowledge about this potential. We evaluate the above-ground biomass (AGB) of rain forests managed for sustainable production and compare production forest AGB with that of intact primary forests. We also determine the environmental and spatial factors that influence AGB. We estimated the AGB of 141 permanent sampling plots in Costa Rican rain forests (70 plots in production forests and 71 plots in primary forests) with data for the 2000-2015 period. We compared the AGB of production forests with that of primary using linear mixed models and examined the relationship between forest AGB and climate, soil fertility and spatial variables (PCNM eigenvalues) using variation partitioning (VARPART) and multiple linear regression inn the nixed model framework. Mean AGB was higher in production forests than in primary forests. In VARPART, spatial variables had the strongest effect on AGB with a small but significant effect of soil. Regression showed soil K to be positively related to AGB. There was no significant effect of climate, probably because of the short temperature and precipitation gradients. Sustainable forest management in these Costa Rican forests has enabled them to store as much carbon in biomass as primary forests, due to the low intensity logging stipulated by the country's forestry legislation. As a result, sustainable forest management, in addition to the sustainable timber ecosystem service, is also a natural climate solution, maintaining the mitigation potential of Costa Rica´s tropical forests in the current climate context. **Keywords:** Primary forests, sustainable forest management, climate change mitigation, permanent sampling

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Ecological and Food Importance of Vitex Doniana Sweet (Verbenaceae) in Southern Benin

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Non-timber forest products play important ecological, economic, nutritional and medicinal roles. This study aims to determine the ecological and food importance of *Vitex doniana* in Southern Benin. Data on the presence, threats to the ecology, food transformations and others uses of *V. doniana* were collected in the agro-climatic zones of Guinea-Congolese located between 6 ° 25' N and 7 ° 30' N, Sudano-Guinean located between 7 ° 30' and 9 ° 45' N and Sudanese located between 9 ° 45' N and 12 ° 30' N. All data were analyzed using the software R v 4.0.2. The results show that the species is use for food and or commercial need in the local markets. The leaves and fruits of *V. doniana* are sold in the southern region of Benin as a more commercialized species in the markets. But, these uses affect the distribution of the species and reduce considerably its fruit production (35-40%). However, 30-70% of the population of *V. doniana* is threatened by husking and pruning. As the species has multiple uses and its ecology is compromised by poor management, it is therefore essential to restore its habitat and also make its plantations in order to limit the threats weighing on the species in natural habitat. **Keywords:** Ecology, fruit, threats, uses.

Bees and Wasps Responses to Soy Cultivation in 43 Agricultural Landscapes across the Amazon-Cerrado Transition

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Tropical ecosystems have experienced the highest rates of native habitat conversion into agriculture. Agricultural expansions have major negative impacts on terrestrial biodiversity, directly affecting ecosystem services that contribute to increase crop productivity. Bees and wasps play an important role in global crop pollination and biological control of pests. Here, we assess the effects of the type, complexity and amount of native vegetation (Legal Reserves) on bees and wasps within soy monoculture and adjacent Amazonian Forest fragments, Cerrado savannahs, and transitional vegetation between these biomes. Using Malaise traps, we sampled 43 landscapes distributed throughout the state of Mato Grosso, where nearly a third of all Brazilian soy is cultivated. At each landscape we sampled a gradient including three contexts: native remnant core vegetation, remnant edge and adjacent soybean plantation. We evaluated the effect of the amount and complexity of habitat structure on the richness and composition of bees and wasps, considering two scales (buffer 5000 and 1000 m). In total, we collected 143 bee species and 43 social wasp species. Amazonian forest landscapes hosted the highest bee and wasp species richness and abundance. Bee species richness differed between soybean and core native only in Amazonian Forest landscapes while wasp species richness did not differ. The amount of native habitat remaining had a positive effect on both species richness and composition of bees and social wasps. Habitat complexity was a good predictor of wasp species richness. We suggest that further studies would elucidate appropriate land use management guidelines to enhance soybean production while simultaneously promoting natural habitat conservation where intensified agriculture is expanding. **Keywords:** Agribusiness, ecosystem services, fragmentation, Landscape ecology, Legal Reserves

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Agriculture, Forestry and sustainable alternatives III

Cashew Expansion in the Tropics – a Cause for Conservation Concern?

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Agricultural expansion in the tropics is a leading threat to forests and biodiversity. Based on statistics from the United Nations Food and Agriculture Organisation, cashew (*Anacardium occidentale* L.) crop is grown across 33 countries covering 7,101,967 ha and could pose a threat to tropical biodiversity. While the environmental and social impacts of other tropical crops such as palm oil and rubber have been relatively well studied, crops such as cashew nuts have not received adequate research attention despite their expansion in regions of high endemic biodiversity. Here we conducted a systematic literature review to investigate how cashew plantations affect biodiversity and people globally. We applied MaxEnt models to develop maps of cashew land suitability globally and evaluated the spatial overlap of high cashew suitability and global biodiversity hotspots, threatened vertebrates and live aboveground woody biomass. We found that literature was concentrated from Indian and West African regions, showing that cashew harboured a subset of generalist fauna found in reference habitats. Cashew was farmed by smallholders and the increasing reliance on cultivar cashew varieties may put farmers' livelihoods at risk. Under a scenario where the top 40% most suitable for cashew cultivation was considered, the global land area for potential cashew cultivation amounted to ~2,387,400 km^2. The Asian and Latin American regions were most vulnerable to cashew cultivation due to overlaps with global biodiversity hotspots and areas with threatened vertebrates and live aboveground woody biomass. Further research on cashew land use systems is needed to quantify the social and environmental effects. There is a need to evaluate the potential of managing cashew land uses systems to include agroforestry systems that host wildlife and set up sustainability initiatives for the cashew industry to promote better agricultural practices for the environment and people. Our study highlights the importance of studying tropical crops that lack large, apparent land-use conversion footprints but nevertheless affect biodiverse regions through steady, small-scale expansion. **Keywords:** Deforestation, land use conversion, smallholders, cultivar cashew, tropics, spatial modelling

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Effects of Trade Destination on the Environmental Outcomes of the Production of Agricultural Commodities

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Introduction: Drivers of land change in tropical regions vary according to different contexts. This is particularly the case of agricultural commodities, which are increasingly being produced for international markets. For instance, over the last couple of decades, Brazil has exhibited a rapid expansion in soybean production in response to the increasing demand of this agricultural commodity by markets in Asia and Europe. Since around 80% of the soybean produced in Brazil is exported, it has generated much research and policy interventions, yet its socioeconomic and environmental outcomes are still not fully understood. **Objective:** The goal of this study is to evaluate the effects of soybean production for domestic vs. international markets on the spatio-temporal dynamics of land cover and floristic composition. **Methods:** The spatio-temporal trajectories (2000-2020) of land cover and floristic composition in the Brazilian state of Mato Grosso were evaluated, using data and information obtained from multiple sources. These include geospatial data repositories (e.g., Mapbiomas), satellite imagery (Moderate Resolution Imaging Spectroradiometer, MODIS), peer-reviewed literature, and government reports. A synoptic assessment of floristic composition was obtained using an approach based on the direct relationship between floristic similarity (based on plant species composition) and phenologic similarity (based on land surface phenology derived from MODIS imagery). The effectiveness of this approach is attributed to its sensitivity to the stoichiometry of foliar pigments, which varies spatially as a function of plant species composition and temporally with the onset of greenness/senescence. Results: The expansion of soybean in the study area is associated with land cover change while also contributes to floristic homogenization. However, preliminary results show that municipalities with a higher soybean production for domestic markets exhibit stronger associations with land cover change and with floristic homogenization than those for international markets. The simultaneous evaluation of soybean production for international and domestic markets allows the quantification of the environmental effects of trade destination, a frequently neglected factor influencing environmental degradation. **Conclusions:** While the environmental effects of international markets have received much attention by researchers and stakeholders to foster sustainable agricultural practices, the effects of domestic markets have been neglected. Our findings, using soybean as the main agricultural commodity, suggest that supply chain agreements and environmental governance systems need to also consider domestic markets in their management decisions, particularly the implementation of sustainable agricultural practices (e.g., sustainable agricultural intensification) not only in Mato Grosso but throughout Brazil and around the world. **Keywords:** Agricultural commodity, floristic composition, global trade, land cover

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Tree Planting as a Conservation Threat: Assessing the Pan-tropical Expansion of Tree Plantations into Drylands and Protected Areas

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Introduction: As we enter the UN Decade of Ecosystem Restoration, many countries are seeking to meet their restoration commitments through expanding commercial tree plantation cover. Plantation expansions are not well characterized at continental scales, but they have been observed to replace native tropical forests and grasslands. Spatially explicit, consistent estimates of increases in plantation area are needed to assess their impacts on regional conservation efforts. **Objective:** in this study, we use remote sensing data to distinguish tree plantations from natural regrowth and then evaluate the expansion of tree plantations across tropical ecosystems and protected areas. **Methods:** Using the Hansen et al. Global Forest Change (HGFC) dataset to select patches of tropical tree cover gain (25° N to 25° S) between the years 2000 and 2012, we reclassified all large gain patches into one of three classes in 2015 (natural regrowth, tree plantations, and non-forest). The classification incorporated satellite imagery (Landsat, Alos PalSAR, and Sentinel 1), a large, pan-tropical training dataset (n>600,000) and an ensemble machine learning approach to predict the land cover across HGFC gain footprints in the tropics (>90% model accuracy). We then assessed recent plantation expansion into protected areas and sensitive dryland ecosystems, using high-resolution imagery to verify predicted expansions into protected areas and identify the production system involved. **Results:** Expansion of tree plantations dominated increases in tree cover across the tropics (32.2 $\pm$9.4 Mha) with 92% of predicted plantation expansion occurring in biodiversity hotspots. Although prediction uncertainty led to under-detection of tree plantation footprints, overall, we found that expansion of tree plantations into arid biomes was widespread (14% of predicted expansion), particularly in southern Brazil and eastern Africa. Plantation expansion into protected areas varied across continents, biomes, and metrics of accessibility. However, we estimate that tree plantations expanded into 9.2% of accessible protected areas across the humid tropics, most frequently in southeast Asia, west Africa, and Brazil. The most common production systems observed expanding into protected areas were eucalyptus, pine, acacia, rubber, and oil palm. In Latin America and Asia, protected status was unrelated to the presence of tree plantations within parks, potentially reflecting high encroachment pressure there. **Implications:** The observed expansion of plantations indicates that economic considerations frequently took precedence over conservation policies and interests during this time period. These patterns in recent plantation extensification indicate that future expansion may place significant pressure on tropical forest and savanna ecosystems. **Keywords:** Tree crops, restoration, LCLUC, conservation, agroforestry, remote sensing

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Timber Production and Revenue from Secondary Cloud Forest: a Case Study from Mexico

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At present, ambitious international initiatives are in place supporting extensive tree planting programs. However, less attention is paid to existing naturally regenerated areas and how to promote their long-term permanence. Secondary forests account for more than half of tropical forest cover worldwide, sequester carbon rapidly, provide essential ecosystem services and are at high risk of being recleared. Secondary cloud forests (SCF) in particular play a critical role in hydrological regulation and as refuges for biodiversity. To promote their persistence, it is necessary to foster sustainable management, but there is limited information regarding their potential to produce timber. We analyzed: (1) the structure and composition of SCF from Mexico´s forest inventory data (62 plots, 1 ha each), and (2) the selective logging revenue taken from a pilot study. With sensitivity analysis, we explored the effect of timber volume, production costs and price of forest products on the net present value (NPV). The SCF attributes were tree density = 429.4 $\pm$ 35.3 ind/ha (10 cm diameter), basal area = 12.0 $\pm$ 1.1 m2/ha, and wood volume = 78.8 $\pm$ 8.4 m3/ha (including all species present). A total of 298 tree species were reported. Oaks were abundant and their timber has high economic value. They are also used to produce charcoal, an important energy source for rural communities. Improving the processing and marketing for this group has potential for advancing the management of SCF. In the 20-year-old SCF pilot study, standing wood volume was 104.5 $\pm$ 13.7 m3/ha. Landowners could only extract 3% of the standing volume because 34% of the existing volume belonged to species with no market, a high number of trees were of insufficient size (10 -15 cm DBH), and the smallholders had a reduced capacity to process timber. Labour accounted for 55% of production costs, and the financial returns were negative. A positive NPV may result with at least 10% of harvesting intensity, a 20% reduction in productions costs, or a 20% increase in timber price. Major barriers to financial viability include restrictive regulations, low volume and prices of SCF timber species, and a limited market and capacity of smallholders to process timber. Given the high diversity and low income from SCF timber harvesting, multiple use of resources is strategic. The results stress the need for policies fostering multiple use management in SCF in order to alleviate poverty and meet national and global restoration and climate mitigation goals. **Keywords:** Biodiversity, financial analysis, natural regeneration, restoration, selective logging, small-scale forestry

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Agriculture, Forestry and sustainable alternatives IV

Sharing Land with Giants: Habitat Preferences of Galapagos Tortoises on Farms

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Introduction: One of the most pressing dilemmas of our time is determining how to satisfy the demands of a growing human population while still conserving biodiversity. Worldwide, land modification to accommodate human resource needs has caused significant declines in wildlife populations. To help minimize biodiversity loss, we must support wildlife on human-dominated land, such as farms and urban areas, but our knowledge of how to do so is lacking. Agriculture is a major driver of land modification, but also has the potential to play a role in conserving biodiversity. **Objectives:** To support critically endangered ecosystem engineers that use farms, such as giant Galapagos tortoises, we need to understand the characteristics encouraging or hindering them. Methods: To quantify tortoise habitat preferences, we assessed the relationship between tortoise density, habitat structure, and land-use type, by recording tortoise density on farms on Santa Cruz Island, Galapagos, over two years. **Results:** Tortoise density was lowest in abandoned farmland and highest in tourist areas and was most strongly positively correlated with abundant ground cover, short vegetation, and few shrubs. Implications: The habitat features favoured by tortoises could potentially be manipulated to help support tortoise conservation on farms. Measuring wildlife preferences in human-dominated areas is an important step towards balancing biodiversity conservation and human-enterprise. **Keywords:** Habitat preference, wildlife-friendly farming, habitat structure, land sharing, giant tortoise

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Habitat Preferences and Space Use by Blackpoll Warblers in Agroforestry Systems in Colombia

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Introduction / Background / Justification: Habitat is key for survival of migratory species during the non-breeding season and may have profound effects on their annual cycle. Patterns of space use in migrant birds are mostly related to habitat availability and territorial behavior. Space use in migrant birds may also change in response to transformed landscape structure mainly associated to anthropic actions. However, few studies have examined how space use varies between agroforestry systems on the wintering grounds of Nearctic-Neotropical migrants. The Blackpoll warbler (*Setophaga striata*) population is drastically declining and is one of the few that uses the Orinoquia-Amazonian region of South America. Winter habitat use by Blackpoll Warblers has not been described and yet large-scale transformations have occurred in the core of their wintering range. **Objective(s)/Hypothesis(es):** To determine habitat preferences among four land use types and collect space use (e.g. territory size) information on Blackpoll Warblers as an indicator of winter habitat quality. **Methods:** We first carried out occupancy surveys across four habitat types: forest, silvopastures, shade-grown cocoa and citrus plantations. We then selected two habitats with high occupancy rates, cocoa and citric crops in Meta Department, Colombia, to examine space use. We installed 20 Lotek VHF nanotags on Blackpoll Warblers captured in two citrus and two cacao farms on January 2021. Birds was radio-tracked on foot with a handheld antenna during at least 13 days after capture from January to February 2021. We recorded coordinates for

each individual and registered habitat structure´s characteristics. We estimated home-range sizes of individuals using minimum convex polygons. **Results:** Occupancy surveys revealed higher occupancy rate in agricultural habitats than in native forest, with highest predicted occupancy in shade-grown cocoa. Manual radiotelemetry results suggest that Blackpoll warblers exhibit high site fidelity during the mid-winter period in citrus and shade-grown cocoa crops. Home range estimates varied between habitats, being more extensive in citrus crops than shade-grown cocoa. **Implications/Conclusions:** Contrary to expectations, Blackpoll warblers showed higher occupancy rates in agroforestry systems than in the native forest they have replaced. Blackpoll warblers showed high fidelity to these systems, with both occupancy rates and space use data indicating that shade-grown cacao was of higher quality for the species. These results suggest that agroforestry systems (e.g.. Shade-grown cocoa) offer more resources for Blackpoll warblers than natural forest, considering high rates of deforestation and expansion of intensive agriculture/livestock increasing the area of agroforestry systems could help to combat population declines. **Keywords:** Habitat, occupancy, telemetry, Blackpoll Warbler, agroforestry, shade-grown cocoa, Colombia

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Conserving Colombia's Agrobiodiversity: the Case of Wild Cacao

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The biodiversity of native crops in Colombia is under threat due to mainly human activity including land use, climate change and most recently deforestation in conflict-affected areas. The Amazon and the Choco regions that host many wild species of cacao (*Theobroma cacao*, *Theobroma* or *Herrania*) have been significantly affected by such threats. Assessments of the extent of damage is often focused on wild species, however, rarely do they cover crop wild relatives. Surveys of crop wild relatives need to be undertaken to understand the impact of human activity and find ways to mitigate these losses. This scientific evidence should be the basis of any conservation policy established by government. Between 2018 and 2019, expeditions were conducted in the Bajo Caguan-Caqueta and La Victoria Choco regions to explore the potential of wild species of cacao for the development of cacao agriculture in Colombia. These genetic resources are essential for the future of the cacao industry but have experienced extensive loss of habitat. Detailed field surveys in search of cacao crop wild relatives allowed us to identify extreme climate refugia. *Theobroma chocoense* were sampled as well as numerous types of wild *Theobroma cacao* found on the riverbanks of the Caguan and Caquetá rivers. Based on data gathered during these expeditions, we estimate that deforestation is occurring at a rate of 0.7% annually in the Amazon region, which could reduce refugia for wild cacao by half in the next 50 years. We propose the creation of an agrobiodiversity zone of 700,000 hectares in the Bajo Caguán-Caquetá region to conserve wild cacao and other threatened species and habitat. Agrobiodiversity zones were first established in Peru to protect wild species of potatoes and would be the first of its kind in Colombia. This strategy would underpin Colombia's commitment to increase conservation areas by 30 percent by 2030, announced as part of the COP26 Goals. **Keywords:** Agrobiodiversity, conservation, cacao, parientes silvestres, Colombia

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Agriculture, Forestry and sustainable alternatives V

Socio-ecological Production Landscapes for Biodiversity Conservation and Resilient Rural Development: The Case of Las Cruces, San Vicente De Chucuri, Colombia

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Background: Social-ecological production landscapes (SEPLs) are dynamic mosaics of land-uses that have been shaped by interactions between people and nature in ways that maintain biodiversity and provide humans with goods and services. SEPLs can be considered an opportunity for biodiversity conservation and for sustainable and resilient rural development. The mountain landscape of Las Cruces in San Vicente de Chucurí (Santander, Colombia) is made up of a dynamic mosaic of pastures, agroforestry systems with cacao or coffee, and other fruit trees, as well as forest fragments and the Andean forests of the Serranía de Los Yariguíes National Natural Park. **Objective:** Here we present an integral evaluation of Las Cruces and demonstrate how this SEPL (1) maintains biodiversity and ecological services through a gradient of agroforestry management, (2) shapes the socio-economic conditions of the inhabitants, and (3) the perception about social-ecological resilience. **Methods:** We assessed the biodiversity of plants, birds, mammals, and dung beetles as well as vegetation structure across an agroforestry management gradient and natural forests. We evaluated socio-economic conditions and ecosystem services using semi-structured interviews and perceptions about the landscape using social-ecological resilience indicators. Synthesizing the obtained information allowed us to develop spatially explicit land-use scenarios and narratives for future development. **Results:** We find that the SEPL of Las Cruces conserves a complex habitat structure with high levels of carbon storage and biodiversity (e.g., more than 200 bird species) that produces a diversity of goods (i.e. mainly food) for the local population as well as global markets. Social-ecological resilience indicators highlight that people consider Las Cruces strong in biodiversity and ecosystem protection as well as in natural resources and agrobiodiversity whereas they identify opportunities for improvement of well-being, governance, innovation and knowledge, and social equity. Scenario development and analysis of trade-offs show expanding agroforestry as an opportunity for maintaining biodiversity while increasing food production and carbon storage. Finally, we show how Las Cruces has evolved from a history of land-use change driven by civil war, rural land reforms, displacement, and agricultural innovation. **Implications:** Las Cruces serves as an inspiration for navigating towards sustainability and resilience in the Andean landscapes of Colombia. The lessons learned from this study may not only foster a transdisciplinary dialogue between academics and local communities for the integral study of SEPLs in Colombia but also empower them to actively shape their future. **Keywords:** Social-ecological production landscapes, land-use change, biodiversity, ecosystem services

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Potential Native Timber Production in Tropical Forest Restoration Plantations

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Introduction: Forest restoration is a remarkably effective method of mitigating climate change, biodiversity, and ecosystem services. The activity is still viewed as non-competitive because of its high associated costs and low direct monetary return, resulting in the necessity of making it an attractive activity to multiple stakeholders. For the restoration of tropical forests, a central issue is acquiring reliable growth data for timber-producing species, which is necessary for determining optimized management plans. **Objective:** To Assess ecological and economic aspects of native timber throughout the calculation of harvest cycles in restored forest systems established for ecological purposes. **Methods :** We analyzed data from 13 inventories performed in restored forests in São Paulo State, Brazil, and used Growth-Oriented Logging (GOL) to build growth models and define harvest cycles, and we compared it with a multi-species established diameter used to define harvest time (35 cm DBH). Finally, we designed an optimized scenario based on 30% higher diameter values for silvicultural improvements applied to native species. **Results:** Harvest time criteria must be improved once each species shows different minimum and ideal harvest times, which do not fit in the criteria for harvesting based on the diameter of a multi-species tree. As **a result of our** study, tree species can be divided into four growth-rate classes based on their ideal harvest age: 1. Fast (before 25 years), 2. Medium (25-50), 3. Slow (50-75) and, 4. Super slow (75-100), 30% of the species do not reach the previously established 35 cm stem diameter before 100 years. There is a trade-off between time and productivity where (1) the rotation following GOL would be 40% longer and the basal area would increase 45%, while (2) the rotation following the diameter criteria is 61% shorter but leads to a loss of 58% in the basal area. An optimized scenario resulted in trees that can be harvested, on average, 25% earlier with a 37% higher basal area, reinforcing the need for silvicultural programs to increase native timber productivity. **Conclusions:** Within 15 to 92 years after tropical ecological forest restoration, wood can be harvested. Harvest cycles for successive harvests including different species vary from 6 to 20 years. This study provides guidance for native timber management in restored forests, presenting criteria to be applied in economic-ecological principles and making forest restoration a competitive land-use strategy. **Keywords:** Tropical forestry, benefits from biodiversity, productive forest restoration models

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Farmers' Dilemma: Sell Crops to Improve Income or Consume Them for Better Nutrition?

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Introduction: Farming systems are key to attaining the Sustainable Development goals of Zero Poverty, Zero Hunger, and Life on Land. Yet, more than half of the food-insecure people live in rural areas. Agriculture often fails to satisfy the nutritional and economic needs of constrained smallholder farming systems. In addition, an increasing population and lack of job opportunities can result in higher land pressure and agricultural expansion. Ensuring farmers have adequate nutrition and stay above the living income is essential for reducing agricultural encroachment and (agro)biodiversity loss. **Goal:** This is a transdisciplinary study that assesses the complexity of food insecurity across smallholder farming systems, as affected by the agrobiodiversity and farmers' objectives, drivers, assets, and economic performance. **Methods:** The study was conducted in Donomadé, a marginalized rural village in Togo located next to the Togodo national park. Through 81 surveys and 28 in-depth interviews, qualitative and quantitative data on demography, market integration, production systems, and farmers' perspective on agriculture were gathered. A household archetypal analysis was performed. The mean adequacy ratio (MAR) was calculated based on the consumption of one Adult Male Equivalent (AME) of 18 nutritional elements (e.g., macronutrients, micronutrients, and vitamins). MAR can range from 0 to 1, with 1 meaning that the demand for all elements was met. The MAR was used to compare food security across archetypes. **Results:** On average, households grew a relatively high diversity of crop species in small areas (four species per 0.8 ha). However, crop species compositions usually lacked Ca and vitamins a, b2, and C. No household was food secure. The MAR varied across the five archetypes identified (A-E). Archetypes with the best MAR had low land pressure (expressed in AME ha^{-1}). Households' food security was also impacted by how much food they sold and bought, reducing the MAR potential by up to 46%. Conclusions: Even the most successful households did not consume enough food to meet their dietary requirements. Interventions to improve agrobiodiversity could increase the provision of certain nutritional elements. Due to a lack of income

alternatives, households are forced to sell part of their production. The food sold is often not compensated by the food bought, creating a deeper gap in households' food security. Against a backdrop of demographic growth and land fragmentation, farmers struggle to satisfy their nutritional and financial needs. This often leads to an increasing disinterest in farming, reduction of agrobiodiversity, and migration flows. **Keywords:** Food security,s mallholder farming systems, sub-Saharan Africa

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FiNCO Farms for Knowledge Exchange: a Colombian Seed for a Good Anthropocene

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Background: In the Anthropocene geological epoch, we humans are required to increase our ability to navigate changes and drive social-ecological transformations to return to planetary boundaries. For that, we need to create new ways of connecting to nature and increase our abilities for transdisciplinary work. Family farms in the Colombian Andes have been navigating changes with modalities of integrated management that recognize family interdependence with nature, illustrating how resilience works on a small scale. To highlight the value of family agriculture and to navigate changes at the local scale we designed and implemented a strategy we called FiNCO - farms for knowledge exchange. **Objectives:** Present and synthesize, in the form or step-by-step process, the insights gained from designing and implementing FiNCO in San Vicente de Chucurí (Santander Colombia). Introducing the concept of Seed for good Anthropocene and using it to describe family farming and FiNCO. **Methods:** Personal and collective reflection on designing and ad hoc implementation FiNCO was used for consolidating key insights gained by the core implementing team to propose a step-by-step process. The initiative of seeds for a good Anthropocene was used as a framework for our reflection. Written project reports, presentations, and interviews were used to construct the process timeline, support our arguments and help our memory. **Results:** FiNCO consolidated as a strategy that identifies and strengthens resilient family farms to share their knowledge and life experience with others, establish a space for transdisciplinary dialogue within the university and promote sustainable and resilient forms of landscape stewardship using social-ecological resilience as an inspirational and analytical framework. The sustainability of FiNCO, despite ending research funding, lies in the formation of a transdisciplinary team that continues to be engaged and inspired by the process and its actors. Actors in San Vicente continue implementing actions towards resilience and the strategy is expanding to Zapatoca. **Implications:** FiNCO can be seen as a seed for a good Anthropocene that shows, in a local context, how academic and researcher institutions can engage in a transdisciplinary dialog with rural communities to support landscape stewardship and contribute to the formation of the professionals needed for embracing Anthropocene challenges and creating a larger-scale transformation. The insights and step-by-step process can inspire and guide transformations elsewhere. **Keywords:** Family agriculture, knowledge exchange, landscape stewardship, transdisciplinarity, resilience thinking

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Are Environmental and Social Justice Goals Mutually Exclusive? Exploring Inclusive Businesses in Peru's Cacao and Coffee Sectors

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Sustainability standard certification is the main governance approach aimed at encouraging the adoption of agroecological practices and at enhancing human well-being in global agri-food supply chains. However, evidence points to limited and sometimes even adverse effects of certification schemes on the farmers, workers, and community wellbeing. Alternative or complementary approaches may challenge these barriers with the expectation that they will achieve the same environmental goals. Inclusive business strategies are gaining relevance as such an alternative approach taken by private sector actors. These strategies allow smallholders to have ownership and voice in business enterprises further up the value chain. Examples of these schemes include smallholders having shares in the processing or trading company, given a seat on an enterprises board of directors, or participating in collective enterprises such as farmers' cooperatives. Since certification and inclusive business strategies are studied in isolation, it remains unclear whether inclusive businesses can overcome the barriers to well-being impacts that many certification schemes face while ensuring the adoption of agroecolgoical practices such as agroforests that certification schemes have achieved. This study explores to what extent and how inclusive business strategies are effective in achieving positive well-being and sustainability impacts to strengthen social-ecological resilience . We present an assessment of nine selected cases of inclusive businesses from the cacao and coffee value chains in the Peruvian Amazon. Through 31 key informant interviews of farmer leaders, business executives, regional and national governmental officials, national and international NGO directors, aid agency representatives, and certification agency officials, we evaluated these enterprises on their inclusion of smallholder producers, women, and youth in ownership, degree of smallholder voice in decision making, sharing of risk and benefits, and environmental outcomes. Results show that inclusive business strategies offer entry points to better well-being outcomes for smallholders, enhancing social resilience. However, they are no better than certification schemes in encouraging the adoption of agroecological practices and in some cases fare worse than certification schemes in influencing their adoption. They have had little effect on ecological resilience. We conclude that the institutionalization of environmental justice inclusive business strategies and certification schemes may be better at achieving the dual goals in middle income countries and thorughout the Global South of encouraging the adoption of agroecological practices and enhancing human well-being in agri-food systems, which enhance social-ecological resilience. **Keywords:** Amazon, collective action, value chains, agroecology, agroforestry

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Assessing Resilience to Global Change: a Case Study of Cocoa Agroforestry in the Amazon of Colombia

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In the last fifty years, human activities have altered ecosystems around the world, generating a phenomenon on a planetary scale called global change. This phenomenon has driven transformations in local and national economies, affecting food production processes, and has challenged us to improve our knowledge on how to manage it, respond to it, rethink production systems, and design strategies to restore and protect ecosystems. In the search to understand the responses and adaptation strategies to global change, numerous development agencies, non-governmental organizations, and research networks have found in the concept of resilience an alternative to design more efficient management instruments. Although at the theoretical level there is significant progress, its measurement is still intricate and requires great efforts given the complexity of socio-ecological systems, the low availability of historical data, and the limited knowledge of the social and cultural practices of the communities to respond and adapt. We will present the results of a research study that analyzed the resilience capacity of cocoa production systems in three departments of the Colombian Amazon: Caquetá, Putumayo, and the Guaviare. Resilience is analyzed in relation to climate variability disturbances and the main hypotheses of the research state, on the one hand, that the resilience capacity of production systems depends on five criteria: good production management, technical knowledge of producers, quality of the natural resources available, diversity of associative schemes that promote commercialization, and ecosystems heterogeneity and landscape conservation. On the other hand, another hypothesis proposes that the resilience capacity changes according to the geographical context and the socioeconomic and political particularities where the production systems are developed. The research has a socioecological approach and is qualitative and quantitative. We collect data through interviews, surveys, and a review of secondary sources. For the measurement of resilience, the averages of the sum index and BRIC (Baseline Resilience Indicator Community) were used. Our results show that the resilience of cocoa production systems is low due to three aspects: first, the limitations to manage the production systems, second, the problems in the financial management of the associations, and third, the low heterogeneity of the passages due to deforestation and the growth of livestock activity. The results will contribute to generating knowledge and recommendations for the creation of planning strategies that guarantee a better development of cocoa production systems currently threatened by climatic humidity.
Keywords: Resilience, cocoa agroforestry, climate variability, BRIC index, socio-ecological systems, mixed

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Tree-ring Anatomy and Microdensity of Tree Species from the Central Selva of Peruvian Amazon: Sustainable Forest Management and Biodiversity Conservation

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The Amazon is the largest world neotropical forest with its biodiversity recently recorded by 14,003 species and the importance highlighted for containing 40-60% of the carbon of the world's terrestrial vegetation. In fact, these tropical forests have been registering a high rate of deforestation due to the wood demand increase, requering public policies that guarantee sustainable forest management, biodiversity maintenance and environmental services, especially in a global climate change scenario. To contribute to these objectives, it is recommended the tree-ring analysis and characterization to determine the tree species age, trunk annual growth reconstruction and, also, allow to correlate with climatic parameters and extreme events. The "Selva Central" Peruvian Amazon tropical forests of Chanchamayo, Satipo (Junín) and Oxapampa (Pasco) provinces were surveyed and selected five important families, Caryocaraceae (*Caryocar villosum*, almendro), Juglandaceae (*Juglans neotropica,* nogal), Lauraceae (*Aiouea montana*, moena blanca, *Aniba sp.*, moena amarilla, *Nectandra reticulata,* moena negra, *Nectandra reticulata*, moena rosada, *Ocotea sp.*, moena amarilla), Moraceae (*Brosimum utile*, leche caspi), Rhizophoraceae (*Sterigmapetalum obovatum,* palo verde). The wood samples of each tree species were analyzed applying the wood anatomy, dendrochronology and X-ray densitometry methodologies recommended for the tree-rings characterization and identification. The wood samples cross sections were sanded (80 to 1200 grains/cm2 sandpaper), digitized (Epson Expression 11000XL scanner, 1200 dpi) and the tree-rings were characterized for macroscopic anatomical structure (IAWA, 1989) and classified. according to the distinctness. Subsequently, wood samples were glued to a wooden support and cut transversally (1,5 mm thickness, double parallel circular saw), conditioned (24 hours, 20 °C, 60% relative humidity, 12% humidity) and irradiated in a X-ray equipment chamber (Faxitron X-Ray, LX-60, 5.9 kV, 33 s) with a calibration wedge (cellulose acetate). The results allowed to determine the tree-ring boundaries and width (through digital radiographic images and measurement table). In the sequence, the width and microdensity tree-ring radial profiles were constructed, providing the determination of annual increment of tree species trunk biomass and carbon. The results were discussed in the context of sustainable logging rotation, biodiversity conservation and the potential of Peruvian tropical Amazonian tree species produces and storage annually biomass and carbon in their trunks. **Keywords:** Tropical Amazon, carbon, climatic change, dendrochronology, X-ray densitometry, biomass

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Diversity, Biogeography and Conservation-through-use of Colombian Edible Plants.

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Colombia is the second most biodiverse country on earth, hosting approximately 10% of its total plant diversity. However, despite its unrivaled diversity of natural resources, more than half of its population is affected by malnutrition. This incongruous trend has been triggered by the green revolution and the growing involvement of the country in the global trade market of food products. This portended homologation of food systems to a few commercial crops, often nutrient-poor and little adapted to local environmental conditions, at the expenses of native species, which are progressively disappearing from people's plates, land and, ultimately, memory. By adopting a taxonomic and biogeographic approach, the present study unveils the diversity and distribution of Colombian edible plant species (EPS). Moreover, it advocates the hidden potential of neglected and underutilized edible species (NUS) as an effective tool for tackling poverty, food insecurity and environmental degradation. Finally, it stresses the importance of culinary traditions and innovations for the development of conservation-through-use initiatives. A total of 3,805 EPS were retrieved from a combination of 30 datasets and publications and reconciled to taxonomic backbones. Their distribution and relative abundance were analysed across 13 bioregions through GIS-based tools. Several hotspots were found in the country, both in terms of species richness and conservation importance, such as the Andean humid forests, and a significant level of endemicity was found in EPS composition across the different departments, suggesting the development of department-specific conservation actions. However, substantial conservation gaps are still present from a taxonomic and geographic perspective. Some of the most species-rich genera of EPS, such as *Passiflora*, *Annona*, *Inga* and *Bactris*, still lack comprehensive conservation assessments in the country. Additionally, lack of adequate information about species distribution in the departments of Cesar, Sucre, Atlántico, Vichada, and Guainía indicates the urgent need for focused investigation in the Caribe and Llanos bioregions. Based on the above findings, along with further ethnobotanical study of the diverse regional culinary uses of the Colombian NUS, tailored prioritization for future research and development of conservation-through-use initiatives may effectively be put in place in the country. An example of these could be represented by the collaboration between restaurants and chefs and rural communities, through which a new demand and sustainable value chains for local native ingredients could be created and consolidated. **Keywords:** Edible plants, NUS, conservation-through-use, biogeography, taxonomy, Colombia, food sovereignty

Agriculture, Forestry and sustainable alternatives VI

Delivering Knowledge on Useful Plants and Fungi to Support Conservation and Sustainable Development in Colombia

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Colombia is the second most biodiverse country in the world and is recognised as one of the most ethnically diverse countries. Despite its biocultural richness, the country is marked with vast social inequality and rural poverty. Following decades of internal armed conflict, the country's 2016 Peace Agreement has provided new opportunities for its socio-economic growth, representing a threat to Colombian biodiversity or an opportunity for sustainable development based on its treasured natural capital. In 2019, the Royal Botanic Gardens, Kew delivered "Col*Plant*A: Colombian resources for Plants made Accessible" (http://colplanta.org/), an authoritative, expert-driven, open access, online portal for botanical information on Colombian plants. As a continuation of Col*Plant*A, between 2019 and 2022 we carried out the Useful Plants and Fungi of Colombia (UPFC) project. The overarching aim of UPFC was to document and broadly disseminate knowledge on the useful plants and fungi of Colombia, with the ultimate goal of developing pathways to enhance nature's contribution to the wellbeing of people in this country. This project was completed on Feb. 2022, with 140 outputs, including 5 portals/websites (https://www.kew.org/upfc, https://in-colombia.org/, http://redin-colombia.org/, https://colplanta.org/, and https://colfungi.org/), 160k updated species profiles for plants and fungi, 4 books (including the Catalogue of Useful Plants of Colombia, and the Catalogue of Fungi of Colombia), 5 booklets, 7 scientific reports, 13 manuscripts (2 published, others under review), 23 conference presentations, 9 videos, and 4 apps. It involved 119 researchers (50 from Kew, 35 from Humboldt Institute and 34 external collaborators). The project provided a framework to develop and promote a market for useful indigenous species and their high-value products whilst protecting the surrounding natural resources (REDin-Colombia) and supporting local communities' livelihoods. Likewise, it delivered capacity building activities, reaching a broad audience. With the participation of a multinational team, the project compiled and generated knowledge on over 36,000 plants and fungi, and developed pathways for tackling socio-environmental challenges and contributing to Colombia's biodiversity-based Bioeconomy. This presentation provides an overview of the project's main highlights and achievements, as well as reflections on lessons learned and future steps. **Keywords:** Bioeconomy, uses, green growth, useful plants, useful fungi, sustainable development

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Resilience To Climate Change In Small Scale Food Production Systems: Pacific And Caribbean Tropical Islands

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Food production has played an important role both being cause of many environmental problems and being greatly affected by environmental changes such those from climate change. Countries around the world are struggling to find sustainable solutions to improve food security and sovereignty, especially island territories. Over 2 billion of people globally are involved and depend on small scale agriculture and fisheries and produce one third of the food consumed by humans. Thus, many of these systems still base their production in traditional, indigenous, and local practices that have been inherited for many generations. These practices

have been shaped from a close relationship between humans and nature and are now being challenged by the effects of the changing climate. In particular, those small-scale food production systems located in tropical islands are at the frontlines of climate change need to be prioritized and include in decision-making at different scales. The study aims to identify drivers that determinates resilience to climate change in food production systems such fisheries and agriculture in different islands from a comparative approach. With the support of local community's stakeholders, surveys and focus group discussions took place between July 2021 to February 2022 in three case studies: Republic of the Marshall Islands, Pohnpei in the Federated States of Micronesia and San Andres y Providencia in Colombia. Preliminary findings from 221 surveys are: a) transition to *cash cropping* (including monoculture copra and the use of chemical inputs) has represented a strong shift away from traditional low-input and diversified agroecological/agroforestry systems, b) major challenges for food production in islands communities *are* related to *soil erosion and overfishing,* c) main strategies to adapt the impacts of climate change are adjusting sites (planting/harvesting *grounds, changing land/sea use*) and times (*seasons/schedules, modifying months and hours to fish*) for farming/fishing (nearshore). Lastly, *recovering ecosystems* and the *revitalization of traditional/local knowledge* (home gardening, agroforestry, traditional plant associations, mulching and natural fertilization) were perceived by the respondents as the main factors to decrease vulnerabilities and increase resilience to the impacts of climate change, which are starting to be implemented mainly from government initiatives. These findings are allowing to acknowledge the need for expansion of ecologically sensitive production such as implementation nature-based solutions (nutrient and pest management in farming / fishing techniques) and integrating ridge to reef approach. **Keywords:** food systems, traditional/indigenous/local knowledge, resilience, climate change, islands

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Long-term Demography of Guaiacum Sanctum (Zygophyllaceae) in Southeast Mexico May Help in Defining Ecological Basis for Sustainable Timber Harvesting

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Timber harvesting from natural tree populations generates mortality of individuals due to logging and associated damage to non-commercial stems. *Guaiacum sanctum* (Lignum vitae) is a threatened slow-growing timber tree species listed on CITES-Appendix II and in the IUCN Red List. The species was intensively logged in several Central American countries and this illegal use plus deforestation and changes in land use led it to decline and to the border of extinction in some areas. At the moment, Mexico is the only country with important populations under timber harvesting. We analysed the dynamics of exploited and unexploited populations of this species Guaiacum sanctum (Lignum Vitae) during the 2004-2022 period on the Yucatan Peninsula, Mexico, and explored possible sustainable harvesting regimes. Stage-specific survivorship, growth, and fecundity rates were estimated from permanent 1-ha plots at three sites (under harvesting, 40 ys Old-harvested populations and 40 ys old population in protected areas). Transition matrix models were constructed to simulate different hypothetical mortality scenarios on non-commercial (1-25 cm diameter at breast height, dbh) and commercial trees ($>$ 35 cm dbh) considering different rotation lengths. Population density was five orders of magnitude higher at the exploited than at the unexploited sites, but three populations had abundant regeneration. Populations showed the highest mortality rates in the seedling ($<$ 25 cm height) and juvenile stages (25.1-149.9 cm height) and very low mortality in the adult stages (individuals $>$ 1 cm DBH). Growth was slow for seedlings and saplings ($<$8 cm height per year) and for adults (mean + s.e. = 1.9 + 0.2 mm in dbh per year). Populations have been growing, although the finite population growth rate was faster in the unexploited (l.081) than in the exploited population (1.033). Permanence in the non-commercial sizes had by far the highest elasticity values, indicating that survival at these stages had paramount importance for l. Simulations suggested that logging of commercial trees ($>$ 35 cm dbh) had a low impact on l for a harvesting intensity even up to 100% of all stems. In contrast, small increases ($<$ 10%) in the mortality rate of non-commercial trees (1-25 cm dbh) generated strong negative effects on l. Our simulations suggest that an optimum sustainable harvesting regime depends on a combination of very low damage to non-commercial trees (2-8 %), high harvest levels (75 %), and rotation periods of 10 years. **Keywords:** Campeche, Semi deciduous forests, Yucatan Peninsula

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Maintaining Andean Bear Populations and Improving Productive Practices of Rural Communities at the Western Range of Colombia

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Andean bears are distributed throughout the tropical Andes region at elevational ranges from sea level to *paramo* ecosystems. One of the main threats to the species across its range is habitat loss and fragmentation. How fragmentation of natural habitats and potential geographic isolation may impact the occupancy patterns of the species had not been evaluated in Colombia. As a way to assess the effects of conservation strategies, the *Conservamos la Vida* initiative has been evaluating bear occupancy pattens along approximately 8600 km^2 in one of five core conservation units identified for Andean bear conservation in Colombia. The Tatamá-Farallones-Munchique conservation unit (TFM-CU) is located along the western range of Colombia and encompasses three National Natural Parks. We implemented participative conservation strategies and adjustments to farming practices to improve habitat connectivity along the TFM-CU, in 87 private properties, through the signature of 65 conservation agreements that resulted in the isolation of 1,455 ha for strict conservation and the improved management of 1,325 ha. Using dynamic occupancy models, we evaluated occupancy patterns between 2016-2021 as a proxy of change in population status since the initiative started. Results showed that occupancy levels increased between 2016 (ψ=0.53 $\pm$0.039) and 2021 (ψ= 0.75 $\pm$ 0.049). This increase in occupancy was related with the increase in habitat availability across the TFM-CU. Average site extinction probability was low (ε= 0.24) and is explained by the proximity to roads. Management and productive vulnerabilities and negative perceptions towards Andean bears of the communities co-existing with Andean bears at the localities where *Conservamos la Vida* performed actions decreased significantly along the core unit. Currently, 13 coffee producer's beneficiaries are organized and created a community association for selling a high-quality coffee that promotes Andean bear conservation. The initiative generated an environmental education program that have been implemented in 1have been implemented in 14 rural schools promoting the importance of Andean bear conservation. *Conservamos la Vida* initiative allowed the generation of a robust baseline about the conservation status of Andean bear and improved the income of families in the TFM-CU, increasing the quality of life of rural communities that co-exist with Andean bears in the western range of Colombia. **Keywords:** Occupancy, ecology, human-bear bonflicts, bonservation agreement, Trmarctos ornatus.

Animal functional ecology

Repeated Evolution of Unorthodox Feeding Styles Drives a Negative Correlation between Foot Size and Bill Length in Hummingbirds

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Introduction: Differences among hummingbird species in bill length and shape have rightly been viewed as adaptive, in relation to the morphology of the flowers they visit for nectar. In this study we examined functional variation in a behaviorally related, but neglected feature: hummingbird feet. *Hypothesis:* Hummingbird species that cling sideways or upside down by their feet while feeding on flowers—or illegitimately as nectar-robbers—have larger feet and shorter bills than species that feed exclusively while hovering. *Methods:* We gathered records of hummingbirds that cling to feed—an *unorthodox* feeding style. We measured key features of bills and feet for 220 species of hummingbirds and compared the 66 known "clinger" species to the 144 presumed "non-clinger" species. We mapped these behaviors on a phylogeny of hummingbirds to estimate the number of independent origins of clinging while feeding on flowers. After applying a statistical technique to filter out the confounding effects of body size, phylogeny, and elevation on the characters we measured, we looked for the hypothesized differences between clingers and non-clingers. Results: Once the confounding effects of body size, phylogeny, and elevation have been accounted for, hummingbirds display a surprising, but functionally interpretable negative correlation. Short-billed species have evolved exceptionally long hallux (hind-toe) claws—independently, more than 20 times, and in every major clade, that allow them to cling while feeding on flowers—legitimately or illegitimately. Compared with clingers, non-clingers have longer bills and smaller feet. **Conclusions:** The biomechanically enhanced feet of clingers allow them to save energy by clinging, especially at high elevations, where hovering is exceptionally costly. In contrast, long-billed species forfeit the energetic advantage of clinging to feed, as most plant species with long-corolla flowers—by their morphology—enforce hovering, but generally offer large energetic rewards per flower, driving a tradeoff that accounts for this unusual negative correlation in hummingbird morphology. **Keywords:** Hallux claw, tarsometatarsus, functional morphology, behavioral phylogenetics, clinging, nectar robbing

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Deconstructing Functional Diversity to Better Conservation Research and Application Using a Case Study of Colombian Butterflies

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The study of ecological communities increasingly and necessarily incorporates species traits to more wholly understand effects of environmental change on community structure and function. However, consideration of traits is often limited due to incomplete sampling across taxonomy and the narrow suites of trait categories most often measured and considered. This burgeoning topic of functional diversity (FD), as informed by multi-dimensional analyses of species traits, can provide key insights into cascading consequences of changing ecological communities and can be key to the field of conservation. This utility, however, is contingent on the adequate interpretation of functional diversity and deconstruction of the multivariate statistical tools used to calculate FD metrics. Here we examine the patterns of functional diversity across elevation and land use in the Colombian Andes, and the relationships between trait and species richness. We comprehensively sampled butterflies of the family Nymphalidae in paired forest-pasture sites at two distinct elevations and measured fine-scale trait data of individuals of all species corresponding to three categories: size, appearance, and physiology.

We expected FD to differ across sites and had several predictions regarding trait diversity across habitat types, including for forests generally to harbor more species and trait diversity than pastures in all categories, and for higher elevations to have lower morphological but higher physiological trait diversity. While we detected distinct taxonomic structure and richness across habitat types and lower species diversity in open compared to closed canopy habitats, patterns of trait richness across habitats were less conclusive. We found distinctly different patterns when traits were analyzed together as in classic FD studies compared to when exploring one trait category at a time. Functional diversity, no matter how measured, was largely decoupled from taxonomic species richness. This study demonstrates that despite low species richness, within the existing landscape of the Colombian Andes, open-canopy habitats harbor high trait diversity. It also highlights the disparate behavior of patterns of trait diversity across different trait categories and the importance of fine-scale data to deeply explore patterns of ecologically and evolutionarily related traits. Finally, these analyses demonstrate the need to more carefully interpret FD analyses to understand which traits are most likely to differ across space and time and which traits are at highest conservation risk. **Keywords:** Nymphalidae, Colombia, Andes, Lepidoptera, traits, diversity

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Animal and Plant Functional Diversity Play a Key Role in the Biogeochemical Carbon Cycle in the Amazon

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Introduction/Background/Justification: Global diversity loss may be altering the functional diversity and composition of biotic communities, thus affecting ecosystem functioning, such as soil carbon storage. The influence of mammal and tree richness and trophic interactions on carbon cycling has been recently reported in the Amazon Forest (Guyana). However, it remains unclear whether trait diversity of these mammal and tree communities affects soil organic matter composition and whether the link between this biodiversity and soil carbon is mediated by effects on microbial communities. **Objective/Hypothesis:** Our work aims to investigate the role of mammal and plant functional diversity in the quantity and type of soil organic matter (SOM) accumulated in the Amazon. We hypothesized that variation in mammal and plant richness and phenotypic diversity promotes variation in SOM composition mediated by effects on microbial communities and their carbon consumption. **Methods:** We combined field observational richness data and open-access trait data of 48 mammal species and 171 plant species recorded across 4,800,000 ha of Amazon rainforest (Guyana), to assess multidimensional functional diversity (FD) indices for 72 mammal and tree communities. Molecular composition of SOM was analyzed in 532 topsoil samples using attenuated total reflectance Fourier-Transform Infrared (FTIR-ATR) spectroscopy, and sole-carbon source utilization patterns of soil microbes were obtained by using EcoPlates^{TM}. **Results:** Mammal and plant diversity contributed to the accumulation of different SOM components. Carbonyl and aliphatic SOM content decreased in mammal communities with higher functional richness and evenness but was not related to plant functional diversity. Moreover, soil microbial communities differed in global carbon source utilization and these differences were highly correlated with plant and mammal functional diversity from each community. **Implications/Conclusions:** We show that microbial communities are linked to aboveground mammal and tree functional diversity and to SOM composition in the Amazon. Our results will help to better understand the mechanisms regulating the relationship found between biodiversity and carbon concentration in soils, and thus, help inform decisions about biodiversity conservation and ecosystem restoration in the context of global change. **Keywords:** Aboveground diversity, Amazon soils, carbon cycle, functional diversity, microbial communities

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Climate change: impacts and solutions I

Projecting Climate Change Impacts on the Butterflies of Tropical Asia: Overcoming Data Challenges for Diverse Insect Communities

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Introduction / Background / Justification: While research on the climate change impacts on species distributions is widespread, major data gaps remain. Butterflies in particular have been the subject of key studies on climate-driven range shifts but the possible consequences for tropical butterflies are largely unknown despite the fact that most butterflies are tropical (~%90). Objective(s)/Hypothesis(es): Collect distribution data on the butterflies of tropical Asia , evaluate environmental correlates of distributions and relationships to climate and estimate possible warming impacts on region-wide diversity. **Methods:** We compiled a species occurrence dataset for the butterflies of tropical Asia through GBIF accessions and literature extraction, specifically targeting geographic gaps in the database. For regions not well represented by GBIF, we gleaned 16,127 additional records from published literature, including books, articles, and checklists. Altogether we amassed over 298K records for 3167 species (of ~4000 species estimated in the region). We constructed species distribution models only using records that were separated by at least 10 km, and only analyzed species with at least ten records. We extracted climatic conditions such as precipitation seasonality and mean temperature of wettest quarter for each record, and modeled species occurrence against these climatic variables using regression and machine-learning techniques. We further projected an optimistic (RCP26) and pessimistic (RCP85) climate change scenario to evaluate possible warming impacts. **Results:** We successfully ran species distribution models for 1031 species. We identified North Sumatra, Peninsular Malaysia, South Sulawesi as butterfly diversity hotspots. Our results also indicated widespread projected declines in species diversity in East Asia and parts of Southeast Asia (e.g. Borneo) but also large areas of no decline or change (e.g. mainland Southeast Asia). Overall, we estimated an average decline of eight species in 50 years for any given location with a wide range across the region (95% CI for RCP26: -61-36, RCP85: -67-42). **Implications/Conclusions:** In light of on-going evidence of insect declines globally, major holes in our knowledge of insect communities in the tropics challenge accurate detection of trends and informed conservation intervention. Species distribution models can help to identify potentially vulnerable regions or demonstrate the effectiveness of different conservation actions (e.g. protected areas) – however, care must be taken to understand biases in the data, especially in poorly sampled tropical insects. **Keywords:** Climate change, butterflies, species distribution models, tropical Asia.

Glacier Influence on Bird Assemblages in Habitat Islands of the High Bolivian Andes

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Global trends in ice mass loss imply important changes on biodiversity. Glacier regression is expected to be more pronounced in narrow-sized glaciers with relatively small accumulation zones, particularly in tropical mountains. The effects of these changes further affect glacier-related ecosystems that strongly depend on glacier runoffs and count for important aquatic and terrestrial biodiversity. Wetlands in the dry landscapes of high-altitude Andes support a unique avifauna, providing resources for adapted species and stopover during migration, particularly during the dry season. There is increasing evidence of changes in glaciers affecting bird communities through direct and indirect effects on area, heterogeneity and quality of habitats, but few studies concern tropical mountains. We aimed to study the relationships between bird diversity and glacier-influenced environmental conditions under the context of glacier retreat in Andean high-altitude wetlands. We surveyed bird communities and environmental characteristics of 40 wetlands of the Cordillera Real of Bolivia along a gradient of glacier influence. We studied taxonomic, phylogenetic and functional diversity in relation to wetland area and further explored environmental factors influencing bird diversity, as elevation, glacier cover, heterogeneity and productivity and we assessed bird assemblages associated with wetter or drier habitats within wetlands. Birds' diversity was strongly influenced by wetland's area, productivity and elevation, while maximized at intermediate levels of glacier influence. Within wetlands, productivity and humidity determined bird community composition along a gradient of glacier influence, potentially reflecting ongoing changes on wetland habitats under glacier retreat trends. Wetland-related ponds and cushions may be affected by precipitation and glacier runoff trends, changing in turn substantial portions of aquatic habitats. Thus, glacier retreat in these high-altitude ecosystems might affect particularly birds associated to wetter habitats and threaten uncommon species depending on aquatic resources. Owing to global change processes, glacier retreat and extinction is expected to have important consequences on biodiversity and human livelihoods, especially in highly water-dependent systems. High-altitude wetlands of tropical Andes provide an unique opportunity to broadly monitor effects of glacier decrease on biodiversity. **Keywords:** Bird diversity, glacier retreat, habitat heterogeneity, tropical Andes, wetlands, bofedales

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Species Distribution Modelling for Limestone and Forest Langurs in Tropical Asia and Its Conservation Implications

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Leaf monkeys of the genus *Trachypithecus* are largely folivorious primates, which currently contain a total of 22 species that are grouped into four species groups. The genus is mainly distributed in Southeast Asia and most of the species are listed as critically endangered or endangered in the IUCN red list. The main threats are hunting and habitat degradation, but climate change is a potential impact in the future as well. Ecological niche models can predict the trend of the species distribution under climate change using species locality data and bioclimatic variables, and can help to improve primate conservation management programs. In this study, we applied maximum entropy (MaXent) to understand the current and potential future distribution of forest (*T. crepusculus*) and limestone (*T. delacouri*, *T. hatinhensis*, *T. ebenus*) langurs. Therefore, we obtained occurrence data of these four species from various sources, downloaded the spatial resolution of Bioclim layers 30 arc-second resolution including 19 bioclimatic variables from WorldClim 2.1 database, modeled the species' potential current (1970s – 2000s) and future (2050s and 2070s) distributions under two scenarios RCP 4.5 and RCP 8.5. The results show the predictive models are highly reliable and accurate in capturing the bioclimatic variables and the occurrence records. For *T. crepusculus* suitable habitat is averagely increasing between 2050 (+121%) and 2070 (+128%) with a predicted expansion towards the North and Southwest of its current range, making additional areas of Mu Cang Chai Species Habitat and Conservation Area and Muong La Natural Reserve suitable. The habitat of *T. delacouri* and *T. hatinhensis* remains stable, in contrast, *T. ebenus* will experience a reduction in suitable habitat (2050: -24%, 2070: -28%), especially in the East of Phong Nha Ke Bang National Park, in the Southeast of Hin Nam No Protected Area, and the central/boundary region between both protected areas. Based on our findings, we strongly recommend efficient protection of the current protected areas and transboundary projects between Vietnam and Laos to improve primate conservation in the context of climate change. Our study is limited to 19 bioclimatic variables. To gain a better understanding of the species' distributions future studies should include additional variables such as main threats and karst geology.
Keywords: Trachypithecus, Forest langur, Limestone langur, Species distribution model, Conservation.

Climate change: impacts and solutions II

World Heritage Forests: Carbon Sinks under Continuing Pressure

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Background: While forests play an important role in the global carbon cycle, evaluating the climate impacts of specific sites across diverse regions is often hampered by a lack of data. Around a quarter of the more than one thousand sites on the UNESCO World Heritage List have been inscribed specifically for their natural values, and many contain large tracts of forests. Covering 69 million hectares, World Heritage forests provide multiple goods and services, benefitting nature and people. Despite having a general understanding of the climate benefits provided by these forested sites, the degree to which they serve as sources or sinks for atmospheric CO2 was only recently quantified (joint UNESCO/WRI/IUCN report: "World Heritage Forests: Carbon Sinks Under Pressure"). This analysis updates that report to examine the most recent carbon fluxes from forests. **Objectives:** This analysis reports forest greenhouse gas (GHG) emissions and sequestration within 257 forested UNESCO World Heritage sites between 2001 and 2021. It also reports forest carbon storage in World Heritage sites in 2000. **Methods:** Published maps of global forest carbon emissions, sequestration, and storage were overlaid with World Heritage site boundaries to estimate GHG fluxes and carbon storage. Existing site-level monitoring systems were used to identify key threats to forest carbon in World Heritage sites. **Results:** On average, forests in natural and mixed UNESCO World Heritage sites absorbed approximately 190 million more tonnes of CO2 from the atmosphere annually than they emitted between 2001 and 2021. The sites with the largest net carbon sinks and stores were generally in tropical and temperate regions. Despite their globally recognized and protected status, forests in several World Heritage sites were net carbon sources during the 2001-2021 period. Main reasons for this include climate-related hazards such as wildfires and storms, and increased land use pressures. **Implications:** Even some of the most iconic, protected forests in the world have become net emitters. Ongoing removal of atmospheric CO2 by forests at World Heritage sites is not guaranteed if threats to their conservation continue. World Heritage forests and their surrounding landscapes require strong and sustained protection to maintain their roles as carbon sinks and stable carbon stores. Multiple pathways can protect forest carbon in World Heritage sites, which require the use of best available knowledge generated through reliable data and interdisciplinary decision-making, as well as the mobilization of public and political support for sustainable financing and investments. **Keywords:** Forests, climate change, emissions, sequestration

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Spatial Patterns of CH_4 and CO_2 Peat Soil Emissions from Different Vegetation Types in the Colombian Amazon

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Peatlands are the terrestrial ecosystems with the highest amount of carbon C, exceeding several times the amount of C of tropical forests. In addition, peatlands store the equivalent of the world's atmospheric CO2 reserves in only 3% of the surface. It is currently estimated that Amazonian peatlands are larger and contain more carbon than peatlands in Asia and Africa. In Colombia, there is an estimated 4% of the peatland extension of the entire Amazon, however, the magnitude of GHG emissions from these ecosystems is not known. Our research aimed to quantify GHG emissions from the main peat forming vegetation ecosystems and in contrasting geological contexts and understand how the methane and carbon dioxide fluxes are influenced by geological context, geomorphic setting, water table and air and soil temperature. We selected 5 peatlands from the east to the south of the Colombian Amazonia under several vegetation types: flooded forest, varillal and flooded savanna, cananguchal and swamp. We estimated annual methane and carbon dioxide soil fluxes using static chambers and standard methods for aboveground biomass. Site, geology and vegetation type had an influence on methane and carbon dioxide overall fluxes. Carbon dioxide fluxes was higher in the varillal (2.1 Mg CO_2 /ha/y) compared to the other sites. Methane patterns showed relevant emissions and absorptions patterns, the varillal was the vegetation type with the highest uptake (-1.5 Mg CH_4 /ha/y). Methane emissions were higher at the palm-swamp areas (cananguchal) (1.5 Mg CH_4 /ha/y) doubling the emission rates of the other vegetation types and almost 5 times the rates of peat-swamp forests (0.3 Mg CH_4 /ha/y). Methane fluxes are influenced by por water pH and depth to the water table highlighting the influence of the local hydrology and water chemistry. Our results bring forward an important source of spatial variation on the patterns of methane and carbon dioxide emissions of Amazonian wetlands. The lack of agreement between the top-down and bottom-up models of GHG emissions has hampered the development of large scale strategies to manage those emissions, our research brings an additional element highlighting the relevance of the different vegetation types to the overall GHG budget. However, the effects of forest degradation and degradation of Amazonian peatlands is still largely unknown but necessary to better understand the potential role of Amazonian peatlands on climate mitigation. **Keywords:** Amazonian peatland, GHG emissions, mitigation, climatic change, methane, carbon dioxide

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Unraveling the Influence of Climate Change in the Largest Cushion Peatland in the Colombian Andes (Colombia)

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Introduction: High elevations peatlands of the tropical Andes, above 4000 m, are vulnerable to climate change as evidenced by the die-off of peat forming vegetation in different locations. Peatlands have an important role in climate change mitigation because of the large amounts of carbon stored in peat soils. El Valle de los Cojines, the cushions valley, is the largest cushion peatland in the Colombian Andes, is dominated by Distichia muscoides, and it has an average peat depth of 6 m and around 900 Mg C ha^{-1}. However, recent observations evidenced die-offs of large areas of cushions in the valley. **Objective/Hypothesis:** Several competing hypotheses have been presented to explain the rapid decay of the cushions including the removal of grazers, lower precipitation, erosion from glacier melt and soil warming. Our research was focused in understanding the environmental factors that could explain recent changes in peatland vegetation patterns. **Methods:** We obtained two high resolution images one year apart and analyze the main changes in the spatial distribution of vegetation, soil and water. Additionally, we set 12 permanent plots and 180 survey plots throughout the valley recording soil temperature, plant composition, pH, water electrical conductivity and water table depth. **Results:** We identified six types of vegetation cover: grasses (29%), dead cushions (16%), water (14%), and healthy Distichia muscoides cushions (8,7%), rocky soil and mosses covered less than 5% of the area. Dominance of dead cushions is associated with areas where water table was lower, and soil temperatures and water electrical conductivity were higher. We also observed a replacement of the Distichia cushions by mosses and grasses. Ordination analysis (MDS) showed a drastic change in plant composition between 2021 and 2022. The Distichia cover decreased 0,7 % after one year, while grasses and mosses species increased, 1,2% and 2,4% respectively. **Implications:** Our results suggests that cushion deterioration is not homogeneous in the peatland and could be explained by changes in soil temperature and hydrological conditions. High temperatures could be increasing decomposition rates, causing peat subsidence together with the development of pipe-flow channels draining the lower peat layers. This study represents the first ecological characterization of the Valle de los Cojines and highlights those variables that are useful indicators of the effects of climate change on high elevation ecosystems. Management options are limited, under the supported hypothesis of increased temperatures and peat erosion, and climate change adaptation strategies should be followed. **Keywords:** Tropical, Andes, peatland, climate change, cushion, plants, ecosystem dynamics

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What Is the Future of Páramos in a Warmer World? Insight from a Warming Experiment Using Open Top Chambers

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Understanding the response of tropical vegetation and soils to rising temperatures represents a key uncertainty limiting our ability to predict biosphere-atmosphere feedback in a warming world. One key tropical ecosystem, yet understudied, is the Páramo. Páramos are tropical alpine ecosystems that host one of the worlds´ most diverse alpine floras with around 60% of endemic species. Páramos also account for the largest water reservoirs in the Andes and some of the largest soil carbon pools worldwide. Here we present the results of large-scale *in situ* warming experiments in two Colombian páramos (Sumapaz and Matarredonda) using Open Top Chambers (OTC). We evaluated the response to warming of several ecosystem carbon balance-related processes such as decomposition, soil respiration, photosynthesis, plant productivity, and vegetation structure. Twenty OTC were established in 2016 in two paramo sites located in the oriental range of the Andes, ten on each site. Environmental variables monitored inside and outside the OTC indicates that OTCs are warming and drying the soil and the air, especially during the dry season. OTC increased mean air temperature by 1.7 °C and the daytime temperature by 3.4 °C, while soil temperature increased only by 0.1°C. After three years of warming, we found no evidence that warming increased CO_2 emissions from soil respiration, nor did it increase decomposition rate, photosynthesis, or productivity (below and aboveground) in the two páramos studied. However, total C and N in the soil and vegetation structure is slowly changing because of warming, and changes are site-dependent. In Sumapaz, shrubs and graminoids cover increased in response to warming, while in Matarredonda, we observed an increase in mosses and lichen cover. Whether this change in vegetation might influence the carbon sequestration potential of the páramo needs to be further evaluated. Our results suggest that páramos ecosystems can resist an increase in temperature with no significant alteration of ecosystem processes related to carbon storage in the short term. We might expect that paramos could shift from carbon sink to sources only if longer-term changes in vegetation and soil community composition and/or metabolism, combined with warmer and drier conditions, lead to changes in substrate stoichiometry that contribute to increases in decomposition and soil respiration. **Keywords:** Carbon emission, OTC, Páramos, tropical alpine ecosystem, warming

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Climate change: impacts and solutions III

Migration in the Times of Uncertainty

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Introduction: Understanding the effect of fluctuations on populations is crucial in the context of increasing habitat fragmentation, climate change, and biological invasions, each of which are increasingly rampant across the tropics. Migration is an important strategy in response to environmental disturbances as it enables populations to escape unfavourable conditions, benefit from new environments and thereby ride out fluctuations in tropical environments. **Hypothesis/Objectives and Methods:** We start with a basic question: would populations disperse if there is no uncertainty? Karlin showed in his 1982 paper that for sub-populations experiencing differing but fixed growth rates at different sites, greater mixing of populations will lower the overall growth rate relative to the most favorable site. Here we ask if and when environmental variability favors migration over no-migration? Specifically, we ask if random environments enable populations to increase their long-run stochastic growth rate by migration to an otherwise unfavorable site? Would introducing a small amount of migration increase the overall long-run growth rate relative to the zero migration case? We use analysis and simulations to show how long-run growth rate changes with migration rate. **Results:** We show that when there is one best site with highest growth rate, effect of migration on long-run growth-rate depends on the difference in expected growth between sites, scaled by the variance of the difference. When variance is large, the probability of an inferior site having a large growth-rate is also large. Thus, a high variance can compensate for a fixed difference in growth-rates between sites. We find positively correlated fluctuations in growth rates lead to reduced rates of migration. Intuitively, populations are less likely to survive through long runs of poor conditions. We also examine the effect of path-length between sites. When fluctuations are large, the longest path to arrive at best site leads to more gain in overall growth rate compared to short path-lengths. **Implications:** Our results show that when fitness (dis)advantages fluctuate over time across sites, migration allows populations to benefit from the variability. Our findings indicate that habitat quality and fluctuations are both important determinants of migration evolution and the results have implications for tropical conservation biology since the systems are characterized by variability. When there are superior sites in a sea of poor habitat (such as national parks, wildlife reserves), variability across space may be key to persistence. **Keywords:** Migration, dispersal, disturbances, fluctuations, migration evolution, variability, habitat quality

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The Biogeochemical Consequences of Warming Tropical Forests

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Introduction: Tropical forests exchange vast amounts of carbon, water, and energy with the atmosphere, thus there is substantial interest in improving our understanding of how these forests will respond to environmental change,such as a warming climate. While a high level of biodiversity in lowland tropical forests indicates a potential for ecosystem resilience, other evaluations suggest theseforests could be quite sensitive to even subtle temperature change due to their already warm conditions and organisms that evolved and developed with low diurnal, seasonal, and interannual temperature variation. **Objectives:** Our objective was to push tropical forests into the novel temperature regimes expected for these systems and to assess multiple aspects of forest response. **Methods:** We built a lowland tropical forest warming experiment in Puerto Rico, using infrared warming lamps to heat understory plants, litter, and soils, as well as used a canopy tower to heat leaves along a canopy profile, in order to explore the biogeochemical consequences of increasing global temperatures. **Results:** After a year of 4 ºC above ambient warming, we found tropical forest plant, litter, and soil carbon and nutrient cycling did indeed respond. For example, both CO2 uptake and loss were quickly affected by the warming treatment (photosynthesis, plant respiration, soil respiration), as was soil microbial biomass and the availability of soil nutrients. After a year of warming, two major hurricanes struck Puerto Rico and offered the opportunity to assess the interacting effects of large disturbances (i.e., hurricanes) and warming. In this talk, we will synthesize our understanding of the coupled biogeochemical patterns observed in this unique tropical forest in situ warming x hurricane experiment. Implications and conclusions: The results suggest strong potential for tropical forests to quickly respond to warming and for large interactions between climate and physical disturbances, including biogeochemical feedbacks that could significantly affect future climate and biogeochemical cycles at the global-scale. **Keywords:** Tropical rain forests, climate change, feedbacks, coupled biogeochemical cycles, warming

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Integrating Biodiversity in a National Integrated Assessment Model

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Biodiversity maintenance and climate change are among the biggest challenges humanity faces today. Integrated assessment models (IAMs) are important tools for the understanding of possible impacts caused by adopting new policies. IAMs are increasingly used by the climate community, and they are valuable for modelling climate mitigation pathways that incorporate multiple Sustainable Development Goals (SDGs). We investigated possible co-benefits and trade-offs between clean energy (SDG 7), climate action (SDG 13) and life on land (terrestrial biodiversity) (SDG 15) in three different mitigation scenarios for Brazil: (1) One scenario compatible with a world that maintains its current policies with an imposed deforestation rate, (2) One in which Brazil fulfils its Nationally Determined Contribution (NDC), and (3) One compatible with a world that limits warming to 1.5° C. We use the BLUES model, a national IAM, to show the benefits and opportunities of a transition from the current economy to a low-carbon economy in Brazil up to 2050. The BLUES model is an optimisation model whose main objective function is to meet the demand for goods and services at the lowest possible cost. However, as of today BLUES does not consider biodiversity. We conduct a post-processing analysis using consolidated biodiversity indicators to emphasise how different IAM solutions present distinct co-benefits and trade-offs between greenhouse gas (GHG) emissions mitigation, biodiversity, and energy production options in Brazil. **Keywords:** integrated assessment models, biodiversity, climate mitigation, land-use, SDGs, Energy

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Reduced Soil Respiration in Response to 2 Years of Warming

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Introduction / Background / Justification: Soil CO2 respiration (Rs) tends to increase with short-term experimental warming around the world, which indicates an alarming potential for positive soil carbon-climate change feedbacks. However, Rs is often observed to either return to baseline or become lower than ambient soils in the longer term (>3 years), pointing to ecosystem resiliency. The vast majority of experimental warming experiments are found in temperate regions, therefore we know very little about the response and resiliency of Rs to warming in tropical ecosystems. Climate, vegetation type, and the size of standing carbon stocks play an important role in the magnitude and direction of warming effects of Rs. However, the temperate bias in the number of warming experiments globally limits our ability to fully understand the factors mediating the effects of experimental warming on Rs. **Objectives/ Hypotheses:** We aimed to determine how soil carbon cycling in the páramo responded to warming, specifically we hypothesized that soil carbon losses in the form of Rs would increase in response to warming in such a cool, high elevation ecosystem. **Methods:** Our study, an OTC warming experiment part of the International Paramo and Puna Experimental Network (IPPEX), is located in the páramo of Chirripó National Park in Costa Rica. We monitored Rs, soil temperature, soil moisture, and air temperature in response to warming over the course of 4.5 months, spanning the wet and dry seasons. **Results:** Contrary to increases in Rs commonly observed in response to short-term experimental warming in temperate ecosystems, we found that an increase in soil temperature of about 1.0°C (with an increase in air temperature of over 3°C) generally reduced Rs after just 1.5 years in a tropical alpine ecosystem (treatment: $t=-1.7$, $p=0.09$), with the most marked difference in the wet season. We also observed spatial and temporal patterns in the response of Rs to warming (location: $t=5.5$, $p<0.001$, time of day: $t=2.6$, $p=0.01$, month of year: $t=5.2$, $p<0.001$). In addition to Rs and microclimate data, we will present pending results (including carbon and nitrogen pools and vegetation cover) that will help elucidate the factors driving the warming-induced reduction in Rs as well as the factors driving spatial and temporal variability in the response. **Implications/ Conclusions:** Warming experiments in the tropics such as this one are essential to determine whether the drivers and patterns of Rs response to warming hold across biomes. **Keywords:** Páramo, climate change, warming, OTCs, alpine, soil respiration

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Climate change: impacts and solutions IV

Holocene Fire in the Amazon Basin

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The Amazon Basin, with its fuel-rich environment, is becoming a fire-prone environment due to widespread and prolonged climate-driven drought and the reduction of aerial rivers due to deforestation. There is an urgent need to control fire events in the region and the understanding of historical fire regimes is critical for contemporary fire management. Charcoal is one of the fire proxies deposited in the lake and peat profiles, and records from 35 sites across the Amazon Basin were collected from the existing public databases and publications to examine the temporal and spatial variability of fire regimes over the Holocene period. Scales of fire in the paleorecords were primarily explained by the size of charcoal as smaller particles are expected to travel longer distances. Back trajectories based on the modern meteorological data were used to trace the possible distant origin of smaller size of charcoal. The preliminary results suggest local fire inferred from charcoal showed a general increasing trend during the Holocene period, while fires of the mixed signals (local and regional scale) showed smaller variation throughout the period with a slight decrease during the mid-Holocene. Western Amazonia is likely to be relatively more vulnerable to future fires as they had the most fire-free period sites. For sites that are closer together and within the same sub-region, fire events may be more dependent on human activity because of large differences between their fire-free periods. The results from back trajectories analysis demonstrated that easterly trajectories could bring particles to the basin from northern/southern Africa in the wet/dry season. The globally and locally distributed palaeoecological proxies are needed to diagnose the nature of climate-fire-human linkages. **Keywords:** Amazon Basin, Holocene, fire, charcoal

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Changing Fire Regime in the Amazon

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Fire regime is described by a set of properties that capture the temporal and spatial variability of fire as a disturbance event on a landscape. Amazon is known as a fire-sensitive ecosystem that rarely buns under natural conditions, with fire return intervals ranging between 200 to 1000 years. However, anthropogenic activities have contributed to an intensification of fire regimes in the region. Over the past four decades, 41.3% of Brazil's burned area occurred in the Amazon, with 18% burning only forests. Land use and climate change are impacting fire frequency and intervals, causing an increased burned area each year. Here, we explored spatial and temporal characteristics of the Amazon Forest fire regime such as fire frequency, intervals, and extent. We also assessed the main changes in fire properties over time and how land neighboring land use contributed to those changes. These characteristics were assessed using a 36-yr (1985 to 2020) monthly time series of forest fire scar maps retrieved from Landsat imagery, which was developed using deep learning neural network modeling for the Brazilian Amazon. Our results indicate that 65% of the fires in the Amazon burned a given area more than two times during the study period. The fire return interval averaged 18 years for the majority of the forests burned. This return interval is at least 11 times higher than the minimum natural fire return interval modeled for the region. The forest areas more affected by higher frequencies were in landscapes historically more fragmented and dominated by surrounding pasture fields. Changes in fire regime can demonstrate the increasing importance of fire as a driver of current and future landscape transformation in a scenario of warmer

climate and higher anthropogenic pressure. Indication of areas with higher fire frequencies and altered by fire regimes can lead to extensive forest degradation and increased fire-induced carbon emissions. **Keywords:** Fire regime, Amazon, fire frequency, fire mapping, land use change

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Artificial Water Reduction Causes Population Collapse of *Faramea anisocalyx* (Rubiaceae) in an Ombrophilous Forest in the Eastern Amazon

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Global climate change impacts biodiversity. One of the examples of these changes is the anomaly called "El Nino", which results in an increase in the temperature of the waters of the Pacific Ocean, causing a reduction in precipitation in the Amazon biome. In order to monitor these changes and their impacts, an experiment was created in 2001 in the Amazon that simulates an artificial reduction in precipitation called the "Drought Forest Study Project" (ESECAFLOR). In a 1-hectare plot 50% of the rainwater is excluded by roofs and drainage. We chose *Faramea anisocalyx* (Rubiaceae) as study plant, being one of the most abundant shrubs in the understory of the Amazon forest and little tolerant to micro-climatic changes. The objective was to compare the population structure in two age strata of *F. anisocalyx* in the experimental and control plot (with normal precipitation) in the ESECAFLOR Project. Results show significant reductions in the *F. anisocalyx* population structure in relation to density (X=8.5, dp=3.47) and (X=1.4, dp=0.52), diameter (X=1.94, dp=0.38) and (X=1.45, dp=0.39) and height (X=1.97, dp=0.33) and (X=1.2, dp=0.41) between experimental and control plot. The population structure of *F.anisocalyx* was drastically reduced in the two strata as a result of the non-tolerance of reduced soil moisture caused by artificial water reduction. These results are important, because in the climate change scenarios of reduced rainfall in the Amazon Biome, there is a prediction of population collapse of understory plant species that are not tolerant to microclimatic changes. **Keywords:** Population structure, micro-climatic changes, artificial drought, precipitation reduction

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How Much Could Be the Uncertainty of C-fire Emissions over the Amazon Forest?

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Forest and grassland fires represent roughly one-third of total emissions in Brazil from land-use and land-cover change (SEEG, 2018). However, most modelling estimates come from the same remote sensing products, which have limitations in detecting burning events in cloudy areas or detecting small intensity fires (understorey). So far, validating the differences in model estimates based on observational data is not accessible due to the extent and lack of temporal resolution. Therefore, we compared Amazonian C-fire emissions from 2010 to 2016 using atmospheric vertical profiles (Gatti et al. 2021) with the Global Fire Emissions Database – GFED (Van der Werf, 2017) over the same region of influence (Cassol et al. 2020). C-Fire was obtained from the CO/CO2 ratio to estimate the proportion of burning from the total CO2 in profile observation. The highest C-Fire emission was 220 Tg C in 2010 in the southwestern Amazon and the lowest 40 Tg C in 2011 in the northwestern Amazon. On the other hand, the highest emission of GFED was 120 Tg C in the southwestern in 2014 and the lowest 4 Tg C in southeastern in 2014. On average, GFED had 50% lower emissions, although it varied from 95% lower to 200% higher than observed in profiles. Despite some underlying uncertainties in both methods, this comparison may improve our understanding of the critical differences in Carbon-fire sources over tropical regions. **Keywords:** Climate Change, combustion, rainforest, Carbon dioxide, Savanna

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Climate change: impacts and solutions V

Changes in Mangrove Carbon Stocks and Exposure to Sea Level Rise (SLR) under Future Climate Scenarios

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Introduction: Mangrove ecosystems that provide vital carbon sequestration services are threatened by a variety of anthropogenic factors, including climate and landcover change. Climate-related factors such as increasing temperatures, altered precipitation patterns, changes in sea level, and frequency of storms are threatening mangroves at regional scales. While a significant proportion of mangrove carbon studies have focussed on above ground carbon (AGC) stocks of different mangrove ecosystems, blue carbon, an important focus of climate mitigation efforts, includes aboveground (AGC), belowground (BGC), and soil organic carbon (SOC). Additionally, national and regional scale mangrove carbon stock studies limit our understanding of regions most likely to suffer adverse consequences under future climate and sea-level change scenarios. The Marine Ecoregions of the World, or MEOW, is a nested system of 12 realms, 62 provinces, and 232 ecoregions that covers coastal and shelf areas across the world. Using the MEOW system as the basis of global mangrove carbon variation can support consistent regional comparisons and thus support conservation prioritisation for climate mitigation via mangrove retention Objectives: (i) quantify the variation in mangrove carbon (AGC, BGC, and SOC) stocks across different marine bioregion settings under the present climatic conditions, (ii) quantify the variation in mangrove carbon stocks across marine bioregions under different emissions scenarios for 2070, and (iii) identify the most important variables that explain the variation in mangrove carbon stocks under future scenarios. Methods: We used a combination of bioclimatic variables (including precipitation and temperature) obtained from the WorldClim database, along with soil erosion and sea-level rise (SLR) data along with secondary data within the framework of a machine learning algorithm (random forests) to model the spatial variation in AGC, BGC and SOC stocks under the present and future climatic (2070) scenarios. In this study, three future scenarios were considered: RCP 2.6, 4.5, and 8.5 were considered for 2070. Results: The average predicted global AGC and BGC values were projected to decline under all future climate scenarios while SOC values were projected to increase for the provinces of Tropical NW Atlantic and West African Transitions under RCP 2.6. Mangroves of Vantau, Papua and Nadamans are projected to lose all 3 C stocks under all future scenarios whereas Western Sumatra, Southern Java are projected to decrease only in both AGC and BGC stocks. Conclusions: This study identified the ecoregions that are most vulnerable and these include mangroves of SE Asia, Amazonia and island mangroves (Vanatua) **Keywords:** Mangroves, climate change, mitigation, above-ground biomass, machine learning

Climate Warming Impacts the Taxonomic and Phylogenetic Diversity Patterns of Plants Associated with Neotropical Seasonally Dry Forests

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Global climate change (GCC) is causing severe impacts on biodiversity. These impacts include novel and intensive environmental pressure on many species, forcing them to shift their distributional ranges and even generating local/global extinctions. Such range shifts may also lead to significant biotic rearrangements of communities, including taxonomic, phylogenetic, and functional dimensions. Here, we analyzed how future GCC scenarios (years 2040, 2060, and 2080) will impact alpha and beta taxonomic and phylogenetic diversity patterns of plants closely associated with the endangered Neotropical seasonally dry forests (NSDF), namely the families Cactaceae, Capparaceae, Fabaceae, Malvaceae, and Zygophyllaceae. We sought to answer the following questions: (1) will GCC cause a reduction in the taxonomic and phylogenetic diversity for NSDF plant communities?, (2) is GCC a homogenization/heterogenization driver of plant species' taxonomic and phylogenetic diversity?, and (3) will the current Protected Areas (PAs) fulfill their role as reservoirs of the biodiversity of the NSDF under these global change scenarios?. We used ecological niche modeling to estimate the geographical distributions of >600 species under current and future climate projections. Further, using a presence-absence matrix and a mega-phylogeny, we calculated alpha diversity as well as beta-diversity (based on Sorensen´s index) patterns across the geographic distribution of NSDF. Under GCC for species, we observed a reduction (from 2.3$\pm$1.9 spp. [2040s] to10.3$\pm$5.1 spp. [2080s]) of taxonomic alpha diversity across the NSDF (specifically in Colombia, Venezuela, and Ecuador) but an increase of alpha phylogenetic diversity (0.5$\pm$14.8 MPD [2040s] to 1.1$\pm$18.3 MPD [2080s]). We also observed changes in the composition of communities, increasing the dissimilarity between sites (i.e., biotic heterogenization process) in future scenarios (0.31$\pm$0.19 [2040s] – 0.37$\pm$0.20 [2080´s]) compared to the current one (0.29 $\pm$0.18). Unfortunately, the PAs are no exception for these changes in biodiversity organization. This picture implies a threat to the conservation of this highly diverse and fragile ecosystem. Nonetheless, because we provide novel evidence about which species and NSDF areas are most vulnerable, the projected spatio-temporal patterns identified herein can guide future conservation efforts by decision-makers. **Keywords:** Climate change, dry forest, plants diversity, biotic heterogenization

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Assessing the Rapid Loss of Different Facets of Amphibian Diversity in the Neotropics

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Introduction: Human activities have caused alarming trends of biodiversity loss at a global scale. However, at regional and local scales, patterns of species responses to anthropogenic pressures are less clear. A better understanding of the contemporary re-shaping of communities and how these shifts might affect stability of ecosystems functioning is critical specially for some groups that are declining stronger such as amphibian and reptiles. **Objectives:** Here we empirically address the response of seven anuran communities from Neotropical highlands, a highly vulnerable region, to human-caused environmental changes over the last 50 years. We ask (1) whether changes in anuran communities are dominated by species losses, (2) if local species extinctions are associated with anthropogenic environmental changes, such as climate warming or habitat loss, (3) if taxonomic diversity changes translate into proportional changes in phylogenetic and functional diversity, and (4) if anuran communities have become more similar across space. **Methods:** We use Bayesian modelling and combine data from long-term historic and recent monitoring efforts, to explore the drivers of community change across the different facets of biodiversity (i.e., taxonomic, phylogenetic and functional). **Results:** First, we found that most communities showed a substantial decrease in species richness, in average almost 52% of species were locally lost. Second, local species losses were strongly associated with species climatic niches and extreme warm temperature events. Third, we show that the reduction of local taxonomic diversity has resulted in larger phylogenetic and functional diversity reduction, which could hamper ecosystem functioning. Finally, we found that communities re-shaping has yielded an increase in functional homogenization across space. **Implications:** Our results suggest climate warming might have played a significant role on amphibian

montane diversity erosion and highlight the need to evaluate biodiversity shifts beyond species richness. A focus only on taxonomic diversity might underestimate impacts of global change on biodiversity. For instance, it is only when we combine information on evolutionary history and functional traits that we are able to reveal temporal trends towards increasing biotic homogeneity. Functional homogenization could exacerbate the effects of amphibian extirpations on ecosystem functioning and stability. **Keywords:** Amphibian communities, phylogenetic diversity, functional diversity, climate change, habitat loss

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Phylogeography and Adaptive Genomic Variation in Guazuma

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An understanding of how plants have adapted to climate change in the past may provide information on how adaptable they are to future change. Guazuma is a representative of the tribe Theobromeae (Malvaceae) with three accepted species: *G. crinita* (rain forest of Perú and Bolivia), *G. ulmifolia* (humid and dry areas in the Neotropics) and *G. longipedicellata* (dry forest, restricted to El Salvador). Patterns of diversity and genetic structure have not been widely investigated including all species across their ranges of distribution. The genomics of local adaptation in the genus also require investigation. My project aims to explore the phylogeography, adaptive genomics of drought adaptation and domestication patterns within Guazuma. Specifically, I aim to understand a) how barriers have impacted contemporary distributions and genetic structure and b) if tolerance to drought is correlated to the current phylogeographic structure. To accomplish this, a set of Hybrid Capture baits will be used to produce two set of sequences: a) Phylogenetically useful genes to infer species relationships and explore genetic divergence along with morphological data, and b) drought-related genes to uncover signs of selection by correlation with environmental variables. To select the target genes of interest I have obtained transcriptomic data using RNA-seq from a living plant of *G. ulmifolia*. Preliminary bioinformatic explorations of the transcriptomic data has shown close relationships to other members of the Theobromeae tribe, that includes rain forest restricted taxa, in particular the economically important source of chocolate, Theobroma cacao. Some insights on genetic structure is provided. **Keywords:** Drought Neotropics, theobromeae, guazuma, genetics population, Malvaceae, dry forest

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Unburnable Fossil Fuels in Tropical Rainforests: Collateral Benefits of Climate Mitigation Policies

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The Paris Agreement aims to limit global warming to well below 2°C, preferably to 1.5°C, compared to pre-industrial levels. In order to limit the increase in global mean temperature to 1.5°C, CO_2 emissions from 2020 onwards should be capped at 440Gigatonnes (Matthews et al. 2021). To remain within this limit, about 89%, 56% and 58% of existing coal, gas and oil reserves, respectively, would need to remain under the soil to limit global warming to 1.5°C (Welsby et al. 2021). To maximize the collateral benefits of climate policies, here we develop an integrated spatial assessment model that uses estimates and locations of the world's conventional oil resources and economic and socio-environmental criteria to construct the first global atlas of unburnable oil resources: those oil reserves higher extraction costs that overlap with highly biodiverse regions and/or coincide with outstanding socio-environmental values should be left untapped. The results show that the pantropical rainforests should be kept entirely off-limits to oil extraction, as they only account for 4% (76 Gbl) of conventional oil resources, well below the 1035 Gbl required to keep global warming under 1.5°C. The world's tropical rainforests zones contain minor quantities of oil, but 12% of them are overlapped with oil resources. Our model provides clear spatial guidelines to guide fossil fuel phase-out and divestment strategies for the green transition to limit carbon emissions while enhancing collateral socio-environmental benefits. Keywords : Unextractable carbon, climate change, fossil fuels, extractive industry

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Communities: Disturbance and Recovery

Effects of Dams on Riparian Vegetation in the Amazon: Cumulative Impacts and Linkages to Hydrology

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Riparian forests are critical transitional ecosystems linking aquatic and terrestrial habitats, providing important ecosystem services such as sediment control and nutrient regulation. The function of riparian forest is intimately linked to river hydrology and floodplain dynamics. Dams drastically alter river hydrology, impacting riparian forest composition, structure, and function. The Amazon basin is undergoing a dam-building boom, but few studies have focused on the impacts of multiple dams on riparian ecosystems. This landscape perspective is needed to better understand how the cumulative impacts of multiple dams alter riparian areas across large scales. We performed a longitudinal study using water level, land cover and remote sensing data collected between 1985 and 2018 to quantify landscape scale changes in floodplain hydrology and riparian forests at two extents: (1) a 145-km stretch of Tocantins River downstream of five dams and (2) across the Tocantins River watershed where six mega dams were installed between 1996 and 2012. We investigated how changes in floodplain extent, flood timing, and hydroperiod resulting from dam operation affected the land cover type and phenology of riparian vegetation along the Tocantins River. We also developed a framework to better understand the impacts of climate and land cover change on this landscape. Installation of the first dam on the Tocantins River reduced flooded extent by 63%, decreased hydroperiod by 11%, and made flooding start an average of five days earlier. After all five dams were installed upstream of our study area, 72% of the average pre-dam flooded area no longer flooded, average hydroperiod decreased by 35%, and the flooding started 12 days later on average. Reservoir filling created hundreds of square kilometers of new upland riparian areas dominated by dry-adapted savanna ecosystems instead of the wetland riparian forests. After all reservoirs on the Tocantins River were filled, only 29% of the riparian vegetation occurred around free-flowing river. Dry season greenness was higher in both riparian regions and in the upland "control" area in the post-damming period, indicating changes in greenness may not be related to changed hydrology. Changes to flooding regimes and riparian land cover can affect important ecosystem services such as nutrient flow and fisheries management. As multiple dams are installed along Amazonian rivers, a better understanding of how dams impact extent and function of riparian forests is necessary to guide forest restoration and management practices as well as to minimize impacts of future dams to riparian ecosystems. **Keywords:** Cerrado, Amazon, riparian vegetation, remote sensing, floodplain, hydroelectric dams

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Fruit-frugivore Interactions Mediated by Human-disturbance in Amazonian Forests

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Amazonian biodiversity is threatened not only by forest loss and fragmentation, but also by disturbance from wildfires and selective logging. Although such forest degradation is widespread and we increasingly understand its effects on community composition, our knowledge of its impacts on processes is limited. Animal-plant interactions, such as frugivory interactions, underpin the important ecological processes of seed dispersal and predation, both fundamental to understand ecosystem functioning and predict forest maintenance and resilience. Here, we investigate the consequences of human disturbances on frugivory interactions between plants and frugivorous animals across a range of (i) undisturbed forests, (ii) selective logged forests, (iii) forests burned in the past (18 years before sampling), and (iv) forest recently burned in consequence of the 2015-16 El Niño (3 years before sampling). From February 2019 to March 2020, frugivory interactions involving fleshy-fruited plants and frugivorous birds and non-volant mammals was monitored across 17 transects distributed among the above forest disturbance classes in which we compared the overall structure of frugivory networks. The sampling comprised two seasons to capture higher taxonomic diversity and tree phenological variation. In each transect, all plants with ripe fruits were monitored. Forests logged and burned at least 18 years before the study had the lowest number of species and unique interactions compared with the other forest classes. In contrast, there were no effects on network structure: all networks were modular and highly specialized than by chance. Moreover, forest burned at least 18 years before the study had the most distinct interaction composition. Our study provides empirical evidence for the negative effects of historical logging and fires on frugivory interactions in Amazonian forests. The loss of species and their interactions following logging and fires may indicate changes in ecosystem process. In the long-term, fires associated with logging are likely to lead to significant changes in fruit-frugivore interactions with likely effects to the future of forest dynamics. **Keywords:** Beta-diversity, forest fires, frugivory networks, functional redundancy, seed dispersal

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Contrasting Effects of Increasing Chronic Anthropogenic Disturbances and Aridity on Pollination of *Tacinga palmadora* (Cactaceae) in a Caatinga Dry Forest

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Ecological interactions in tropical ecosystems are modified by human disturbances and climate change. Human disturbances can become chronic when they cause subtle but long-lasting removal of biomass and thus alter ecosystems. Pollination is a key mutualistic interaction that can be affected by disturbances and climate change due to alterations in the composition, diversity and distribution of plants, floral resources and pollinators. The Caatinga dry forest, one of the largest and most diversified seasonally dry tropical forests in the world, located in northeastern Brazil, currently faces several anthropogenic pressures, including cattle ranching and wood extraction, and is characterized by its low water availability, with low annual precipitation levels. Thus, we tested if increasing chronic anthropogenic disturbances (CAD) and aridity induce changes in pollen traits and female reproductive success of *Tacinga palmadora*, a self-compatible cactus that performs as an important food source for nectar-feeding and fruit-eating animals in the Caatinga dry forest. The study was carried out in eight plots at the Catimbau National Park, northeastern Brazil. In each plot, we measured pollen traits (total pollen production, pollen viability, and pollen-ovule ratio) and female reproductive success fruit- and seed-set by both open and spontaneous self-pollination) of *T. palmadora*. Each plot had a different level of disturbance and aridity, which were used as predictor variables for pollen traits and female reproductive success in generalized linear models. All pollen traits were negatively associated with increasing CAD and aridity levels, while the seed- and fruit-set by open pollination were positively associated with increasing CAD and aridity, respectively. Spontaneous self-pollination was not influenced by increasing CAD and aridity. Our results revealed that even though pollen traits decrease with higher CAD and aridity, pollination of *T. palmadora* is maintained or even increased in the most arid and disturbed areas of the park. We conclude that, in terms of pollination effectiveness, *T. palmadora* might be thriving under disturbances and aridity in the Caatinga dry forest. **Keywords:** Human disturbances, plant-pollinator interaction, plant reproductive success, pollen traits

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Canopy Disturbance Explains Long-Term Increases in Liana Abundance

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Introduction: Liana abundance is increasing in many neotropical forests, which may alter tropical forest diversity and functioning. Disturbance is one of the leading hypotheses to explain the widespread pattern of increasing liana abundance. Liana density and diversity are high following local canopy disturbance (e.g., in treefall gaps), and greater forest disturbance may explain increasing liana abundance. This hypothesis, however, remains untested. **Hypothesis:** We tested whether local canopy disturbance explains increasing liana abundance. Methods: We used a 10-year study (2007–2017) of 117,100 rooted lianas (1 cm diameter) in a 50-ha plot the old-growth forest on Barro Colorado Island (BCI), Panama. We calculated liana recruitment, mortality, and growth of existing stems from 2007 to 2017 for all rooted stems (both individual and clonal stems) and tested whether liana density and basal area increased on the BCI 50-ha plot from 2007 to 2017. We determined canopy disturbance throughout the 50-ha plot using two independent datasets that quantified the change in canopy height and canopy tree basal area. We used changes in canopy height rank to classify the quadrats into four distinct categories. 1) Undisturbed high-canopy forest, the quadrats in the top 20% canopy height rank (n=185). 2) Persistent low-canopy gaps, the quadrats that remained in the lowest 20% canopy height rank (n=151). 3) Recent canopy gaps, the 250 quadrats that lost the greatest canopy height rank. 4) Former canopy gaps (recovering forest), the 250 quadrats with the greatest canopy height rank increase. We bootstrapped spatially independent replicates 4999 times and compared the median model estimates of liana recruitment, mortality, growth, and the change in liana density and BA among the four canopy disturbance categories using one-way ANOVAs. **Results:** We found that liana density increased 29.2% and basal area 12.5% on BCI. The vast majority of these increases were associated with disturbance, particularly in liana-dense, low-canopy gaps, which had far greater liana increases than did undisturbed forest. Furthermore, clonal stem proliferation following disturbance was responsible for most of the liana increases. **Implications/Conclusions:** Lianas appear to be ecological niche constructors, arresting tree regeneration following disturbance and thus maintaining the high-light canopy gap environment that favors sustained liana proliferation. Our findings demonstrate that liana abundance is increasing rapidly on BCI and their ability to proliferate via clonal stem production in canopy gaps explains much of their increase in this and possibly other tropical forests. **Keywords:** Tropical forest change, lianas, trees, diversity, disturbance, treefall gaps

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High Sensitivity of Tropical Forest Birds to Deforestation at Lower Altitudes

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Background: Habitat conversion is a major driver of tropical biodiversity loss, but its effects are poorly understood in montane environments. While community-level responses to habitat loss display strong elevational dependencies, it is unclear whether these arise via elevational turnover in community composition and interspecific differences in sensitivity, or elevational variation in environmental conditions and proximity to thermal thresholds. **Objectives:** To assess the relative importance of inter and intraspecific variation across elevational gradients by quantifying how birds vary in sensitivity to landscape-scale forest loss across a 3000 m elevational gradient in the Colombian Andes. **Methods:** We carried out replicated point counts at 200 forest points throughout the Eastern Cordillera of Colombia, and use a Bayesian hierarchical occupancy-detection model to assess how species and population responses to forest loss vary with elevation. **Results:** We find that species that live at lower elevations are strongly affected by loss of forest in the nearby landscape, while those at higher elevations appear relatively unperturbed, an effect that is independent of phylogeny. Conversely, we find limited evidence of intraspecific elevational gradients in sensitivity, with populations displaying similar sensitivities to forest loss, regardless of where they exist in a species' elevational range. **Implications:** Gradients in biodiversity response to habitat loss appear to arise via interspecific gradients in sensitivity rather than proximity to climatically limiting conditions or through elevational gradients in pre-disturbance species richness. These results further suggest that biodiversity losses due to deforestation may be particularly severe towards lower elevations, which are also regions that are experiencing high levels of contemporary deforestation (e.g. Caqueta deforestation frontier). **Keywords:** Montane tropics, elevational gradients, forest conversion, tropical conservation

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Effect of Fire Regimes on Tree Species Diversity and Composition in Miombo Woodland

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Fire disturbances strongly impact forest succession, thus influencing the composition and structure of forest ecosystems. Increasing demands from the growing human population and the effects of climate change are currently modifying the fire regimes in the miombo woodlands of southern Africa, with consequences that are yet to be understood. Improved understanding of the effect of different fire regimes on miombo woodlands is required to develop integrated fire-management approaches. This study aimed to investigate the effect of varying fire regimes in the miombo woodlands of central Mozambique. We used MODIS data to map fire frequency and fire intensity. Combining the fire frequency, fire intensity map and land use pattern of the study area, we ended with five fire regimes: high frequency and high intensity (HfHi), high frequency and low intensity (HfLi), intermediate frequency and high intensity (IfHi), low frequency and intermediate intensity (LfIi), and low frequency and low intensity (LfLi). We computed aboveground biomass, carbon stocks, basal area, and tree density as vegetation parameters to assess the effect of different fire regimes on tree vegetation. Tree species diversity was evaluated and compared using rarefaction curves based on Hill's numbers for the species richness, the Shannon index, and the inverse Simpson index. We found low aboveground biomass (58.7 Mg ha^{1}), carbon stock (29.3 Mg ha^{1}), basal area (9.5 m^{2} ha^{-1}), and tree density values (125 stems ha^{1}) in HfLi fire regimes areas. Basal area (12.2 Mg ha^{1}), aboveground biomass (77.6 Mg ha^{1}) and carbon stock (38.8 Mg ha^{1}) were significantly higher under the LfIi fire regime. The regenerating trees were high in the HfLi fire regimes (3,938 stems ha^{1}), an area highly accessible to humans. Repeated and intense fire occurrence strongly decreased the species richness and composition. Our results contribute to better understanding the effect of different fire regimes, which are crucial in determining specific objectives of sustainable miombo management and producing effective fire management strategies and policies in miombo woodlands. **Keywords:** Fire frequency, fire intensity, land use, tree adults, regeneration

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Different Responses of Avian Community to Chronic Disturbance and Vegetation Structural Complexity in a Seasonally Dry Neotropical Forest

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Human-induced habitat modification is the main threat affecting biodiversity, so understanding how species respond to these modifications is one of the biggest challenges for ecologists. Birds have been widely used as bioindicators because they are susceptible to changes in vegetation structure and habitat degradation. However, most studies have focused on the effects of land use change, while chronic disturbances, such as selective logging or open grazing by livestock, have received less attention. We used a structural equation model to test the response of the bird community to both landscape modification and chronic disturbance. We assume that land use change can directly modify bird abundance and richness, while chronic disturbance can affect the bird community through changes in the structural complexity of vegetation. The response of the bird community to these pressures could be dependent on the trophic guilds of the birds. We conducted point-count bird surveys between February 2018 and March 2019 in Zapotillo County, southwestern Ecuador. Within an area of 12,400 ha, we located three grids of 4.2 x 2.2 km with different vegetation cover and anthropogenic disturbance level. We divided the grids into 200x200 m cells. We randomly selected 60 cells (20 per grid) where we performed a bird point-count per cell. At each point, three field campaigns were carried out, each one consisting of three sample visits. In total each point was visited 9 times. At each visit, all individuals observed or heard were recorded and the distance from the recording was recorded. We recorded 11225 individual records comprising 113 species of 38 families and 19 orders. Our results showed positive effects of both pressures on bird richness, as we expected, landscape-level changes directly increased richness of bird, while chronic disturbance did so through changes in forest height and abundance of birds. These effects depended on the trophic guild, with granivores being the group that showed positive effects, while frugivores and insectivores showing negative effects with a reduction in bird richness. **Keywords:** Seasonally dry tropical forest, bird community, chronic disturbance, structural complexity

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Divergent Successional Trajectories in Mid-to-late Successional Tropical Forest in Panama

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Introduction: Secondary forests regenerating on abandoned land across the tropics are increasingly important for biodiversity and ecosystem services. Despite this, our understanding of how forest structure, tree species diversity and community composition recover throughout succession is incomplete. Most tropical forest chronosequence studies focus on younger forests ($<$ 40 years old) and consequently there are knowledge gaps concerning continued recovery in mid- and late succession. We address this by examining successional trajectories in an old secondary forest chronosequence (40 – 120 years old) in Central Panama. **Objectives:** We aimed to: Quantify the time taken for forest structure, species diversity and community composition to recover to old-growth levels. Identify aspects of community composition that do not recover through the duration of the chronosequence i.e. old-growth specialists and rare species. **Methods:** We conducted censuses of all trees and palms 5cm DBH in eight 1-ha secondary forest plots (40 – 120 years old) and five 1-ha plots old-growth plots across the Barro Colorado Nature Monument, Panama. Diversity and community composition indices were calculated and the effects of stand age, site slope and soil nitrogen and phosphorous were analysed via GLMs and beta regressions. Community composition was also examined via NMDS, and a multinomial model was used to identify old-growth specialist and rare species. **Results:** We found that species diversity recovers in $<$ 40 years and forest structure within 90 years of forest succession. However, recovery of species composition takes longer, and rare species, and old-growth specialists, are still missing in the mid- and late secondary forest (40 – 120 years old). We find evidence for divergent successional trajectories which are exemplified by the two 120-year-old sites exhibiting very different compositional trends. One site has similar composition to old-growth composition, while the other site has only 38 % similarity to old growth and is dominated by a long-lived pioneer species, *Gustavia superba*. **Conclusions:** Our results illustrate that although species diversity and forest structure recover relatively quickly in secondary forest, community composition recovery takes place over longer time scales ($>$ 100 years). We demonstrate the value of old-growth forests as, even after 120-years of recovery, rare species and old-growth specialists are often missing from secondary forests. Thus, it is imperative that old-growth forests are protected to safeguard unique tree communities, while secondary forests are afforded long-term protection to enable them to recover the complexity of old-growth systems. **Keywords:** Barro Colorado Island, community composition, Chronosequence, old-growth, secondary forest, rarity

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Communities: Spatio-temporal Patterns and Environmental Gradients I

Phenology and Developmental Rhythmicity of the *Cerberiopsis* Species (Apocynaceae): The Growth Trajectories Of *C. candelabra*, a Monocarpic Pioneer Tree

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Introduction: Monocarpy, the strategy of a plant that flowers once then die is rare among long-lived tree species. Only known in tropical forests, it concerns three genera worldwide including the genus *Cerberiopsis* (Apocynaceae), endemic to New Caledonia. The genus comprises three species, of which only one, *Cerberiopsis candelabra,* is a monocarpic pioneer tree. The tree can reach about thirty meters high, and could live for more than a century before flowering massively and dying. **Objectives:** This study aims to describe the growth trajectories and rhythmicity of *Cerberiopsis* species in order to (i) compare the phenology of the processes underlying the development of individuals and (ii) identify morpho-anatomical markers in *C. candelabra* for initiation of the unique flowering episode. Methods: 6 *C. candelabra*, 3 *C. neriifolia* and 3 *C. obtusifolia* at adult stage in natural conditions were investigated. The trunk and crown phyllotactic spires of all individuals were traced. For each spire, we measured (i) the internode lengths and (ii) 10 axial and foliar morpho-anatomical markers. Data were coded in MTG format to retrospectively reconstruct the tree's growth trajectories. A growth monitoring of 135 seedlings was also conducted from June 2020 to February 2022. **Results:** We identify morpho-anatomical marker complexes in *Cerberiopsis* species that (i) vary synchronously (number of growth rings, internode lengths, pith area, branching location) and (ii) indicate a rhythmic primary growth with polycyclism during establishment phase. Growth monitoring of seedlings confirms that rhythmicity is annual in *C. candelabra*. Besides, we noticed in all three species a significant fluctuation of the pith surface along axes, especially during branching and flowering. **Implications:** This study highlights the growth trajectories of *Cerberiopsis* species. Our results suggest that in *C. candelabra* there is a minimum pith surface threshold for branching and flowering. This threshold could reflect optimal conditions associated with flowering induction: the size of apical meristem and the amount of mobilizable carbon resources. Moreover, the rhythmic growth of *C. candelabra* and the annual nature of wood rings production allows us to retrospectively date the studied axes and the age of trees. These results offer promising perspectives to better understand (i) the life history strategy of this rare species and (ii) the triggers of flowering. **Keywords:** Cerberiopsis, growth trajectories, monocarpy, phenology, rhythmicity, pith area, MTG.

Forest–lake Ecotones in a Tropical Forest: Terrestrial Invertebrate Inputs to Lakes Decrease with Forest Distance

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The cross-boundary flux of matter and energy between forests and lakes composes an important ecosystem interconnection where terrestrial invertebrate fluxes represent an outstanding resource for the aquatic fauna. However, there is still little quantitative information on forest contribution in terms of invertebrate inputs into tropical lacustrine systems and on the environmental factors controlling it. Aimed at assessing the terrestrial invertebrate contribution into tropical lakes, we studied six ecotones (i.e., lakeshores and canopy transitions) in the Atlantic Forest, Southeastern, Brazil. Using pan-traps placed in the lakeshore we assessed the influence of forest distance on terrestrial invertebrates inputs into lakes by measuring the distance between forest border and lakeshore. In addition, we measured the effect of lake perimeter-to-area ratio (P/A ratio) on invertebrates' influx into lakes. As expected, forest proximity showed to be an important predictor of invertebrate inputs into lakes, being invertebrate species richness and biomass greater where the forest canopy is closer to the lakeshore. The beta-diversity of invertebrates also increased with distance from the forest, meaning that as far as the forest is from the lake, more dissimilar is the invertebrates community composition. P/A ratio also negatively affected invertebrates abundance, suggesting that the bigger and more dendritic are the lakes, higher matter inputs from the forest. As an average, we estimated that 21 tons of terrestrial invertebrates fall annually into the studied lakes, representing a massive food resource for the aquatic ecosystem. The observed evidence on how ecotone extension affects the flux of organisms between forests and lakes calls attention to how natural and/or human-made disturbance can alter the landscape configuration and consequently, the trophic aquatic web and whole ecosystem functioning. As far as we know, our study is the first to define the dimension of invertebrates biomass contribution to tropical lakes, indicating the importance of forest proximity in linking contrasting ecosystems. Therefore, we accomplish those anthropogenic impacts directly and/or indirectly may compromise the whole trophic-web dynamics and ecosystem functioning. **Keywords:** Atlantic rainforest, β diversity, energy flux, insect biomass, tropical lakes

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How Do Centuries of Taxonomic Change Affect the Species Richness of Amazonian Palms?

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Introduction/Justification: Species richness rises and falls as new taxa are described or existing taxa are reclassified. While such taxonomic change can have a profound impact on biodiversity patterns, it is rarely accounted for in ecological models and conservation strategies. This shortcoming persists partially because studies quantifying taxonomic change over time are still scarce, particularly for hyper-diverse groups such as tropical plants. **Objectives:** This study explores the impact of taxonomic change on patterns of species richness. For that, we uncover temporal and geographic trends of taxonomic descriptions and reclassifications of Amazonian palms. We chose palms because it is a well-studied group of tropical plants. Moreover, palms are known to display a strong spatial phylogenetic structure, implying that different regions are often characterized by different taxa. Thus, if certain palm taxa have a strong spatial phylogenetic structure, then taxonomic change may indeed reshape their pattern of species richness. **Methods**: We integrate three checklists of Amazonian palms, compile information about synonyms from four nomenclatural databases, and track historical nomenclatural changes by consulting botanical monographs. **Results:** Of the c.a. 1690 unique taxa names published over the last 250 years, almost 80% are currently considered as synonyms. Taxonomic lumping, splitting, and reassignments have been particularly frequent in western Amazonia. There, palm species have been associated with more than 400 different names, but according to the current taxonomy, the region only hosts about 80 palm species. We also find that the likelihood and number of synonymizations are not randomly distributed across taxa but are higher for taxa subject to intensive taxonomic investigations and with a large geographical range. **Implications/Conclusions**: Our study shows that taxonomic change has a considerable impact on the documented identity and number of species of Amazonian palms, which in turn triggers a cascade of uncertainty in macroecological models. Such uncertainty presents a challenge for quantifying biodiversity loss due to deforestation or predicting species' response to climate change. Although unavoidable this uncertainty can be quantified and accounted for. We suggest to 1) document in a systematic manner temporal trends in taxonomic descriptions and reclassification, and 2) adopt a probabilistic view on species names and species richness. This ultimately requires bridging taxonomy and macroecology, two disciplines that still operate in relative isolation. **Keywords:** Amazonia, palms, species richness, taxonomy, macroecology

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A New Methodological Framework to Model Tree Diversity Trajectories after Disturbances in Tropical Forests, Integrating Both Disturbance Type and Intensity

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Tropical forests increasingly suffer from anthropogenic disturbances and about 82% of these ecosystems are degraded to some extent. In the meantime, these ecosystems constitute biodiversity hotspots. They account for nearly half of the world's forest ecosystems and play a crucial role in the provision of many ecosystem services. In a global context of biodiversity erosion, investigating the response of these hyperdiverse ecological systems to anthropogenic disturbances is a crucial issue to predict their fate. Our work focuses on the understanding of tree diversity trajectories in disturbed forests. We define biodiversity trajectories as the potential dynamics of tree diversity indices over time in permanent sampling plots (PSPs). We aim at modelling trajectories of tree diversity recovery in logged and secondary forests. We considered both of them as disturbed ecosystems along a disturbance intensity gradient, with various disturbance types. To assess the impact of anthropogenic disturbances on the studied PSPs, we developed a new conceptual framework characterizing the effect of disturbance intensity and type on diversity relative recovery rate following disturbances. We worked in Costa Rica, characterized by a highly fragmented landscape, and in French Guiana, part of the Amazon basin. We used 55*PSPs with an area ?1ha (25 in old-growth forests, 22 in logged forests, 8 in secondary forests) within the rainforest ecoregion, where trees with a DBH?10cm were inventoried at least 5 times over 20 years. We computed both basal area values and Shannon diversity indices for each census, as data to infer a hierarchical bayesian model, retrieving both metrics trajectories. We defined disturbance intensity as the difference between the asymptotic and initial basal area value, and looked at its effect with disturbance type on diversity relative recovery rate. We modelled tree diversity trajectories for each PSP and found that: Diversity recovers more slowly as timber logging intensity increases, diversity recovers more quickly as sylvicultural treatment intensity increases in Costa Rican Atlantic rainforests dominated by a single highly dynamic species, diversity trajectories are predictable but also uncertain, disturbance types have a different impact on diversity and biomass relative recovery rates, bridging the gap between various disturbance types and intensities in terms of tree diversity recovery with the kind of conceptual modelling framework we developed would be the first step to integrate disturbed forest in a single landscape conservation framework, while being aware of each forest specificities.
Keywords: Biodiversity, trajectories, Neotropics, permanent sample plots, hierarchical bayesian modelling

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Communities: Spatio-temporal Patterns and Environmental Gradients II

Tree Growth Rates along a Tropical Elevational Gradient

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Introduction / Background / Justification: The scarcity of information about long-term tree growth rates is a serious impediment to establishing sustainable forest management (SFM) systems in tropical forests as it is a prerequisite for determining biological and economic cutting cycles. Dendrochronology is a powerful tool for examining long-term growth patterns that can potentially be applied to tropical species with clear rhythmic growth (i.e., tree rings), allowing for the development of diameter (D) growth equations as a function of tree age (t). **Objective(s)/Hypothesis(es)/Methods:** Here, we analyze the growth rates, i.e., current annual increment (CAI), mean annual increment (MAI), and relative increment (RI) of three tree species (*Carapa guianensis*, *Cedrela tonduzii*, and *Quercus costaricensis*) located in natural forest along an elevation gradient in Costa Rica. For each species, we compared these parameters within two populations growing at different elevations. We hypothesized that trees from the lower, hotter elevations will exhibit faster growth rates (CAI) than trees at higher elevations, leading to increased rates of carbon uptake and storage. We combined tree-ring data with mathematical modeling (i.e., von Bertalanffy´s model) to estimate growth parameters as a function of tree age: cumulative growth [D(t)], current mean annual increment [dD/dt], Mean annual increment [D(t)/t] and relative increment [(dD/dt)(1/D)]. **Results:** We found that maximum CAI was faster in higher elevation populations of the three species and ranged from 0.90 to 2.07 cm per year. However, the populations located at lower elevations reached their maximum CAI faster than their higher elevation conspecifics, except in *Q. costaricensis* in which the opposite occurred. The mean species residence time showed the same pattern as maximum CAI, it was higher for low elevation populations in *C. guianensis* (256 years) and *C. tonduzii* (132 years) but in *Q. costaricensis* was greater in the high elevation population (103 years). **Implications/Conclusions:** Information about tree growth rates is fundamental for understanding the function and dynamics of montane tropical forests. Our study helps to elucidate how variation in elevation and temperature within species' distributions affect their growth rates. This information will help inform management programs in Costa Rica and guide the sustainable forest management of valuable timber species that have been used for generations by local communities. **Keywords:** Tree-rings, dendrochronology, forest dynamics, tropical elevational gradient, diameter growth modeling

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Local and Landscape Scale Drivers of Understory Herbaceous Plant Diversity and Cover along a Tropical Rainfall Gradient in Western Ghats

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Much of our understanding of the patterns and drivers on tropical plant diversity comes from trees, despite the fact that trees form only a quarter of all plant species in tropical forests. Previous studies have found water availability to be the main driver of tropical tree diversity, but it is unclear whether this finding can be extrapolated to other life forms. Understory herbaceous angiosperms, which form ~10-45% of plant biodiversity in some tropical forests, have received relatively little attention. We hypothesized that the diversity of herbs may be equally or more limited by other factors besides moisture, namely understory light availability. To test the relative importance of water and understory light availability in shaping the abundance and diversity of tropical forest herbaceous angiosperms, we surveyed understory herb communities in 13 one-hectare plots (627 1x1m subplots) along a strong rainfall gradient (750 mm over 36 km E-W) in a seasonally dry tropical forest landscape in India. We examined how herbaceous species richness and cover varied with rainfall across the gradient, using simple linear regression. At the local scale, we tested whether soil moisture and light availability drove micro-site level variation in herb diversity and abundance, using a linear mixed model. We found that understory herb diversity and cover decreased linearly with increasing rainfall at the landscape scale ($P = 1.63e-05$, $R^2 = 0.81$ and $P = 0.0026$, $R^2 = 0.54$, respectively), indicating that water availability was not limiting. Instead, herb diversity and cover were likely driven by light availability, which was negatively correlated with rainfall along the gradient ($r = -0.97$). This is supported by our microsite-level results, where understory cover ($P = 2.69e-06$, marginal $R^2 = 0.244$), and herb diversity ($P = 0.000585$, marginal $R^2 = 0.157$) increased with increasing light availability, while diversity decreased with increasing soil moisture ($P = 0.00132$, marginal $R^2 = 0.157$). Our results contrast with those of previous studies of trees across the same gradient, as well as in other tropical forest regions, which have found increasing tree diversity and biomass with increasing water availability. Instead, understory light availability appears to be the main stress for understory herbaceous plants, limiting herb diversity at both local and landscape scales. Our study shows that patterns of tropical tree diversity cannot be assumed to hold for other plant lifeforms. Plant conservation efforts in tropical forests may therefore need to employ different strategies for different lifeforms. **Keywords:** Herbaceous, diversity, abundance, tropical, gradients, filtering, seasonally dry forests, abiotic

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Seasonal Variation in Patterns of Anuran Diversity along a Subtropical Elevational Gradient Is Partly Explained by Thermal Niches

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Understanding the patterns and processes behind distribution and composition of biodiversity through space and time is a central goal in biogeography. This knowledge can be vital for effective conservation management, specially concerning montane regions, given that they are strongly exposed to higher rates of climatic change. Although many studies have described and explained spatial patterns along elevational gradients, only a handful have investigated their temporal dynamics. Our aim here was to investigate the spatiotemporal diversity patterns of frogs (Amphibian: Anuran) along an extensive subtropical elevational gradient in the Brazilian Atlantic Forest. We also evaluated the importance of temperature in driving observed patterns because of its marked effects on frog physiology and activity. We therefore deployed monthly surveys of anuran assemblages from September 2017 to August 2018 at 38 ponds spanning elevations between 312 m to 1,798 m. We then applied generalized additive models to evaluate the spatiotemporal patterns of frog diversity (measured as Hill's numbers of order $q = 0$, 1 and 2) and abundance, but also to understand how much of this variation could be explained by changes in mean monthly temperature. We found seasonal changes in the shape and magnitude of frog diversity along the elevational gradient. While frog diversity peaked at mid-elevations between late spring (November) and early summer (December), a low-to-mid elevation plateau was observed during other seasons. Frog abundance peaked at mid-elevations between mid-spring (October) and late summer (February), and low-elevation plateau pattern was observed between autumn and winter. Overall, frog diversity and abundance increased from early spring to early summer and then sharply declined towards early winter, showing a nonlinear negative relationship with mean temperature. Temperature accounted for most of the observed spatial and spatiotemporal variation, rather than temporal trends in frog diversity and abundance. Our results suggest that in addition to temperature, other factors such as intrinsic species characteristics may regulate anuran activity patterns throughout the year along the elevational gradient. This study highlights how frog diversity is dynamic across the elevational gradient, bringing up the relevance of considering seasonality to better understand diversity patterns along subtropical mountains, which can be critical to inform conservation strategies. **Keywords:** Atlantic Forest, Altitude, mountains, temperature, seasonality, amphibians, frogs, biodiversity

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The Diversity of Migratory Behaviors in Amazonian Fishes: a Literature Synthesis

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Introduction: Fish migration is one of the most captivating biological phenomena in aquatic systems. In large tropical river basins, such as the Amazon, migrations restricted to freshwaters are the predominant strategy. The flood pulse and the extensive river network provide aquatic organisms with temporal and spatial accessibility to a heterogeneous mosaic of freshwater habitats. However, most ecological knowledge regarding Amazon fish migration currently relies on anecdotal and scattered information, lacking a unifying methodological and conceptual framework to quantify its occurrence. This situation has led to a limited scientific understanding of the environmental and evolutionary forces shaping the diversity of migration in freshwaters as a life-history strategy. **Objectives:** We aimed to progress the need to understand fish migration by integrating the available evidence of this biological phenomenon in the Amazon basin by conducting a literature review to answer: 1) Which species migrate? 2) Where does migration occur? and 3) When and why do migrations occur? Methods: We performed an extensive literature review for evidence of migratory behavior in Amazonian fish species through Web of Science and Scopus, using keywords in English, Spanish, and Portuguese. We constructed a reference database for fish migratory events in the Amazon basin including: species, life-stage, purpose, direction, habitats linked, and basin. **Results:** 1) We found evidence for 219 species performing freshwater migrations in the Amazon Basin. This number corresponds to ~8% of the primary freshwater fish species reported from the Amazon basin. Scientifically documented migratory fishes were distributed in 7 orders (~39% of the basin), 29 families (~48% of the basin), and 106 genera (~17% of the basin). We detected a significant phylogenetic signal in longitudinal and lateral migratory species. 2) Fish migratory events have been reported mainly in the Andean basins, the Amazon main stem, and the Tocantins basins. 3) Reproduction is the most frequently documented migration purpose across events (83) and species (48 spp), Followed by feeding (36 events, 27 spp) and refuge (29 events, 20 spp) migrations. For the migration events with a known hydrological timing and purpose, there exists a significant association between the hydrological time and the start and end of migrations. **Conclusions:** This review synthesizes the knowledge of the diversity of freshwater fish migration in the Amazon from an evolutionary, spatial, and temporal perspective. than previously considered, many species depend on the connectivity of freshwater systems in the Amazon basin to complete their history life cycles. **Keywords:** Potamodromy, freshwaters, hydrology, Tocantins, neotropical, movement, connectivity

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Patterns of Resistance and Resilience in Forest Bird Populations Subjected to Hurricanes and Droughts

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Background: A recent meta-analysis (Patrick et al. 2022) found a repeated pattern of tradeoffs between resistance and resilience in coastal ecosystems subjected to cyclonic storms. This pattern held across ecosystem types and categories of response and may constitute a general pattern of ecosystem susceptibility to tropical cyclones. The study calls for additional research on species traits that could help explain patterns of resistance and resilience at the population level as well as on how past disturbance events may affect the response to future disturbance. **Objective(s)/Hypothesis(es):** We use a long-term (33 year) record of avian abundance to examine how communities, guilds, and populations of individual species respond to repeated disturbance in tropical forest in Puerto Rico. Since 1988, four major hurricanes (Hugo, Georges, and Irma/Maria) and two droughts have affected bird populations in a landscape with significant legacies from historical logging and agriculture. We compare resistance and resilience to hurricanes of different intensity, between different disturbance types, and between different degrees of historical land use. We identify potential species traits that could contribute to resistance and resilience and examine the effect of disturbance history on ecosystem response. **Methods:** We measured bird abundance annually using forty 25-m radius circular plots and 20 mist nets in the Luquillo Forest Dynamics Plot. Resistance was measured using displacement from original conditions, and resilience as the rate of return to pre-disturbance conditions. Ordination techniques were employed to compare community patterns in areas of differing historical land use. We developed preliminary occupancy estimates for all species using a hierarchical modeling framework. **Results:** In 1989, Hurricane Hugo and the following three-month drought negatively affected abundance of frugivores, nectarivores, and granivores, but numbers rebounded with a year of the hurricane. Foraging behavior and diet of insectivores changed after Hugo, but abundance was resistant to the storm. The response to Georges, a less intense

storm, was similar but more muted. The combination of Irma and Maria, occurring within two weeks in 2017, again affected granivores and nectarivores most severely. Species richness and abundance of birds are resilient to hurricanes in Puerto Rico, probably because of the long history of evolutionary adaptation to such disturbances. **Implications/Conclusions:** Avian abundance and community composition are affected by hurricanes and droughts, but the strength of the effects depends on the initial environmental conditions and the characteristics of each disturbance. Predicted increasing hurricane strength and drought duration may result in significant changes in community composition over the long-term. **Keywords:** Birds, hurricane, drought, resistance, resilience

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Frugivorous Fish Species Diversity in the Amazon Drainage Basin

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Introduction: The interaction between fruit-eating fishes and flooded forest plants is very ancient in South America, dating back to the Late Cretaceous. Almost half of all the fish species that consume fruits inhabit South American wetlands (up to 150 of 275). The synchronicity between fruiting and the flooding season to facilitate seed dispersal by water or fish and that during lengthy flooded seasons, fishes spend ˜ 87% of their time in floodplain habitats are part of the evidence of the close relationship between flooded forests and frugivorous fishes. However, it is not clear yet what are the factors that sustain the high diversity of frugivorous fishes in the Amazon River basin. Objective. The aim of this work is to assess the influence of variables such as flooded forest diversity, flooded forest extent, white-water river proportion, and elevation on the frugivorous fish species in the Amazon River basin. We expect that all the predictor variables have a positive relationship with frugivorous fish richness except for elevation, as lower elevation values relate with more floodable area, providing habitat for the fishes. **Methods:** The area of study corresponds to the Amazon River basin. The units of analysis were sub-basins (n=144). We used occurrence data for frugivorous fishes from the Amazon Fish Database. We calculated vegetation diversity using occurrence data for tree species present in the floodplain forest retrieved from GBIF. To estimate the flooded forest extent, we used the floodplain delineation database compiled by Nardi et al (2019). White-water river proportion was retrieved from SNAAP. Elevation data for each spatial analysis unit was extracted from a Digital Elevation Model with 90m of spatial resolution (Saatchi, 2013). To test our hypothesis, we performed a Generalized Linear Model, using the Poisson distribution. **Results:** The results of the GLM showed that vegetation richness, flood extent area and white-water river proportion have significant effects on frugivorous fish diversity ($p<0.001$). However white-water proportion has a negative relationship, while vegetation richness and flood extent area showed a positive relationship with frugivorous fish diversity. **Conclusions:** The results, in part, supported our hypothesis that more diversity in vegetation could offer more diversity of food resources for frugivorous fishes, and that a bigger flood extent area is associated with providing habitat for fishes around forests. This study provides valuable information for a better understanding of the intricate relationship between forests and fish that can be used to inform conservation management decisions. **Keywords:** Lchthyochory, vegetation diversity, Amazon river basin

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Range Overlap and Species Divergence in Birds along a Tropical Elevational Gradient

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Numerous studies have described parapatric distributions of closely related bird species along tropical elevational gradients. It is hypothesized that "species replacements" are maintained by competitive interactions that reinforce elevational range limits of tropical montane congeners. With long-sustained competitive interactions, we may expect competing species to show distributions along a gradient that minimize range overlap and maximize the distance between optima of species' distributions. Yet, with divergence and continued ecological sorting of species along gradients, related species pairs could vary in the degree of distributional overlap, this variation could depend on divergence of traits related to resource use and phylogenetic distance of species pairs. Here we use extensive survey data from point counts, mist-netting, flocking and nest observations to examine species abundance distributions and overlap along a 3000-m elevational gradient in Manu National Park, Peru. We apply Huisman-Olff-Fresco models to evaluate the shape of species' responses and relative position along the gradient and quantify range overlap of congeners. We assess whether congeners show uniformly distributed optima along the gradient and test the prediction that range overlap in species pairs increases with increasing phylogenetic distance and accumulated trait differences. We use species representing distinct families to ask whether differences exist in the 'time to achieve sympatry' with divergence, which may depend on how species with different ecologies experience interspecific competition. Preliminary results show variable degrees of elevational overlap in tropical montane congeners, ranging from gaps between species' elevational ranges, low to moderate range overlap and complete range overlap. The most common pattern among congeners was low to moderate degrees of elevational range overlap with uniformly spaced optima, consistent with ecological niche theory and competition. Our results have implications for understanding the ecological and evolutionary role of competition in structuring tropical avian communities. **Keywords:** Amazon, Andes, altitudinal gradient, avian, congeners, phylogenetic distance, range overlap

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Communities: Spatio-temporal Patterns and Environmental Gradients III

The Geographic Range Size and Vulnerability to Extinction of Epiphytes in the Atlantic Forest of Brazil

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Epiphytes – plants that germinate and grow non-parasitically on other plants – are fascinating components of tropical plant diversity. They comprise 10 to 39% of the vascular plant species in neotropical Floras. Despite a growing number of studies, knowledge of the macroecology and conservation of epiphytes remains incomplete. Epiphytes have long been reported to have larger geographic range sizes than terrestrial species, based on a handful of decades-old studies. In contrast, epiphytes are often reported to have higher endemicity than terrestrial species. This apparent contradiction is intriguing, and it has consequences for conservation since range size is a key predictor of extinction risk in plants. Here, we test the theoretical expectation that epiphytes have larger geographic ranges than terrestrial species in the Atlantic Forest of Brazil, a global center of epiphyte diversity. Using plant occurrence records available through the SpeciesLink and GBIF databases, we estimated the extent of occurrence and area of occupancy of all flowering plant species in Brazil's Atlantic Forest according to the Brazilian Flora 2020. We compared the range size of epiphytes with other life forms at broad taxonomic scales and among close relatives. We tested for mean differences based on raw and weighted values corrected for phylogenetic distance, using general linear approaches and phylogenetic regressions. Our results demonstrate that the geographic range of epiphytes is strikingly smaller than the average geographic range of flowering plants. Along with lithophytes, epiphytes have the highest proportion of species with vulnerably small ranges among plant life forms, placing them at high extinction risk. However, epiphytes' small range and high vulnerability are typically shared with closely related terrestrial and lithophytic species, indicating that the reasons for epiphytes' small geographic range are largely shared with the non-epiphytic species in lineages where epiphytism evolved. The small species ranges in epiphytic lineages correlate with unusually large numbers of species per genus, suggesting that high net diversification can partially explain the small range size and consequent vulnerability of species in these lineages. The combination of small ranges and slow life histories among epiphytes and closely related species is deeply concerning for biodiversity conservation, helping to understand why these species are likely among those at greatest risk of extinction in the Atlantic Forest flora. **Keywords:** Rarity, extinction risk, tropical forest, flowering plants

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Flowering Cues in a Costa Rican Cloud Forest: Analyzing the Effect of Climate

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Introduction: The influence of a changing climate on the phenology of organisms in a region is dependent on how regional climate cues or modifies the timing of local life history events and how those cues are changing over time. There is extensive evidence of phenolological shifts in flowering time over the past 50 years in response to increasing temperatures in temperate regions, but far less is known about tropical regions where seasonality is less temperature driven. **Objective**: We examined historical datasets of flowering patterns in two guilds of ornithophilous plants in the montane cloud forests of Monteverde, Costa Rica in order to identify environmental cues for flowering in nine species of plant that are important resources for hummingbirds. **Methods**: Bimonthly censuses of flower production were used to quantify flower production during two sampling periods:1981-1983,

1986-1991. We developed a predictive model incorporating chill units and drought units to explain flowering abundance of the focal plant species that flower in the dry season. **Results**: Our results indicate that the species studied here appear to cue flowering patterns predominantly to accumulated drought units. Species varied in terms of the predictability of drought versus chill regarding flowering cues. **Conclusions**: In contrast, to temperate plant species, cloud forest species appear less dependent on temperature for flowering cues. These results have implications for how tropical cloud forest plants will respond to climate change to the extent that drought and chill patterns are changing with time. **Keywords:** Phenology, Monteverde, ornithophilous, precipitation, temperature, model selection, climate change

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Desiccation Risk Responses in Anurans of an Extreme Environment: the Inselbergs in Colombian Orinoquía

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An environment is considered extreme when there is a drastic variation in physical factors or when resources have low availability or predictability. The rocky outcrops in South America, known as inselbergs, have exceptionally high and fluctuating temperatures and a marked seasonality in precipitation patterns. On these outcrops, eroded depressions form precipitation-dependent pools. During the rainy seasons, these ponds fill with water and harbor numerous anurans who depend on water to reproduce and survive. These pools are typically short-lasted and can experience very high temperatures, hence representing truly extreme environments for amphibian development. One of the expected effects of climate change on these rocky ponds is a progressive reduction in pond duration (hydroperiod), but the consequences of this phenomenon on tadpole survival and development of inselberg ponds' amphibians have not yet been studied. *Leptodactylus lithonaetes* is a frog specialized in breeding on the rocky outcrops in the Orinoquía of Colombia and Venezuela. As inhabitants of an extreme environment, tadpoles of this species must cope with the changing and challenging conditions of rocky ponds. We aim to evaluate the responses to the risk of pond drying in *Leptodactylus lithonaetes* tadpoles, experimentally manipulating different levels of pond drying regimes. For this purpose, we characterized the biotope of pools in a rocky outcrop in Colombian Orinoquía and evaluated morphological and locomotor responses of *Leptodactylus lithonaetes* tadpoles exposed to different levels of desiccation risk. Our preliminary results show that physical and environmental conditions were heterogeneous across rocky ponds. We found that the water volume of some ponds decreased in just a few days, and water temperatures can exceed critical thermal values of tadpoles, compromising tadpole survival. Simulated pond-drying induced enhanced growth and larger size at metamorphosis in *L lithonaetes* larvae. In addition, tadpoles at risk of pond drying showed greater maximum swimming acceleration than tadpoles from constant high-water levels. These results are opposed to findings reported for other species, where tadpoles usually respond to desiccation risk by developing faster but attaining smaller sizes at metamorphosis. In order to improve our understanding of the vulnerability of anuran species to climate change, our findings highlight the importance of continuing exploring responses to desiccation risk in amphibians, including those already adapted to extreme environments. **Keywords:** Inselbergs, extreme environment, anuran, desiccation risk, morphological and locomotor responses

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Phenology of Woody Climbing Plants in Two Forest Ecosystem Types in Ghana

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Introduction/Background/Justification: Phenology refers to the timing of life cycle events in plants and animals, and is an effective way to determine the impact of climate change on structure, function and dynamics of ecosystems. To be worth the time, phenology monitoring must be dedicated to important components of tropical forests that are both useful and sensitive to climatic changes. Woody climbing plants, also termed as lianas, are a good example due to their response to microclimatic changes in tropical forests by rapid proliferation and deployment of leaves in tropical forest canopies. **Objective/Hypothesis**: The study objective was to determine patterns of liana phenology and their association with climatic variables in two forest ecosystem types in Ghana. I hypothesize that liana phenology will negatively correlate with climatic variables, based on their seasonal growth advantage in dry/seasonal forests. **Methods**: Two 1ha plots each were demarcated in a moist semi-deciduous forest and a dry semi-deciduous forest. In each plot, lianas expressing leaf, fruit or flower phenophases were tagged and monitored over a 13-month period. Climate data (rainfall, temperature and relative humidity) was obtained for the same period. Using pearson correlation, the relationship between monthly mean proportions of phenology events and monthly mean climatic variables were determined. **Results**: Our results show varying patterns of phenology in moist and dry forests and their association climatic variables. In moist semi-deciduous forest, association with climatic variables of the preceding month were stronger than with the current month whereas the opposite was true for dry semi-deciduous forest. Climatic variables showed important association with leaf phenology but not reproductive phenology in the two ecosystems studied. **Implications/Conclusions**: Patterns of phenology differed between the two ecosystems. Climatic variables showed important association with leaf phenology but not reproductive phenology in both ecosystems. **Keywords:** Phenology monitoring, lianas, rainfall, temperature, humidity

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Community assembly I

Species of Unusual Effect: The Important Things That Run the World

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Introduction / Background / Justification: Following the theme of this year's ATBC meeting ("Conserving Tropical Biodiversity and Achieving Socio-ecological Resilience in the Anthropocene: Opportunities and Challenges"), I wish to explore the various ways in which a few species in some communities or ecosystems play especially consequential roles. To understand the causes and consequences of these species' influences on communities should substantially improve our ability to conserve, manage, and restore their communities on our human-dominated planet. Several years ago, E. O. Wilson (1987) commented on the extreme diversity, the relative proportion of all animal biomass, and the mediating influence of energy flow through ecosystems of invertebrate taxa, and he described them as "the little things that run the world." Soon thereafter, John Terborgh (1988) observed that, especially owing to their cascading, top-down influences on communities, apex predators and other large-bodied species should be considered "the big things that run the world." Others have similarly identified species whose influences on community assembly, ecosystem function, etc. are extreme: ecosystem engineers, foundation species, keystone species, as well as dominant species, invasive species, and humans (the "ubiquitous keystone pest," G. Polis, 1999). **Objective(s)/Hypothesis(es):** I propose an overarching category for all species whose influence is extreme in the communities and ecosystems they inhabit: Species of Unusual Effect (i.e., SUEs). SUEs are the "important things that run the world." These species are especially important for community assembly, ecosystem function, or any other defined emergent property of communities and ecosystems. **Results:** Based on their original definitions, and focusing specifically on community assembly, I show how selected principal categories of SUEs are interrelated. I further show how this conceptual framework is flexible and easily accommodates additional categories of SUEs. Finally, I show how understanding SUEs is especially useful for conservation, management, and restoration of communities and ecosystems. **Implications/Conclusions:** To understand the causes and consequences of the extreme influences of Species of Unusual Effect (SUEs) on community assembly should substantially improve our ability to conserve, manage, and restore the communities they inhabit. The flexible conceptual framework that I propose can accommodate all types of SUEs and can help guide a good portion of our basic and applied science efforts toward these influential taxa. **Keywords:** Community assembly, ecosystem engineer, keystone species, foundation species

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Diversity and Distance Decay in Terra-firme Forests in the Chocó Biogeographic Region, One of the Most Unexplored Areas in Colombia

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Introduction: The tropical forests of the Biogeographic Chocó have been recognized by numerous authors for their high biological diversity. The unique conditions of this region, due to the enormous variability in its climatic and edaphic conditions and its spatial location, have generated an enormous floristic richness in the forests of this territory. However, there are almost no studies that have analyzed or modeled the rates of floristic change in this region. Colombia being a country with an enormous diversity of plants, there is still a profound lack of knowledge about the distribution of species and patterns of floristic change in the Colombian Pacific, being one of the regions with the greatest diversity of flora species in the national territory. **Objective:** The purpose of this study is to estimate the distribution patterns of tree species, the rates of floristic turnover and the mechanisms that influence them, in the tropical terra-firme forests of

the Choco Biogeographic Region. **Methods:** Information from 12 permanent plots of 1 hectare, distributed from the border with Panama to Buenaventura, all located in terra firme forests, was used. Information on climatic variables downloaded from the Chelsa platform and the results of soil analysis of the plots were also used. Similarity between plots was assessed using Jaccard's index and floristic turnover rates were constructed from a regression model relating floristic similarity to log-transformed geographic distance. Subsequently, to evaluate the effect of environmental variables on the variation in species composition between plots, a (RDA) was applied. And to determine the effect of geographic distances on species composition between plots, a (PCNM) was applied. Finally, to determine the effect of limited dispersion and environmental variability, a partition analysis of variance was calculated. **Results:** We recorded 6,503 individuals with DBH 10 cm, these corresponded to 932 species, 315 genera and 83 taxonomic families. Similarity values ranged from (0.6%-37.4%) and similarity decreased significantly with distance. The (RDA) and the variance partitioning analysis indicated that environmental variability is the most determinant mechanism in the turnover of woody species in the terra firme forests of this region. Finally, limited dispersal also had an effect on species turnover, although it was smaller than environmental variability. **Conclusions:** The most abundant families were Fabaceae, Arecaceae and Moraceae. 465 species (49%) recorded only two or fewer individuals. Environmental variability can be considered the most determining factor in the turnover of plant species in these forests, however, limited dispersal also influences this species turnover, and its effect can be considered greater than in other tropical forests. **Keywords:** Chocó Biogeographic Region, Terra-firme forests, diversity, distance decay, community ecology

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The Contribution of Environmental and Dispersal Filters on Phylogenetic and Taxonomic Beta Diversity Patterns in Amazonian Tree Communities

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Environmental and dispersal filters are key determinants of species distributions of Amazonian tree communities. However, a comprehensive analysis of the role of environmental and dispersal filters is needed to understand the ecological and evolutionary processes that drive phylogenetic and taxonomic turnover of Amazonian tree communities. We compare measures of taxonomic and phylogenetic beta diversity in 41 one-hectare plots to test the relative importance of climate, soils, geology, geomorphology, pure spatial variables and the spatial variation of environmental drivers of phylogenetic and taxonomic turnover in Ecuadorian Amazon tree communities. We found low phylogenetic and high taxonomic turnover with respect to environmental and dispersal filters. In addition, our results suggest that climate is a significantly better predictor of phylogenetic turnover and taxonomic turnover than geomorphology and soils at all spatial scales. The influence of climate as a predictor of phylogenetic turnover was stronger at broader spatial scales (50 km^2) whereas geomorphology and soils appear to be better predictors of taxonomic turnover at mid (5 km^2) and fine spatial scales (0.5 km^2) but a weak predictor of phylogenetic turnover at broad spatial scales. We also found that the combined effect of geomorphology and soils was significantly higher for taxonomic turnover at all spatial scales but not for phylogenetic turnover at large spatial scales. Geographic distances as proxy of dispersal limitation was a better predictor of phylogenetic turnover at distances of $50<500$ km. Our findings suggest that climatic variation at regional scales can better predict phylogenetic and taxonomic turnover than geomorphology and soils. **Keywords:** Lineages, beta diversity, environmental filters, Amazon, biogeography

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Community assembly II

Environmental Filtering, Not Competition, Drives Forest Specialist Replacement by Non-forest Species in Fragmented Landscapes

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Anthropogenic disturbances are known to cause biotic homogenization, a global pattern arising from the replacement of native, endemic, or specialist species by exotic, widespread or generalist species. Despite the strong empirical evidence from around the world, there are few formal tests of alternative pathways leading to species replacement. Yet, the negative impacts of invasive or widespread species on native species are thought to be a relevant pathway. We tested two alternative hypotheses regarding the processes underlying specialists replacement by generalists in landscapes affected by habitat loss, the major threat to global biodiversity: a) environmental filtering – environmental changes associated with habitat loss filter out specialists while favouring the establishment of generalists, and b) interaction with generalists – environmental changes favour generalists, which via ecological interactions lead to the decline of specialists. Through a high-quality dataset encompassing eight metazoan taxa and 1,285 sampling locations at the Atlantic Forest – a hyperdiverse and globally threatened biome, we used structural equations to model: (1) direct and indirect effects (via fragmentation) of habitat loss on the richness of both forest specialists and non-forest species (i.e., generalists) (environmental filtering), and the direct effect of the richness of non-forest species on forest specialists (interaction with generalists). We ran the model considering the following gradients of forest cover, based on thresholds of abrupt changes in landscape configuration: 100–60%, 60–30%, and 30–0%. Our results support the environmental filtering hypothesis as the analyses indicate a significant effect of habitat loss on both forest specialists (negative effect) and non-forest species (positive effect), while no negative effect of non-forest species on forest specialists. Habitat loss affected forest specialists only in landscapes with less than 60% of habitat and non-forest species only in landscapes with more than 30% of habitat. These differences in the response to habitat loss between groups of species highlight the challenge of detecting the processes underlying species replacement, which requires a well-designed conceptual and methodological approach, and large, good-quality datasets covering the whole gradient of habitat loss. Our findings suggest habitat loss *per se* – rather than the expansion of widespread, generalist species - is the critical driver of the decline of native, specialist species. In certain situations – as in landscapes with more than 60% of habitat - the arrival of generalists indeed result in the increase of the number of species, as the negative effect of habitat loss on specialists is not observed at these landscapes. **Keywords:** Biotic homogenization, habitat loss, species replacement

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Species Differences in Foliar Secondary Metabolites Represent a Fundamental Niche Dimension on Barro Colorado Island, Panama

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Introduction / Background / Justification: Fundamental hypotheses concerning the maintenance and generation of diversity in ecological communities posit a central role for the chemical differences among plants, namely in their ecological function as defenses against herbivores and pathogens. Yet the vast diversity of plant chemical defenses has traditionally precluded community-level studies of chemical ecology. Here, we take advantage of novel methods for untargeted metabolomics based on data generated with liquid chromatograph-tandem mass spectrometry to identify, classify, and compare the structures of >10,000 unique foliar metabolites from

314 tree species recorded in the 50-ha forest dynamics plot on Barro Colorado Island (BCI) and ask whether they represent niche differences in the tree community. **Objective(s)/Hypothesis(es):** If species differences in secondary metabolites represent niche differences that influence demographics, community composition, and species coexistence, we expect seedling survival to decline with increasing chemical similarity to neighboring plants. **Methods:** We extracted leaf samples in 90% methanol and analyzed the extracts on a Thermo QExactive quadrupole-orbitrap mass spectrometer. We then examined the data using the latest metabolomics techniques following Sedio et al. (2021). Specifically, we aligned LC-MS chromatograms using MZmine 2 (Pluskal et al., 2010), calculated molecular formulae using SIRIUS (Dührkop et al., 2019), predicted molecular structures using CSI:FingerID (Dührkop et al., 2015), and classified compounds using ClassyFire (Djoumbou Feunang et al., 2016). We then generated a molecular network on the Global Natural Products Social (GNPS) Molecular Networking platform (Wang et al., 2016) using the Feature-Based Molecular Networking (FBMN) technique (Nothias et al., 2020) and calculated chemical structural-compositional similarity (CSCS, Sedio et al. 2017) for every pair of species with respect to the whole metabolome and specific chemical classes involved in defense. We modeled seedling survival as a function of chemical similarity to neighboring trees using generalized linear models. **Results:** Seedling survival in the tropical forest at BCI was greater in the presence of chemically dissimilar neighbors. The effect was stronger when chemical similarity was measured in terms of defensive chemical classes, rather than the metabolome as a whole, and was pervasive among the 314 species in the BCI tree community. Implications/Conclusions: These results suggest that secondary metabolites define niche differences at the community level, most likely by shaping host-use patterns of insect herbivores and microbial pathogens. Further, our results suggest that chemically mediated species interactions range from enemy-mediated competition to niche partitioning with the potential to contribute to species coexistence.
Keywords: Chemical ecology, metabolomics ,pathogen, herbivore, niche seedling survival

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Edge Effects on Arboreal and Terrestrial Herpetofauna across Vertical Strata in a Tropical Dry Forest

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Background: Forest biodiversity is commonly stratified from forest floor to canopy, as species track optimal microclimate and resource availability vertically. Edge effects from habitat fragmentation can alter both vertical and horizontal distribution of microclimates and drive changes in species assemblages. However, the impact of edge effects on arboreal communities remains poorly understood. Additionally, the vertical structuring of microclimates and horizontal impacts from edge effects can vary between day and night. Thus, edge impacts on biodiversity may depend on both species vertical niche and diel activity patterns. **Objective:** We sought to characterize edge effects on microclimates across vertical forest strata and assess their impact on herpetofauna distribution in a tropical dry forest in Kenya. We expected edge effects would more strongly impact microclimate at the ground than canopy, with vertical structuring of microclimates breaking down at the forest edge. We hypothesized that biodiversity patterns of the arboreal community would be less affected by edge effects than terrestrial species, but would exhibit a downward shift in perch height in response to forest edges. **Methods:** To assess edge effects on microclimates and biodiversity patterns, we used arborist climbing techniques to conduct 144 one-hour stratified surveys from forest floor to canopy, searching for reptiles and amphibians. Surveys were conducted across an edge-core gradient, during both day and night. We recorded temperature and humidity every three minutes throughout each survey with dataloggers to characterize microclimates. **Results:** Edge effects on microclimates were stronger at the ground than canopy, with edges hotter and dryer than the forest core. However, at night, edge effects were weaker and vertical stratification of microclimates collapsed. Contrary to our predictions, arboreal species showed stronger edge signals that terrestrial species, with arboreal abundance and diversity declining towards forest core, and terrestrial diversity showing no edge effect. Mixed effect models showed perch heights were higher at the edge and declined toward the core, which was driven by responses of nocturnal species. **Conclusion:** Our findings demonstrate that edge effects on microclimate can differ across forest strata and affect arboreal and terrestrial species differently. The lack of microclimate stratification and dampening of edge effects at night suggests vertical structure of microclimates may sometimes be less important for nocturnal than diurnal species. Higher perch heights at the forest edge suggests arboreal species can leverage their vertical mobility to accommodate edge effects via changes in their perch height, possibly conferring greater resilience to habitat fragmentation. **Keywords:** Edge effects, stratification, microclimates, herpetofauna, canopy, habitat fragmentation

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Community assembly III

Analyses of Three-dimensional Species Associations Reveal Departures from Neutrality in a Tropical Forest

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Introduction/Background/Justification: The study of community spatial structure is central to understanding diversity patterns over space and species co-occurrence at local scales. Most studies on tree species spatial distribution typically focus on "space" as being either the two-dimensional horizontal dimension or the vertical dimension, but not both. As a result, we do not know, at a given scale, the relative importance of the horizontal dimension vs. the vertical dimension for the co-occurrence of species. **Objectives/Hypotheses:** We introduce a novel three-dimensional spatial analysis that considers horizontal and vertical associations among tree species simultaneously. Associations can be positive (species aggregate in space) or negative (species segregate in space) or random (species are not particularly close to or far from each other). To describe such associations in space, we estimate the crown overlap between each pair of neighboring trees to capture processes that result in species aggregating or segregating in space. **Methods:** To describe associations in space, we estimate the crown overlap between each pair of neighboring trees to capture processes that result in species aggregating or segregating in space. We use data from four censuses spanning 16 years (2000–2016) from the tree communities in the Luquillo Forest Dynamics Plot, Puerto Rico. **Results:** We show that spatial organization becomes less random over time as the forest recovered from land-use legacy effects and hurricane disturbance. Tree species vertical segregation is predominant in the forest with almost all species that co-occur in the horizontal plane avoiding each other in the vertical dimension. Horizontal segregation is less common than vertical, while three-dimensional aggregation (a proxy for direct tree competition) is the least frequent type of spatial association. Furthermore, dominant species are involved in more non-random spatial associations, implying that species co-occurrence is facilitated by species segregation in space. **Implications/Conclusions:** This novel three-dimensional analysis allowed us to identify and quantify tree species spatial distributions, how interspecific competition was reduced through forest structure, and how it changed over time after disturbance, in ways not detectable from two-dimensional analyses alone. Our results provide strong evidence for species segregation in space, supporting the idea that co-occurrence of species in tropical forests is promoted by species-specific realized niches. **Keywords:** Forest succession, habitat association, spatial associations, species co-occurrence, vertical stratification.

Using Coexistence Theory to Test Liana Community Coexistence in a 50-ha Plot

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Introduction: Determining the mechanisms for species coexistence is a central goal in ecology. One of the core theories for species coexistence is the resource niche, where species coexist by partitioning resources in the community. In contrast, the neutral theory posits that species are competitively equivalent and thus resource partitioning is not necessary for species to coexist. Testing between these two alternative explanations in a single theoretical framework is critical to understand species coexistence. **Hypotheses/Question:** We tested the niche (deterministic) versus a neutral (non-deterministic) hypothesis to explain plant species coexistence. **Methods:** We examined whether three key theoretical properties of plant communities were more consistent with niche or neutral processes. These properties were derived from commonly used coexistence theory and include: 1) the relationship between intraspecific and interspecific frequency dependence for each species – a

test of whether populations are self-limiting (negative frequency-dependence (NFD)), 2) population frequency at demographic equilibrium (equilibrium frequency (EF)) – a test of the relative abundance of a species when its population growth rate was stable, and 3) the strength at which a species recruits into an area where it is not present (invasibility criterion) – a test of the speed at which a species recovers or repopulates an area where it is not present. By examining these three properties, we can test whether the plant community is controlled by deterministic or non-deterministic properties. We used Bayesian statistical methods on a 10-year longitudinal survey of over 117,000 lianas in a Panamanian 50-ha plot to calculate the three key theoretical properties of plant communities for 86 species that had at least 100 individuals. Species subpopulations were created by dividing the plot into 20mx20m quadrats. **Results:** For all 86 liana species, intraspecific density dependence was greater than interspecific density dependence, the strength of which correlated with rank abundance. Population frequency at equilibrium varied with species identity and was highly correlated with species rank abundance. Every species had positive growth rates when rare, thus, all species were capable of invading new areas, however, invasibility and rank abundance were not correlated. **Interpretation / conclusions:** The liana community on BCI is highly structured and species rank abundance is deterministic, not neutral. Both the NFD and EF criteria were consistent with deterministic processes and the invasibility criterion was similar and positive for each species, which could explain species coexistence. This study demonstrates liana coexistence is deterministic and the liana community is a non-random assemblage of species. **Keywords:** Coexistence, lianas, demographic study, negative frequency-dependence, equilibrium-frequency, invaisibility criterion

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Hydro-edaphic Gradient Shapes the Local Community Assembly of Trees in a Neotropical Forest

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Hydrological and edaphic gradients are known to determine local community assembly in tropical forests, but are often summarised in discrete categories. These approaches disregard the continuous response of species abundance to waterlogging. This methodological issue is critical in the context of climate change because water gradient at a local scale is expected to fluctuate due to unstable rain patterns. The use of a continuous proxy for soil moisture such as the Topographic Wetness Index (TWI) overcomes the limits of punctual measurements with hydrological grounded algorithms. The TWI allows the interpolation of the soil moisture based solely on the topography. Taking advantage of interpolation property, the TWI recently unveiled a pervasive hydro-edaphic niche differentiation mechanism in neotropical species complexes. Thus, an evaluation of the predictive efficiency of TWI calculation methods at the local community scale is a crucial step to study local determinants of tropical tree species' niche. In this study we tested the effects of a set of topographic wetness index variants on the community composition of trees in a neotropical forest. We investigated the consistency of community composition response to TWI with hilltop and lowland classifications already available for the studied species. We further studied the phylogenetic signal of species association with TWI to explore niche differentiation mechanisms in the local community. Combining spatially explicit inventories, botanical determination and LiDAR-derived topographic data over 120 ha of permanent plots in French Guiana, we used a Bayesian modelling framework to infer a joint species distribution model. We relied on a hydrogeology-based algorithm to compute ten different indexes of topographic wetness and compared their information criteria in a model selection process. We classified the effect of TWI for each species based on the sign of the credibility interval. We used Blomberg's K and variance partitioning to explore the phylogenetic signal of species association with TWI. Our results demonstrate that TWI is an integrative proxy for local-scale community patterns of tropical trees. Using a joint species modelling of the TWI effect on species distribution, we found that several species differed from their classification in the literature, questioning their true habitat preference. The phylogenetic analysis of the TWI effect on species distribution shows that the hydro-edaphic niche differentiation is present for more genera than previously described. These results highlight the interest of adapted continuous proxy to retrieve fine scale community assembly along studied gradient and shed light on the mechanisms behind habitat specialisation of tropical trees. **Keywords:** Species distribution, habitat specialisation, hydro-edaphic gradient, TWI, Paracou

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Community assembly IV

Biotic and Abiotic Factors Regulate Multiple Aspects of Grassland Biodiversity in the Andean Humid Puna of Bolivia

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The Andean grassland diversity and ecosystem functioning are threatened due to changes in climatic patterns and land use intensification. We studied to what extent grazing intensity (GI) and its interaction with abiotic factors explain plant diversity in northwestern Bolivia. We hypothesize that grazing and abiotic factors are regulating diversity of grasslands under a regime of low nutrient and water availability so that higher GI relates to lower diversity. This is relevant for the conservation of grasslands with high plant diversity to secure the stability of primary productivity and therefore the economy of indigenous communities facing the challenges of climate change. However, the extent to which changes in herbivore-plant interactions are regulating plant diversity is not well understood for large areas in the Andes and shifts in trait values within the grasslands remain equivocal. We investigated multiple measures of diversity along a gradient of GI in six indigenous communities. We installed 105 plots along the gradient maintaining constant aspect and slope. For each plot we measured species cover, leaf traits of dominant species and soil parameters. Climatic conditions were extracted from global databases. Results show that abiotic factors correlate strongly with altitude, i.e. pH and mean annual temperature are regulating changes in species composition at the plot level. Ordination analysis confirms that those abiotic variables explain the distribution of plant communities along the study area. At a larger scale, for sites with higher biotic homogenization GI seems to be an important factor regulating diversity. Furthermore, plant communities where GI and precipitation seasonality are main regulators are characterized by higher Specific Leaf Area (SLA) and Leaf Nitrogen Content (LNC) and plant communities where altitude is the main regulator are characterized by higher Leaf Dry Matter Content (LDMC) and Leaf Carbon Content (LCC). These results are aligned with other studies in the Andes where high SLA is associated with lower costs of leaf construction and higher rates of herbivory, whereas plants with low SLA seem to predominate when GI is moderate or low and at higher altitude. Overall, grasslands' diversity at the humid puna of Bolivia is regulated by interdependent factors including climate, nutrient availability and GI. Further research can be undertaken to confirm whether the long history of grazing has favoured the dominance of short plants with high regrowth at sites with lower beta diversity. This study highlights the importance of investigating the impact of grazing intensification at diferent spatial scales to provide relevant ecological information concerning the consequences of changes in diversity on ecosystem functioning and stability. **Keywords:** Andes, climate change, diversity, functional traits, grasslands, grazing, indigenous communities

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Living in Aggregation in the North-Western Amazon: How Plants Evade the Conspecific Negative Density Dependence (CNDD) Effects

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Introduction / Background / Justification: For plant species living in aggregation, CNDD implies potential enemy transmission and competition for nutrients. However, evidence suggests that clumped species could be better defended than those with isolated individuals, allowing for more investment in growth or reproduction. Additionally, early studies in temperate forests showed that leaf-litter decomposed significantly faster under the parental or conspecific trees - called the 'Home Field Advantage' hypothesis (HFA). Experiments testing the HFA in the tropics are scarce and previous studies have shown that the NW-Amazon forest floor is "carpeted" with a relatively high diversity of physical-chemical types of leaf-litter, making it more difficult to form homogeneous microcosms like those at higher latitudes that promote HFA. These microhabitats may however be found at ground level where aggregated conspecific individuals proliferate, the so-called 'home'. **Objective(s)/Hypothes(is/es):** Here we hypothesized (1) that six common plant species that live in aggregation differ in soil invertebrate species composition (at home) comparing to what is found out of their spatial distribution (out of home), (2) that leaf-litter decomposes significantly faster in areas of highest conspecific density in and out of home, and (3) there is a strong relationship between soil nutrients content (N, P +micronutrients) and the invertebrate community structure and leaf-litter decomposition rates. **Methods:** The experiment took place in Yasuní National Park, Ecuador. Invertebrates were collected at 'in home' and 'out of home' sites using Winkler and pitfall traps in the same places we tested for leaf-litter decomposition. For decomposition we used coarse and fine mesh-bags where invertebrates were free to manipulate leaf-litter. Soil nutrient data was taken from previous studies: sampling consisted of a grid of $50m^2$ in a 50Ha plot, and data was kriged for interpolations. **Results:** Among treatments, we found that soil litter transformers were significantly clustered in small-scale patches in the areas of plant aggregation. Decomposition however was faster for non-aggregated plants, both inside and outside their highest density distribution zones. Nutrients and soil acidity were positively (Ca) and negatively (Al, pH) related with leaf-litter decomposition, while no soil characteristics were related to invertebrate richness and functional diversity. **Implications/Conclusions:** Results suggest that plants may create habitats that promote the association of particular soil invertebrate species (and potentially microbiome) to efficiently exploit local nutrients. HFA may be considered in hyperdiverse tropical forests as leaf-litter of aggregated plant species seems to be more labile, favoring the nutrient up-take of its own parental trees. **Keywords:** Cluster distribution, decomposition, edaphic functional groups, litter transformers, soil chemistry

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Long-term Dynamics of Tropical Old-growth Rainforests Reveal Thinning Processes in Tree Communities Associated with Soil Properties, Disturbance, and Species Diversity

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The relationship between mean plant mass and plant density (number of plants per unit area) has been used to explore competitive plant-plant interactions. A negative slope of the relationship between log(plant mass) vs. log(plan density) is indicative of a thinning process, presumably due to the occurrence of competitive interactions. In tropical forests, thinning processes in tree communities have been documented mainly in the phases of early succession, when there is a high availability of resources and the trees compete for a position in the forest canopy. However, to date, no thinning processes have been reported in the old-growth phase of the forest. We conducted a long-term study (28 years) in the tropical rainforest of Mexico's Selva Lacandona region to document thinning processes in tree communities of old-growth forests. We predicted that thinning occurs when the availability of soil resources is low and the number of interacting species is high. In 1994, we established 14 plots (0.5 ha each) in which all trees with $>=$ 10 cm DBH were marked, identified, and measured. Every year, we measured in DBH all surviving trees and recorded, identified, and measured all newly recruited trees that reached 10 cm DBH. We used allometric models based on DBH and species wood density to estimate the aboveground biomass of each tree. We used a principal component analysis to summarize 12 soil, topographic, and tree-fall disturbance variables into two dimensions. Over the 28 years, we recorded 4,385 trees and about 300 species. We found significant negative log(plant mass) vs. log(plant density) relationships in 12 (slope varied from -3.10 to -.48) of the 14 plots. No thinning occurred in two plots disturbed by large tree-falls (positive slopes: 0.43, 1.72), indicating that chronic tree-falls release resources that reduce tree competition. Thinning increased in plots with lower pH, higher aluminum content, lower soil nitrogen, and higher species diversity. Therefore, as predicted, thinning was stronger when an increasing number of species come into play in environments limited in soil resources. All these results, suggest an important role of interspecific competition in long-term forest dynamics and show that thinning processes are not restricted to early phases of forest succession. **Keywords:** Competition, Montez Azules Biosphere Reserve, biomass, species coexistence, gap dynamics

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Habitat Niche Partitioning of Understory Herbaceous Plants in a Lowland Tropical Rain Forest

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Introduction: Explaining why and how tropical rain forests are among the most diverse plant communities in the world remains a major question in ecology. In particular, whether the same factors drive patterns of diversity in different life forms such as trees and herbaceous plants. At regional to landscape-scales (mesoscale) the distribution of herbs, similar to trees, can be driven by variation in climate, soil, altitude and topography, and/or light conditions, as well as dispersal limitation and random chance. However, our understanding of the microscale distribution of herbs remains limited. **Objectives:** In this study we examined patterns of the spatial distribution and habitat association with respect to topography for coexisting populations of erect perennial herbaceous plants in the genera Heliconia (n = 6 species), Renealmia (6), Aphelandra (2), Besleria (3), and Costus (6) on a large mapped tree plot in Amazonian Ecuador. We hypothesized that the coexisting species exhibit: (1) different species composition between ridge, slope and valley habitat, (2) distinct habitat associations, (3) non-overlapping co-occurrence, and (4) higher abundance in the wetter valley habitat. **Methods:** To test these hypotheses, we surveyed our study species in 25-ha forest dynamics plot in the lowland terre firme ever-wet rain forest of Yasuní National Park. Two drier and brighter ridges surround a shadier and wetter valley. Within each of the 10,000 quadrats (5x5 m) of the tree plot, we recorded the incidence and abundance of all erect perennial herbaceous plants, as well as a measure of light availability. Information on tree locations, soil nutrients, and topographic habitat were also available. **Results**: Species varied widely in abundance and spatial aggregation. We found some evidence of habitat filtering and habitat niche partitioning within all the study genera. Although some study taxa were found throughout the plot, most species were more abundant in the wetter valley habitats. Other taxa responded more to variation in light availability and soil nutrients. **Conclusions:** To fully address the drivers of plant community diversity, long-term population dynamic data is needed for herbaceous plants, comparable to that which exists for trees. Standardized survey protocols for herbs are needed, alongside the measurement of likely abiotic drivers at the appropriate temporal and spatial scales. **Keywords:** Understory, forest, herbaceous, Yasuni, Ecuador

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Community assembly V

Eco-evolutionary Dynamics in Tropical Oceanic and Sky Islands

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Introduction: There is an increase necessity to develop and to apply mechanistic, predictive models for biodiversity to understand the role of eco-evolutionary processes on past environmental, colonization and differentiation events as well as to explore potential consequences of human-induced environmental change. Indeed, moving beyond correlative models, such as species distribution models, to accommodate non-equilibrium, changing conditions has been one key motivation to develop dynamic simulation models of biodiversity. Here, we provide an overview of the application of a recently developed model (GEMM) that is individual-based and genomically explicit to a series of evolutionary, biogeographical and conservation-relevant questions. **Methods:** The simulation experiments vary from local evolutionary rescue under land-use scenarios to biodiversity dynamics across environmental gradients represented by oceanic and sky islands. These experiments include plant and bird communities. **Results:** We show that plant lineages with low genetic linkage can exhibit faster and more exuberant diversification than lineages with low genetic linkage on oceanic islands, whereas the evolution of dispersal and niche trait syndromes in bird communities on sky islands is more defined for ecological speciation in contrast to mutation-order speciation mode. Moreover, we show that evolutionary rescue via low levels of hybridization-driven introgression is possible for endemic sky island birds. **Implications:** Based on these results, conservation and mitigation policies can be tailored for maintain both eco-evolutionary processes and species cohesion. These insights were possible by using a model that explicitly consider genomic and ecological traits. Popularizing the use of these models, many of which are publicly available, should be pursued for improving our understanding of biodiversity dynamics in species-rich system as well as to develop adequate conservation assessments, planning and policy. **Keywords:** Biodiversity dynamics, mechanistic modelling, agent-based models, eco-evolutionary feedbacks, environmental change

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Evolution and Conservation of Rocky Grasslands in South America

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Biome delimitation is one of the most important challenges in the field of evolutionary biogeography. Surprisingly, the poor delimitation of many biomes, particularly of highly fragmented formations, is a major impediment to our understanding of the processes that led to present-day biodiversity. One such formation is the Rocky Grasslands biome, which comprises scattered patches of varying sizes found on high-elevation regions of South America, and which is essentially a floristic archipelago over quartzite and ferruginous substrates. Some of these fragmented formations in eastern Brazil, such as those in the Espinhaço Range, are well studied due to their high biodiversity, but ecologically comparable habitats in other parts of South America remain poorly studied. Most hypotheses proposed to explain the unique diversity found in Rocky Grasslands emphasize *in situ* diversification as the main factor explaining the uniqueness of these regions. Taken as a whole, the diversity of this system is particularly high, with approximately 7,000 plant species recorded to date, but these formations have never been the focus of integrative analyses. The main reasons for this are: (i) unclear and vague definition of Rocky Grasslands, (ii) inconsistencies between point occurrence data and vegetation maps and (iii) the limited availability of time-calibrated phylogenetic trees of groups centred in the system. Here, to remediate this situation we ask: [1] Where are these outcrops situated and how is diversity distributed within and between them? [2] From where do lineages centred in Rocky Grasslands originate? [3] What are the knowledge gaps and what are their implications for conservation? We compiled taxonomically verified checklists for six Rocky Grassland areas across South America, i.e. Tepuis in the Guiana Shield, Chochis mountains in the Chiquitania in Bolivia, and four regions in Brazil: the Espinhaço Range, Serra dos Carajás, the Brazilian Central Plateau mountains, and the Urucum Massif. We are using these checklists to investigate the diversity in terms of species richness, endemism, beta-diversity, and phylogenetic diversity, as well as the origin of predominant lineages and geographical concentrations of threatened taxa. In addition, we are identifying taxonomic, geographic, molecular, and morphological knowledge gaps for the Rocky Grasslands as a whole. Pinpointing these gaps will allow us to quantify key knowledge shortfalls, which in turn will help ensure that the uncertainties in biodiversity data are effectively factored into conservation planning and practice in this unique and geographically scattered biome. **Keywords:** Campos Rupestres, outcrops, quartzite, ironstone, mountains, diversity, endemism, rarity

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New Neotropical Fossils and Their Role in Understanding Extant Biodiversity

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Introduction: The evolutionary history of the extant tropical biodiversity is relatively well known based on biological and molecular studies. However, a key aspect of its evolution that can be obtained from the fossil record is still poorly explored, particularly in the Neotropics. **Objective:** Present new fossils and localities from Colombia, Venezuela, Ecuador and Ecuador that shed light on the complex evolutionary history of the northern South America faunas. **Methods:** This research project included extensive and continuous paleontological fieldwork over several years. Lab work involved preparation of the fossil material using mechanical and chemical techniques, as well as elemental methods such as SEM-EDS, FTIR, and mass spectrometry were used to analyze and characterize their composition and soft tissue preservation. Additional techniques were computed tomography for internal visualization of structures and databases, as for example paleobiology database. **Results:** Fossil vertebrates from at least eigth different localities show that the evolutionary history of neotropical faunas have changed over the past 135 million years, with most of the extant lineages closer relatives preserved in the fossil record since the beginning of the Cenozoic. The last 66 million years show drastic changes in faunas' composition, body size trends, and biogeography distribution of some groups, all this mediated by geological, climatic and ecological events that have affected this part of the planet. **Implications/Conclusions:** Some of the fossils presented here are for example, the first and oldest record of the turtle genus *Mesoclemmys*, which includes one of the most current threatened and critically in danger species of turtle of Colombia. Connecting the fossil record with extant biodiversity can be contribute to conservation plans and education. A link that I hope we continue developing with more fossil discoveries and collaborative work between paleontologists and conservation biologists. **Keywords:** Paleontology, Neotropics, vertebrates, fossils, Cenozoic, Mesozoic, paleobiogeography, paleobiology, conservation

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Decoupling the Climatic and Geomorphological Imprint on the Patterns of Phylogenetic Turnover, Nestedness and Community Assembly in Amazon Tree Communities

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The study of beta diversity is fundamental in order to understand the ecological, evolutionary and biogeographic processes responsible of the patterns of species and lineages composition across spatial and environmental gradients. In recent years several studies have proposed that in order to better understand the different ecological and evolutionary mechanisms underlying patterns of lineages and species composition across spatial and environmental gradients we need to incorporate the nestedness and turnover components of beta diversity. Both climate and the interplay between geomorphology and soils are major environmental filters for Amazon plant communities and current evidence suggests that the synergistic effect of the west-east rainfall gradient along the equatorial band of South America along with Andean orogeny might promote lineage and species turnover across this west-east axis. It has been demonstrated that a great proportion of tree species in the Western neotropics shown wet-conditions affiliation and therefore exhibit range restriction to this extreme of the climate gradient, meanwhile a small proportion of trees appear to be restricted to dry environments. The interplay between soils and geomorphology or the "geological control" hypothesis proposes that contemporary geological and edaphic patterns in Western and Central Amazon are the result of both gradual and abrupt transitions from nutrient-rich Miocene-Pleistocene sediments in areas close to Andean foothills to poor Pliocene-Pleistocene sediments to the east of the basin. In this study we first analyzed the contribution of geomorphology, soils and climate as historic environmental drivers on nestedness and turnover components of phylogenetic beta diversity along a longitudinal gradient in terra firme Amazon tree communities. Second, we explore patterns of phylogentic structure of these communities. Third, we explore the contribution of current and historical climate as driver of lineages and species turnover in Amazon tree communities. We hypothesize that 1) If long term climatic stability has been the main driver of community structure along the west-east axis of Amazon basin early divergent lineages will dominate forest to the west of Amazon basin (regions close to Andean foothills) and older divergent lineages will dominate forests on lowlands. 2) If recent Quaternary climatic fluctuations are the main driver of species and lineages turnover, we predict that high taxonomic beta diversity but but low phylogenetic beta diversity may arise as the result of adaptive speciation of lineages recently adapted to drier conditions toward the east of the basin. **Keywords:** Extinction, colonization, phylogenetic beta diversity, longitudinal gradient, gentry

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Conservation Planning, Management, Practice: animal I

Conservation of Birds in Fragmented Landscapes Requires Protected Areas

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For successful conservation of biodiversity, it is vital to know whether protected areas in increasingly fragmented landscapes effectively safeguard species. However, how large habitat fragments must be, and what level of protection is required to sustain species, remains poorly known. We compiled a global dataset on almost 2000 bird species in 741 forest fragments varying in size and protection status, and show that protection is associated with higher bird occurrence, especially for threatened species. Protection becomes increasingly effective with increasing size of forest fragments. For forest fragments >50 ha our results show that strict protection (International Union for Conservation of Nature [IUCN] categories I–IV) is strongly associated with higher bird occurrence, whereas fragments had to be at least 175 ha for moderate protection (IUCN categories V and VI) to have a positive effect. This meta-analysis quantifies the importance of fragment size, protection status, and their interaction for the conservation of bird species communities, and stresses that protection should not be limited to large pristine areas. **Keywords:** biodiversity conservation, bird occurrences, forest fragments, fragmentation, global meta-analysis, protection

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Diminishing Kingdom: Identifying Important Areas for Andean Condor (*Vultur Gryphus*) Conservation in Colombia.

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Identifying priority areas to focus conservation efforts, including local social and economic context, enables effective management of threatened species, especially those with high mobility capacity. Condor is considered Vulnerable to extinction, and at its northern range limits, it is even considered Critically Endangered because of threats originating from conflict with local communities. Despite the need for Condor conservation action, there is little ecological information about the species and the associated threats to its habitat. From guarantee the effective management of Condor conservation in Colombia. Our objective in this study is: (1) to identify priority conservation areas based on the movement ecology of the Andean Condor and, (2) To assess the socioeconomic conditions and perception of local communities about the species in these areas to identify and better understand potential conflicts. We used satellite tracking GPS and field monitoring to identify roosting sites across the Colombian Andes. Using generalized linear models, we identified potential roosts where individuals could refuge in the country. Intersecting this information with the Colombian human footprint map, we identified areas of priority for conservation where potential threats are present or are likely to arise. We used semi-structured interviews with local communities to assess condor-human relationships and better understand conflict causes. We identified inter-specific interactions between Andean condors and other scavengers' species with a camera trap. We find that roost selection by the Andean condor depends upon the presence of sites where the air density is high, with high wind speed, steep slopes, high radiation, prominent mountain formations, and north-facing slopes. According to our results, The Colombian Andes has 341.76 Km2 of priority areas for the conservation of the Andean Condor, with nearly 50 % (163.3 Km2) of this area at high risk from human intervention. Focusing on these high-risk areas, we identified social and livestock management to drive human-condor conflict, an emerging threat to New and Old-world vulture species worldwide. The combination of ecological

and socioeconomic factors has reduced and continues to risk the most important areas for the species, seriously reducing available areas for their survival. Our results contribute essential knowledge for conservationists and policymakers to effectively address suitable adaptive management actions to reverse the potential population decline problems identified at different scales. **Keywords:** Explicit spatial models, reintroductions, threatened raptors, endangered species management

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Impacts of Selective Logging on Forest Elephants (*Loxodonta cyclotis*) in Two Timber Concessions of Central Africa

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Facing increasing human pressure, forest elephant (*Loxodonta cyclotis*) populations have been seriously declining for many years. As they are key actors in shaping ecosystems, their decline will have severe ecological consequences. Covering 30 percent of the central African rainforest, timber concessions constitute areas with a great stake in the conservation of this emblematic and critically endangered species. Although several studies have documented a high presence of forest elephants in some logged forests, many uncertainties remain about the impacts of logging on forest elephants. Using camera traps, acoustic recorders and dung counts, we explored the short-term consequences of logging on forest elephants' abundance in two certified timber concessions, one in Cameroon and one in Gabon. In Cameroon, 24 camera traps and 12 acoustic recorders were set up for two months in two nearby areas: one that had just been logged and one where the last logging operation was conducted over 17 years ago. In Gabon, dung counts along 73 km of line transects were conducted in one annual allowable cut, eight months before and nine months after logging. The camera trap study in Cameroon showed no significantly different forest elephant detection rates between the recently and the formerly logged areas. A similar result was obtained with the acoustic data. In Gabon, the post-logging survey recorded more than twice as many forest elephant dung as the pre-logging survey. These results support the suggestion that selective logging, when carried out under controlled and sustainable management (ie., closure of old logging roads, law enforcement, low impact logging, etc.), is compatible with forest elephant conservation. Nevertheless, additional studies are needed, especially to assess long-term and behavioral impacts. Ongoing studies on the use of skidding trails and logging roads by large mammals, forest elephant-mediated seed dispersal and herbivory damage in timber concessions, will provide new insights on the coexistence of forest elephants and selective logging. **Keywords:** *Loxodonta cyclotis*, forest, elephant, central Africa, selective logging, abundance, camera trap, dung count

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Conserva Aves: Streamlining the Protection of the Most Critical Places for Migratory and Resident Birds in Latin America

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Large-scale habitat conversion, degradation, and alarming biodiversity loss are advancing rapidly in Latin America and the Caribbean. Protected areas are a proven strategy for safeguarding biodiversity, climate change mitigation, and adaption through nature-based solutions, but most Key Biodiversity Areas (KBAs) for birds are unprotected and many migratory species are underrepresented in KBAs. Effective protection of declining migrants and threatened residents through new protections thus requires cutting-edge geospatial prioritization analyses. For 183 species of North American migrants we used a three-stage modeling framework integrating tracking, banding, occurrence, and migratory connectivity data to estimate spatial patterns across the Western Hemisphere. For threatened and endemic residents in seven countries from Mexico to Chile we developed habitat-based distribution models using the best available national data sources. Conservation importance was determined with Zonation for migrants and Marxan for residents, totaling 2,135,790 km^2 in priority areas (migrants: 1,725,003 km^2, residents: 669,657 km^2) across all seven countries, with 258,870 km^2 (12.1%) being a priority for both migrants and residents. Existing KBAs overlap with only 22.2% of all priority areas, and only 40.8% of this area is currently under some form of protection. Conserva Aves, implemented by a consortium of science-based hemispheric biodiversity conservation leaders, has established a competitive grant fund to streamline the creation and financially sustainable management of at least 2M ha of new subnational (e.g. municipal, indigenous) protected areas by local conservation and sustainable development leaders in the seven countries by 2028. **Keywords:** Conservation planning, marxan, area of habitat modeling, birds, kbas

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Establishing Conservation Targets for Amazon Freshwater Ecosystems at Basin Scale

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The Amazon is a global center of biological and cultural richness. To that end, the conservation of Amazonian forests has been the focus of extensive financial investment and international attention for at least the past four decades. This investment is on top of the stewardship of forests by numerous Indigenous groups over multiple generations, and has been largely focused on halting deforestation by establishing and managing protected areas that center Amazonian forests. Collaborative scientific studies, aiming to understand 'tipping points' for Amazon forests, have helped to identify broad-scale conservation targets, or thresholds of deforestation that should not be crossed, for maintaining the Amazon biome. Accordingly, many conservation organizations, governments, and the private sector have rallied around common goals of maintaining a certain percentage of Amazon forests standing. There is a need to turn more attention towards conservation of another critical component of the Amazon: freshwater ecosystems. The Amazon is the world's largest fluvial system and contains an array of freshwater habitats that host unparalleled biodiversity of freshwater organisims. Additionally, an estimated 50 million people inhabit the Amazon Basin, where human life, culture, and livelihood are intimately connected to freshwaters. Amazon freshwaters, especially rivers, integrate what happens across the region, even land-based processes like deforestation, road construction, fires, and agricultural expansion have implications for the integrity of freshwater ecosystems. Although infrastructure, pollution, and overfishing have already affected the connectivity, quality, and quantity of Amazon freshwaters in certain areas, the Amazon still contains among the highest number and length of unimpeded, unaltered rivers of any watershed in the world. There is still an opportunity to protect Amazon freshwaters and the species and human populations that depend on them. Through a collaborative effort involving ~25 scientists, we defined three initial conservation targets for Amazon freshwaters at a basin scale: (1) protect connected riverscapes of the Western Amazon, (2) maintain functional floodplains, and (3) avoid the collapse of fisheries, particularly migratory species. Here, we discuss the process for defining these targets, establishing baselines, and proposals for monitoring change over time. These efforts are part of a larger movement worldwide to recognize freshwater ecosystems as objects of conservation and to secure durable protection that considers their inherent dynamism over time and space.
Keywords: River, wetland, South America, fish, social-ecological systems, hydrology, protected areas

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Assessing Woodpeckers as Indicators of Bird Diversity and Habitat Structure in Managed Forests

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Woodpeckers (family Picidae) are a specialized group of insectivores sensitive to forest degradation and fragmentation. More than half of all published woodpecker studies come from North America and Europe, which account for only 17% of Picidae species. They are largely under studied in their hotspots of diversity (Southeast Asia, Equatorial Africa, and South and Central America) despite the forests here facing high levels of threat. There is therefore an urgent need for studies on woodpecker assemblages, particularly on their habitat requirements, their ecological function and, in turn, their possible role as conservation surrogates. We evaluated the woodpecker taxa as potential indicators of habitat quality and forest bird diversity in sub-tropical moist hardwood forests, a threatened biome in the Western Himalaya, India. 74 forest sites were selected to represent a gradient of anthropogenic use. Birds were sampled at each site 12 times over 2 years (equally in the summer and winter) using fixed-radius point counts. Vegetation structure was assessed using three 100 m^2 circular plots. A land-use land-cover map of the study region was used to assess the proportion of land under dense forest within 500m of each site (forest proportion). Individual woodpecker species were observed to quantify their foraging niche preferences. We ran Generalized Linear Models to evaluate how vegetation structure and forest proportion affects the richness and abundance of woodpeckers and all other forest birds. We found that forest sites with higher woodpecker richness were also rich in all other bird species. Further, the richness and abundance of woodpeckers and all other birds were affected by similar habitat variables. Four out of the eight woodpecker species occurring in the study area were found to fit our habitat models suitably. Both woodpeckers and the larger forest bird community preferred sites with higher canopy cover, lower tree density, and higher proportions of dense forest in the vicinity. Behavioral observations showed that the same four woodpecker species significantly preferred larger and taller trees for foraging. Given the difficulty

of directly monitoring forest characteristics and total bird diversity over large landscapes, indicator species like woodpeckers have great management value as they can help expand the spatial scale of a monitoring effort with the efficient use of limited resources. Further, as most woodpeckers described in this study are moderately common and conspicuous throughout their range in South and Southeast Asia, areas with high woodpecker diversity can be easily identified and prioritized for conservation. **Keywords:** Woodpeckers, indicator species, conservation surrogates, managed forests, Himalaya

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Re-wilding Experience: Stimulating Foraging Competency in Captive Red Pandas (*Ailurus fulgens fulgens*) Selected for Augmentation Programme at Darjeeling Zoo, India

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The ultimate goal of conservation breeding is to reintroduce zoo bred animals into their wild habitats. Enhancing naturalistic behavior like foraging is essential for successful reintroduction. Four red pandas were selected for augmentation to be released in Singalila National Park, India. Feeding enrichments were designed and performed to induce foraging competency in individuals. The experiment was divided into two phases i.e. training and test. Results showed increased foraging in subjects during the experiment ($p < 0.001$, $R^2 = 0.44$, range 0.21 – 7.5 min). Mean foraging was significantly different from zero between the training and test phase ($p < 0.001$, $t = -4.92$). Activity budget was positively shifted analogous to wild counterparts. The hypothesis that an individual maintains foraging behavior with consistent enrichments was found to be true for the subjects. The study conclusively recommends appropriately designed feeding enrichments to stimulate foraging behaviors in captive animals to be reintroduced. **Keywords:** Conservation breeding, endangered, feeding enrichment, foraging, red panda, reintroduction

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Participation for Conservation: Three Different Participatory Monitoring Experiences for the Conservation of Colombian Fauna

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In participatory monitoring, institutions of different nature and local communities collaborate in processes of biodiversity monitoring oriented to understand the state of local diversity, to detect the effect of different pressures on it, and to generate possible conservation strategies based on empirical data and local knowledge. Recently, it has been gaining strength due to its ability to empower local people and to create trustworthy relationships between communities and public/private institutions, as well as its lower implementation costs. In Colombia, there are still few well-known experiences of participatory monitoring, so key points that could lead to successful and sustainable overtime processes remain unclear. Here, we present three experiences of this kind of approach focused on different species, methods, and socioecological contexts, implemented by WCS Colombia. Our target species were the Striped-Catfish in the middle Magdalena, Cauca-Guan, and Red Howler-Monkey in the coffee-growing region, and large and medium-sized terrestrial mammals and birds in the Andean-Amazonian foothills. All participatory processes were developed in four steps as follows: 1) socialization and internalization of the importance of monitoring and the relevance of the information obtained for institutions and communities, 2) theoretical and practical training for the collection of information and constant supervision associated with the learning curve, 3) technical support for data analysis and results discussion, and 4) results socialization with the communities involved. In general, participatory monitoring has reinforced the relationship between communities and their local biodiversity, while generating relevant information for species conservation. For Catfish, the signature and compliance of 70% of the agreements for good fishing practices in the last 6 years, as well as the establishment of banning seasons, have allowed fishermen to negotiate, based on empirical evidence, with de National Fishing Authority. For Cauca-Guan and Howler-Monkey, we were able to determine that species occupancy (0.80 and 0.36 respectively) depends mainly on the presence of forest areas between 50-80 ha, this information stresses out the importance of local Civil Society Reserves Networks composed of small and medium-sized forest patches highly connected. In the Andean-Amazonian foothills, lower species richness (20) was found in strongly disturbed places, compared to 40 found in the protected area and 35 in the buffer zone, these results have reconnected local people with fauna they consider already extinct, thus strengthening

their commitment with the development of conservation actions in their productive lands. **Keywords:** Fishing, good-practices, occupancy, mammals, biodiversity

Conservation Planning, Management, Practice: animal II

Understanding Interactions between People, Elephants and Fires in the Miombo Woodlands of Niassa Special Reserve in Support of Conservation Action

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Miombo woodlands cover ca. 1.9 million sq. Km across seven countries in southern Africa including Mozambique and support ca. 8,500 plant species, of which 54% are endemic. Miombo has evolved with both fires, human activities and herbivory by elephants, all playing a key role in the ecosystem composition, structure and functioning. Understanding elephant movements and interactions with anthropogenic fires are key in managing habitats, especially in protected areas where most of elephant populations are concentrated and people live within protected area boundaries. This study aimed to improve the understanding of the interaction between human activity, fires, elephants and habitat in support of management actions in Niassa Special Reserve (NSR). Remotely sensed data (Landsat 8, Sentinel 2 and Shuttle Radar Terrain Mission-SRTM) and ground biophysical data collected in a factorial randomized block design were combined to address our objectives. A Google Earth Engine API protocol was used to determine fire frequency (2014 to 2019) and map habitat distribution as predictors of elephant spatial distribution. A maximum entropy model (Maxent)) was used to investigate the spatial and seasonal distributions of elephant. A Principal Component Analysis (PCA) was run to identify variables that better segregate habitats as a function of the disturbance factors. Our results revealed high likelihood of elephants' concentration in particular places of NSR irrespective of the season. However, the pattern changes to a scattered distribution with exclusion of human-related variables (fire, roads and villages). The most influential factors on elephant distribution are distance from villages (64.4% in wet, 35% in dry), distance from roads (18.2% in wet, 34% in dry) and habitat distribution (11.7% in wet, 22.8 in dry). Fire frequency have shown small contribution (1.3% in wet, 5% in dry). Human factor has an important role on spatial distribution of elephants, which in turn influences patterns of vegetation structure and composition.
Keywords: Maximum entropy model (Maxent), fire frequency, remote sensing, habitat, elephants

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Conservation Genomics of the Andean Bear, *Tremarctos ornatus*, in Colombia: Implications for Management Species at Risk of Extinction

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The Andean bear *Tremarctos ornatus* is the only living species of bear in South America. Increasingly, its distribution has become fragmented due to anthropogenic habitat change, and population sizes have reduced to the extent that it is classified as vulnerable to extinction by the IUCN and listed in Appendix I of CITES. In Colombia, Natural National Parks has focused its conservation efforts for the species through the development and implementation of five core conservation units across the three Andean Cordilleras. Each unit is characterized by having habitat patches composed of 80% or more by protected areas of the National System of Protected Areas and 20% or less of anthropic effect. Likewise, each unit is managed under the assumptions that an area of 3,800 km^2 maintains a viable population of spectacled bear and that its structure and forest composition allows connectivity between the remnants of habitat. However, very little is known about the structure and

integrity of the Andean bear population in these units and there is a lack of spatially explicit knowledge of the degree of genetic connectivity to determine if the established area – equal to or greater than 3,800 km^2 – is enough to maintain viable bear populations. The aim of the present research is to assess the population viability and genomic diversity of the species, using non-invasive sampling and DNA sequencing of both modern-day bears (faecal samples) and ancient Andean bears up to 100 years old from museum collections. We have currently assembled a chromosome-level reference genome and at the moment we have processed 25 samples from contemporary bears and 34 from museum samples. Preliminary results from museum specimens show that despite marked population structure, there is continuity across time. The most differentiated individuals correspond to an isolated population in Santander (north-east Colombia). Contrastingly, an individual outside the reported distribution range in Cordoba (north-west Colombia) clusters closely with southern populations, likely indicating connectivity across the western corridor (which coincides with one mountain range). We will assess whether there is a reduced genetic diversity and increased levels of inbreeding within populations, and will examine the time-scale over which this may have occurred. We anticipate our results will directly inform conservation policy and management at a national level, as we look to identify 'conservation corridors', areas of suitable habitat connecting their current protected areas to allow ongoing gene flow. **Keywords:** Conservation genomics, national parks, non-invasive sampling, museum collections, Andean bear

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The Role of Riparian Communities in Cross-scalar Policies for Freshwater Ecosystems Conservation in the Peruvian Amazon

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Studying human-water coupled systems require a more complex set of mechanisms that can analyze different phases of interactions as well as the heterogeneity and behavioral responses that humans have at individual and collective levels depending on a determined socio-political context. As the largest river basin on the planet with a rich biocultural heritage, the Amazon River basin has highly complex social and hydrological services that local riparian communities live in integral relationship with. For example, local communities depend on floodplain farming and fishing for food and income, and their cultural and spiritual practices are linked with the rhythm of rivers. Current freshwater management policies in Peru are discordant with riparian communities broader socioeconomic and environmental realities. For Peru's national freshwater management policies to produce the best outcomes for people and the environment, they must consider the social, economic, and cultural realities of the people they impact. This can only be achieved by taking a radically inclusive approach to policymaking in which local communities and other vital stakeholders are treated as co-designers in the policymaking process. The present paper proposes to conduct a case study of one of the major freshwater policies that have been implemented within the Peruvian Amazon in the last decades, the Fishing Management Regulation of the Peruvian Amazon (Reglamento de Manejo Pesquero de la Amazonia Peruana, ROP). The case study has the objective to analyze in depth the relationship and potential alignment or not of this policy with riparian communities' well-being. Through this case study and accompanying literature review, I intend to address the following questions 1) What is the evidential basis and justification for this freshwater policy within the Marañon watershed? And 2) How does the ROP align with the interests of riparian communities? This paper further aims to shed light on the process of how to place communities at the center of the decision-making process for freshwater policies in the Peruvian Amazon and determine whether adopting a more stakeholder-centric approach can produce policies that more effectively serve riparian communities' interests. **Keywords:** Freshwater policy, riparian communities, sustainable development, decision making, conservation

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Plastic Ingestion in Giant Tortoises: a Novel Threat to Wildlife Conservation in the Galapagos Islands

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Introduction: Galapagos tortoises are one of the most emblematic animals worldwide. Two centuries of overhunting led to the extinction of two species and reduced others to critically small population size. These giants play multiple roles across the archipelago: as ecosystem engineers and mega vertebrates, they help maintaining healthy ecosystems within the archipelago and may act as sentinel species, as a conservation icon, tortoises strongly contribute to the local economy through tourism. Today, tortoises remain endangered due to several threats all related to human activities (i.e., climate change, invasive species, habitat loss and fragmentation, illegal trade, antimicrobial resistance, and the introduction of novel pathogens). **Objective:** To effectively preserve giant tortoises and the integrity of their ecosystems, we need to better understand how human pollution may be affecting their health and well-being within the most human-populated island of the archipelago, Santa Cruz. **Methods:** To determine how human debris (mainly plastics) may impact tortoise health, we analyzed tortoise fecal samples from free-living tortoises within human and non-human modified landscapes and assessed tortoise density by a capture-recapture method. The field work was conducted from April to November 2021. **Results:** We collected 1039 fecal samples from the protected area and found two human debris (plastics). In contrast, out of the 5590 samples collected from human-modified areas we found 591 debris. The majority of those items were plastics (86 %), followed by clothing (8 %), and metal pieces (2 %). Four sanitary face masks were also found. A total of 361 tortoises were identify using the different sampling areas, with a total of 643 recaptures. Some tortoises were recapture up to 24 times, showing a clear philopatry for their feeding areas within the anthropogenic areas. **Implications:** These results highlight a novel threat not only to tortoise conservation but for the health and integrity of Galapagos ecosystems. Tourism and local population are increasing, together with land fragmentation, modification, and pollution of the ecosystems. This rapid transformation may have severe consequences for the well-being of unique and iconic species like Galapagos tortoises and in turn result into a Public Health concern impacting humans and animals alike. We will use these conclusions to inform local management decisions and stakeholders with the final goal to reduce human pollution, reinforce current laws, and create awareness within the local community to reduce littering. **Keywords:** One Health, plastic pollution, Anthropocene, giant tortoises

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Integrating Social and Ecological Dimensions for Better Conservation Decisions

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Wildlife managers and conservationists often have to make hard decisions about which species or areas to protect. Better conservation decisions are those made upon a broader evidence base that includes both ecological and social considerations. In this interdisciplinary study we explore approaches to improve conservation decisions in the rather common situations where (1) decision-makers and managers have limited or no access to the sophisticated computational tools for conservation planning, (ii) capacity in interdisciplinary data analysis is limited, (iii) ecological and social datasets available have been obtained in an independent, non-integrated manner, and (iv) social data are more scarce than ecological ones. More specifically, we describe a species and area conservation prioritization exercise that combines findings from independent ecological and social research conducted in a Neotropical hotspot of biodiversity, the Atlantic Forest of South America, and propose a framework to integrate, analyze and visualize data for conservation decisions, elucidating a wide-range of choices that decision-makers face as their task. The ecological research addressed species rarity and composition and taxonomic, functional, and phylogenetic diversity from camera-trapping data, whereas the social research used face-to-face interviews to assess local attitudes towards wildlife and protected areas (PAs). Decision outcomes regarding the prioritization of mammal species and protected areas based on each of the lines of evidence alone, and on both combined, differed significantly. Findings reiterate the importance and cost-effectiveness of incorporating social considerations to make better conservation decisions, and corroborate the potential of transdisciplinary collaboration to bridge researchers, practitioners and decision-makers to more effective conservation strategies. **Keywords:** Atlantic Forest, conservation planning, decision-making, mammal diversity, social research

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Fish Can Be Charismatic Megafauna, Too: *Arapaima spp.* as a Flagship Species in the Colombian Trapezium

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Human-wildlife interactions can increase the chance of conflict between the two parties in the form of overexploitation or overharvesting for personal consumption. This is common in freshwater fisheries, particularly in the Amazon basin, where human and natural systems are inextricably Studies on the extent of these interactions require a qualitative approach, which has become popular in human-wildlife interactions research over the last 20 years, yet needs to be further explored in freshwater systems. A megafaunal, charismatic fish of importance in the Amazon, is *Arapaima*. It is pan-Amazonian distribution, and unique lateral migration makes it a desirable source of protein for riparian human communities. Much research on its biology, conservation, and exploitation has been concentrated in Brazil. For that reason, ourstudy focuses on the perceptions of the people within the tri-national region of the Amazon Trapezium, with a focus on the area near Leticia and Puerto Nariño. Employing a qualitative methodology of semi-structured surveys and key informant interviews, we sampled the resident and tourist populations of two border-towns, Leticia, and Puerto Nariño. Our questions focused on awareness of ecology, management actions, and attitudes toward the species and future management actions.

Piscilago: a Relevant Actor in the Conservation of the Orinoco Crocodile and the White-footed Tamarin

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Throughout its 38 years of existence, Piscilago the Aquatic and Conservation Park has been involved with different public and private institutions in the development of conservation projects for endangered species. Two of the most relevant initiatives are the Orinoco crocodile (*Crocodylus intermedius*) conservation project led by the Ministry of Environment and the National University of Colombia, and the international project for the conservation of the white-footed tamarin (*Saguinus leucopus*) led by the Colombian Association of Zoos and Aquariums ACOPAZOA and supported by the European Association of Zoos and Aquariums EAZA, projects that involve two species with several conservation problems and facing a high risk of extinction. The objectives of these projects are to contribute to ex situ conservation through the creation of breeding pairs, and to maintain a viable population under controlled conditions. Since 2002, the Orinoco crocodile individuals obtained in artificial nests have been monitored, incubated and transferred to the Roberto Franco Tropical Biology Station to continue with the releases and repopulation program. The successful recovery of more than 481 eggs, the completion of two specialized training courses and the release into the wild of 10 individuals from the Piscilago breeding nucleus are the main contributions to the conservation of Orinoco crocodiles in the country. On the other hand, for the white-footed tamarin group, individuals have been kept since 2005 in reproductive areas specially designed for the formation of parental families, resulting in more than 60 offspring born in Piscilago within the reproduction program, those individuals have formed successful reproductive groups that have allowed us to learn more about their management in controlled conditions, behavior, health, distribution, genetics, among other unknown aspects for this population. In addition, the realization of a great variety of academic activities and a total of 4 international training workshops for its management have positioned the institution as a reference for the conservation of the species. All the technical, scientific and academic effort is complemented with an ongoing education program for the conservation, that have reach thousands of people among students, technicians and scientists regarding the value of these species for our country. **Keywords:** Ex situ conservation, endangered species, orinoco crocodile, white-footed tamarin, conservation

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Conservation Planning, Management, Practice: Plants Ecosystems I

Cats, Cattle, and Conflict: Using Agent-based Modeling to Understand How Pastoral Management Affects Jaguar-cattle Predation

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Prey depletion is a known driver of human-wildlife conflict for carnivores worldwide. In Latin America, the largest global exporter of beef and where livestock husbandry accounts for ˜45% of agricultural GDP, local prey availability is a strong predictor of jaguar (Panthera onca) conflicts with cattle ranchers. Despite the documented association between prey depletion and jaguar-cattle attack rates, few studies have sought to understand how different management interventions moderate the de-coupling of predator-prey relationships and consequently influence attack incidence on domestic prey. To address this knowledge gap, we used the Netlogo agent-based model environment to test how common anti-predation management tools such as electric fencing, livestock breed (i.e. Zebu vs. Criollo), and guard dogs influenced the strength of the relationship between prey depletion and jaguar conflict. Models were parameterized based on peer-reviewed literature on jaguar movement, attack rates, and cattle behavior. We found that the use of Criollo cattle and electric fencing weakened the relationship between prey depletion and conflict frequency while the presence of guard dogs did not affect it. However, before broad adoption of electric fences, we must consider the secondary effects of this approach because of the lethality to non-target wildlife species and local villagers. Our work provides the necessary theoretical framework for further empirical research on interactions between prey depletion and carnivore conflict. We demonstrate how agent-based models are a powerful tool to help inform management interventions and improve conservation outcomes for jaguars and other large carnivores. **Keywords:** Human wildlife conflict, carnivore, livestock, prey depletion

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Participatory Mapping as a Tool for Land Management around Protected Area of the Abdoulaye Faunal Reserve (North of Mono River)

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Introduction: Effective management of the resources of the Abdoulaye Faunal Reserve (AFR) and the surrounding areas requires a collective approach that involves geographic information systems (GIS) and local stakeholders. Thus, participatory mapping is emerging as a powerful tool that allows people to spatialize local knowledge about their terroir and to locate important elements of the terroir (forests, markets, trails, waterways, fields, terroir boundaries, etc.). **Objectives:** The objective of this study is to contribute to the sustainable management of the AFR. More specifically, it aimed to: (i) improve agricultural practices both in planning and in the promotion of good agricultural practices and (ii) guide the development and management of natural resources, ecological monitoring devices as well as the organization of actors around the AFR and surrounding community forests. The methodology is based on the identification of "local cartographers", training in spatial data collection techniques and participatory resource mapping. This mapping is completed by semi-directive surveys through individual interviews of 120 people. Results: The participatory maps highlight the knowledge of the natural resources of the riparian areas and those of the RFA. In addition, four (04) modes of access to land were reported in the surrounding villages: inheritance (60.50%), donation (23.53%), rental

(14.29%) and purchase (1.68%). As for land productivity, low crop yields are due to poor soils (excessive use of pesticides and chemical fertilizers), disruption of the agricultural calendar (97.46% of respondents), scarcity or early cessation of rainfall, insects, poor agricultural practices and drought. **Keywords:** Participatory mapping, protected areas, land management, geographic information system

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Indigenous Land and Protected Areas Are Key to Moderate Climate in the Cerrado and the Amazon

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Avoid deforestation and forest degradation are among the most effective ways to maintain the provision of ecosystem processes in the tropics. For example, the Brazilian Conservation Units (CUs) and Indigenous Lands (ILs) have been effective in blocking deforestation, ensuring the provision of ecosystem processes, including climate regulation. However, these protected areas have been subject to degradation processes such as forest fires, extreme droughts, and selective logging in recent decades. Additionally, deforestation in areas of multiple uses (MUs - outside CUs and ILs), can also represent an external factor of disturbance for protected areas. Despite this, we know little if the capacity of CUs and ILs to regulate climate have been affected by these degradation processes, and if the response to disturbance is similar in the Amazon and Cerrado biomes. Here, we used a 20-year time series (2001-2020) of remote sensing products to evaluate how three key processes for climate regulation (surface temperature [LST], evapotranspiration [ET], and albedo) changed in CUs, ILs, and MUs located in the Amazon and Cerrado portions of the Brazilian state of Mato Grosso. We tested if the CUs and ILs present higher ET fluxes, lower LST, and albedo compared to MUs, and whether the differences in management of these two types of protected areas cause different patterns in these processes. The results showed reduced ET (˜10%) and higher LST day (˜1.5 °C) and albedo (˜10%) in the MUs compared to CUs or ILs in both biomes. The yearly averages of LST, ET and albedo were higher in the ILs than UCs in both biomes. We verified greater trends of increase in LST (Amazon: ˜1.4 ºC and Cerrado: ˜1.1 ºC) and albedo (Amazon: ˜6% and Cerrado: ˜3%) in the areas of MUs than in the UCs and ILs regardless of the biome, which were mainly explained by the substitution of native vegetation, forest fires and water stress. We conclude that despite multiple stress factors that have affected protected areas in recent years, these areas still contribute efficiently to the stabilization of components of climate by maintaining a higher ET flux and lower LST and albedo, but the long-term maintenance of the stabilizing effect in protected areas will depend on the actions developed in the adjacent areas, meanly for plant species in rainforest, once those are much less drought tolerant and take longer to recover than species frequently exposed and adapted to seasonal water stress and fires. **Keywords:** Land use change, drought, fires, albedo, evapotranspiration, surface temperature

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Conservation Planning, Management, Practice: Plants Ecosystems II

Community-sourced Knowledge Uses for Improving Biodiversity Management in Madagascar's National Parks

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Madagascar is one of the most important centers of biodiversity in the world. Unfortunately, what remains of its natural habitats are under strong anthropogenic pressure, but resources are limited for managers of protected areas to track the biodiversity responses to global change. Collaborations with local populations in the management of protected areas was initiated by Madagascar National Parks (MNP) in 1998 and can improve biodiversity protection. However, such community-based approaches to monitoring biodiversity are not currently well integrated management. The objective of this study was to develop a process of data collection by local communities based (CLPs) on their local knowledge of biodiversity and to assess whether the data recorded by local communities can be used for the management of protected areas. Data collection began in 2019 in three main types of ecosystems within the network of protected areas of MNP: two dry forests, two transitional forests and two rainforests, with observations focused upon bird, mammal, and herpetofaunal biodiversity. After combining local vernacular name from CLPs and scientific name in species identification guides. A training on standardized observation methodologies was performed visual and audio encounter surveys, and such observations were validated via surveys performed by graduate student researchers with taxonomic expertise (experts). To quantify the capacity of CLPs to identify species and record their abundance relative to expert performance, we developed species accumulation, separately for each taxonomic group, park, and for CLPs and experts, and extracted estimates of species richness. Results suggest that community members saw about as many species as experts. However, experts saw higher per-species abundance on average, in large part because they saw far more individuals of common species. For improving in observation ability. We also measured the number of survey days necessary to observe all species in the estimated community, and found that the number of days was higher for CLPs. This difference varies from 50 days for Andringitra and 150 days for Andohahela for community members, compared to 15 days for Isalo and 30 days for Ranomafana. However, this study helps develop good indicators of the impact of conservation and could be used in the management of protected areas. In addition, permanent support from these CLPs is necessary to have good data and strengthen the collaboration of managers and CLPs in the conservation of these protected areas
Keywords: Madagascar, MNP, Local community knowledge, biodiversity, conservation, protected areas

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Global Conservation Consortium for Magnolia: Establishment of a Global Network to Conserve Magnolia Biodiversity

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Introduction: Botanic Gardens Conservation International (BGCI) promotes a cost-efficient, rational, botanic garden-led global system for the conservation and management of plant diversity. As part of this system, the global botanic garden community is establishing a series of consortia of specialists with knowledge of genera that are technically challenging to conserve and manage. The genus *Magnolia* is a group of tree species with centers of diversity in South America and East Asia. With over 50% of *Magnolia* species globally assessed as threatened and around 30% as Data Deficient on the IUCN Red List, this group requires collaborative and coordinated efforts to ensure no species goes extinct. **Objectives:** The Global Conservation Consortium for *Magnolia* (GCCM) is a coordinated network of institutions and experts who work collaboratively to develop and implement a comprehensive conservation strategy to prevent extinction of the world's *Magnolia* species. The main objectives of the GCCM are to identify species of greatest conservation concern and prioritize conservation action, establish, expand and manage ex situ and in situ conservation programs for threatened *Magnolia* species, foster applied research to support species conservation and build capacity across threatened species ranges. Additionally, the GCCM aims to increase public awareness and engagement with *Magnolia* conservation issues and collaboratively fundraise to scale up conservation efforts. **Methods:** Coordinated by a lead institution, Atlanta Botanical Garden, with a global steering committee representing six high diversity regions, the GCCM brings together researchers, conservationists, land managers and all others engaged in *Magnolia* conservation. Individuals and institutions can join the Consortium as Affiliates to contribute expertise in areas including taxonomy, research, technical assistance and outreach or Species Stewards who manage threatened species at ex situ, in situ and near situ conservation sites. **Results:** In 2021, the GCCM submitted over 25 IUCN Red List assessments of newly described Magnolia species, held virtual: regional meetings in South America, Mexico & Central America and the US/Canada and conducted a global conservation gap analysis of Magnolia species in *ex situ* and *in situ* conservation. The GCCM supported funding proposals for conservation projects in Colombia, India and Vietnam and engaged with partners on projects for threatened species in Mexico and Guatemala. Implications The continued development of this multi-sector consortium will deliver integrated conservation of threatened *Magnolia* on a global scale. This presentation will present the GCCM, highlight case studies of current projects and invite new participants to engage with *Magnolia* conservation. **Keywords:** Magnolia, conservation, ex situ, networking, in situ

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Hyperdiversity in the Anthropocene. Tiputini: Present and Future of Forests in Remote Amazonia

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Tiputini Biodiversity Station-TBS, located in a remote area of Yasuní Biosphere Reserve-YBR in Ecuador, protects ˜700-ha of, arguably, the most biodiverse forest on Earth. TBS is also located in one of the better preserved and largely undisturbed areas in the tropical world. Investigations performed in the past decade have shown that the region where TBS lies, occupies a unique biogeographic position where species richness for amphibians, birds, mammals, and plants reaches continental and, in some cases, global diversity maxima. Recent updates to such species records, presented here, have allowed us to currently document around 200 species of mammals, 250 of amphibian and reptiles, 434 birds and more than 600 species of fish, in an area smaller than 7 sq km or 0.2% of the total size of Rhode Island. It is also estimated that the Ecuadorian Amazon where TBS is located, records ˜5000 species of trees, roughly 7% of the total number of tree species of the world (˜73,000). This means TBS and YBR, records more species of these taxonomic groups than both continental US and Canada together, and in most cases, of other tropical areas of similar or bigger area. Unfortunately, this astonishing diversity and TBS are directly threatened by very pressing anthropogenic processes occurring in the near and surrounding vicinity, such as oil expansion, deforestation, and illegal mining. In recent analyses, Finer (2019), calculated an area of 655-ha deforested just for the construction of drilling platforms in a year at YBR. New roads and platforms are bringing oil activity very close to the "Intangible Zone" of this unique park too. Additionally, is also important to highlight that other indirect and unexplained processes are apparently causing widespread declines of important taxonomic groups, such as birds. Bird declines are occurring at an alarming pace (captures in mist nets now, are about half what they were in 2009) despite the remoteness and undisturbed nature of TBS. Here, we discuss potential explanations for such negative trends and the overall impacts for the ecological function and conservation of TBS and YBR. In summary, in this talk we present data that demonstrate the hyperdiversity of TBS and the threats to the most biodiverse place on earth. We also describe future initiatives planned for this renowned station, expected to help transform it into a control site for intact tropical forests and an observatory for the conservation of the region. **Keywords:** Tiputini, Yasuní, Amazonia, Ecuador, hyperdiversity, population decline

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Mapping Biodiversity Ignorance on the Great Escarpment of Angola and Namibia

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The Great Escarpment region of Angola and Namibia host remarkable levels of biodiversity and endemism, though preliminary analysis suggests that this is poorly reflected in global biodiversity information systems such as the GBIF. To investigate this in more detail we calculated a recently suggested metric of biodiversity knowledge, the ignorance score, for each 10 x 10km grid square within the study area. Ignorance scores are ideal for investigating areas with poor sampling coverage because they are intuitive and are sensitive to very low numbers of records. As anticipated, we observed high levels of biodiversity ignorance for mammals and flowering plants across the escarpment in both countries, with an alarming lack of knowledge for almost all the Escarpment in Angola. Our results highlight the urgent need for: i) new surveys and expeditions to areas of the Escarpment with few or no data points, and, ii) renewed efforts to mobilize existing biodiversity data and make it available on international biodiversity information systems such as the GBIF. **Keywords:** Digital biodiversity information, maps of ignoranc, recording biases, Africa

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Conservation Planning, Management, Practice: Plants Ecosystems III

Introduced Goats Negatively Affect the Caatinga Dry Forest at Multiple Levels of Ecological Organization

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Extensive livestock can reduce natural vegetation ability to regenerate and cause persistent degradation. This is particularly the case of low-productive and fragile dry forests, through which livestock production is the predominant land use. We used an exclosure experiment to assess the impact of exotic goats on forest regeneration mechanisms (seed and seedling banks), herbaceous and woody assemblages, forest productivity and soil physicochemical properties in a human-modified landscape of the Caatinga dry forest, northeast Brazil. The study was based on 14 pairs of 400-m^2- plots, each pair consisting of a free-access plot and another where goats were excluded in the last five years by fences in the Catimbau National Park. Our findings indicate a low-dense (14 seeds/m^2), taxonomically impoverished (a total of 24 species) and short-lived seed bank, with no goat effects on this regeneration mechanism. Woody plant species exhibited reduced recruitment (0.8 seedlings/m^2) and impoverished seedling assemblages (a total of 36 species). Goats negatively impact seedling assemblages by causing increased mortality (2.3 times higher than in exclusion areas) and decreased alpha and beta diversity. Moreover, goat exclosure increased herb aboveground biomass (a total of 70 species) with positive effects across all levels of herb species diversity (rare, common and dominant species). Finally, goat exclosure also permitted increments on the aboveground biomass by woody plant species (a total of 34 species) with indirect effects on litter production and soil organic matter, nitrogen, phosphorus and carbon stocks. Collectively, these findings demonstrate the negative impact by goats at multiple levels of Caatinga ecological organization, most of them recognized as indicators of forest degradation. Considering the current goat rates across the Caatinga dry forest (over 9 million animals), better practices (e.g. reduced animal rates, rotation and transhumance practices) should be investigated and proposed to guarantee forest resilience and the persistence of the Caatinga socioecological systems while climate changes proceeds. **Keywords:** Biomass, nutrient stocks, plant assemblages, regeneration, seed and seedling bank

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Tropical Dry Forests: Natural History, Relevance and Perspectives

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Since seminal papers in the 80's, dry forests have been under the academic spotlight with a proliferation of both academic and conservation initiatives supporting a constant flux of information on natural history, conservation guidelines and research/policy priorities. Here we offer an additional synthesis on tropical dry forests relative to distribution, biogeography, forest structure, ecosystem services, threats, conservation status and a prospect for dry forests by reviewing the available literature. Depending on the attributes adopted to map dry forests globally, original cover ranges from 15 up to 20 million km^2. Such variation result from a lack of consensus about the range of vegetation types covered by the term dry forests. Accordingly, dry forests cover a large spectrum of physical conditions, habitats, vegetation types and their vernacular designations such as thicket, bushland, spiny-forest ticket, tall forest, woodland, scrub, mixed forest, wine tickets, maqui and dry thorn forest. In most cases, dry forests represent reservoirs of endemic species achieving up to 90% of all species depending on the

taxa. However, they also should be recognized by their individual evolutionary history, heritage, singularity and relevance at appropriate spatial resolution from biogeography to conservation/sustainability purposes. In fact, traditional and modern human cultures remain in some extent deeply dependent on forest ecosystem services, particularly provisioning services as forest provides fuelwood, fodder, building materials, manure, and medicinal products, but also food items. Forest products required for millions of people through economically undeveloped and highly-populated regions make tropical dry forests as global asset, but also make this biota highly vulnerable as forest exploitation plus traditional forms of land use have resulted into forest degradation and increased poverty. Such a global trend benefits from a low coverage by protected areas ($< 5\%$ of original cover), and it is expected to speed up by climate changes, such as higher aridity, and an increasing demand for natural resources. Apparently, dry forest regions have achieved a critical cross-road requiring not only better practices or mitigation/adaptative approaches but a new paradigm regarding forest use and socioeconomic development. Precisely, we argue in favor of sustainable landscapes possibly achieved by intense biomass production via modern technology and agropastoral-forestry system able to guarantee revenues and protect native forest from degradation and thus the source of key regulating/supporting ecosystem services. The present discussion on climate change and mitigation of carbon emissions by reducing deforestation and forest degradation represents a timely opportunity to revisit dry forest conservation strategies. **Keywords:** Tropical dry forests, biodiversity conservation, ecosystem services, sustainability

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Two New and Endangered Leafless Vanilla Species from Eastern Madagascar with a Focus on Associated Conservation Issues

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In recent years, the number of newly discovered *Vanilla* species has multiplied. The *Vanilla* genus is a taxonomically complex group subject to frequent taxonomic revisions, emphasizing the importance of understanding the genus evolutionary mechanisms, especially in biodiversity hotspots. Of the approximately 132 described species, 16 are leafless. Madagascar is the most species-rich country in leafless *Vanilla* with four endemics and one native species known so far, mainly distributed along the West coast. Two additional leafless *Vanilla* species from the East of the island were revealed, described and named, following an integrative taxonomy approach combining phylogenetics, genotypic and morphological analyses. Compared to the western species, the eastern species have very large flowers with specific colors and textures of the labellum, and they also form distinct genotypic and phylogenetic groups. Because they have been so far found in only two localities, there is strong concern about the determination of possible threats and conservation status related to these two new Malagasy *Vanilla* species. Analyses in genetic diversity, reproductive biology and distribution modelling were therefore conducted. According to our results, the studied population of *V. atsinananensis sp. nov.*, located in a northeastern forest, has a small population size, therefore is vulnerable to genetic drift and inbreeding. The *V. allorgeae sp. nov.* population, found in altitude in a forest near the Andringitra mountain, is threatened by a strong clonality rate and low genetic diversity. Indeed, it showed low natural fruit set, probably due to the loss of interaction with pollinators. Nevertheless, modelling indicated a fairly wide potential distribution range of both species in Madagascar. For planification of effective conservation of these two new species, prospecting suitable habitats revealed by the modelling to identify other populations should therefore be conducted. In the meantime, a conservation plan should be established to protect the present two populations identified so far. **Keywords:** Phylogeny, morphology, microsatellite, reproductive biology, conservation genetic, species delimitation modelling

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Bridging the Gap between Users and Producers to Develop Essential Biodiversity Variables in the Tropical Andes Region

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Introduction / Background / Justification: The Tropical Andes is an important biodiversity hotspot and a key priority for biodiversity conservation. To successfully respond to current biodiversity challenges, it is vital to bridge the gap between the scientific communities that produce biodiversity information and the relevant stakeholders that utilize this information. **Objective(s)/Hypothesis(es)**: Explore user needs of biodiversity information compared to what is being produced. This will help identify priority needs to develop essential biodiversity variables for the region. **Methods:** We engaged key users and producers from different sectors within the Tropical Andes region using national surveys and national/regional workshops. **Results:** We found large spatial, temporal, and taxonomic gaps between users and producers of biodiversity information in the region, with a high percentage of users indicating the currently available data does not meet their requirements. We defined six major thematic groups from relevant economic and societal sectors that use biodiversity information, which was then synthesized into two major themes. Four essential biodiversity variables were then developed for the Tropical Andes region. **Implications/Conclusions:** Incorporating the various economic and societal sectors that benefit from, care for, and are constrained by biodiversity is critical when considering biodiversity conservation issues. Establishing direct connections in response to demand and mutual recognition is required to allow stakeholders to understand the importance and facilitate the process of including biodiversity information in decision-making. By bridging the gap between the scientific communities that produce biodiversity information and the stakeholders that utilize this information, we can optimize currently existing efforts and begin to more effectively respond to biodiversity challenges. **Keywords:** Decision-makers, biodiversity monitoring, policy, essential biodiversity, Ecuador, Peru, Bolivia, monitoring

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Conservation Planning, Management, Practice: Plants Ecosystems IV

Jigsaw Puzzle in Local-lead Conservation of Endemic Plants in Waigeo Island, Raja Ampat, West Papua

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About eight endemic plant species of Waigeo, Raja Ampat, are currently rare and threatened. One essential effort in saving these endemic plants is by employed locals as key actor as well as initiator in species and habitat conservation. Several approaches have been used in developing conservation actions, where each approach has an important role to play in getting the big picture of conservation goals, like a "jigsaw puzzle". This study was carried out in 3 villages on Waigeo Island, over a period of 2019-2021. Situational analyses approach was used to identify issues in endemic plants conservation of Raja Ampat. Strategy has been developed by using a jigsaw analogy to link the components of each issues. Three strategic issues then have been identified and served as guidance in efforts to protect endemic plants, namely the protection of species and habitats, reducing threats and increasing the capacity of local actors. During the study period, various treatments in conservation actions have been tested with the participation of local actors as the key approach. As a result, 6 endemic plant species were recorded for their distribution, namely *Wallaceodoxa raja-ampat*, *Alstonia beatricis*, *Dendrobium azureum*, *Rhododendron cornu-bovis*, *Rhodamnia waigeoensis* and *Nepenthes danseri*. The community managed to protect an endemic plant habitat area of 59.63 km^2 from patrol activities. A total of 94 people have received training for the capacity to recognize endemic plant species and strategic conservation action. Each strategic puzzle has a specific role with a different portion of intensity and can be paired and combined together. **Keywords:** Local-lead, conservation, endemic, plant, Raja Ampat

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Communal Conservation Practices and the Dialogue with Conservation Scientists: a Case Study from Colombia

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As an interdisciplinary research group seeking to understand the motivations of local communities to implement conservation actions and conservation agreements we identified a very interesting case study in northern Colombia. During the last decade we have worked with the local peasant and fisher communities in the Ciénaga de la Rinconada (Magdalena), where environmental governance has been successful for the last six decades thanks to the communal management agreed by the elders based on their knowledge of the forest and swamp ecosystems. These agreements have not been formally recognized by local, regional or national environmental authorities and the land property rights, according to Colombian legislation, should not be assigned individually or collectively. During the period of 2020 – 2021 we established a transdisciplinary dialogue with the people from Playas Blancas, a small town in Ciénaga de la Rinconada, to co-construct the management plan, recover the environmental management history and good practices of the Playón del Iguá, a community managed area of 137 hectares that provides environmental services to the town of Playas Blancas and the whole Ciénaga. With a series of interviews and workshops we exchanged local and scientific knowledge and produced a robust management plan for this area. We were able to identify the most important ecosystems and associated

tree species and the ecosystem services provided by this area. We also co-created a reforestation plan which included the establishment of a native tree species nursery and a planting plant for the next five years. The plan includes the use of certain areas within the Playón for sustainable production practices such as low impact cattle ranching, harvest of firewood and the production of honey from honeybees. We established a monitoring system for the management plan and the governance system. With the plan and the formalization of the local community environmental governance the area was successfully presented as a candidate to be recognized by the national government as other effective area-based conservation measures (OECMs) on December 2021.
Keywords: OMEC, TICCA, local community, sustainable livelihoods, Colombian caribbean.

Boosting Conservation in Colombia through the Study and Prioritization of Its Useful Flora: a Case Study in Three Biodiverse Areas

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Introduction/Background/Justification: Megadiverse countries face the challenge to develop sustainable economies while preserving biodiversity. Colombia is looking for nature-based solutions to improve local livelihoods and strengthen conservation in highly biodiverse areas with complex socio-economic contexts. Sustainable communitarian projects based on the use and transformation of certain Useful Plant Species (UPS) emerge as a feasible solution in order to buffer the degradation of ecosystems. Non-Timber Forest Products (NTFPs) and Natural Ingredients (NI) derived from native UPS may enhance conservation, leading Colombia towards developing a greener economy. **Objective(s):** This study aims to strengthen an applied understanding of Colombia´s UPS, boosting the interest, study and use of its botanical diversity to improve people´s livelihoods. Specifically, it is necessary to: a.) Gather functional data about UPS from three heterogeneous and biodiverse localities, b.) Identify and prioritize sustainable alternatives of livelihood for local people based on this data, the community's aspirations/traditional knowledge and scientific information. **Methods:** A community-based inventory and prioritization process was conducted to gather data about UPS, NTFPs and NI in Becerril, Otanche and Bahía Solano. Interdisciplinary methodologies were implemented, involving both social and natural sciences, workshops, interviews and ethnobotanical expeditions with local informants. Ten UPS with their NTFP and NI were prioritized in each study area. The primary information (fieldwork-workshops-surveys) was complemented with secondary information from literature. **Results:** Together, between workshops, literature and fieldwork, over 1922 records of 1588 species, 598 genera and 162 families of UPS were reported, with at least three chorological novelties for Colombia. The most representative families were Arecaceae, Fabaceae, Malvaceae, and Marantaceae, and the most important use categories were: Medicine, Food and Materials. Bahía Solano was the locality with more species (752), followed by Otanche (581), and Becerril (427). The top-prioritized species were Corozo (*Bactris guineensis*), Nacuma (*Carludovica palmata*) and Borojó (*Alibertia patinoi*) for Becerril, Otanche and Bahía Solano respectively. Conclusions: A significant taxonomic and use diversity was found, providing an extensive contribution to the useful flora of Colombia. Fieldwork was the most prolific source of information, confirming the need for more expeditions to continue gathering primary-quality botanical information. Decision-makers, environmental authorities, academy, industry and communities, are encouraged to use these results as a guide. Closing the gaps between institutions and communities, with jointly productive projects involving prioritized UPS from each locality, may help to preserve Colombia´s natural heritage. **Keywords:** Bahía/Solano-Becerril-Otanche, bioeconomy, conservation, non-timber forest-products, traditional knowledge, useful plant species.

Agroforest as a Tool for Species Conservation in the Neotropics

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Agroecosystems are one of the main sources of income in developing countries, which includes food, timber, and fiber needs worldwide. Complex agroecosystems such as agroforests have been considered as an alternative for sustainable land use options in agricultural landscapes. Agroforests may enhance biodiversity conservation by maintaining high structural and floristic diversity. The main goal of this study is to analyze at which extent different types of agroforestry systems can be used as a tool for biodiversity conservation in increasingly human-dominated landscapes in the Neotropics. We performed a meta-analysis using raw data from studies comparing faunal richness between agroforestry systems and nearby native forests in the Neotropics. We explored the following questions: (i) which is the general pattern on species richness between agroforests and native forests? (ii) how species richness varies across types of agroforests compared to native forests?, and (iii) how species richness varies across taxonomic groups compared to native forests? At general, we detected lower and significant species richness in agroforests than in native forests. However, species richness across types of agroforests was not statistically different from the richness observed in native forests, except for shaded coffee and mixed plantations which exhibited lower richness than native forests. Most groups did not exhibit differences in species richness between agroforests and native forests. Birds, reptiles, and non-flying mammals exhibited lower richness in agroforests than in native forests. Ants, beetles, other invertebrates, amphibians, and bats did not exhibit any difference in species richness between agroforests and native forests. For most taxonomic groups, species richness was not statistically different among types of agroforest and native forests. Despite the general trend in decreasing species richness in agroforests, we concluded that agroforest structural complexity, high floristic diversity and close resemblance to forest ecosystems hold the potential to provide habitat and food resources for fauna, except for shaded coffee and mixed plantations. Since most comparisons were not statistically significant, we found evidence of the potential of agroforests for species conservation.
Keywords: Agroforestry, conflict agriculture-conservation, habitat complexity, land share, land use, species

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Conservation Planning, Management, Practice: Plants Ecosystems V

The Andes-Amazon-Atlantic Freshwater Corridor: a Globally-important Pathway for Tropical Conservation

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Freshwater ecosystems of the Amazon basin– spanning from the Andes mountains, to the Amazon rainforest, to the Atlantic coast– are integral to sustaining unparalleled biodiversity and millions of human livelihoods both within and beyond the basin's boundaries. However, as with most tropical river basins, conservation planning and management in the Amazon has largely been conducted from a terrestrial ecosystem perspective, rather than an aquatic one. The multi-scale and multi-faceted complexity of freshwater ecosystems is one of the major challenges to understanding what, where, and how durable freshwater protections should be put in place. Our work provides an interdisciplinary perspective on the regional and global importance of Amazon freshwater ecosystems and frames the Andes-Amazon-Atlantic freshwater ecosystem corridor as an interconnected and global pathway that is critical to conserve. Our work is synthesis-based, emerging from two week-long workshops (2021-2022), literature review, and several months of collaborations of an interdisciplinary team of researchers (e.g., ecologists, hydrologists, anthropologists) with diverse experiences in the Amazon. We distinguished three aspects that showcase the singular nature and regional/global importance of Amazon freshwaters: (1) biological and ecosystem diversity in both terrestrial and aquatic perspectives, (2) water cycle and climate pattern influences regionally and globally, and (3) human livelihood and heritage connections. These aspects are interdependent and rely on hydrologic and biocultural connectivity along the entire Andes-Amazon-Atlantic freshwater corridor. This comprehensive understanding of freshwater ecosystem connectivity encompasses elements such as two-way feedbacks between water flows along the land surface and in the atmosphere, lateral connectivity between rivers and floodplains that allow aquatic species migration across wetlands, and customary fishing practices by Amazonian people for nutrition, income, and biocultural linkages. However, the dimensions of freshwater connectivity are threatened by intertwined factors such as dams, mining, overfishing, deforestation, and climate change. Thus, the resilience of Amazon Basin freshwater ecosystems and their far-reaching impacts are at risk without prompt conservation planning and action through a freshwater lens. Effective conservation planning and management in the Amazon requires the clear understanding of the regional- and global-scale contributions of Amazon freshwater ecosystems and importance of Andes-Amazon-Atlantic connectivity that we show here. Our work further reflects the need for transboundary aquatic governance that holistically integrates the hydrologic, socio-economic, and biocultural nature of Amazon freshwaters. **Keywords:** Amazon, Andes, Atlantic, river, freshwater ecosystems, aquatic biodiversity, hydrology, biocultural

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Successional Stage Classification of Atlantic Forest Fragments Based on Field and Remote Sensing Metrics

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The Atlantic Forest Biome overlaps the territories of three South American countries, with the majority (92%) falling under the jurisdiction and legislation of Brazil. In the Brazilian Atlantic Forest, only ˜22% of native forest cover remains. The Biome is protected by federal law 11,428/2006, which implements forest use restrictions based on successional stages, with more advanced stages receiving more protection. Decisions are based on parameters established per state. Based on legislation parameters we aimed to test estimates of successional stages (pioneer, initial, medium, and advanced) using field and remote sensing derived variables. We used old-growth and second-growth forests field data (structure and diversity field inventory) and remote sensing (RS) data derived metrics (canopy height from lidar and secondary forest age from Landsat) from 70 forest plots (NewFor project). The data were collected from semi-deciduous fragments of seasonal Atlantic Forest of São Paulo State. Despite the completeness of our data, only half of the law-parameters could be answered with field and RS variables (field: 'maximum height, 'mean diameter at breast height (DBH)', 'DBH distribution', 'biomass, 'species occurrence', and Field and RS: 'canopy height'), meaning that more thorough inventory measurements would be necessary to cover all the law-established parameters. The agreement to estimate successional stage between field parameters was about 53% (being 'mean DBH' and 'DBH distribution' the most consistent predictors), and 82% between remote sensing parameters ('Canopy Height' and 'Rugosity'), but only 31% of field parameters stage classification matched with remote sensing derived classification. In general, RS parameters overestimate successional stages. Comparing predicted successional stages with second-growth forest age showed that 'mean DBH' and 'canopy rugosity' classification had 40% and 35% correlation, respectively. Only two out of six law-parameters ('max. height' and 'mean DBH') used were objective, meaning the law has a lot of space for misinterpretations. The lack of area unit definition in the legislation was a hurdle to interpreting the results since all the parameters depend on an area definition to allow comparisons (e.g., number of dominant species per hectare). The canopy height was the major source of misclassification since the law establishes that forests with a maximum height greater than 10 m are in an advanced stage, which rarely agreed with other parameters. The law needs to be reviewed urgently in order to prevent wrong successional stage classifications. Compliance with the law and clarity in its interpretation are keys to protecting existing primary and secondary Atlantic Forest fragments. **Keywords:** Native vegetation protection law, Mata Atlantica, secondary forests, tropical

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Half-earth Mexico: An Ecoregion Scale Analysis of Costs and Benefits

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Human activities have modified over 50% of terrestrial ecosystems, particularly in tropical regions. This scenario is expected to continue, jeopardizing previously wild and low disturbed areas and their biodiversity. Given this scenario, scientists and practitioners have made urgent calls to develop policies and explore radically different initiatives for halting land degradation and deforestation. One of these initiatives is Half-Earth, which proposes setting aside at least half the planet as interconnected reserves, however, this proposal entails numerous challenges, including the socio-economic impacts of the intervened places and the costs of implementation. In this study, we assessed the feasibility of the Half-Earth conservation initiative at the ecoregion scale in Mexico by addressing the the following questions: 1) what proportion of each of the 45 terrestrial ecoregions in Mexico is currently protected? 2) for ecoregions where less than 50% of land is protected, is there sufficient "natural" land that could theoretically be purchased for conservation? 3) If land is available, what would be the cost to conserve 50% of each of the 45 ecoregions in Mexico? To address these questions, we used a variety of spatial data sets (e.g., terrestrial ecoregions, Protected Areas (PAs), land-use/cover maps), searched online land prices across the ecoregions, and performed different spatial analyses. Of the 45 ecoregions, seven have more than 50% of their territory with some level of protection. Twelve ecoregions have enough natural land outside the PAs and therefore could potentially reach the 50% goal. Seventeen ecoregions could reach the goal if all the remaining natural areas and part of the secondary vegetation were protected. In the remaining nine ecoregions (mainly moist and dry forests), there is not enough natural and secondary vegetation to reach

the 50% protection threshold. To reach the 50% threshold in these ecoregions would require purchasing agricultural lands, which would have strong socioeconomic impacts and would be much more expensive than purchasing pastures or natural land. In addition to determining the extent needed in each ecoregion, we have modeled the location of these new PAs by prioritizing areas with low human footprint, high species richness, and low acquisition costs. In an effort to best allocate land that maximize biodiversity and use of resources, this exercise brings more elements to the discussion. **Keywords:** Protected Areas, land cover, land cost, biodiversity, conservation.

Uses, Threats and Conservation Status of Climbing Plants in Colombia

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Climbing plants are providers of ecosystem services and an ancestral ethnobotanical legacy, they are distributed from sea level to the paramo in forests and transformed areas, however a comprehensive analysis of its conservation status in Colombia is unknown. This work presents a preliminary diagnosis of the threatened species, and the context is analyzed against the application of the precautionary principle used to avoid the impacts of the Anthropocene on biodiversity. It seeks to establish the advances, challenges, and opportunities to favor of climbing species conservation, and the tradition of use in the associated communities. The information was obtained from the catalog of plants and lichens of Colombia, red books, scientific articles, online herbarium collections (COL, HUA, etc.), JSTOR. Tropics, SiB-Colombia, GBIF, IUCN RedList, RUNAP, SIAC and regulations, among others. Distribution maps were generated in QGis (3.10). More than 3500 species of climbing plants (90-families) were identified, of which 126 are in some threat category , 5-CR, 17-EN, 2-EN/CR, 2-VU/EN, 28-VU, 1 -NT/VU, 4-NT and 67-LC, more than 3200 NE and 11 DD. Passifloraceae, the most threatened (3-CR, 7-EN, 2-EN/CR, 15-VU, 1-VU/EN, 2-NT, 105-LC, 20 NE and 8 DD) and Melastomataceae with two endemic species -CR protected in National Parks: *Meriania selvaflorensis* (PNN Selva de Florencia) and *Miconia punctibullata* (PNN Munchique). More than 13 species distributed from the mangroves of the Pacific to the tropical humid forests of the Caribbean, Andes and Amazon, are used in handicrafts and as food by peasant, indigenous and Afro-descendant communities, activity that promotes economy in territories. The precautionary principle is considered insufficient for the conservation of climbing plants, which has been applied in prevention of the impacts of productive sector (mining and hydroelectric) in large areas of forest or strategic ecosystems and excludes semi-natural and transformed areas where processes of ecological succession that express ecosystems resilience can be configured, where the role of these species is evident. It is a challenge for decision makers to understand that vegetation fragments conservation is fundamental in climbers protection, which can be considered umbrella species, in addition to contributing to the configuration of regions ecological and socioeconomic dynamics. This scenario offers opportunities and new challenges for research in conservation biology and ethnobotany. **Keywords:** Lianas, vines, biodiversity, ethnobiology, biogeography, precautionary principle

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Conservation Planning, Management, Practice: Plants Ecosystems VI

Assessing Human-nature Relationships for Transformative Conservation - a New Mixed Tool to Identify Shared-ways of Thinking among Local Actors

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Giving voice to the diversity of human-nature relationships (HNRs) is key to transformative nature conservation. HNRs consist of the intricate set of beliefs individuals hold about the more-than-human environment and encompass different dimensions, such as affective, ethical and ontological. They are built through mental processes shaped by socio-cultural contexts and are the basis for the way people relate to and value nature. They allow understanding the plurality of views on how to interact and treat nature, supporting conflict mediation and conservation of biocultural diversity. They are, thus, especially relevant among local, territorially contextualized actors in socio-environmental conflict areas. Grasping how people - who have an intimate, culturally established relationship with nature - think of the more-than-human environment is crucial for making conservation plural, fair, and effective. Yet, assessing HNRs is challenging, given the complexity and immateriality of such relationships. Most research in this area is based either on quantitative psychometric scales ranking people on few dimensions of HNRs and constructed for - and applied in and across - western groups/societies, or on in-depth qualitative interviews rooted in local contexts rather than general conceptual (and comparable) HNRs dimensions. Using the well-established mixed (quantitative/qualitative) Q Methodology from psychology and a comprehensive conceptual framework on the dimensions/types of HNRs, we developed a tool for identifying, qualitatively describing and comparing shared ways of thinking on HNRs and tested it among local actors in the artisanal fishery community of Siribinha, Bahia, northeastern Brazil. We started by revising the literature to identify a coherent, plural framework of human-nature relational models to conceptually support the development of statements expressing the complete set of HNR dimensions/types. We then developed 44 statements based on the chosen framework, and conducted an iterative process of language and context adaptation to suit the application among heterogeneous actors. The application of the tool revealed three main shared ways of thinking about HNR in the fishery community, allowed their detailed description and comparison with conceptual HNR types, and provided insights on the roots of local socio-environmental conflicts. Given its transparent and replicable methodological development and the amplitude of its conceptual base, the tool can be easily adapted to assess and compare HNRs among local actors within and across different social and cultural contexts. This open a new avenue for fostering plurality and effectiveness in conservation by giving voice to marginalized people and helping dialogue and conflict resolution. **Keywords:** Human-nature relationships, nature contributions to people, relational values, Q methodology

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Brazil Inequalities in Biodiversity Research Investment and the Impacts for Amazon Conservation

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The Amazon encompasses 1/3 of Earth's remaining tropical forests and is one of the most biodiverse regions for most taxonomic groups. Yet, there is an urgent need to improve research infrastructures and human resources in the region. Brazil plays a central role in this context, as it harbors 2/3 of the Amazon, and is the largest producer of knowledge in South America. Despite Brazil having one of the largest gross domestic expenditures on research in Latin America, this investment is uneven within country regions and is generally determined by socioeconomic factors that disregard regional needs. Assessing how much of this resource has been destined for biodiversity research in the Amazon is a fundamental step for the country to fulfill the global environmental agendas. Our work aims to evaluate the distribution of public investment for biodiversity research across macro-regions of Brazil using four indicators. We use these results to discuss the actions needed to improve policy science suited to Amazon's needs. The indicators analyzed are: i. Number of postgrad scholarships for biodiversity research, ii. Number of researchers working in biodiversity postgraduate courses, iii. Number of permanent biodiversity research sites, iv. Number of biological collections and herbaria. The Amazon region receives the least investment for human resources, and only 11.6% of all biodiversity specialists in Brazil are working in amazonian institutions. The Brazilian Amazon has only 11% of all herbaria and biological collections in the country and received just 6% of public investment for structural improvements in the last decade. Sixty-two of the 116 permanent biodiversity research sites are in the Amazon, but only four are being systematically monitored over the last five years. Investment inequalities also occur within the Brazilian Amazon, with two municipalities receiving 85% of all funding for human resources. Our results demonstrate the fragility of public investment for biodiversity research in the Brazilian Amazon, and reflect the recent history of most research institutions in the region. The large information gaps will only be solved through new science policies that increase the training and retention of biodiversity specialists in the biome. Permanent research sites need to receive investment to ensure the maintenance of infrastructure and human capacity, while new long-term projects need to be initiated within less studied regions. Finally, it is essential to strengthen internal collaboration networks in the Amazon, to guarantee knowledge and technology transfer between centers of excellence and emergent institutions. **Keywords:** Biodiversity research, funding inequality, Amazon, Brazil, public policy

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Locating KBAs: An Automated Workflow for Identifying Potential Key Biodiversity Areas

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The world's biodiversity is declining at an alarming rate, primarily due to the increasing impact of human activities on natural ecosystems. It is therefore imperative to safeguard the most important places for biodiversity to effectively reduce the loss of species and their habitats. The IUCN Species Survival and World Protected Areas Commissions recently developed a standardized approach to identify critical places for the persistence of biodiversity, the Key Biodiversity Areas (KBAs). The Global Standard for the Identification of KBAs provides a set of criteria and quantitative thresholds that make their establishment process objective and repeatable. Although the standard provides a scientifically rigorous approach to identifying KBAs, it is difficult to obtain, compile, and analyze spatial data for many taxonomic groups, and it is often unclear where it is most effective to apply the criteria. The objective of this work is to develop an automated workflow that facilitates and accelerates the identification of potential KBA criteria trigger species and the sites where they occur in considerable numbers within a study area. I conducted a revision of the Guidelines for using the Global Standard for the Identification of KBAs, focusing on the steps for the initial scoping analysis. Based on the steps and possible sources for species-specific information, I developed the Locating KBAs workflow, which uses the R programming language and leverages GBIF data to automatize the KBAs scoping analysis. Overall, the workflow script uses the GBIF API to access species occurrence data within a user-defined area. For each species, it retrieves information on threat category, range, and migratory status by accessing the IUCN, KBA, and Birdlife Datazone portals. Then, it creates a table of potential trigger species in the study area and allows to explore their spatial location, highlighting the places where they occur in significant numbers. For bird species, it also retrieves information on the global number of mature individuals and calculates the thresholds for different criteria. Finally, the code allows creating an interactive map showing the sites where

bird counts potentially meet criteria thresholds. This workflow is intended to be used by individuals and entities involved in biodiversity research and conservation planning. The code is available in an open-source repository (https://github.com/dLinero-KBAs/dlinero-KBAs.github.io), allowing users to efficiently identify places to focus efforts on applying the KBA criteria. In conclusion, the Locating KBAs workflow has the potential to improve the ability of individuals and organizations to locate sites of global biodiversity significance. **Keywords:** Biodiversity conservation, conservation planning, protected areas

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A Binational Rapid Social and Biological Inventory of 2.7 Million Hectares of a Massive Conservation Corridor in the Putumayo Watershed

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Intact forests are considered an "exceptional value" for conservation, and forest corridors are increasingly lauded as critical for achieving global conservation goals and sustaining traditional livelihoods. However, there is a shortage of blueprints for ensuring that intact forests remain standing and healthy. One model is consolidating a conservation corridor, which hinges on bringing together diverse actors, integrating management across a land-use mosaic (including protected areas and indigenous territories), and ensuring a coordinated and consistent response in the face of threats. We report on our latest multi-institutional effort to use rapid inventories and binational encounters to build a conservation corridor in the Putumayo watershed, a basin shared by Peru, Colombia, Ecuador, and Brazil. In November 2019, a 35-person multidisciplinary team of geologists, biologists, social scientists, and local residents conducted a rapid inventory in the forests, rivers, and human communities in a 2.7-million-ha landscape near the junction of the Putumayo and Cotuhé rivers in lowland Amazonia in Colombia and Peru. The geological and biological team surveyed four sites, each in a different land use category: undesignated public lands (now proposed for conservation) in Peru and a national park, indigenous reserve, and forestry concession in Colombia. At each site, scientists characterized the region's geology, hydrology, and plant, fish, amphibian, reptile, bird, and mammal communities. At the same time, social scientists visited seven communities in Peru and Colombia along the lower Putumayo River, focusing on cultural and settlement history, demography, community governance, social infrastructure, public programs, natural resource use and household economies of local people. The social inventory culminated in a three-day event that brought residents together for the first binational meeting about their aspirations for their shared landscape. Together, the biological and social inventory resulted in a series of recommendations at different scales (individual areas, individual watersheds, binational landscape, entire corridor) for strengthening the shared governance in this extraordinary landscape and protecting and managing the region's natural resources in partnership and with leadership by local indigenous and *campesino* residents. The Bajo Putumayo-Yaguas-Cotuhé is a remote frontier region where national governments are largely absent and where cooperation between the Peruvian and Colombian governments has not been sufficient to address shared problems (illegal gold mining, illicit crops, drug trafficking, illegal timber). Our shared belief is that solutions must be local. However, local, regional, national and international efforts must align for those local solutions to be durable and long-lasting. **Keywords:** Corridor, Putumayo, rapid inventory, indigenous, campesino, biodiversity, Peru, Colombia

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Impact Evaluation in Conservation Programs in the Tropics: Approaches and Tools

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Introduction: Assessing the effectiveness of conservation programs or policies is an essential step in conservation practice. However, environmental program evaluation is usually limited to the monitoring of indicators, instead of empirical analysis designed to assess the impact of the intervention relative to a scenario with no intervention at all. Thus, there has been a growing call for mainstreaming rigorous methods of impact evaluation in conservation. Quasi-experimental designs have been applied in the evaluation of the effectiveness of protected areas in reducing deforestation. However, such analyses are commonly applied by researchers, while managers face challenges to implement these kinds of evaluations. There is a need for more accesible tools to implement statistical matching analyses or other impact evaluation methods of avoided forest loss. In a similar fashion, conservation programs focused on particular species, do not usually test whether actions had an effect in the species, assessing causality, controling for confounding factors and using counterfactual approaches. **Objective:** We present a conceptual framework and a novel tool to evaluate the impact of conservation interventions focused on reducing deforestation or protecting particular vertebrate species. **Methods/Results:** For assessing reduced deforestation, we developed a Shiny R App that evaluates the impact of area-based conservation interventions using a statistical matching approach. This is as a technique that identifies control units that are closely matched to treatment units according to predefined measurable characteristics and a measure of similarity. We test the functionality of the developed App by studying the effect of Colombia´s protected area network in reducing forest loss in the Amazon region from 2000 to 2020. To assess the effectiveness of conservation programs for vertebrate species, we applied a multi-season occupancy approach, to a set of data from a three-year camera trap study in the middle Magdalena Valley of Colombia. The Shiny R App developed is an open Access tool, easily run by practitioners with little experience in R. Results using the counterfactual tool indicate that although protected areas have forest loss, they have reduced deforestation when compared to non-protected areas. The methodological approach used for assessing the effectiveness of conservation agreements on vertebrates, indicated that such agreements increased colonization rates and decreased extinction rates of some species, including the Brown-spider monkey, the Blue-billed Curassaw and the Agouti. **Implications:** The counterfactual Shiny R app and occupancy approach presented are tools and methods that shall be used more frequently for impact evaluation in tropical conservation programs. **Keywords:** Impact evaluation, conservation, deforestation, Shiny R App, vertebrates

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Community-based Participatory Design of Coastal-Marine Protected Areas in the Pacific Coast of Colombia

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Marine Protected Areas (MPA) networks are cornerstones of biodiversity preservation, however, few are effectively managed to preserve critical coastal ecosystems and habitats for species in the Neotropics. In recent years, the Colombian government has significantly increased the marine and coastal areas under legal protection by creating new MPAs. A central strategy during the design process for the effectiveness of a new MPA is the participatory definition/identification of the conservation objectives and targets, as well as the conflicts, threats and uses of the natural resources within the area. The new MPAs will be then designed based on the local vision of the communities about the value of the natural resources for their wellbeing, and the management category of the new MPA will be agreed between the environmental authorities and local communities. Here, we show the studies carried for the establishment of the Ají Island MPA as Regional District of Integrated Management (RDIM) (category VI - IUCN) for the sustainable use of the natural resources based on the traditional use and dependence of ethnic communities on the marine and terrestrial biological resources. The methodology included the implementation of participative: (I) biological, socio-economic and cultural surveys, (ii) strategic design including scope, vision and conservation objectives and targets, transformation drivers and socio-environmental conflicts, (iii) delimitation and zoning (use regimes for each zone), (iv) a governance structure, (v) and optimal strategies that will allow addressing the threats identified. Finally, a consultation process (required by law) was carried out between local communities and the government regarding the trade-offs in creating the MPA and evaluations of the potential socio-economic benefits for local communities. The participative establishment of the new protected area will improve its effective management and effectively reduce threats by establishing limits to the development of certain areas and activities, and promote the sustainable use of natural resources and

socio-economic benefits. **Keywords:** Marine Protected Areas (MPA), community-based participative strategic design, effective management

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Piscilago: a Model of Sustainable Tourism and Conservation

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Piscilago maintains a biodiverse territory that connects human beings as part of nature and directs its efforts to the preservation of endangered species of fauna and flora. It protects one of the last relicts of the country's tropical dry forest ecosystem and adequately manages its resources, prioritizing water and proper waste management. The main objectives of its sustainability strategy are conservation, research, education, and animal welfare that are aligned with the strategies of the World Association of Zoos and Aquariums WAZA. Through strategic alliances with 28 academic and conservation institutions, 74 research and conservation projects have been carried out over 38 years of history. Research conducted in the forest has reported the presence of 81 species of flora and more than 250 species of fauna. Within those a total of 190 bird species (including 17 migratory and 2 endemic), 31 reptiles, 24 mammals, and 18 terrestrial amphibians. The park is catalogued as an Important Bird Conservation Area (AICAS). Since 2000, nearly 1,550 animals have been rescued from wildlife trafficking. The institution keeps under excellent welfare conditions a population of 150 species, 82% of these species are in some level of endangered. For this reason, initiatives are being developed with endangered species, such as the conservation project for the Orinoco crocodile (*Crocodylus intermedius*) and the international conservation project for the White-footed Tamarin (*Saguinus leucopus*), which have made progress in maintaining viable populations under controlled conditions, achieving successful reproduction, generating relevant information through research, and developing educational strategies with broad coverage. Regarding conservation education, 1,000,000 visitors per year and nearly 15,000 people, including students, technicians and scientists, have been impacted by the programs developed in the last 10 years. Piscilago is now an environmentally certified park, and had been recognized as the Best Sustainable Tourism Company in the country (2013). It is currently undergoing a process of transformation into a conservation park, formulating a master plan and strengthening the research and conservation plan focused especially on the tropical dry forest and endangered native fauna species, actions that will consolidate the institution as a benchmark for conservation and for sustainable tourism. **Keywords:** Conservation park, ex situ conservation, endangered species, dried forest, conservation

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Conservation Planning, Management, Practice: Plants Ecosystems VII

Connecting Transdisciplinarity: a Citation Network Review of the Multitude of Approaches to Integrate Science and Practice across Scientific Communities

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Real-world problems, as conservation issues, are complex, involving multifaceted consequences and conflicts of values and interests. Helping solve such problems has been claimed to be a key contribution of science to society. Yet, this requires navigating the science-practice/policy arena by integrating disciplines to deal with the complexity of societal problems, and promoting dialogue with non-academic actors to encompass the multiplicity of interests and values, allowing problem delimitation and going beyond insufficient technocratic solutions. Transdisciplinary-related approaches - by focusing on sharing scientific and non-scientific knowledge and values - seem to be effective to deal with these underlying challenges. However, they are numerous, spread across a multitude of scientific fields, and distinct in how they tackle challenges related to sharing and coproducing knowledge. Identifying and analyzing the distribution of the various transdisciplinary approaches across scientific communities can help connect distinct views, avoid "reinventing the wheel" and speed up the learning and practice of transdisciplinarity. By means of a comprehensive literature review and citation network analysis, we identified the different scientific communities that use transdisciplinary-related approaches, distinguishing the approaches that characterize them. We identified 55 transdisciplinary-related approaches used in 59,889 publications. Direct citation network analysis identified eight main scientific communities. Four communities are related to policy and sustainability: one associated with conservation and dominated by the adaptive management approach, one with sustainable development and dominated by transdisciplinarity mode 2, one with organizational boundaries focused on boundary spanning, and one with climate change mitigation and dominated by integrated assessment. In addition, there are three communities associated with health: one related to clinical medicine dominated by translational science, one to health promotion dominated by participatory research, and one to teaching dominated by action research. Finally, there is one community associated with technology focused on triple-helix. While our findings indicate that many approaches have spread from the original disciplines across diverse fields, they suggest that strengthening connection among them would bring improvements to the practice of transdisciplinarity, as communities are still dominated by particular approaches. Hence, to find the best transdisciplinary approach to specific conservation issues, it is key that researchers go beyond the conservation literature. Our work serves as a roadmap for conservationists to identify the areas and topics in which transdisciplinary-related approaches have been used, helping to pinpoint those that have been employed in similar or analogous situations to that in hand, speeding up the learning and adaptation of transdisciplinary practice in conservation. **Keywords:** integration, knowledge co-producing, real-world problems, societal actors,values.

Strategic Planning and Conservation Based on Community Participation in the Itapicuru Estuary, Conde-ba, Brazil

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A serious environmental crisis caused mostly by anthropic actions has been unfolding in the last decades, with substantial impact on global biodiversity. Facing this crisis, conservational approaches usually consider technical and scientific aspects, but it has been increasingly recognized that one also needs to pay attention to other kinds of knowledge involved in the relationships between humans and nature, such as traditional, local and indigenous knowledge. Considering that participatory strategies have been often carried out to deal with the demand of including such a diversity of knowledge systems, the present work analyzes to what extent participatory planning influences a community's opinion of environmental conservation and how this perception and its dynamics are reflected on the process of stakeholders' decision-making. The analysis is based on an empirical study which was conducted in the fishing village of Siribinha, Conde municipality, Bahia, Brazil. Since 2018 we began carrying out Informative and Participatory Workshops aimed at building knowledge with the community about nature, and other issues relevant to their participation in decision-making regarding the conservation of the place where they live. The participatory workshops also involved the community members' reflection on the problems they face, their causes, and actions that can be carried out to confront them. Indeed, it led them to conceive, organize, and accomplish actions by themselves aimed at solving the highlighted problems during this process. Semi-structured interviews were conducted with people from the community in order to understand the workshops' influence on the community's understanding about conservation as well as its participation in the decision-making processes. The interviews were submitted to content analysis using categorial analysis techniques. The results show that the workshops improved the understanding of conservation among the participants. There has been an increase in the understanding of environmental problems that affect the community, which measures can be taken, the ongoing political decisions in the municipality to conserve the region they live in, and their consequences to the community. These findings support that participatory strategic planning can have an impact on how a local community conceives of conservation, as a relevant factor for its participation in decision-making toward conservation that affects its life. In this way, we can understand what kinds of can be successful in engaging the community in conservation-related actions, which can in turn serve as a blueprint for similar projects in other regions. **Keywords:** Conservation biology, participatory action research, community knowledge, traditional knowledge, decision-making

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Integrative Evaluation of Dry Tropical Forest Degradation in Colombia

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Extent of Dry Tropical Forests (DFT) in Colombia has been reduced by 92% with remnants embedded in a matrix with high cumulative human footprint. Preserving these forest patches and restoring DTF implies unraveling how historic forest transformations interact with drivers, how biological communities are impacted by these interactions and how production practices could be curve to halt further forest loss. However, there has been little integration between forest degradation, biodiversity patterns and land production practices, which prevents realistic DTF management strategies from being designed. To address this knowledge gap, we answer three questions: Which anthropogenic drivers at the landscape level are exerting the most pressure on DTF remnants?, How and where local land management decision and productive activities most impact DTF remnants?, Which of these drivers and land management practices most impact forest integrity, and alpha/beta biodiversity?. For question 1, we explored relations among variables on climate, historical human pressure, and ecological condition trends for 298 remnants, for question 2, we built an SEM with these variables and socio-economic variables at the municipal level, mainly from the National Agriculture Census, for question 3, we explored biodiversity group-specific and multi taxa models with diversity variables for vegetation, birds, ants, and mammals in 6 watersheds distributed in 4 DTF regions. Our results indicate that beyond the strongest influence of regional climatic variables, remnants condition differ among groups experiencing stronger pressures due to proximity to roads, settlements or land production. At the municipality level, wherever conservation-prone forest management decisions prevail, forest integrity improved and these practices increased as average

natural forest per property and cumulative human impact decrease, which could represent feasible restoration opportunities. Despite this, forest integrity decreases as production for self-consumption and cumulative human footprint increase, suggesting a trade-off between forest conservation and food security. None of the tested factors explained changes in forest integrity in the last 5 years suggesting longer time scale effects. Finally, forest structural integrity -SCI- correlated with forest condition nationwide but its importance of this and other forest change drivers in explaining biodiversity variables is group-specific and context-dependent. These results imply that DTF management strategies should consider differential localized consequences of human pressures on forests, possible trade-offs between food security and forest integrity, and uncertainties of using highly inconsistent biodiversity surrogates during conservation and restoration planning **Keywords:** Dry tropical forest, conservation, biodiversity, degradation, land management

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Conservation Lifestyle: A Formula for Local Communities Empowerment in Tropical Forest Case Study of West Papua, Indonesia

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As the largest tropical forest in the Asia Pacific, Papua Island is a habitat for endemic and protected animals. It has more than 250 indigenous tribes with no less than 276 divergences of local languages. West Papua is one province on Papua Island with marine to mountainous landscape biodiversity and culturale richness. It also has a high population growth and acculturation rate. The conservation concept is usually not prioritized by local communities since it could not provide direct benefits for their lives, so conservation-related programs are generally unattractive. This research aims to encounter a suitable formulation so that local communities will accept conservation and become their way of life to maintain tropical forests, oceans, and biodiversity. This research is an observation completed by researchers for three years assisting local communities in several areas in the Bird's Head Peninsula area from Misool Island to Arfak Mountain. Three main approaches are applied: Maslow's hierarchy of needs theory, innovation adoption theory, and participatory theory. Through those approaches, conservation programs will be effectively formulated to be more contextual for the socio-cultural needs of local communities around tropical forests and provide direct and sustainable benefits. Generally, the Bird's Head Peninsula community profession is hunters and gatherers. Their subsistence needs are met by hunting wildlife, harvesting fruit in the forest, cutting down trees, and fishing. People's needs are continually growing in the global era will also certainly impact increased hunting and gathering activities as the primary source of livelihood, which will impact forests and seas destruction and extinction. In the implementation process, the community has fully engaged in planning, implementation, learning, and evaluation. In addition, the local champions has a significant role on the implementation process. So, the facilitator's willingness to understand the social community context becomes essential from the begining of the interaction. Through the formulation has been implemented, several assisted local community groups are carrying out conservation programs developed collaboratively. Programs running include ecotourism, SMART-Patrol, strengthening local knowledge in protecting nature, developing productive economies, planting mangroves, social forestry, and protecting biodiversity. Through these programs, the harmful interaction between assisted local communities towards tropical forests, oceans, and biodiversity is almost non-existent. Moreover, the implementation of developed conservation programs for local community groups could continue despite being impacted by the Covid-19 Pandemic. It occurs since conservation has become their way of life. **Keywords:** Bird's Head Peninsula, conservation lifestyle, empowerment, formula, local Communities

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Assessing and Improving Equitable Governance in Protected and Conserved Areas: Preliminary Analysis of the 'Site-level Assessment of Equity and Governance'

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Equitable forms of governance are increasingly understood as vital to improve the social and ecological outcomes of protected and conserved areas. The CBD's post-2020 Global Biodiversity Framework reflects this by incorporating key aspects of social equity in its targets. This includes equity in the distribution of costs and benefits, participation, transparency, accountability, and rule of law, and in recognising the diversity of stakeholders and rightsholders, their cultures and ways of knowing and valuing nature. However, many gaps remain in understanding how equitable governance contributes to, or may stand in conflict with, the ecological effectiveness, sustainability and resilience of conservation efforts. This is partially due to the lack of evaluations of equity at different conservation sites and over time. We applied the recently developed 'Site-level Assessment for Governance and Equity' (SAGE) tool to evaluate and monitor the quality of governance and equity in seven conservation sites in Asia, Africa and Europe. SAGE is a participatory methodology developed by the International Institute for Environment and Development (iied) and partners, based on the CBD's endorsed equity framework and ten underlying normative equity principles. Based on a questionnaire, different actor groups first deliberate their perspectives separately before presenting and discussing their evaluations and ideas for improvements in multi-stakeholder dialogue. Results show that SAGE can effectively identify strengths and weaknesses of governance within a site, that different actors can, and often do, have different opinions and perceptions on key aspects of equity, and that bringing these divergent perceptions into dialogue can create innovative ideas for actions to improve equitable governance. Whilst SAGE primarily provides a framework to start practically addressing and improving equitable governance at the site-level, in the long run, it allows to collect comprehensive and comparable data for global level analyses on the contribution of equity towards ecological sustainability. Our next research steps are to conduct a more detailed quantitative analysis of 25-30 SAGEs, and a qualitative outcome harvesting study to investigate the social and ecological governance changes brought through SAGE. Presenting this work at the ATBC 2022 conference has the objective, next to informing our upcoming analyses, to discuss the wider role of equitable governance towards socio-ecological resilience of conservation areas. **Keywords:** Equitable governance, protected and conserved areas, participatory evaluation

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What We Talk about When We Talk about Protected Areas Governance?

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The recognition of governance as a fundamental tool in the effectiveness of protected areas around the world, was formalized within institutional discourses during the last decades. Under this scenario, it was established as a "central factor for the conservation of protected areas around the world". Hence, during the last decades, the incursion of this concept in conservation debates has increased, in response to the challenges faced by protected areas, particularly those whose territories are inhabited by human populations. Latin America and the Caribbean comprise a region where a large proportion of protected areas overlaps with both peasant and ethnic communities, which positions their territories as strategic zones for these conservation figures to be implemented. In this sense, governance becomes a necessary exploration foci for the fulfilment of conservation targets, which in turn requires its sound understanding, so that the division between discourses and practices is reduced. Through a systematic literature review, this study analyses the trajectories and operational frameworks that, from academic grounds, have attempted to explain the concept of governance in the management of protected areas of Category II of the IUCN (i.e Conservation and protection of ecosystems under the figure of natural parks) during the last 20 years. The methodology used to carry out this review was proposed following the guidelines established in the PRISMA protocol, which based on predefined exclusion criteria, allowed the selection of 36 articles for qualitative analysis. Our results revealed that: (i) there is a remarkable polysemy of the governance concept that makes it difficult to define operationalization frameworks through which it can be characterized, and (ii) the most representative changes in the evolution of the governance concept during the last 20 years correspond to complementary elements that define new approaches or particular characteristics drawn upon the researcher perspective, the research objective and the territorial context. Finally, "limiting" and "enabling" elements in the governance of national parks were identified, which expose the needs of the regional contexts. The concept of governance, being adaptable, dynamic and context-dependent, poses a challenge both for the institutions in charge of its application and for the academia. Nevertheless, it is necessary to prioritize the generation of an institutional consensus for its operationalization, in addition to addressing efforts to its territorialization, so as to allow a collective construction of the concept driven by the needs of the context in which it developed. **Keywords:** Concept, conservation, governance, national parks, protected areas, local knowledge

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Determining the Socio-ecological Factors That Influence Land Use Decisions in Tropical Agricultural Systems in the Atlantic Forest Region, Brazil

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In Brazil, the restoration of native forest vegetation on a large scale will only be achieved by fostering the effective participation of rural landowners, thus, it is essential to understand the socio-ecological factors that influence landowner decision-making. The rural properties in the state of São Paulo have a high dynamic of native forest cover and vary as to property size. To effectively inform policy regarding the restoration of these agricultural lands, we aim to determine the socio-ecological factors that led small (1 to 4 fiscal modules), medium (>4 to 15) and large (>15) rural owners to suppress, conserve and/or restore (actively or passively) the native vegetation of their rural properties in the past 30 years. To do this we will conduct structured interviews with 90 rural landowners across fifteen municipalities in the state of São Paulo, with high dynamics of native forest between 1985 and 2015. The interviews will address social-ecological factors including: i) perception of ecosystem services provide or not by the native forest in their properties ii) social characteristics of rural owners and family, iii) property characteristics and production system, iv) motivations and factors on land use, namely the decision to degrade, conserve and/or restore the cover of native forest vegetation. We predict variation in the socio-ecological factors and valuing of ecosystem services (ES) across landowners, particularly with regard to size of the property, education and presence of conserved native forest in the property. These data on landowner perception of forests and ES will contribute to developing effective conservation management approaches and strategies across land use types in rural São Paulo. **Keywords:** Forest landscape restoration, forest management, landowners, ecosystem services

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Design of Conservation Strategies with the Participation of Social Actors in Post-conflict Areas: El Prodigio, San Luis (Antioquia-Colombia)

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Colombia is one of the megadiverse countries on the planet, and for this reason the conservation of biodiversity and ecosystems is one of the challenges of the millennium, although the fact that there are currently public politics and technical-scientific tools for compliance, it is essential to highlight the role of social actors and institutions as drivers of change to develop strategies that persuade politic makers to prioritize sustainable use of tropical ecosystems and their ecosystem goods and services. About it, in Colombia there is a growing interest from actors such as academia, public and private organizations, and ONGs, to generate technically and legally viable ecosystem management strategies, as well as in socioeconomic matters for individuals and organizations that inhabit the territories, such as the case of economic incentives for conservation, known worldwide as Credit Trading Programs. Schemes that promote public-private alliances and with local communities, configuring new models of rural development. This interest motivated the realization of this research, in which it is proposed to design ecosystem conservation strategies with viable environmental, social and productive solutions for public and private organizations and local communities in the corregimiento El Prodigio, municipality of San Luis, which has been strongly affected by the armed conflict in Colombia. The study area has strategic ecosystems at the regional and national levels, has a high agricultural dynamics and deforestation problems, as well as the presence of companies dedicated to the exploitation of limestone and cement. The research was developed under an interdisciplinary approach with professionals from the environmental, agronomic and cadastral sciences, allowing, through the application of descriptive research methods of participatory action research, to find a broad vision that prioritizes conservation, but that guarantees the socioeconomic viability of the territories. The field work was made in four rural properties, which allowed gathering information for the evaluation of cadastral and land tenure, identification of ecosystem services, environmental quality, and the definition of sustainable production strategies, mediated with the coordination of conservation spaces. The results of this research project will be presented at this event through a presentation. **Keywords:** Conservation spaces, ecosystem services, conservation, biodiversity, sustainability.

Conservation Planning, Management, Practice: Plants Ecosystems VIII

From Lemurs to Lobsters: Land to Sea Links in a Coastal Socio-ecological System in Western Madagascar

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Half of the world's wildlife and plant species are threatened by overexploitation (Morton et al., 2021, Pitman & Jorgersen, 2002). When humans use wildlife species in adjacent ecosystems, hunting may have feedback effects on neighboring environments. Coastal environments tend to be among the most resource-rich ecosystems, yet they receive far less attention than terrestrial forests and integrated socio-ecological studies of human activity and ecology are rare (Williams et al., 2021). The lack of such integrated studies is concerning. Given that access to marine wildlife may indirectly affect the demand for forest animals (Agnew et al., 2009). This is especially pertinent in coastal biodiversity hotspots, such as the West Coast of Madagascar. To address this gap in the literature regarding the relationships between terrestrial and marine resources, we examined the socioeconomic drivers of wildlife exploitation over six months (September 2018 - March 2019) in a village adjacent to Kirindy Mitea National Park (N = 89 households). We explore the relationship between terrestrial and marine resources to clarify who captures wildlife, what species they catch, the methods they use, and the relationships between hunting and fishing behavior. All households relied on natural resources, with 11.1 % exclusively hunting, 26.7% exclusively fishing, and 47.8% both fishing and hunting. This presents an indirect pathway between marine resource use and forest resource utilization. As such, a cohesive, regional landscape conservation approach which considers the cross-ecosystem consequences of resource extraction is essential to the future viability of the human, marine, and forest ecosystems of Madagascar. **Keywords:** Wildmeat, fisheries, social-ecological systems, coastal ecosystems, hunting, fishing

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A New Platform to Mobilize Global Biodiversity Data for Tropical Conservation

Nigel C. Pitman

Field Museum of Natural History, Chicago, IL

The vast amount of information in natural history museums and global biodiversity databases has the potential to guide urgent, on-the-ground work of tropical land managers—but it rarely does so. In 2020 the Field Museum and Yale University launched a digital tool that addresses this problem by translating millions of biodiversity occurrence records from natural history museum and other global databases into actionable recommendations for land managers in Colombia, Ecuador, and Peru. Users of the tool (https://mol.org/places/) can select any park, indigenous territory, watershed, or province in the three countries, obtain lists of the vertebrate species expected and confirmed to occur in the selected area, and view photos and distribution maps of each of the listed species. The tool also allows users to filter these results to only include threatened species, CITES-listed species, endemic species, or species that are not found in any other protected area in the world, and thereby generate an individualized 'red list' for a particular piece of land. Built in collaboration with Peruvian and Ecuadorean governments, the biodiversity dashboards are built on the Map of Life digital platform (http://mol.org) and populated with hundreds of thousands of individual records from natural history museums, citizen science sightings, scientific journals, and other sources. In this talk I describe the design and function of the tool,

discuss the lessons learned building and promoting it, and explore its use by South American conservationists. More broadly, I invite scientists to reflect on how we can translate the petabytes of complex biodiversity data we curate into simple, actionable recommendations for land managers. **Keywords:** Biodiversity, Colombia, Ecuador, Peru, land management, protected areas, species lists

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The Lemuindex: a Simple, Transparent and Efficient Spatial Conservation Prioritisation Method

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In the face of the biodiversity crisis and restricted economic support to solve it, we need to rally all available resources as efficiently as possible. Mobilising civil society actors and individuals not currently involved in biodiversity conservation requires simple, transparent strategies to attract support. Spatial conservation prioritisation (SCP) can be used to identify those areas of the world of importance in terms of their evolutionary past and potential as centres of species accumulation (species assemblages and their spatial distributions) and ecosystem services (services to human societies). The focus of SCPs has recently changed from using biodiversity measures such as species richness, endemism, threat status and representativeness to incorporating progressively more complex issues such as conservation costs, protected area connectivity, functional and phylogenetic diversity and ecosystem services. The academic literature tends to use complex and advanced prioritisation methods but there is no single silver bullet to achieve this. At the same time there is also an increasing trend for private engagement in conservation action, willingness-to-pay as well as citizen science. This constituency prefers simple and understandable prioritisation schemes rather than ´black box´ modelling. With this in mind, we use a simple index, the Lemuindex, to prioritise ecosystem services and evolutionary history and their future on a global scale. The index equilibrates anthropocentric and ecocentric approaches and aims to balance academic rigour and complexity with user-oriented simplicity. It augments other, equally valid prioritisation approaches. This index uses the latest data maps available on ecosystem services (currently carbon sequestering, water balance, outdoor recreation and soil retention) and biodiversity (currently richness in total species, endemics, richness-adjusted endemism, threatened species, Alliance for Zero Extinction, AZE, and Evolutionarily Distinct and Globally Endangered, EDGE, species, and WWF´s Global 200 and Conservation International´s Hotspots) corrected by human footprint, and is flexible by adding new relevant data layers as they become available. **Keywords:** Conservation, prioritisation, ecosystem services, biodiversity, conservation management

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Which Is the Role of Spatial Landscape Literacy in Public Participation Processes and Opinions on Environmental Issues and Ecosystem Services?

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Introduction: Participatory environmental management, GIS and Public Participatory GIS (PPGIS) studies have assessed the dynamic among landscapes, their processes and ecosystem services, as well as society's needs, perceptions, and values towards these. Key to these assessments is the use and application of spatially explicit information, primarily maps, and in-person participatory processes with stakeholders to locate, identify, capture and understand people's knowledge of landscapes. However, little is known about how spatial literacy influences mapping and the decision-making related to environmental management and ecosystem services. Further, very little is known about the spatial and cognitive abilities of participants of middle- and low-income countries. **Objectives:** Our study aim is to evaluate the role of spatial landscape literacy in participatory environmental management and ecosystem service assessment processes as well as survey instruments based on maps and digital geographical representations. We used peri-urban Bogotá landscapes as a case study. **Methods:** Spatial landscape literacy (SL) was evaluated by testing stakeholder's ability to locate specific landscapes and landmarks. We then assessed if opinions on environmental decisions and ecosystem services were significantly related to SL. We used an online instrument to capture 2,397 respondent's socio-economic characteristics, SL, ecosystem service perceptions, and opinions concerning relevant local environmental issues.

We evaluated and measured respondents' self-perceived SL and ability to locate four landscapes in an integrated online map. Positional accuracy was calculated using a Spatial Landscape Literacy Index (SLI). We then tested for effects of socio-demographics on SLI, modelled the relationship between socio-demographics and SL, and tested the relationship between respondents' SL and their opinions on relevant environmental issues and ecosystem services. **Results:** We found that about 75% of the respondents correctly located only 2 of the 4 landscapes. The SLI model was also poorly predicted by socio-demographic variables. However, we found significant relationships between SLI and opinions concerning the environment. No relationship was found between respondents' levels of active participation in local governance and SLI. Overall, SL was little affected by education levels. **Implications:** Participatory processes using maps should ideally measure SL, and not assume a priori that participants are spatially literate. Further research is needed to evaluate how spatial technologies and understanding stakeholder's values towards the environment can democratize participatory-based decision-making. **Keywords:** PPGIS, landscape planning, environmental management, spatial literacy

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Defaunation/Refaunation I

Direct and Cascading Effects of Forest Loss on Tropical Arboreal Mammals and Vegetation Structure

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Introduction: Landscape-scale deforestation poses a major threat to global biodiversity, not only because it causes habitat loss, but also because it can drive the degradation of the remaining habitat. However, the multiple pathways in which deforestation directly and indirectly affects wildlife remains poorly understood, especially for elusive forest-dependent species such as arboreal mammals. **Objectives:** To assess the direct and indirect effects of deforestation on arboreal mammal communities through its changes in vegetation structure. **Methods:** Using structural equation models, we assessed the direct and indirect effects of landscape forest loss on arboreal mammal assemblages in the Lacandona rainforest, Mexico. We placed camera traps in 100 canopy trees (7,387 camera trap days) and assessed the direct effect of forest cover in the landscape and its indirect effects via tree basal area and canopy cover on the abundance and diversity (i.e. species richness and exponential of Shannon entropy) of arboreal mammals. **Results and Implications:** We found that forest loss had negative indirect effects on mammal richness through the decrease of canopy cover. This suggests that a reduction in resource availability and/or canopy connectivity in more deforested landscapes may be causing population declines of arboreal mammals. Canopy cover also increases in old-growth forests, where tree basal area typically increases. Therefore, the fact that, independently of forest loss, tree basal area was positively related to arboreal mammal abundance and richness, suggests that arboreal mammals generally prefer old-growth vegetation. However, unexpectedly, forest loss was directly and positively (not negatively) related to the abundance and richness of mammals, probably due to a crowding effect – a reasonable possibility given the relatively short history (~40 years) of deforestation in the study region. Conversely, the Shannon diversity was not affected by the predictors we evaluated, suggesting that rare mammals (not the common species) are the ones most affected by these changes. **Conclusions:** Our results emphasize that conservation measures ought to focus on increasing forest cover in the landscape, preventing the loss of large trees in forest remnants, and designing and implementing recovery plans for rare arboreal mammals. **Keywords:** Anthropogenic landscapes, endangered species, habitat amount, landscape structure, primates, management

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Megafauna Extinctions Produce Idiosyncratic Assemblages in Southeast Asia

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The "trophic downgrading of planet earth" refers to the disproportionate decline of the world's largest terrestrial vertebrates with reverberating consequences that degrade ecosystem processes. Megafauna are disproportionally threatened by habitat loss and poaching and nowhere is this issue more pronounced than in Southeast Asian tropical forests, which retains high megafaunal diversity yet suffers from extreme deforestation and poaching. However, our understanding of why megafauna extinction risk varies through time and the importance of site- or species-specific factors remains unclear. In this presentation, I describe unexpected variability in remaining megafauna assemblages across 10 Southeast Asian tropical forests by determining local extinctions that occurred during the Holocene and Anthropocene epochs and I predict future extirpations by assessing abundance trends using data from 21 camera trapping surveys. Consistent with global trends, every landscape experienced Holocene and/or Anthropocene megafauna extirpations and the four most disturbed landscapes experienced

2.5 times more extirpations than the six least disturbed landscapes. However, there was no consistent size- or guild- related trends, no two tropical forests possessed identical assemblages, and the abundance of four species showed positive relationships with forest degradation or humans. Given the profound habitat changes that occurred in Southeast Asia prior to the Holocene epoch, remaining megafauna species may have passed through an extinction filter and are more disturbance-resistant than previously appreciated, potentially explaining how some megafauna can persist in disturbed tropical forests near settlements. In this presentation, I suggest the region's megafauna assemblages are the product of a convoluted geo-climatic legacy interacting with modern disturbances, though the complex synergy between multiple threats and the unique responses of each species appear to be eroding megafaunal assemblages in ways unique to each landscape. Taken together, Southeast Asia's Anthropocene megafauna assemblages appear more idiosyncratic than previously appreciated and do not clearly reflect globally emergent trends in trophic downgrading. **Keywords:** Holocene, Anthropocene, local-extinctions, camera-trapping, megafauna, abundance, macroecology, community-ecology, poaching, deforestation

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Long-term Declines in Bird Populations in Tropical Agricultural Countryside

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Tropical agriculture is a major driver of biodiversity loss, yet it can provide conservation opportunities, especially where protected areas are inadequate. To investigate the long-term biodiversity capacity of agricultural countryside, we quantified bird population trends in Costa Rica by mist netting 57,255 birds of 265 species between 1999 and 2010 in sun coffee plantations, riparian corridors, secondary forests, forest fragments and primary forest reserves. More bird populations (69) were declining as were stable (39) or increasing (4). Declines were common in resident, insectivorous, and more specialized species. There was no relationship between the species richness of a habitat and its conservation value. High-value Forest bird communities were characterized by their distinct species composition, and habitat and dietary functional signatures. While 49% of bird species preferred forest to coffee, 39% preferred coffee to forest and 12% used both habitats, indicating that coffee plantations have some conservation value. Coffee plantations, although lacking most of the forest specialists, hosted 185 bird species, had the highest capture rates, and supported increasing numbers of some forest species. Coffee plantations with higher tree cover (7% vs 13%) had more species with increasing capture rates, twice as many forest specialists and half as many non-forest species. Costa Rican countryside habitats, especially those with greater tree cover, host many bird species and are critical for connecting bird populations in forest remnants. Diversified agricultural landscapes can enhance the biodiversity capacity of tropical countryside, but for the long-term persistence of all forest bird species, large (>1000 ha) protected areas are essential. **Keywords:** Avian ecology, ecosystem services, global change, ornithology, tropical biology, extinctions

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The Timing and Ecological Consequences of Pleistocene Megafauna Collapse in the Eastern Andes of Colombia

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The timing and consequences of the functional extinction of Ice Age megafauna remain debated and geographically concentrated across the continents. However, these answers remain unknown within Colombia, tropical Andean country known for its great diversity of environmental niches. We present a multi-proxy palaeoecological record from the peatland Monquentiva, Colombia, to determine the timing of collapse and its ecological consequences. We quantify *Sporormiella*, alongside all identifiable coprophilous (dung) and semi-coprophilous fungi spores, to reconstruct megafaunal abundance across the Late Pleistocene and into the Holocene (spanning ca. 30,000 – 6,500 yr BP). Fossilised pollen and charcoal data are used to examine the possible consequences of extinction within the high Andes during a period of major climatic oscillations and human expansion. Enhanced by the incorporation of additional fungal spores (including *Arnium imitans* and *Sordaria*), the record of Monquentiva showed an absence of *Sporormiella* and all other key (coprophilous/semi-coprophilous) spores from ca. 22,900 yr BP. We infer the first of a multi-phasic decline in megafaunal populations occurring at 22,900 yr BP, with the local functional extinction of most species occurring ca. 11,600 yr BP. Additionally, a regime shifts analyses on the spore records showed that Monquentiva experienced key spore reorganisations that tracked megafaunal declines. These declines corresponded with warm, wet interstadials in the Colombian

Andes and observed some of the ecological consequences attributed to megafaunal extinction. In terms of ecological consequences, Monquentiva showed a fall in the abundance of some animal pollinated (zoophilous) flora during the first megafaunal absence. Also, the functional extinction of megafauna coincided with a novel plant community, increases in palatable and woody flora and fire activity. Our data revealed that a synergy between climatic oscillations and Monquentiva's megafaunal population collapse triggered ecological repercussions surrounding the site. As modern ecosystems are facing extinctions and climate change, these are valuable lessons that can be used to help understand ecological dynamics and inform conservation today. **Keywords:** Megafauna, functional extinction, Sporormiella, Coprophilous fungal spores, palaeoecology, pollen, charcoal

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Defaunation/Refaunation II

The Indirect Effects of Mammal Defaunation on Bird Communities and Ecosystem Functioning

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Introduction: Defaunation (the population decline or extinction of wildlife) is a global conservation concern that disproportionately affects large-bodied animals, particularly mammals. At least 60% of the world's 74 largest mammalian herbivores and 31 largest carnivores are threatened with extinction. Due to their prominent role in the provisioning of many ecological processes, the loss of these species can directly disrupt ecosystem functioning. However, their central position in many interaction networks means that their decline can also have cascading impacts on other taxa, such as birds, with further indirect consequences for ecosystems. Describing the relationship between the restructuring of bird communities and changes in mammal abundance is key for understanding the secondary outcomes of defaunation and for preserving ecological functions. **Objectives:** Using a meta-analysis, we aim to identify which groups of birds are most impacted by changes in mammal abundance and in which ecosystems those effects are most prominent. Additionally, using differences in the responses of separate avian guilds, we aim to examine which ecological processes are likely to be influenced by the secondary effects of mammal loss. **Methods:** We conducted a literature review selecting studies which compared species-specific bird abundances between control (non-defaunated) areas and those impacted by defaunation. Using Hedge's g effect sizes, we contrasted the responses of different species of bird across multiple ecosystems and conditions of mammal loss. We then constructed an optimized inverse variance-weighted mixed effects meta-regression to tease apart the parameters which best explain patterns of avian response across all studies. **Results:** Our search yielded 36 publications comparing the response of 732 different populations of birds to changes in mammal abundance. From the optimized meta-regression, we identified three major determinants of these responses: avian diet guild, the biome of study, and the median body mass of the mammal removed as a treatment. Across publications, avian granivores were nearly three times more negatively affected by mammal loss than other birds while frugivorous and nectivorous species were positively affected. Mean avian responses were also more pronounced in tropical ecosystems and when intermediate-sized mammals were removed. **Implications**: Here we describe the nuanced, cascading effects of mammalian defaunation on bird communities, with distinct winners and losers. The heightened responses of granivores and frugivores may indicate the disruption of avian seed dispersal and seed predation networks. We posit that the ongoing collapse of the world's mammals could trigger considerable secondary impacts on bird communities and alter ecosystem processes around the world. **Keywords:** Defaunation, bird communities, mammals, ecosystem function, meta-analysis

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Recolonization of Secondary Forests by Locally Extinct Fauna through the Lens of Range Expansion

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Introduction / Background / Justification: While deforestation is ongoing, forest recovery is becoming increasingly common, particularly in the tropics where animal species richness can recover in < 40 years. The eco-evolutionary mechanisms at the population level driving this re-colonization process are mostly unknown in part due to a lack of a refined theoretical framework. To fill this gap, we describe four hypotheses of forest re-colonization stemming from range expansion theory. **Objective(s)/Hypothesis(es):** We hypothesize that animal populations re-colonizing secondary forests (1) will be composed of more dispersive individuals

with physical characteristics that reflect this trait, (2) will experience higher population growth rates due to less density regulation, (3) will experience escape and release from co-evolved natural enemies, and (4) have lower genetic diversity and distinct allele frequencies, when compared to the core population in old-growth forests. **Methods:** Here we discuss a framework, rooted in range expansion theory, to better understand the recolonization of secondary forests by locally extinct fauna. **Results:** While we can expect similarities between the mechanisms driving invasions and secondary habitat re-colonization at a population level, sharp contrasts between these expansion processes are also likely. Re-colonizers arrive from nearby source forests while invasive species arrival is often related to human activities. Connectivity to old-growth forests can potentially, over time, synchronize population dynamics and facilitate a bridge of gene flow, increase genetic diversity, and improve adaptability to the novel conditions in secondary forests. Therefore, we also describe alternative scenarios that may result due to this set of unique circumstances. **Implications/Conclusions:** If animal populations re-colonizing secondary forests follow the general predictions from range expansion theory, it provides evidence to support the generality and robustness of the theory. If not, it suggests the need to modify and recast the theory to better predict other types of expansions. **Keywords:** Recolonization, secondary forest, range expansion, dispersal, parasitism, genomic diversity

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Turnover-driven Loss of Forest-dependent Species Changes Avian Species Richness, Functional Diversity, and Community Composition in Andean Forest Fragments

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Andean forests, a hotspot of biodiversity, have suffered extensive fragmentation, yet we have little understanding of how this process has affected biodiversity. We surveyed bird communities across a gradient of fragment sizes (10–170 ha) and a continuous forest reference site in the Colombian Western Andes. Using a multi-species occupancy model to combine survey data from audio-visual transect surveys, mist netting, and playbacks for owls, we estimated alpha and beta taxonomic and functional diversity. We asked whether (1) habitat amount (patch size), edge effects, or selective logging affect bird occupancy and drive changes to diversity, (2) functional and taxonomic diversity respond similarly to fragmentation, and (3) compositional changes result from species turnover or nested species loss. Species richness declined with decreasing habitat amount, increasing edge density, and increasing disturbance through selective logging. These effects were driven by the loss of forest-dependent species, which were also area sensitive: 30 such species were absent from fragments, even the largest ones (>150 ha). Area-sensitive species were also edge sensitive and increased in occupancy in unlogged forest. We further found high beta diversity (0.78) driven by species turnover (85% of dissimilarity) along the gradient. Despite extensive turnover to non-forest species within functional groups, functional trait richness and dispersion significantly declined with habitat amount. Small fragments may mimic the structure and composition of early-successional Andean forests, driving spatial turnover patterns favoring disturbance-adapted species at the expense of primary-forest specialists. Large forest reserves are therefore required to conserve forest-dependent Andean birds. **Keywords:** Forest fragmentation, Functional diversity, Selective logging, area sensitivity, multi-species, occupancy model, nestedness

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Recovery of Vertebrate Diversity during Secondary Forest Succession in the Tropics: A Meta-analysis

Orlando Acevedo-Charry

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Tropical vegetation recovers after agricultural abandonment during secondary forests succession. The change in forest structure and increase of canopy height during natural regeneration creates new conditions that could facilitate animal recovery. Faunal diversity provides ecosystem functioning during this process of population disequilibrium. Still, less is known about the variation of diversity patterns among and within different faunal groups during natural regeneration, and the potential influence of local, landscape or biogeographic covariables to that recovery. I synthesized the scientific literature to describe overall patterns of vertebrate (amphibian, reptile, bird, and mammal diversity) recovery and explored potential variables explaining these dynamics during secondary forest recovery in the tropics. I predicted a general pattern of recovery toward mature forests in secondary forests stages, with greater difference in diversity metrics at the beginning of natural succession, as well as high correlation of the response variables with different covariables for each taxonomic group. I

conducted a meta-analysis to synthesize vertebrate's recovery patterns in tropical secondary forests during natural regeneration. My effect size was a response ratio of mean diversity values for treatment (early succession, young secondary, mid-successional, and old secondary forests) and control (old or mature tropical forest). Species richness for the four groups reached levels of the reference forests during the 15-30 years of recovery of secondary forests (mid-successional secondary forest stage), but species compositional similarity takes longer (over 65 years). Virtually all diversity metrics increased with successional stage for the four vertebrate groups, but the influence of other covariates explained also the variation. For example, with an increase in forest patches surrounding the secondary forests stages, the amount of habitat increases in the landscape and species composition similarity of amphibians, reptiles, and mammals increase, amphibian and reptile species compositional similarity recovered rapidly on islands and slowly on continents, mammal species richness and compositional similarity recovered faster in regions of low rainfall, but bird species richness recovered faster on sites with greater rainfall. Although secondary forest provide habitat for many animals, the few sites with old-secondary forests (27-65 years after abandonment) reflect the challenge of persistence of secondary forests in the tropics, thus, the faunal recovery will depend on conservation of mature or old growth forest as source for secondary forests species. I identified general patterns for faunal recovery in four taxonomic groups with this meta-analysis, but further studies should work on the underlying mechanisms within these patterns at the population level. **Keywords:** Biodiversity recovery, natural regeneration, tropical secondary forest, terrestrial vertebrates

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Evolutionary Consequences of a Caribbean Anole Recolonizing Secondary Forest

Carly Fankhauser[1], Miguel Acevedo[1]

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Introduction: Over half of tropical forests worldwide are regenerated forests which, over time, undergo secondary succession and can eventually provide suitable habitat for recolonization by locally extinct fauna. Although the community-level patterns of tropical secondary forest recolonization are well-documented, less is known about the evolutionary processes that underlie them. What understanding we have stems from range expansion theory and its fundamental prediction that a genetic bottleneck will occur in the expanding population due to the small number of founding individuals. Generally, however, support for this theory is from studies of biological invasions or the novel range expansion of a native species—these evolutionary processes may be significantly different during recolonization due to, for example, the proximity of the source population, or a shared evolutionary history with secondary habitat. **Objectives/Hypotheses:** To advance our understanding of the evolutionary processes involved in tropical secondary forest recolonization, we pose two questions grounded in range expansion theory: 1) do recolonized populations have lower genetic diversity and high genetic variation relative to the source population? and 2) is there evidence of different selection pressures in recolonized populations compared to the source population? **Methods:** To answer these questions, we are conducting a comparative genetic study between populations of *Anolis gundlachi*, an endemic shade-specialist lizard that is recolonizing tropical wet forest in Puerto Rico, in forest succession chronosequences. **Preliminary Results:** Using SNP data from across the genome, the preliminary results of our genetic clustering analysis have shown no clear evidence of genetic structure, contrary to what is predicted by range expansion theory. **Conclusion** This suggests high connectivity to nearby remnants of old forest that provide a constant source of individuals to recolonizing populations. **Keywords:** Population genetics, evolution, Caribbean, range expansion

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Non-native Mammals Are Poor Surrogates for Extinct Native Frugivores

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Introduction: Although prominent examples exist of non-native species causing substantial ecological harm, many have neutral or positive effects on native biodiversity. Rats (*Rattus* spp.) and feral pigs (*Sus scrofa*) are common invasive species on many oceanic islands, causing harm to native species, usually through direct predation. However, both are omnivorous and highly adaptive, and have been known to play some beneficial roles in some systems through mutualisms with native species. **Objective**: We tested the roles of these two non-native mammals as seed dispersers or seed predators on the island of Guam, which, due to invasive brown treesnakes (*Boiga irregularis*), is devoid of native seed dispersers – birds and bats. **Methods**: We conducted feeding trials with captive rats and pigs, first to examine whether and how they interacted with fruits of native and non-native fleshy-fruited species, and then to compare how these gut-passed or handled seeds germinated compared to seeds left in whole fruit or mechanically-handled seeds. **Results**: Whether rats and pigs would have negative interactions with a fruit (by ignoring or destroying seeds) or positive interactions (by spitting out or passing intact seeds through their gut) depended on fruit species. Rats and pigs interacted with most of the fruits and seeds (>80%) that they were fed. Of those, most were destroyed – 78% for rats and 90% for pigs. Compared to seeds germinating within whole fruits, rats improved germination of the seeds that they handled without ingesting, while pigs actually diminished the germination of seeds that they handled. The small percentage of seeds (approximately 1.5% for rats and 5% for pigs) that survived gut-passage germinated in higher proportions than those in whole fruits. Implications: Our results suggest that these normally harmful invasive mammals have mixed effects, but are not commensurate surrogates for native frugivores. **Keywords:** Pigs, rats, invasive species, seed dispersal, frugivory, islands

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Impacts of Lemur Extinction: the Loss of Large-bodied Generalist Lemurs Threatens Plant Communities

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The interactions between plants and animals, such as plant-seed disperser mutualisms, are essential for the functioning of ecosystems. Such interactions are unfortunately at risk, as animal partners face extinction. Using a dataset encompassing plant-lemur interactions across Madagascar we examined first the structure of these interactions and then how they may change when lemur species are lost. We examined the structure of the interaction network, in terms of nestedness and modularity. We tested for significant pattterns in lemur diets, examining interactions with plants of varying native status, use of multiple plant parts (leaves and fruits) from a given species, and the phylogenetic relationship of the plants included in lemur diest. We also studied if lemur diet preference (diet breath, diversity of leaves, diversity of fruits) is phylogenetically conserved, and if closely related lemurs interact with similar sets of plants. We then studied how the extinction of critically endangered lemurs can alter this structure, impacting the survival of the plants that depend on them. We also tested the robustness of the interaction network to the loss of species varying in their endangered status, degree of specialization, and body size. We found a structure indicative of coevolution, highlighting the importance of evolutionary history and the risks associated with loosing co-evolved partners. We found that loosing critically endangered species left 164 plant species without frugivore partners. This increased the nestedness of the network and rearranged the composition of its modules. The interaction network was not sensitive to the loss of critically endangered species. Instead, the network was least robust to the loss of large-bodied, generalists lemurs. These results suggest the importance of the structure of plant-animal interactions for informing our understating of conservation priorities. **Keywords:** Extinction, lemurs, network, frugivory, nestedness, modularity, species interactions, tropical forests

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Megafaunal Herbivory Reversibly Reduces Tree Alpha Diversity

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Members of our group have been investigating the impacts of rainforest megafauna in Gabon and Peninsular Malaysia since 2009. Here we offer a synthesis of results. In both regions we employed stratified sampling to evaluate the plant communities from seedlings to trees in forests that were faunally intact vs. partially defaunated (lacking elephants and other large herbivores). In both African and Asian forests, megafauna reduce the density of saplings, alter the size distribution of stems, and lower Fisher's alpha. This much we were able to deduce from plant sampling and analyzing the scars resulting from stem breaks. Scars tell us which stems survived foraging breaks but leave us ignorant of stems that died. We have recently surmounted this limitation of stem break analysis with new data that provide insights into foraging selectivity and differential mortality of foraged stems. African forest elephants are true browsers whereas Asian elephants are grazers that somewhat anomalously occupy closed-canopy rainforests. African forest elephants forage heavily on dicot

saplings, whereas Asian elephants strongly select monocots (grass, bamboo, pandans and, especially, palms). Selective foraging and differential mortality of plant species resulting from megafaunal foraging sharply reduce alpha diversity at small spatial scales but apparently not at the scale of 50-hectare plots. The main effect is to reduce the frequency of favored species and enhance the frequency of disfavored species. That these effects operate mainly at small spatial scales is indicated by evidence of stem density and diversity recovery (bounce-back) in partly defaunated forests in both Gabon and Malaysia. The bottom line: megafaunal foraging alters forest structure in major ways and massively skews species-abundance relationships at small (1-ha) scales while appearing not to reduce plant diversity at the landscape scale.

Eco-physiology I

Drought Mortality Is Determined by Topography and Embolism Vulnerability of Tropical Trees

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Climate change leads to a global increase in tree drought mortality, affecting the structure and composition of forests across the globe. A better understanding of tree hydraulic traits is necessary to determine the underlying mechanisms of tree mortality. Hydraulically sensitive plants may not be vulnerable to droughts if associated to environments that are buffered from droughts. It is well known that changes in precipitation affect tree mortality risk, but how local hydrological environments within the same macroclimate modulate tree responses according to their hydraulic traits is yet unknown. This study evaluates how, within the same macroclimate, tree mortality rates vary across local topo-hydrological environments (deep water tables on plateaus versus shallow water tables in valleys) according to the hydraulic features of the species. We postulate that the interplay between local hydrological environments and tree hydraulic traits controls drought-induced tree mortality. We measured eight hydraulic traits of small individuals (<10cm DBH) of 28 tree species associated with either valleys (shallow water tables) or plateaus (deep water tables), over 72 1-ha permanent plots in the Central Amazon, and linked these traits to species-specific mortality rates. Vulnerability to xylem embolism (P50) and xylem vessel grouping increased drought related tree mortality, but only on dry plateaus. A higher vessel grouping index and a greater length of contact between the walls of the shared vessels were related to a lower resistance to embolism, which favors the "rare-pit" hypothesis, the high connectivity between the grouped vessels generates less resistance to the propagation of cavitation. Local environments with lower water availability act as survival filters for juvenile trees during droughts, given their limited access to more stable and deeper water sources. At the same time, wet valleys act as hydrological refugia under atmospheric drought conditions, irrespective of plant hydraulic traits. We conclude that accounting for local hydrological environments within the same macroclimatic conditions, together with hydraulic traits, is critical for assessing the future of forests under climate change. **Keywords:** Amazonian Forest, drought, embolism vulnerability, topography, hydraulics traits, tree mortality

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Good Days, Bad Days: Weather as a Driver of Bryophyte Carbon-exchange Dynamics in Tropical Rainforest Canopies

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Introduction: Tropical Forest canopies harbour incredible biodiversity. While tree crowns provide rich resources to insects and other animals, they represent a physiologically stressful environment for plants. In spite of this, many plant groups have developed the ability to live epiphytically on rainforest trees, obtaining water and nutrients from atmospheric sources or from other canopy organisms. While vascular epiphytes abound in most tropical wet forests, bryophytes (mosses and liverworts) rarely develop much biomass in lowland forests, though species diversity can still be high there. This is in stark contrast with the luxurious development of bryophytes in tropical montane cloud forests. **Hypothesis:** A hypothesized reason is the unfavorable timing of photosynthetic and respiratory activity (which are possible only when the bryophytes are hydrated) on many days in tropical lowland areas. We tested and elaborated on this hypothesis by modeling how bryophyte diel carbon balances are affected by different weather patterns in a tropical lowland rainforest. Thereby, we distinguished bryophytes of

various life forms, differing in their desiccation speeds and physiological responses to environmental conditions. **Methods:** We applied a model of bryophyte carbon exchange based on empirically-determined physiological responses projected on time courses of canopy climate, using data collected in the lowland forest surrounding the Yasuní Scientific Station in the Ecuadorian Amazon. We fed the model with life-form-specific parameters and with high-resolution canopy climate data to simulate bryophyte water-content and carbon-exchange dynamics at a temporal resolution of 10 minutes for nearly 300 days. **Results:** Our model simulations indicated strong differences in the diel carbon balances depending on weather conditions, with quantitative but no qualitative differences between life forms. For example, dry conditions without nightly remoistening resulted in carbon balances near zero due to inactivity, balances near zero were also observed under some moist conditions, but there it was due to a balancing of daytime gains and nightly losses. The effect of precipitation depended on its timing, with morning wetting favoring carbon gain but afternoon rains causing nightly carbon release and thereby lowering diel balances. **Implications:** Quantifying the importance of weather patterns for obtaining long-term carbon gains, i.e. for allowing the build-up of biomass, in tropical rainforest bryophytes deepens our understanding of their functional role in these ecosystems. Additionally, the insights gained from our study are an important prerequisite for predicting impacts of climate change on the bryophyte communities in these tropical ecosystems and possible consequences for other co-occurring and interacting biota. **Keywords:** Canopy bryophytes, carbon balance, photosynthesis, poikilohydry, rain timing, respiration.

Stem Photosynthesis Is Common in Neotropical Trees and Lianas

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Background: Plants with photosynthetic stems are common in both temperate and tropical regions, particularly drylands. Stem photosynthesis improves plant carbon balance via net carbon fixation or reduced respiratory carbon loss, and is relatively water-use efficient. However, little work has been done to study the occurrence and advantages of photosynthetic stems in moist tropical forests. **Objective**: to test whether stem photosynthesis is widespread in tropical woody species. **Methods**: We measured leaf and stem CO_2 exchange, chlorophyll concentration, stomatal density, and area and biomass investment into leaves and stems in trees and lianas at two tropical forest sites in Panama. Measurements were performed on the top 50 cm of terminal branches. 51 species were studied. **Results:** All species showed either stem net photosynthesis or stem recycling photosynthesis, both of which contributed positively to the carbon economy of the plants. Chlorophyll concentration per unit area was higher in leaves than stems, but there was considerable overlap of values, consistent with a high capability of many stems to perform photosynthesis. Interestingly, lianas had greater stem CO_2 re-assimilation capacity than trees, although there was no difference in chlorophyll concentration. Investment in photosynthetic stem area compared to leaf area is greater in lianas than trees. **Conclusions**: Our results suggest that the contribution of stem photosynthesis to overall carbon gain is particularly important in lianas. Experiments are underway to determine the role of stem photosynthesis in liana and tree species exposed to water-deficit stress. **Keywords:** green stem, plant function, stem net photosynthesis, stem recycling photosynthesis

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Nutrient Use Efficiency Throughout a Canopy Light Gradient of a Terra Firme Forest in the Central Amazon

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Tropical forests are important components of the terrestrial carbon cycle due to their high stored biomass and relatively constant carbon dioxide (CO_2) uptake. Across its dense and continuous canopy, CO_2 assimilation rates of leaves follow the sharp decline of incident light along the vertical profile. In such a heterogeneous light environment the capacity of the photosynthetic machinery is determined by its efficiency to capture incident

light and the nutrients required for C assimilation. Hence a mechanistic understanding of the key parameters in the photosynthetic process can be used to predict how photosynthetic capacity is regulated per nutrient unit in leaves. We here investigate the effect of light on nutrient use efficiency (Vc_{max} / nutrient) based on measurements of photosynthetic capacity (V_{cmax}) and leaf nutrient concentrations, such as nitrogen (N), phosphorous (P), and potassium (K) obtained from leaves (n = 54) of eight trees along a vertical profile of a *terra firme* forest in central Amazon. We used the canopy gap fraction (cGF, %) as a proxy for incident light at the top surface of each leaf. V_{cmax} and cGF showed a positive relationship until cGF of 26% and showed no further relationship above this point. N and NUE had a positive relationship with cGF (*slope* = 3.09 and 75.2, respectively), but up to a certain point. At cGF of 60%, N started to decrease (*slope* = -3.79), and NUE changed the relationship direction at cGF of 25% (*slope* = -9.82). P showed a positive relationship with cGF (*slope* = 1.25) up to 38% before the relationship became negative (*slope* = -0.3602), while PUE increased up to 32% (*slope* = 53.83) when there was no more relationship between PUE and cGF. Although K and cGF showed a positive relationship (*slope* = 22.72) up to 24% before the relationship became negative (slope = -0.3602), KUE did not show any relationship with cGF increases (slope ˜ 1). Even though the light and nutrients profiles are commonly used to upscale leaf-to-canopy level carbon uptake, our results showed that the relationship between the nutrient efficiency was not constant with increases of cGP in the studied species. We conclude that future studies must consider the observed responses of photosynthetic capacity related to the actual light incidence, instead of using tree height or canopy level, when aiming to improve model representation of carbon uptake and leaf nutrient interactions in complex light environments, such as in tropical forests. **Keywords:** Plant ecophysiology, photosynthesis, nutrient use efficiency, nitrogen, phosphorus, Amazon Forest

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Eco-physiology II

Trait Coordination at Leaf Level Explains the Resistance to Excess Light Stress in Shade-tolerant Tropical Tree Species

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Plant functioning in response to the environment is an important issue for vegetation reassembly of degraded lands because both low and excessive sunlight influence the performance of young plants. Although tree responses to light conditions have been widely studied, results about the growth and survival of species with different shade tolerance are often contradictory, suggesting that shade-tolerant species are able to be established under full sunlight conditions. However, how shade-tolerant tree species deal with the excess of light energy remains unclear, due in part to the discrete classifications of shade tolerance and differences in the time duration of the studies. From a quantitative classification of shade tolerance of 12 tropical tree species planted in the field under contrasting light conditions, we hypothesized that shade-tolerant species are capable of effective long-term acclimation to high light conditions. Plant size and survival of species were measured at the beginning and 38 months after planting. We also measured functional traits associated with carbon economy and non-photochemical energy dissipation. Under the high-light condition, more light-demanding species showed higher growth rates associated with higher values of functional traits that improve the CO_2 assimilation capacity. In contrast, more shade-tolerant species showed higher survival which was associated with higher values of non-photochemical quenching (qN), leaf K contents, and leaf thickness (Lt). The concomitant increase in these traits, as well as, their greater plasticity to light in the intrinsic water use efficiency (WUEi), quantum efficiency of photosystem II ($F_v/F_{m)}$ and qN, confer to these species strong photoprotection to avoid high-light stress and to persist under open field conditions. The results challenge the common assumption that only fast-growing and light-demanding tree species are suitable for vegetation reassembly in full sunlight conditions and improving the environmental conditions for other species. **Keywords:** Shade tolerance, functional traits, photosynthesis, acclimation, stress resistance

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Temporal Changes in Tree Physiology, Functioning and Growth in Two Neotropical Genera along a Seasonally Dry Tropical Forest Gradient

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Seasonally dry tropical forests (SDTF) provide key ecosystem services in tropical regions, being an important global climatic regulator and a main driver of dynamics of the global carbon sink. These forests are predicted to suffer productivity reductions due to climate change which could affect their functioning and ecosystem services. Yet, how trees in SDTFs respond to the long-term atmospheric and climatic changes is poorly understood. Here we assessed changes in the physiology, (wood) functional traits and growth rates of SDTF trees as responses to environmental changes over the last ˜45 years. We measured tree rings, stable isotopes and wood functional traits of two common Neotropical genera (*Aspidosperma* and *Handroanthus*) occurring along a gradient of distinct SDTFs (rain forest - savanna - dry forest). We quantified changes in intrinsic water-use efficiency (iWUE) due to increasing atmospheric $[CO_2]$ using stable ^{13}C isotopes. We then evaluated whether iWUE changes affected tree growth, wood density, wood anatomical and chemical traits, what climatic factors drive these changes (precipitation, temperature, El Niño Southern Oscillation), and whether responses differ between distinct SDTF types. iWUE increased over time in all sites, regardless of forest type. This increase was positively correlated to maximum temperature and El Niño indices for the savanna and dry forest sites.

Contrary to our expectations, iWUE increases did not promote SDTF tree growth nor changes in wood density or in anatomical and chemical properties. Trends were found for some species, but patterns did not converge among species. Our results suggest that environmental changes are driving changes in the physiology of SDTF trees, but that these physiological changes do not necessarily lead to changes in the hydraulic architecture of these trees, their chemical balance or their growth rates and above-ground biomass acquisition. Differential responses between species also indicate different strategies of trees to withstand water stress in SDTFs. The lack of concomitant growth responses with the improved water-use efficiency suggest carbon gains due to CO_2-fertilization are not directed to stem growth, with trees possibly allocating this carbon surplus to roots or leaves. These findings increase our understanding of the impact of water-use efficiency changes on the productivity of SDTF trees and can help in improving predictions of the vulnerability of these forests to climate change and their future carbon dynamics. **Keywords:** Climate change, dendrochronology, Caatinga, Cerrado, carbon isotopes, xylem anatomy

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Temperature Increases May Constrain Photosynthesis and Growth of Dominant Amazonian Tree Species

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Introduction: The temperature sensitivity of physiological processes and growth of tropical trees remains a key uncertainty in predicting how Amazon forests will adjust to future climates. As temperature increases tend to be paired with droughts, it is important to understand how the sensitivity of photosynthesis to temperature and the vulnerability of the xylem to embolism interact in determining growth, and ultimately understand those effects over species abundances, thus improving predictions of ecosystem composition and function changes under climate change. **Hypothesis:** The higher optimal temperature for carboxylation associated with lower resistance to embolism implies high growth and abundance in tropical species. **Methods:** We investigate how in situ growth performance of rare and dominant species is linked to physiological traits associated with optimal temperature for photosynthesis in a primary forest in central amazon. We measured leaf CO2 assimilation responses to temperature variation by controlling leaf temperatures at 25, 30, 35, 40 and 45°C, and embolism resistance curves of 33 Amazonian species. **Results:** The optimum temperature for carboxylation of the studied species (37.6 to 44.1 °C) was considerably higher than the actual maximum environmental temperature (30 °C). However, the optimal temperature safety margin associated with the environmental temperature was species-dependent. The species that dominate the forest community were associated with higher assimilation rates but a more vulnerable hydraulic system in accordance with ecological succession theory. **Conclusions/Implications:** Species with higher assimilation capacity and highest optimal temperature safety margin were more abundant and had more vulnerable hydraulic systems. This implies that with increasing temperatures and more frequent droughts, growth rates in some tropical tree species might decrease because the ambient temperature will be above the optimal temperature for carbon fixation, specifically the dominant species. These findings advance our understanding of temperature effects over species composition and biodiversity changes and their implications on forest carbon dynamics. **Keywords:** Biochemistry, hydraulic traits, rare species, temperature sensitivity, climate change

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Rates of Environmental Change Influence the Capacity for Phenotypic and Molecular Adjustments in Tropical Ectotherms

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For ectotherms, environmental temperature (Ta) is the most important abiotic factor that affects their body temperature and a variety of organismal (e.g., fitness, physiology), ecological (distribution, interactions), and evolutionary (speciation) processes. In tropical regions, variation in daily and seasonal Ta is small compared to temperate regions. As a result, tropical ectotherms have evolved to maximize performance and fitness over a narrow range of Ta, living near their thermal physiological limits and optimal temperatures. Because of this, tropical ectotherms are particularly vulnerable to climate change since even small perturbations in Ta can lead to important deleterious effects. However, in some extreme tropical zones, natural selection has favoured the evolution of adaptive physiological responses that allow ectotherms to regulate thermal stress by entering into metabolic arrest. As part of this adaptive response, both cellular and physiological processes are actively suppressed. It is unclear however, whether this adaptive response is regulated by the capacity of tropical ectotherms to sense the magnitude and rate of *Ta*change. Tropical rocky shores offer a natural laboratory to explore this question. These are perhaps one of the most stressful and fluctuating habitatson Earth, characterised by a vertical thermal variability gradient with different rates of temperature change. This study focuses on the physiological and molecular mechanisms of thermoregulation (phenotypic plasticity) using the mussel *Mytiliseptavirgatus*as biological system. Here, I explored the extent to which varying warming rates affect physiological performance and gene expression during rapid heating and acclimation, and how this relationship may differ between populations from different thermal habitats. Using heat ramping experiments, I examined four physiological variables of interest: heart rate, osmolality, weight loss percentage and gene expression profiles. Faster rates significantly decreased weight loss and average thermal equilibrium but did not show changes in heart rate and osmolality. Higher protein-folding genes were upregulated at the expense of pro-survival pathways. Higher-shore populations displayed similar patterns at the fast rate with higher protein folding gene expression, faster signaling activation and transduction as well as stronger repair and immune ability against heat stress. As physiological indicators may not have the resolution to reflect minute changes in molecular machinery in response to thermal stress, an integrative approach that incorporates molecular techniques in physiological studies can provide important insights into the effect of warming rates and climate change on tropical ectotherms. **Keywords:** Thermal physiology, ectotherms, environmental stress, warming, heatwaves, gene expression, metabolism

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Ecosystem services/disservices

Quantifying Ecosystem Services and Disservices Derived from Biodiversity in Cacao Agroforestry: Socio-ecological Opportunities for Smallholder Farming

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Introduction: Animals provide crucial ecosystem services for cacao agroforests, including pest control and pollination, but also disservices that affect crop production. Yet, the combined contribution of different animal groups to cacao yield, and the trophic interactions that drive them, remain poorly understood. A joint evaluation of services and disservices can help accurately quantify biodiversity's contribution to cacao production, and identify the key management strategies to maximize benefits for smallholders. **Methods and research questions:** We used a full-factorial experiment to selectively exclude flying insects, birds, bats, ants and squirrels from native cacao trees in agroforestry systems from Peru. We quantified the contribution of each animal group to cacao fruit set and crop yield, and the overall monetary gains derived from such contributions. Moreover, we asked whether the control of arthropod populations explained benefits from birds and bats to cacao yield. To answer this question, we used artificial sentinel caterpillars to assess predation rates on arthropods, and monitored the abundance of multiple arthropod groups within our exclusion experiments. **Results:** Flying insects, as well as birds and bats contributed to a significant increase in cacao fruit set. Notably, cacao crop yield increased by 114% in the presence of birds and bats, which translates in a gain of ca. USD $522.94 ha^{-1}yr^{-1} for smallholders. However, these benefits were not linked to the control of arthropod populations. On the contrary, predation of arthropods decreased in the presence of birds and bats by ca 30%, pointing to a mesopredator release. Ants were generally associated with fruit loss, and only showed benefits for cacao yield in agroforests close to forest. Finally, we identified a large disservice from squirrels, which led to fruit losses, estimated at 30.1 kg ha^{-1} yr^{-1}. **Implications/Conclusions:** Our results show an unprecedentedly high contribution of birds and bats to cacao yield, but warn that these benefits may be undermined by disservices from other animals. Additional research is needed to understand the multitrophic interactions mediating ecosystem services by birds and bats in tropical agroforestry systems, and likely require species-specific understanding of trophic preferences. We discuss the relevance of our results for a socio-ecological management of cacao agroforestry systems, and for the understanding of ecological interactions affecting ecosystem service provision.
Keywords: Pest control, cacao yield, fruit loss, biodiversity-friendly, ecosystem services

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Water Related Ecosystem Services Modeling for Tropical Dry Forest in Colombia

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Dry tropical forest (DTF) is a critically endangered ecosystem in Colombia. Its remnants are immersed in antropic areas prone to transformation. Additionally, there is uncertainty on how ecosystem loss has affected its Ecosystem Services (ES), its interaction with human communities, and its impact on their livelihoods. Therefore, understanding DTF ES provision is important, to recommend achievable strategies of conservation that restore both DTF and its ES, while helping to increase the overall resilience of the community facing water scarcity. We focus our efforts to understand these questions: How do the remnants of DTF contribute to water provision and regulation?. Which factors could explain variability in water provision and regulation?

Consequently, we selected 6 different areas across Colombia with remnants of DTF. For land cover maps we mainly used the Structural Composition Index map. To ensure replicability and comparability we used the best public spatial information available. These data were used to model Annual Water Yield using the INVEST python package. Which we noticed has the best trade-off between complexity, interpretability, and easy acquisition of inputs. We hypothesize that water provision and regulation ES improves as forest coverage increases, however spatial heterogeneity can impact ES, especially considering that DTF remnants are small, and susceptible to transformation. We run different scenarios (considering average and dry years, and deforestation, actual coverage, and reforestation scenarios) to understand the ES dynamics. Then we performed several multivariate regression analyses, to evaluate ES provision and regulatory proxies. Using annual water provision for all scenarios, proportional forest area, difference of forest area between deforestation and reforestation, range of annual water provision and terrain slope. Results show us general trends indicating that DTF (even in its current reduced condition) is considerably adaptable to changes in dry and average years, providing significant ES locally. Water provision tends to increase in dry years, and its variability is reduced as the forest area increases, meaning the effects of DTF ES are more evident in dry years (when ES are crucial). Thus improving the overall local resilience. Also DTF behaves differently in Andean vs Caribbean regions, probably due to terrain slope, and harsher climate in Caribbean areas. Our results provide an easy and reliable methodology, replicable for different contexts, and a pathway to, in near real time, assess DTF ES and evaluate potential management strategies to restore them. Highlighting the importance of preserving current and reforesting DTF in key areas. **Keywords:** Dry tropical forest, ecosystem services, regulation, modeling water scarcity, INVEST

Ecosystem structure and function I

Seasonal Shifts in Isoprenoid Emission Compositions from Three Hyperdominant Tree Species in Central Amazonia

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Isoprenoids - isoprene (C_5H_8), monoterpenes ($C_{10}H_{16}$), and sesquiterpenes ($C_{15}H_{24}$) - are volatile organic compounds (VOCs) emitted to the atmosphere mostly by plants. They have diverse functional roles at multiple scales, from cellular protection and defense at the foliar level, through chemical signaling within and among plants, up to the regulation of large-scale biogeochemical processes, such as the effect on atmospheric chemical composition and contribution to aerosol formation. Amazon forests comprise the dominant source of isoprenoids to the global atmosphere, still, there is a poor understanding of how isoprenoid emission capacities vary in response to ecophysiological and environmental controls in Amazonian ecosystems. This study measured photosynthesis and isoprenoid emission capacities of three Amazonian hyperdominant tree species—*Protium hebetatum*, *Eschweilera grandiflora*, *Eschweilera coriacea* across seasons and along a topographic and edaphic environmental gradient in the Amazon Tall Tower Observatory (ATTO) in central Amazonia. Our observations showed that photosynthesis and isoprene emission capacities strongly declined from the wet to dry season, while emissions increased among the heavier isoprenoids—monoterpenes and sesquiterpenes. Plasticity across habitats was most evident in *P. hebetatum*, which emitted sesquiterpenes only in the dry season, at rates that significantly increased along the hydro-topographic gradient from white sands (shallow root water access) to upland (deep water table). We suggest that emission composition shifts are part of a plastic response to increasing abiotic stress (e.g., heat and drought) and reduced photosynthetic supply of substrates for isoprenoid synthesis. Our comprehensive measurements indicate that monoterpene and sesquiterpene emissions might be higher than anticipated and more emphasis should be placed on other isoprenoids besides isoprene in response to abiotic stresses. In forest-atmosphere interactions, shifting emission compositions may have synergetic importance in plant ecophysiological processes and the subsequent impact on the atmosphere. **Keywords:** plant secondary metabolism, isoprene, monoterpenes, sesquiterpenes, heat, tropical tree species

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It's Getting Hot: Termite Temperature Sensitivity Drives Global Wood Decay

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Background: Animals, such as termites, have largely been overlooked as global-scale drivers of biogeochemical cycles, despite site-specific findings. Woody species represent important carbon pools, storing ~457 Gt of carbon, perturbations to these pools can lead to increasing greenhouse gases emissions to the atmosphere with feedbacks to the earth system. Deadwood turnover is driven by multiple decay agents. Historically, studies focused on temperate systems, where microbes dominate decay. Microbial decay is sensitive to temperature, typically doubling per 10°C increase (decay effective Q10 = ~2). Termites are important decayers in tropical systems and differ from microbes in their population dynamics, dispersal, and substrate discovery, meaning their climate sensitivities also differ. Objectives: We set out to test the relative decay sensitivities of wood dwelling microbes and wood feeding termites to temperature and precipitation gradients around the globe. Methods: Using a network of 133 sites spanning 6 continents to test sensitivities, we conducted a replicated wood decomposition experiment that allowed microbial access (=microbes) to all samples and manipulated termite access (=microbes+termites). At each site, researchers placed ~40 blocks with 20 per treatment per harvest. In total, we monitored decay in 8,869 wood blocks of a common substrate, *Pinus radiata* (or in a few cases closely related *Pinus* species), wrapped in fine mesh with and without larger holes to allow or exclude termites for up to 48 months. Results: Temperature sensitivity of microbial decay was within previous estimates. Termite discovery and consumption were both much more sensitive to temperature (decay effective Q10 = 6.53), leading to striking differences in deadwood turnover in areas with and without termites. Microbial decay was weakly sensitive while termite decay was insensitive to precipitation. Surprisingly termite discovery was strongly sensitive to precipitation with interactions between temperature and precipitation, meaning the highest termite discovery was in dry tropical sites. Termite impacts were greatest in tropical seasonal forests and savannas and subtropical deserts. Implications: With tropicalization (i.e., warming shifts to a tropical climate), the termite contribution to global wood decay is predicted to increase by >14% as more of the earth's surface becomes accessible to termites. Termite activity is a newly recognized mechanism that may lead to much faster decomposition and less carbon storage in tropical forests as the globe warms. **Keywords:** termites, microbes, wood decay, carbon, temperature & precipitation sensitivities, tropicalization

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Quantifying Spatial and Temporal Variation in Canopy Tree Mortality and Branchfalls on Barro Colorado Island, Panama, Using Drone Photogrammetry

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Motivation: Tropical tree mortality and branchfall rates vary widely over time within sites in relation to temporal variation in climate and disturbance (e.g., storms and droughts), variation that is associated with climate cycles as well as long-term change. Tree mortality rates also vary strongly among sites, and serve as a major control over tropical forest carbon stocks globally. However, we still have a relatively poor understanding of the drivers of tree mortality and branchfall, because their rates are low, requiring frequent and large-scale observations to quantify variation, which is infeasible with labor-intensive traditional field methods. Objectives: Here, we aimed to quantify temporal and spatial variation in canopy tree mortality and branchfall at high resolution and over large scales, and evaluate their relationships with temporal climate variation and spatial variation in soils, topography, and forest age. **Methods:** We used five years of repeat drone photogrammetry to locate canopy disturbances and to quantify their monthly variation within a 50 ha plot and their spatial variation across all of Barro Colorado Island, Panama (1500 ha). Results: We found that on average 1.9% of the forest is affected by canopy disturbance every year, with high spatial and temporal variation in disturbance rates. Spatially, disturbances occurred more frequently in depressions and on steep slopes, in certain soil types, and in older forests. Further, disturbance rates predicted the proportion of low canopy area across the landscape, and mean canopy height in old growth forests. Temporally, disturbance rates were higher during months with more extreme precipitation events. Visual inspection of before and after drone imagery revealed that 23% of canopy disturbance (by area) is associated with branchfalls, while the other 77% is associated with tree mortality. Implications: Our results on spatial variation show that soils and topography drive variation in disturbance rates and thereby old growth forest structure at landscape scales. Our findings on the importance of large storms in explaining temporal variation in disturbance rates highlight the potential vulnerability of tropical forests to global climate change, which is increasing the frequency and magnitude of extreme storms. **Keywords:** tree mortality, canopy disturbance, drone, UAV, photogrammetry, landscape, climate variation

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Quantifying and Valuing the Contribution of Megaherbivores to Tropical Forest Carbon Cycling

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The pervasive ecological role of megaherbivores (body mass $>$ 1000 kg), including their effects on vegetation structure in relation to diet preferences, has been studied mostly in savanna ecosystems. To further our understanding of tropical megaherbivores, we investigate the ecosystemic role of African forest elephants in African rainforests where elephants can increase aboveground carbon, though the mechanisms are unclear. We combine unpublished data of forest elephant feeding with published browsing preferences totaling $>$ 120,000 records covering 700 plant species. To these data we add nutritional values of 102 species. We show that elephants increase carbon stocks through two different pathways: 1) promotion of high wood density tree species via browsing on leaves from low wood density species, which are more digestible, 2) dispersal of seeds of trees that are on average larger and have the higher wood density among tree guilds based on dispersal mode. We estimate that the loss of forest elephants could cause a 5-12% decline in carbon stocks due to regeneration failure of elephant-dispersed trees and an increase in abundance of low wood density trees, which remains to be quantified. Our results suggest that megaherbivores are important in maintaining diverse, high-carbon tropical forests. Conserving elephants will provide ecological and climate mitigation benefits at a scale of global relevance. **Keywords:** Megaherbivores, herbivory, carbon cycle, plant-animal interactions, megafauna, conservation

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Ecosystem structure and function II

Nutrient Limitation of Plant Reproduction in a Tropical Moist Forest

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Introduction: Nutrient addition experiments indicate that nitrogen and phosphorus directly limit plant processes in many tropical forests. However, the long-term consequences for forest structure and species composition remain unexplored. We are positioned to evaluate potential long-term consequences of nutrient addition in central Panama where we have maintained a factorial nitrogen–phosphorus-potassium fertilization experiment for 21 years and an independent study quantified the species-specific nutrient requirements of 550 local tree species. **Objectives/Hypotheses:** We evaluate direct and long-term consequences of nutrient addition in central Panama. Specifically, we ask whether nutrients limit plant reproduction at the species and community levels. We also ask whether species-specific reproductive responses to nutrient addition are stronger among species associated with naturally fertile soils, which could contribute to a shift in species composition. Because species adapted to fertile soils typically respond more to nutrient addition than species adapted to infertile soils, we predict that there will be a positive correlation between species-specific nutrient requirements and reproductive response sizes. Methods: This study takes place on the Gigante Peninsula in central Panama in an ongoing factorial nitrogen–phosphorus–potassium fertilization experiment. We quantified species-level reproductive responses for 38 focal species in the 21st year of the experiment and community-level reproductive litter production for the first 20 years. We use ordinal logistic regressions to evaluate nutrient addition effects on plant reproduction and to analyze the relationship between species-specific nutrient requirements and response sizes. To analyze reproductive litter, we used repeated measures ANOVA for both total reproductive litter as well as the proportion of reproductive litter to fine litter. **Results:** Species-level reproductive responses to nitrogen and potassium addition were weak, inconsistent across species, and insignificant across the 38 focal species. In contrast, species-level responses to phosphorus addition were consistently and significantly positive across the 38 focal species but were unrelated to species-specific phosphorus requirements documented independently for the same species. Community-level reproductive litter production was unaffected by nutrient addition, possibly because spatial and temporal variation is large. **Implications/Conclusions:** We conclude that phosphorus limits reproduction by trees in our experiment but find no evidence that reproductive responses to phosphorus addition favor species associated with naturally phosphorus-rich soils. Studies should continue to test for long-term responses to nutrient addition and attempt to evaluate limitation by nutrients other than nitrogen, phosphorus, and potassium. **Keywords:** Fertilization, nitrogen, nutrient limitation, phosphorus, plant reproduction, potassium, tropical forests

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The Influence of Basal Area and Wood Density in Carbon Estimations from Lidar

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Remote sensing technologies that measure the 3D structure of forests, including airborne and spaceborne lidar, provide novel insights into how forest carbon stores are responding to fires, selective logging, climate change and other degradation processes. Accurate estimation of above-ground biomass is essential for understanding changes in the carbon stored in tropical forests and the contribution of forest protection to climate change mitigation. Yet, there is inconsistency and inaccurate estimation of forest aboveground carbon (ACD) stocks in tropical regions, due to limited field data and different underlying assumptions in modelling and validation methods. Airborne Laser Scanning (ALS) provides an intermediate solution for ACD estimation between satellite data and forest inventories as it can deliver high-resolution 3D representations of forests over a much

larger area than forest inventory plots. Among different regression relationships to estimate carbon biomass from lidar, the most simple and widespread is based on the power-law relationship between top canopy height (TCH) and above-ground carbon density (ACD): $ACD = a \cdot TCH^b$, where model parameters a and b are not universal among forest types and require calibration with ground data. Further improvements in this model suggest coupling regionally fitted sub-models of Basal Area (BA) and Wood Density (WD) as variations in these can give different carbon density estimates for the same forest height measurements. Therefore, it is important to understand how BA and WD influence the ACD-TCH relationship. To answer these questions, roughly 500 forest inventories matching with ALS data across the Amazon basin were processed to fit power-law models of field-measured ACD and lidar TCH using Maximum Likelihood Estimation (MLE). Model combinations coupling BA and WD show that models perform better when both variables are present. Further sub-models of BA and WD as a function of TCH were fitted to test whether these can be predicted from lidar. Results show that despite the strong relationship between field-measured BA and lidar TCH, the slope of this relationship varies across locations, thus noting that local allometries play an important role in calibrating these models when predicting BA from lidar. On the other hand, lidar TCH fails to predict WD as there is no clear relationship. Nevertheless, there is a general tendency for these inventories to have higher WD in Eastern (and central) Amazonia compared to their western counterparts. These results resemble the general notion of the east-west gradient in the Amazon responding to edaphic and climatic conditions. **Keywords:** ALS, lidar, forests, carbon, biomass, allometry, wood density

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Biodiversity Controls Ecosystem Functioning and Associated Services in a Geomorphologic heterogeneous Tropical Forest in Southwestern Costa Rica

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Tropical forests harbor exceptionally high biodiversity and store large amounts of carbon (C) in vegetation biomass. However, regional variation in plant species composition and associated vegetation carbon stocks can be substantial, and may be related to local topoedaphic properties. Aboveground vegetation C storage typically differs between geographic forest regions in association with the locally dominant plant functional group. A better understanding of the factors controlling functional species diversity and vegetation C storage could be critical for predicting tropical forest C sink-strength under future scenarios. We here investigate how climatic and edaphic factors affect tropical plant species diversity and aboveground vegetation C storage across twenty regionally replicated 1-ha forest inventory plots. During the 2012–2015 census period we recorded a total of 11,786 individuals, of which 7,752 individuals and 447 species were located in undisturbed old-growth forests. We found that plant species richness (of trees, palms and lianas $>$10 cm in diameter) ranged from 69 to 127 species ha^{-1} and aboveground vegetation C storage ranged from 114 to 172 tonnes ha^{-1} thus reflecting the geomorphologic heterogeneity of the study region located in Costa Rica. Structural equation modeling identified pathways among interrelated factors affecting tropical plant species diversity and vegetation C storage and indicated that plant species richness increased with soil water availability, while vegetation carbon stocks decreased with soil phosphorus availability. Our findings highlight that local heterogeneity in geomorphology and resource availability must be considered when simulating the functional response of tropical vegetation and its C sink-strength to projected climate change. **Keywords:** biodiversity, plant functional traits, ecosystem dynamics, vegetation model

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Amazon Windthrows Have Regional Characteristics Associated with Environmental and Physical Characteristics

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Across the Amazon, windthrows (tree mortality by winds) are common ranging in size from single trees to large gaps, leading to changes in forest composition and structure, carbon balance, and other ecosystem processes. Yet, our current understanding of windthrows is limited. By integrating remote sensing data and geospatial analysis, we present the first study of the occurrence, area, and direction of windthrows and the control that environmental variables exert on them at the scale of the Amazon Basin. Windthrows are more frequent and larger in the northwestern Amazon (Peru and Colombia), with the central Amazon (Brazil) being another hot spot of windthrows. The predominant direction of windthrows is westward. Mean annual rainfall, extreme rainfall events, and soil properties explain the variability (20-50%) of windthrows but their effects vary regionally. Understanding the spatial and temporal dynamics is windthrows can improve our understanding of the functioning of the Amazon **Keywords:** Windthrows, Amazon, geospatial analysis, regionalization

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Ecosystem structure and function III

Logged Tropical Forests Can Have Amplified and Diverse Ecosystem Energetics

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Logged forests are often characterized as degraded ecosystems, due to their altered structure, loss of biomass and declines in intact-forest specialist species. However, shifts in the strength and resilience of key ecosystem processes in large suites of species have rarely been assessed in an ecologically integrated and quantitative framework. Here we adopt an ecosystem energetics lens to shine a new light on the impacts of disturbance along a gradient (from old-growth forest to logged forest and oil palm plantation on food pathways and community structure of birds and mammals in Borneo. We show that in the logged forest there is a 2.5 times increase in total resource consumption by both birds and mammals compared to old-growth forests, likely driven by greater resource accessibility and vegetation palatability. Most major energetic pathways maintain high diversity and redundancy, except for large mammal herbivory that is dominated by a few hunting-sensitive species. Bird consumption pathways are maintained by a consistently high diversity of species. Overall, up to 50% of ecosystem net primary production may be supporting the bird and mammal communities in logged forests, predominantly via invertebrate pathways, and herbivory by invertebrates may be a substantial constraint on vegetation growth rates. Far from being degraded ecosystems, even heavily logged forests can therefore be vibrant and diverse ecosystems with enhanced levels of ecological function. Our analysis demonstrates the tremendously dynamic and ecological vibrant nature of faunally intact logged forests, even heavily and repeatedly logged forests such as those found across Borneo. We stress, however, that this does not diminish the importance of protecting structurally intact old-growth forests, but rather shines a new light on the ecological value of logged and other structurally "degraded" forests, and reinforcing their significance to the conservation agenda. We have shown that a wide diversity of species can not only persist but thrive, in the logged forest environment, with a more than doubling of total food consumption through a diverse range of bird and mammal taxa. If logged forests can be protected from defaunation, our analysis demonstrates they can be vibrant ecosystems, providing many key ecosystem functions at levels much higher than old-growth forests. **Keywords:** Energetics, ecosystem services, degradation, trophic cascades

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Climatic Drivers of Productivity in Tropical Secondary Forests

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Introduction: Climatic regimes drive large-scale trends in the structure and composition of tropical forests. However, evidence about inter-annual changes in climatic parameters affecting forests is still scarce, particularly for secondary tropical forests. **Objective:** Here, we aim to understand how annual changes in precipitation, temperature, and irradiance drive changes in aboveground net primary productivity (ANPP) in secondary wet and dry tropical forests. **Methods:** We used 20 years of forest dynamics from 37 plots at two sites in Mexico to describe 70 years of secondary succession. Remote-sensing climatic data was matched with forest dynamics trajectories to understand the role of annual climate changes on secondary forest dynamics. **Results:** ANPP in dry forests was very sensitive to climatic changes, with 40 % of growth and mortality explained by climatic parameters. Contrastingly, wet forest ANPP was almost not affected by climate. Seasonality was noteworthy in explaining ANPP at dry forests: growth was negatively affected by wet season temperature, while mortality was positively affected by dry season temperature. Conclusions: Wet forest's stable dynamics might be related to higher species diversity, in turn, associated with a broader range of strategies to cope with environmental temporal variability. Our results indicate that temperature is the most important climatic factor for dry forests, probably due to its promoting effect on stomatal closure and consequential adverse impact on carbon assimilation rates. Based on these two sites, our study suggests that tropical dry forests have a potentially higher risk of catastrophic shifts than tropical wet forests. Our findings support that preserving biodiversity is crucial to maintaining the climatic resilience of tropical forests. **Keywords:** Climate, resilience, net primary productivity, tropical forest dynamics, biodiversity

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Liana Abundance and Host-specificity in Seasonally Dry Tropical Forest in Costa Rica

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Introduction/Background/Justification: While it is established that the frequency of liana colonization and liana loads on host trees are increasing, the consequences of these dynamics for ecosystem processes and whether the impacts of lianas vary among species is poorly known. It is important to resolve these issues, as increasing liana loads can decrease ecosystem carbon storage. Most studies of liana dynamics and associated consequences for host tree demographic rates have occurred in tropical wet forests. In this study, we focused on liana-tree interactions in seasonally dry forests and asked four questions: are liana colonization events increasing through time, how does liana status affect tree growth and mortality, are liana-host tree relationships species-specific, and do liana species vary in where they deploy their foliage relative to host trees? **Methods:** To understand liana colonization and effects on host tree growth and mortality, we leveraged 18 long-term forest dynamics plots in Guanacaste, Costa Rica, where tree diameter growth has been recorded annually. At the same time, we scored each tree on a four-point ordinal scale that binned trees into liana colonization classes ranging from no lianas to >50% of crown infested with lianas. To understand whether tree-liana interactions are species-specific, we counted and identified the number of lianas growing on 748 even-aged trees from nine species growing in plantations in Guanacaste. We also recorded the liana canopy depth relative to tree canopy depths using a clinometer. **Results:** Over 11 years of observations, the number of trees with no lianas declined over time from 52% in 2010 to 45% in 2017. Trees with lianas in more than 10% of their crowns had 34% lower median relative growth rates compared to trees with no lianas and lianas occupying less than 10% of trees' crowns. We found no significant effect of liana status on tree mortality. In our survey of lianas in tree plantations, we found that liana communities were dominated by a handful of species and tree species differed in colonization incidence and liana species. Lianas differed in mean diameter, but overlapped considerably in their crown depths. **Conclusions and Implications:** Our results from seasonally dry tropical forests showed that liana colonization incidences are increasing through time and decreasing tree growth rates, although we suspect that this differs among liana species. Ecosystem simulation models are just starting to incorporate the liana growth form. Empirical data such as these are essential for both developing and validating these models.
Keywords: Lianas, dry forests, species-specific

Ancient Fire Legacy Modified Amazon Forest Soil Fertility

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Introduction: Biomass burning generates not only a short-term nutrient pulse from ash inputs but also pyrogenic carbon (PyC) which is retained long-term in the soil as a recalcitrant legacy of fire. In Amazonia, pre-Columbian inputs of PyC have locally transformed soil fertility by creating Amazonian Dark Earth soils (ADE), yet ADE represents less than 1% of all forest soils and it remains unknown if, where, and how PyC has widespread impacts on soil fertility across the Amazon. **Objective:** We quantified the extent to which PyC, as a legacy of past fire, can explain soil fertility in Amazonia by improving soil nutrient retention in old-growth forests with no record of recent fire. **Methods:** We analysed the PyC and physicochemical soil properties (0-30 cm) of 100 Amazonian non-ADE plots distributed across Amazonia, covering 12 different soil types classified in high activity clay (HAC) and low activity clay (LAC) soils. We considered pH, cations exchange capacity (CEC), sum of bases (SB), total P and exchangeable bases (Ca, Mg, K and Al) as indicators of soil fertility. Besides

PyC, our analyses (linear mixed models) also accounted for the effect of other soil fertility predictors, including organic carbon, clay, silt, maximum age of the soil substrate, precipitation, temperature, and slope). **Results:** We found that PyC in non-ADE soils is significantly correlated with soil fertility in Amazonia, explaining up to 38% in total variance in pH, SB, CEC and total P. The degree to which PyC affected soil fertility was stronger than the effect of any of the proxies for pedogenesis, except for total P in LAC, which is strongly associated with clay. Soil CEC was the fertility attribute most strongly correlated with PyC, and its standardized effect size was 47% (HAC) and 31% (LAC) greater than the standardized effect size of precipitation, the second strongest CEC predictor after PyC. Changes in CEC and SB are caused by the strong association between PyC and Ca and Mg. However, while PyC enhances soil fertility generally, the effect is greater in HAC than low LAC soils, indicating that pyro-nutrient retention in LAC is constrained by interaction between PyC, clay content and aluminium and iron oxides. Conclusion: Our findings suggest that over centennial to millennial time-scales, PyC inputs from ancient fires have reduced long-term nutrient losses by increasing soil pH and cations retention and so increased soil fertility across large areas of Amazon Basin, reframing the often negatively portrayed role of fire in Amazonia. **Keywords:** Soil fertility, pyrogenic carbon, fire, Amazonia, nutrients retention

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Ecosystem structure and function IV

What Are the Primary Sources of Methane Emissions in the Amazon?

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The Amazon region is the largest tropical forest and hosts some of the largest wetlands on Earth, where ˜20% of its area is permanently or seasonally inundated (Hess et al., 2015). Understanding and estimating its contribution to the global methane balance is essential. Although it is important, the Amazon region has a few in-situ observations, which would allow for accurate regional scale flux estimation. Since 2010 we started a lower-troposphere vertical profiles observation program with small aircraft measuring methane concentration over four different Amazon regions. These flights were descending vertical profiles from 4.5 to 0.3 km a.s.l. and represent the sum of all natural and anthropogenic processes in the region. We used carbon monoxide (CO) measurements concomitant in the vertical profiles to estimate the methane emissions from biomass burning. We estimate a total methane emission of 46.2$\pm$10.3 $TgCH_4$ y^{-1}, where ˜73% come from wetlands and ˜28% from anthropogenic sources (17% from biomass burning and 11% from enteric fermentation according to Basso et al., 2021). The contribution of (non-fire) anthropogenic methane fluxes in Amazonia can be significant. These fluxes are primarily from livestock via enteric fermentation (EF) and are more significant in the south and east. Based on 2010–2015 emissions from EDGAR v5.0, we estimate the anthropogenic emissions in our regions of influence, where EF is the primary anthropogenic source, to contribute 90, 84, 71 and 69% of total (non-fire) anthropogenic emissions at ALF, RBA, TAB_TEF and SAN, respectively. The southeast Amazon region have the largest contribution of anthropogenic emissions, ˜51% of total emissions (˜22% from biomass burning and ˜29% from non-fire anthropogenic emissions), followed by the southwest with ˜37% (˜20% from biomass burning and ˜17% from non-fire anthropogenic emissions), and northeast region with ˜29% (˜23% from biomass burning and ˜6% from non-fire anthropogenic emissions). In contrast, the northwest Amazon region has the lowest influence from these activities, with ˜16% of total emissions (˜7% from biomass burning and ˜9% from non-fire anthropogenic emissions). Although the primary methane source in the whole Amazonia area is from a natural source (wetland emissions), in regions with higher levels of deforestation, fires and agricultural regions, anthropogenic emissions are an important source of methane to the atmosphere. These emissions could be reduced, helping Brazil achieve the main goal of the Methane Global Pledge signed in the COP26. **Keywords:** Amazon, methane, wetlands, biomass burning

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Extreme Droughts, Fire and Carbon Uptake in Tropical Transitional Forests of the Amazon

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Amazon forests are expected to experience more frequent and intense droughts in the future. Water deficit during droughts affects photosynthesis and evapotranspiration and, consequently, carbon and water fluxes from these tropical forests. Transitional forests of the southeastern Amazon are characterized by a long dry season and strong water limitation. Historical water deficit in these forests could make them either more resilient or more susceptible to future extreme droughts. Understanding how these forests have responded to atmospheric and soil water stress in the past will to better predictions of how much water stress they could withstand in future droughts. Here, we present the effects of drought and fire in transitional forest of the Amazon. We answer the following questions: (1) What are the main climate drivers of carbon uptake and what are the observed changes during the extreme drought of the 2015-2016 drought? (2) Are ecosystem changes linear or nonlinear with changes in climate or are there climatic thresholds that were exceeded during the drought? (3) What is the role of previous exposure to fire in the ecosystem response to drought? We analyzed carbon uptake between 2014 and 2018 from two tropical transitional forests in the southeastern Amazon, one undisturbed forest and one forest previously exposed to fire. We modeled the relationship between carbon uptake with vapor pressure deficit (VPD) and soil moisture, and used piecewise regression to identify specific thresholds in the response of carbon fluxes to drought. We tested if the effect of drought on carbon uptake was different in the forest previously exposed to fire compared to the undisturbed forest. Carbon uptake largely decreased during the dry season of 2016. Overall, the main driver of carbon uptake for the entire period of study (2014-2018) in these forests is VPD. However, we find that during the drought, carbon uptake decreased along with water content in the deeper soil layers, even under normal VPD conditions. In the forest previously exposed to fire, carbon uptake started to decrease earlier, and under higher soil moisture, than the undisturbed forest. Our results show the importance of atmospheric and soil water deficit for carbon uptake. Low water availability from the deeper soil layers during extreme droughts can lead to reduced carbon uptake from these transitional forests. Fires, which are expected to increase with climate change and deforestation, make these forests more vulnerable to droughts, specifically to decreased soil moisture. **Keywords:** Transitional forests, drought, fire, climate change, carbon uptake

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Impacts of Lianas on Forest Biogeochemistry through Their Lives and Afterlives

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Disturbance and climate change are resulting in increased liana abundance and biomass in tropical forests. The proliferation of lianas may have diverse effects on forest ecosystem processes. For example, the high nutrient concentrations in liana foliage, which differ from those of trees, could influence both green and brown food webs. By growing fast, reducing the growth of their host trees, and investing less carbon in stems, lianas not only reduce the ability of forests to sequester carbon, but also influence carbon emissions and nutrient cycling through their own decomposition. Yet the decomposition of liana tissues is poorly understood compared to that of trees. Here, we aim to stimulate a discussion on the effects of liana proliferation on carbon emissions and nutrient cycling. First, we summarize how adaptive pressures have shaped the structural, chemical, spatial, and temporal differences between the living tissues of lianas and trees. Second, we discuss how these differences may alter the post-mortem state of both growth forms. Third, we highlight the opportunity for empirical studies that make use of these differences to answer ecological questions concerning the influence of afterlife traits on the decomposability of both liana and tree tissues (e.g., effects of complementarity, phylogeny, and distance to ground). Finally, we suggest new research directions that would address these research gaps. Studies on the afterlives of lianas in forest ecosystems will increase our understanding of their contribution to terrestrial biogeochemical cycling and facilitate the inclusion of lianas as an important and distinct woody plant growth form in future terrestrial carbon models. **Keywords:** Decomposition, biogeochemical cycle, litter, nutrients, phylogeny, functional traits, tropical forests

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The Contribution of Terrestrial Crabs (Sesarmidae) on Organic Carbon Sedimentation in Mangrove Ecosystems

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The blue carbon ecosystems such as tropical mangroves are proven that highly efficient at sequestering carbon dioxide. The mangrove is a globally important carbon sink that has been always linked with biological and physiological processes in organic carbon sedimentation. Among the various biological interactions, the terrestrial crabs (sesarmidae) inhabited in this ecosystem play an important role in recycling the carbons and their contribution is not yet studied intensively. Consequently, this study was conducted to quantify the contribution of crabs together with other macrobenthos for the process of carbon sinking in the mangrove ecosystem in southern Sri Lanka. The samples were collected based on disturbed and least disturbed locations according to the degree of anthropogenic influences. The biomass and abundance of the crabs, the weight of the soil organic carbon (SOC), vegetation composition and stem density, soil pH, and salinity were measured for all the sampling locations and compared. The SOC varied between 8.20$\pm$2.05 - 18.52$\pm$4.63 kgm^{-2} among the locations. SOC increased concerning the increment of crab biomass and the stem density indicating the underline mechanism of this biological event in the SOC sedimentation process. Further, there was a significant difference in crab abundance between disturbed and least disturbed locations. Moreover, crab biomass and the abundance of macrobenthos had a positive relationship, revealing the combined effect of dominant soil fauna into this ecological process. In addition, the stem density and soil properties such as salinity were significantly affected the abundance of crabs and macrobenthos. These findings confirmed that crabs and macrobenthos are preferentially living under dense mangrove vegetation and acting as ecosystem engineers through biogenic structures and deeply modifying soil characters. The processing of leaflitter by different feeding behaviors of sesarmids and nutrient transformation into the deep soil greatly enhance the long-term preservation of SOC and thus highlight the importance of plant-animal interactions in mangrove ecosystems as an effective carbon reservoir. **Keywords:** Bioturbation, carbon sequestration, carbon sink, crabs, mangroves, soil organic carbon

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Ecosystem structure and function V

Land Cover Change Data & Carbon Dynamics in the Southeast Amazon

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Amazon forests provide essential ecosystem services. Land use and cover change (LUCC) and climate change have been affecting the function of the Amazon forests as a carbon sink, mainly in the southeast of the Brazilian Amazon. Nine years (2010-2018) of atmospheric CO_2 measurements of the CARBAM project in four sites of the Amazon, showed that the southeast region (ALF) is no longer a carbon sink but a source. The accumulated deforested area until 2018 in ALF is more than 25%. It is necessary to understand how the LUCC dynamics, including annual deforestation, forest degradation and secondary forest (growth and loss), influences the carbon balance inside this deforested area. We analyze an annual LUCC mask from 2010 to 2018, joining different datasets, in order to assign emission factors to each LUCC class. We found that pasture is the predominant class with 60%, followed by secondary forest (15%), water bodies (11%) and grasslands (8%). Deforestation and secondary forest loss is increasing since 2013 and degradation areas are bigger in the extreme drought years (2010, 2015 and 2016). In terms of LUCC related emissions, annual deforestation represents more than 65%, degradation almost 30% and secondary forest loss 7%. The atmospheric CO_2 emissions are linked to deforestation, degradation and drought years, but further research is necessary to fully explain why this region is a source and no longer a carbon sink. The spatial and temporal scale of the LUCC data also constraints the understanding of the atmospheric CO_2 measurements. It is necessary to join the top-down measurements and the LUCC bottom-up approaches to better understand the Amazon C balance under climate change and LUCC pressures. **Keywords:** Amazon, CO2 emissions, land use and cover change, carbon balance

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Tree Rings in Pinus Spp. May Shed Light into Intra-annual Variation of Climatic Conditions in the Sierra De Las Minas

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Introduction: Tree rings of temperate and tropical tree species can provide a unique, long-term record of climatic inter-annual variation. Recently, it has been proposed that false tree rings or intra-annual density fluctuations (IADFs), i.e., narrow tree rings formed between inter-annual rings, may signal intra-annual climatic events that reflect drastic changes of climate or stress situations central to the growing seasons. However, few studies have focused their attention on the significance of IADFs particularly in the Tropics. In Central America, the *canícula* - a midsummer drought that interrupts the May to October rainy season - and the *nortes* - a significant reduction of temperature combined with strong winds during the autumn or winter season - are two important intra-annual climatic events that natural and human-made ecosystem and may cause IADFs. **Objectives:** Focusing on the Sierra de Las Minas of Guatemala-SLM, we ask 1) what relationships exist between climatic conditions and tree ring chronologies, 2) what patterns characterize IADFs in *Pinus* spp., and 3) what is the relationship between IADFs and these two major intra-annual climatic events. **Methods:** We processed 175 tree cores collected at 40 sites in the Pasabien subwatershed of the SLM, used CooRecorder and CDendro software to identify, count, and measure annual and IADFs, and COFECHA to evaluate the cross-dating. We selected an initial sample total of 28 tree-ring series spanning the 1861 – 2019 period to examine relationships between ring width and monthly temperature and precipitation. To examine possible drivers of IADFs we classified the tree-ring series by the proportion of IADFs into two groups: few (<0.25) and many (>0.25). **Results:** Our preliminary data showed that tree-ring width was positively correlated with the current

January and June temperatures whereas negatively correlated with the previous year's July temperature and the current May precipitation. For the period 1985 – 2019 the mean average frequency of IADFs was 33% (range 11%-55%). During the hottest months of the year (July, August, and September), the mean precipitation of July and September was lower among the tree-ring series with many IADFs (539.1 and 518.6 mm/month, respectively) than the series with few IADFs (585.0 and 549.5 mm/month). The August precipitation was low for both groups (483.06 and 491.81 mm/month, respectively). **Implications:** Our data suggest that variation in tree-ring widths results from the interaction between temperature and precipitation. On the other hand, the formation of IADFs, and therefore tree growth, seems to be associated with the *canícula* in the SLM. **Keywords:** Dendroclimatology, intra-annual density fluctuations, false rings, Tropics, canícula

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Influence of Soils on Aboveground Biomass in Areas Degraded by Mining in Chocó Biogeographic

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Introduction: Mining is one of the main drivers of deforestation and degradation of tropical forests. This activity affects the storage of aboveground biomass of these ecosystems, and, therefore, its ability to contribute to the mitigation of global climate change. Objective: The influence of soils on the aboveground biomass of areas degraded by mining in the Colombian Pacific was evaluated. Methods: For this, plots were established in areas previously degraded by mining and with different successional ages (12-15 years, 30-35 years and mature forest), in the locality of Jigualito, in the Colombian Pacific. In each of the plots, the aboveground biomass of the trees was measured using allometric equations and the physicochemical parameters of the soil. **Results:** A aboveground biomass of 15.58 t ha-1, 35.17 t ha-1, and 178.32 t ha-1 was recorded at 12-15 years, 30-35 years and in mature forest, respectively. The aboveground biomass was positively correlated with organic matter (OM), calcium (Ca), magnesium (Mg), CICE, total nitrogen (N) and silt, whereas, with sand, aluminum (Al) and potassium (K) content the relationship was negative. It was evidenced that the relationship between the aboveground biomass and the soils was different in each successional age. When evaluating the changes of the aboveground biomass and the soils in the successional ages, it was observed that the aboveground biomass and the total N increased with the recovery time, while the available P and K decreased with succession. On the other hand, the contents of OM, Mg, Al, Ca and CICE, showed curvilinear tendencies, since they increased in the first stages, and then in the advanced successional stages they decreased. **Conclusions:** In summary, the results showed that the aboveground biomass of the areas degraded by mining was limited by multiple soil nutrients. **Keywords:** Aluminum toxicity, carbon, nutrient limitation, restoration, plant succession

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Responses of Tropical Tree Seedlings to Nutrient Addition: a Meta-analysis to Understand Future Changes in Ecosystem Dynamics

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Background: Fragmentation of tropical forests alters not only the structure of forests due to the loss of timber, but also it produces remotely an increment of doses of pollutants on soils coming from agricultural expansion and industrialization. Despite extensive speculation about nutrient saturation on tropical ecosystems, no study found direct evidence related to changes in nutrient cycles for the region. Thus, throughout the tropics, scientists believe that productivity and relative biodiversity respond better to a limitation by phosphorus than nitrogen, or a co-limitation of both nutrients. **Objective:** We aim (1) to synthesize results concerning species responses to fertilization with N and/or P and NPK to examine to what extent one or more nutrients will trigger stronger effects on species, (2) to contrast seedling experiments' results to determine whether specific responses, in growth and biomass allocation, are similar by type of tropical forests, and (3) to compare differences in experimental approaches conducted on tropical species. **Methods:** We performed a systematic literature search of studies published in Spanish, English, and Portuguese. For each species found, we recorded geographic, climatic, and taxonomic information based on species origin. After refining searches for seedling growth and biomass allocation, we performed a systematic review and hierarchical meta-analyses using climate variables, experimental types, and functional traits information as main moderators. **Results:** We found strong evidence of multiple nutrient limitations. Overall, nutrient fertilization increased shoot biomass accumulation (36%) more than growth (20%), and experimental studies showed stronger positive effects on growth and biomass accumulation than observational studies. Additionally, a combination of nutrients supported most of the seedling growth (NP 28%, NPK 20%), and for shoot biomass accumulation nitrogen was critical (N 56%, NP 62%). Fertilization responses in both cases suggest a co-limitation of N and P for tropical tree species. Our analyses suggested that some functional traits are related to specific seedlings' responses to nutrient deposition. Lastly, climatic conditions also have a major impact on how nutrients to deposited on soils, and how much of the nutrients return for plant acquisition. **Conclusions:** We concluded that the responses of tropical species to deposited nutrients showed high heterogeneity among all tropical regions. Species respond not only to nutrient conditions they are exposed to but also to the interaction with other biotic and abiotic relationships in local or regional ecosystems. Hence, individual-specific responses to new challenges to survive will be the major trigger to changes in ecosystems' dynamics and diversity. **Keywords:** Biomass, fertilization, growth, nutrient deposition, seedling regeneration, tropics, shoot biomass.

Functional Ecology: From Traits to Ecosystems I

Leaf Traits and Endophytic Function Structure Communities of Foliar Endophytic Fungi in a Tropical Forest

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Introduction: Foliar fungal endophytes are symbionts that occur in healthy leaves. Their community composition often differs among co-occurring host species in ways that cannot be explained by environmental conditions or host phylogenetic relationships. One possible framework for better understanding endophyte community composition is through leaf traits. Leaf traits of plants worldwide are classified according to the Leaf Economics Spectrum (LES), which links leaf functional traits to evolutionary life history strategies. As a continuum ranging from thicker, tough leaves that are low in nitrogen (N) to thinner, softer, leaves that are high in N, the LES brings together physical, chemical, and ecological traits. **Objectives:** We tested the hypotheses that LES traits (1) act as habitat filters that shape communities of foliar endophytes, and (2) select for endophytes with particular suites of functional traits. Methods: We used culture-based and culture-free surveys to characterize foliar endophytes in mature leaves of 30 phylogenetically diverse plant species with divergent LES traits in lowland Panama, and then measured functional traits of dominant endophyte taxa *in vitro*. **Results:** Endophytes were less abundant and less diverse in thick, tough, leaves compared to thin, softer, leaves in the same forest, even in closely related plants. Endophyte communities differed according to leaf traits, including leaf punch strength and carbon and nitrogen content. The most common endophyte taxa in leaves at different ends of the LES differ in their cellulase, protease, chitinase, and antipathogen activity. **Conclusions:** Our results extend the LES framework for the first time to diverse foliar endophytes, opening new hypotheses regarding the degree to which foliar symbionts respond to, and extend, the functional traits of leaves they inhabit. **Keywords:** Endophyte, tropical leaf traits, endophyte traits, Panama, leaf economics spectrum

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Leaf Traits Influence, and Are Influenced By, the Fungal Endophyte Communities of Tropical Trees

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Introduction/Background/Justification: Leaves of tropical plants exhibit trade-offs in leaf lifespan associated with growth vs. persistence: short-lived leaves grow rapidly with few structural defenses, while long-lived leaves grow slowly and invest resources in defense. Functional traits such as leaf mass per area, toughness, thickness, and nitrogen/carbon concentrations underpin these tradeoffs. Foliar fungal endophytes (FE) infect leaves of tropical trees starting at leaf emergence, but the extent to which leaf functional traits act as habitat filters of FE remains underexplored. FE, in turn, influence leaf trait development over time. **Objectives/Hypothesis:** We explored how leaf traits influence the community assembly of FE in leaves of tropical plants (Experiment 1), and whether FE communities shape leaf trait development and plant performance over time (Experiment 2). We predicted that leaf traits would explain significant variation in FE communities, that temporal turnover in FE communities would be greater in leaves with a shorter lifespan, and that E+ leaves would become denser and tougher over time relative to E- leaves. **Methods:** Seedlings of 6 plant species ranging in life-history strategies were inoculated with a natural FE community (E+) for ten days, while controls remained in a clean

greenhouse (E-). We measured leaf traits and used the Illumina platform to examine endophyte community metrics in E+ and E- leaves at 1, 2, and 3 weeks after inoculation (Experiment 1), and 1, 2,3 and 6 months after inoculation (Experiment 2). **Results:** FE community composition differed among plant species, despite being inoculated with the same bulk sporefall (E+). When accounting for the effect of time, leaf toughness, thickness, LMA, and N% significantly explained variation in FE community composition. FE communities in plant species with long lived leaves became more compositionally different over time, driven by increases in the relative abundance of persisting FE taxa rather than the gain or loss of new FE taxa. FE communities in short-lived leaves became more compositionally similar over time, due to a decrease in turnover of FE taxa over time. Leaves exposed to endophyte sporefall (E+) were tougher and denser relative to control leaves, but these differences could not be predicted by leaf lifespan. **Implications/Conclusions:** Leaf functional traits act as habitat filters of FE assemblages in tropical leaves. Sporefall exposure (E+) led to the development of denser and tougher leaves, indicating that FE can shape leaf traits in a manner that may be relevant for plant interactions with herbivores and other guilds. **Keywords:** Community assembly, endophytes, leaf traits, community turnover

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Diverse Trait Strategies across Growth Forms in Ghanaian Tropical Wet and Dry Forests

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Justification: During tropical forest succession there is a rapid turnover in growth form composition from herbaceous species early in succession to woody species later in succession. Such changes are partly driven by leaf traits that allow plants to capture light while coping with extreme conditions such as heat and drought. Objective: Here, we analyze how successional growth forms differ in their leaf traits and strategies in dry and wet tropical forests. **Methods:** For six growth forms (i.e., herb, grass, vine, liana, shrub, and tree) and 266 plant species 11 leaf morphological and nutrient traits were measured in Ghanaian tropical wet and dry forests. **Results and Discussion:** A principal component analysis shows that 46% of trait variation is captured by a two-dimensional spectrum of plant form and function, a leaf economics spectrum underpinning fast-slow growth strategies, and a leaf size spectrum related to plant size and heat balance. Herbaceous species had faster leaf economic trait values and, hence, rapid carbon gain explains their success earlier in succession. In contrast, woody species had slower resource conservation trait values, explaining their success later in succession. Wet and dry forests showed largely overlapping traits but the trait hypervolume was smaller in the dry forest, indicating drought-related climatic filtering, i.e., species with smaller plant and leaf size. **Conclusions:** This study advanced the successional theory of growth form replacement and climatic filtering in species composition in early succession by revealing the plant trait dimension across growth forms between dry and wet forests. Successional shifts in growth form from herbaceous species to woody species may be driven by the shifts from resource acquisitive strategy to conservative strategy along with the successional declines in resource availability. Climatic conditions in a dry environment filter in species which can cope with heat and drought stress for their survival while capturing and utilizing light for their growth. **Keywords:** Acquisitive and conservative traits, early tropical forest succession, growth forms

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Context-dependent Functional Responses of Neotropical Tree Assemblages to Forest Loss and Fragmentation

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Background: Tropical forests play a key role in global biodiversity retention and provisioning of ecosystem services from local to global scales, but are increasingly threatened by land-use intensification. Yet, there is a major uncertainty on the traits underlying tree species sensitivity to forest loss and fragmentation, and thus on the mechanisms reorganizing tree assemblages in human-modified tropical landscapes. **Objective/Hypothesis**: Here we examine the independent and combined effects of landscape-scale forest loss (i.e., percent of forest cover) and fragmentation (i.e. edge density) on the functional profiles of tree assemblages within and across seven Neotropical regions in contrasting biogeographic and land-use contexts. We expected independent effects of forest loss and fragmentation, with negative effects in trait diversity related to increased dominance of opportunistic strategies (acquisitive traits, small and abiotically-dispersed seeds). **Methods**: We compiled a large dataset including 416 forest plots covering ~100,000 trees of ~2,000 species, and functional traits related to resource-use, regeneration and dispersal strategies. We assess the response of community functional composition and diversity to varying forest cover and edge density at different-sized landscapes (100 to 2,000 m-radius buffers) surrounding each forest plot, to determine the scale at which landscape effects are stronger. **Results**: Tree community functional profile changed comprehensively in response to forest loss and fragmentation, with 12 to 60% of within-region variation in trait dominance or diversity explained by the combined effects of forest loss and fragmentation. However, such effects varied widely in direction, magnitude and scale across traits and regions, being particularly strong and consistently negative for seed mass, wood density and endozoochory, especially in wetter regions closer to the equator. **Conclusions**: Despite large context-dependence in magnitude and scale of effects, changes in trait dominance in general supports a sort of 'retrogressive succession' as trait values typical of early-successional species (i.e., soft tissues, small seeds, abiotic dispersal) increment with increasing forest loss and fragmentation. Forest loss and fragmentation thus operate as a key assembly force, filtering major tree life-history strategies in fragmented tropical landscapes. Variation in trait sensitivity across regions is still an open question that may be related to disturbance regimes or biogeographic histories. Notwithstanding, regardless of regional differences, habitat loss and fragmentation tend to comprehensively drive Neotropical forests towards a functional composition that is typical of early-successional communities. **Keywords:** Community assembly, landscape structure, functional traits, habitat amount, retrogressive succession

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Functional Relationships of Stem and Twig Wood in Tropical Tree Species

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Background: Wood density is considered a key functional trait affecting plant ecological strategies, yet its biological meaning remains quite unclear. The use of branch instead of stem wood density has been suggested as a possible less destructive method to estimate this trait, but the studies are restricted to few species and the results are inconclusive. Aim: We investigated how stem and twig wood specific gravity (wsg) vary across different Amazonia ecosystems and how investments in stem and twig wsg changes across species in these ecosystems. **Methods:** We used 152 tree species occurring in upland, white-water (várzea) and black-water (igapó) floodplain forests. Collected twig and stems were put into water and its fresh volume was measured using the water displacement method, subsequently, they were dried at 102°C for 72h. The wsg was calculated as the ratio of oven-dry wood over green volume (g.cm-3). Additionally, we used stem wsg values from literature for some várzea species. We tested if wsg changes across ecosystems using an ANOVA and if twig differs from stem wsg across species using a paired t-test. We investigated if the relationship between twig and stem wsg changes across different ecosystems using phylogenetic linear regression models. **Results:** Wood specific gravity varied across ecosystems and between twig and stem tissues. Upland species had on average higher stem wsg (0.70 g.cm-3) than in flooded igapó (0.64 g.cm-3) and várzea (0.59 g.cm-3) species. Interestingly, twig wsg was higher than stem wsg for species in igapó and the opposite for species in upland (stem wsg $>$ twig wsg). The linear regression models indicated that for all ecosystems twig wsg increase with an increase in stem wsg (R^2adj=0.36) but the rates of increase were lower in várzea. **Conclusions:** Twig wsg increase with stem wsg independent of ecosystems, but igapó species invest in denser twigs and várzea species invest in softer stems. Low-wood density is cheap to construct, allowing for rapid growth in stem dimensions when resources are available, as in nutrient-rich várzea forests. Dense twigs can be more efficient for horizontal growth maximizing resistance and can reflect hydraulic safety, which might be important in stressful flooded nutrient-poor igapós, where resources are limited and persistent strategies are more favorable. We suggest that models to estimate stem wsg should be specific for each ecosystem because species differ in strategies for resource allocation across environments. **Keywords:** Functional traits, wood specific gravity, Amazon, ecological strategies

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Using Key Seasonal Dependent Functional Traits to Explain Plant Coexistence

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A core ecological hypothesis for species coexistence is the resource niche hypothesis, where species partition resources across space and time. The distinct wet and dry seasons of most tropical forests may allow temporal resource partitioning, with some plants growing best during the rainy and cloudy wet season, and other plants growing best during the sunny and arid dry season. Recent evidence indicates that trees and lianas partition resources temporally by growing during distinct seasons, trees grow more during the wet season and lianas more during the dry season. However, few studies have tested whether seasonal adjustments in functional traits explain temporal resource partitioning among species. We tested the hypothesis that seasonal adjustments of functional traits explain resource partitioning and thus seasonal growth differences. We examined two key physiological functional traits related to drought tolerance and photosynthetic efficiency: turgor loss point (TLP) and photosynthetic capacity (Amax). Higher Amax during the wet season would allow trees to maximize growth in the light-limited environment compared to lianas. By contrast, lower TLP during the dry season would allow lianas to maintain higher dry season growth than co-occurring trees. We measured Amax and TLP in seven species of lianas and trees (14 total) growing in a common garden for 10 years in central Panama. We measured at least three leaves per individual and three individuals per species in both wet and dry seasons. Our data supported our predictions: trees increased their Amax to fix more carbon during the wet season (Tree wet: 11.77±3.8 µmol m-2 s-1, tree dry: 6.08±3.5 µmol m-2 s-1) compared to lianas that did not change Amax (Liana wet: 8.95±3.4 µmolm-2s-1, liana dry: 7.84±4.2 µmol m-2 s-1), which was consistent with higher tree growth during the wet season. By contrast, lianas adjusted their TLP becoming more drought tolerant during the dry season (Liana wet: -1.597±0.36 MPa, liana dry: -1.703±0.38 MPa, βlifeform:season=0.02, 95%-CI=0.0077, 0.0324) compared to trees which did not change TLP (Tree wet: -1.58±3.0 MPa, tree dry: -1.661±0.37), which was consistent with higher dry-season liana growth. Trees appear to be adapted for high carbon gain during the wet season via increased wet season photosynthetic capacity, whereas lianas are adapted for high dry-season growth via increased drought tolerance. The ability of plants to seasonally adjust these two key functional traits may explain liana-tree coexistence in tropical forests and support the functional trait approach for determining species coexistence. **Keywords:** Species coexistence, niche partitioning, functional traits, tropical woody plants.

Functional Ecology: From Traits to Ecosystems II

How Do Tropical Tree Species Differences in Water Use at the Neighbourhood Scale Shape Growth Response to Climate?

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Climate anomalies, such as extreme drought events, have been shown to affect tropical rainforest dynamics. However, tree growth response to drought may depend on differences in species water-use strategies at the neighbourhood scale. The capacity of local neighbourhoods to mitigate or exacerbate negative drought effects on individual tree performance likely depends on the mechanisms driving local species competition for limiting water resources. Leveraging species traits that are good predictors of water use has the potential to disentangle the relative role of niche differentiation and hierarchical competition in shaping local neighbourhoods. A better understanding of the separate and joint effects of climate, species traits and neighbourhood interactions on individual tree growth may be crucial to improve our predictions of tropical forest dynamics under climate change. In this study, we test how individual tree growth responds to (1) the separate and joint effects of drought and neighbourhood interactions in a tropical rainforest. We further investigate (2) whether neighbourhood interactions are driven by species trait dissimilarities or hierarchies in water use. We use an exceptional dataset covering 30 years of biennial, spatially-explicit inventories of individual tree growth from permanent forest plots at the Cirad experimental site of Paracou, French Guiana, combined with species water use traits, including water potential at turgor loss point and minimal conductance. We test the effects of atmospheric and soil drought via mean anomalies in atmospheric evaporative demands and soil water availability over the census intervals. We use different neighbourhood crowding indices, capturing trait similarities and hierarchies, to evaluate the role of species differences in water use. We use Bayesian hierarchical models for the most abundant 100 species to explore tree growth response to climate anomalies and neighbourhood crowding. Preliminary results demonstrate that both drought and neighbourhood crowding decline tree growth at Paracou. We further show that these two drivers can interact to shape individual tree growth. In particular, we find that high neighbour densities exacerbate negative effects of soil drought, suggesting that competitive interactions play an important role in the individual drought response of trees. Species responses to climate, neighbourhood crowding and their interaction vary greatly at Paracou. Here, we will detail the role of dissimilarities and hierarchies in leaf water use traits, in shaping these neighbourhood effects on individual tree response to climate. Our study highlights the urgent need to integrate biotic interactions at the neighbourhood scale to improve our understanding on how tropical forests will respond to ongoing climate change. **Keywords:** Tropical forests, drought response, biotic interactions, water-use strategies, growth model

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Functional and Taxonomic Variation along a Hydrological Gradient Reveal Multiple Ecological Strategies in Neotropical Grasslands

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Background: Functional traits play a central role in our understanding of species distribution along environmental gradients. Water deficits and soil waterlogging are often strong abiotic filters selecting specific adaptations. Although neotropical grasslands include a high variety of ecosystems subject to contrasting hydrological conditions, little is known about the functional attributes and ecological strategies of herbaceous communities associated with distinct conditions. **Objectives:** Here we investigate how the duration of drought and waterlogging periods affect the taxonomic and functional composition of graminoid communities in grasslands in central Brazil. We predict a high turnover of graminoid species along the hydrological gradient, as well as an increase in abundance of acquisitive strategies in less extreme environments. **Methods:** We obtained the abundance of all graminoid species in twelve 1 x 1 m quadrats in 34 sites from 100 m to 16 km apart from each other, ranging from grasslands subjected to prolonged waterlogging to savannas subjected to five months of drought. In 18 of these sites we also obtained leaf (specific leaf area, leaf dry matter content, leaf nutrient content, predawn and midday leaf water potential), root (specific root length, root diameter) and whole-individual (height, aboveground biomass) traits of three individuals of the species accounting for 80% of the cover of graminoids. In each site we obtained soil properties and monitored water table depth and soil moisture. We used linear models and ordenation analysis to assess the effect of abiotic variation on taxonomic/functional composition, diversity patterns and the community weighted means of traits. **Results:** Well drained savannas and grasslands subjected to prolonged waterlogging showed very distinct taxonomic composition, and soil waterlogging period was negatively associated with leaf area and specific leaf area and positively associated with specific root length. While these findings are consistent with the existence of hydrological niches, both chemical and physical soil properties were also associated with leaf and root traits, so that certain sites subjected to both waterlogging and drought periods showed very distinct functional and taxonomic composition. **Conclusions:** Our findings suggest that the mosaic of species-rich graminoid communities typical of neotropical savannas is associated with changes in taxonomic and functional composition related to local soil and water availability. Therefore, even small changes in these conditions associated with land-use and climatic changes may affect the biodiversity and functioning of these ecosystems. Likewise, actions to restore the graminoid layer in degraded sites should consider the most appropriated set of species and functional traits for distinct hydrological and edaphic conditions. **Keywords:** Soil waterlogging, water deficit, cerrado, hydrological niche, ecological strategy, restoration

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Expression of the Functional Traits and Population Dynamic of the Frailejón Espeletia Hartwegiana in the Páramo Complex Los Nevados, Tolima-Colombia

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Plants in the paramo ecosystem have different morphological attributes due to the adaptations they have developed. Therefore, functional traits and demography are important to obtain information about the role played by the species and its response in the ecosystem. Our objective is to evaluate the functional traits, population structure and vertical life table of Espeletia hartwegiana through an altitudinal gradient. The study was carried out in the páramo complex Los Nevados, Tolima. Three study plots of 250 m2 were marked every 200 m of elevation for which we registered abiotic factors. Consequently, from the selected individuals, we registered morphometric traits, vegetative and reproductive traits. Accordingly, we also recorded 300 individuals in each plot. A life table was elaborated to synthesize the survival and fecundity of the plants, individuals were separated into size classes: Seedlings, Juveniles, and four types of Adults were subdivided according to their total height. Henceforth, as the gradient increases, the individuals exhibited a greater necromass height, total height and rosette height, indicating that these individuals are possibly more resistant and stable to its stem structure, due to the extreme conditions. On the other hand, the individuals in the lowest altitude presented a wider wingspan, potentially indicating a greater resistance to its foliar structure. Additionally, the individuals in the lowest altitude also had a higher quantity of seeds, and moisture content, which suggests that these individuals could be investing their resources in producing more offspring. Likewise, in accordance with the demographic results, the lowest altitude had a higher rate of fertility but lower viability. Nevertheless, in terms of the population growth rate (λ), it is decreasing and will probably lead to the extinction of the population, because in all elevational levels λ value is less than 1 (equilibrium). This may be due to an increase in temperatures at a global level because of climate changes and anthropic pressures on the paramo ecosystem. The most determinant expression of functional traits were total height, rosette height and necromass height, suggesting a higher stem resistance in individuals at a higher altitude. Whilst the rosette height and wingspan indicate higher leaf structure resistance in individuals found at lower altitudes. Nonetheless, to enhance these results, it is necessary to use more variables, i.e., foliar anatomy. Furthermore, it is necessary to carry out more censuses to generate a transition matrix and increase the predictive power of the demographic model. **Keywords:** Andean ecosystem, functional ecology, population ecology, dynamics.

Effects of Fertilization and Water Reduction on Vascular Epiphyte Functional Traits

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Anthropogenic nitrogen (N) and phosphorus (P) deposition are predicted to increase and precipitation is predicted to vary in tropical systems, with wetter wet seasons and drier dry seasons. These changes could have profound effects on vascular epiphytes given their dependence on atmospheric sources of nutrients and water. To determine if changes in nutrient addition and water regimes will impact epiphyte photosynthetic parameters and functional traits, we conducted an *ex-situ*, 2 year nutrient addition and water limitation study on 5 cosmopolitan species from three genera (*Elaphoglossum, Anthurium,* and *Guzmania*) as part of a larger study examining anthropogenic change on epiphyte communities. The selected genera vary in their nutrient acquisition method, which may influence their response to treatments: *Elaphoglossum,* canopy soil roots, *Anthurium,* aerial and canopy soil roots, *Guzmania,* atmospheric sources. Our treatments included: N addition, P addition, and NP addition, and water reduction (30% reduced precipitation) along with two controls (no manipulation and added water as carrier solution of nutrients). Treatments had variable effects on photosynthetic parameters and leaf functional traits across taxa and year. *Elaphoglossum* varied most in response to P variables, with photosynthetic rate and quantum efficiency declining with NP addition and leaf dry matter content (LDMC) declining with P addition. *Guzmania* photosynthetic rate and quantum efficiency declined in the water control and specific leaf area (SLA) varied with year, which was driven mostly by an increase in the P and NP treatments and a decrease in the N treatment. *Anthurium* leaf traits did not change with nutrient and water addition, but did vary in photosynthetic rate and quantum efficiency with year. Leaf nutrients varied across taxa and year. Leaf N increased in *Elaphoglossum* and *Guzmania* but decreased in *Anthurium* with year while leaf P did not change in *Elaphoglossum* and *Anthurium* but increased in *Guzmania* with year, particularly in the P and NP treatments in 2014. Overall, with P-addition, *Elaphoglossum* showed a reduced investment in leaf tissue and no change in leaf nutrients while *Guzmania* exhibited higher SLA and leaf P content, which indicates different approaches to P-limitation. The lack of a response overall by *Anthurium* to treatments suggests either evolutionary constraints or having multiple uptake mechanisms allows it to be more robust to variations in nutrient and water inputs. The differences in response to fertilization and water reduction across these common genera in tropical canopies suggest that anthropogenic change will have profound effects on canopy systems. **Keywords:** Epiphyte, canopy, functional traits, fertilization, anthropogenic change

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Multiscale Factors Drive Functional Composition and Diversity of Second-growth Forests in Agricultural Landscapes in Brazil

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Forest regeneration in human-modified landscapes can be affected by anthropogenic drivers and by local environmental drivers. These multiscale factors influence the plant community composition and diversity. Although it is evident that the tropical forest succession in the human-modified landscape is driven by multiscale factors, few researchers evaluated these factors together using a functional trait approach. We studied how functional composition and diversity is affected by multiscale factors in 43 seasonally dry secondary forests in the Atlantic forest region of Brazil, on pastures and in abandoned eucalyptus plantations, two contrasting former

anthropogenic land uses. We used Community Weighted Mean trait values of leaf area, specific leaf area, leaf thickness, leaf dry matter content, leaf compoundness, wood density and proportion of N-fixing trees to evaluate the effects of multiscale factors: forest age, basal area, soil sand content, soil base saturation, surrounding land use, distance to the forest edge, remnant Eucalyptus basal area, and surrounding forest increase. We expected secondary forests in human-modified landscapes (e.g. low surrounding forest cover, high eucalyptus basal area, more surrounding sugarcane areas, and suffering from edge effects) and growing in more restrictive environmental conditions (e.g., in soils poor in nutrients and high sand content) would predominantly have communities that are low in functional diversity and would be characterized by communities with conservative traits. While older secondary forests with less restrictive environmental conditions would be characterized by communities with acquisitive traits and higher functional diversity. We found that older secondary forests have higher functional richness but age did not affect other functional attributes. Proportion of N-fixing trees was positively affected by surrounding forest cover and by sand content. Specific leaf area increased, while leaf dry matter content decreased with higher base saturation in soils. Longer distance to edge had a negative effect on wood density. We found few direct effects of anthropogenic drivers, only leaf area decreased in sites with high Eucalyptus basal area and with nearby sugarcane plantations. Our findings support the theory that species with conservative traits dominate in resource-poor environments, and species with acquisitive traits dominate in more resource-rich environments in these seasonally dry forests. We conclude that multiscale factors affect resource availability and local environmental conditions, which affects functional composition and diversity. Our results can help forest restoration strategies in the choice of species, by selecting those species with functional attributes more adapted to current and future local environmental conditions. **Keywords:** Functional traits restoration secondary succession biodiversity tropics

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The Assembly of Tropical Dry Forest Tree Communities Reflected in Functional, Phytochemical and Spectral Traits.

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The assembly of plant communities in tropical anthropogenic landscapes still raises many questions that must be addressed to understand the effect of the transformation of tropical forests and their future scenarios. In this study, we aimed to identify potential assemblage rules underlying species coexistence in secondary and mature forests, as well as to assess the ability of spectral data to detect these ecological processes in the Jalisco Tropical Dry Forest (TDF) of Mexico. For this purpose, from 10 tree communities of the TDF of Chamela-Cuixmala (five communities representing secondary forests and other five representing mature forests), we obtained the following data: 1) the foliar content of defense phytochemicals (total phenols, tannins, flavonoids), 2) foliar functional attributes such as the content of chlorophyll, water content, dry matter content, thickness, density, specific leaf area and leaf fresh mass content, 3) leaf spectral signatures from 400 to 2100 nm. Additionally, we characterized both the aerial and edaphic environment of each study site. In general, we found that: 1) the leaves phytochemical content was associated with high leaf density and fresh mass, resulting in leaves resistant to drought and high radiation, with chemical and physical defenses against herbivore/pathogen attack, 2) environmental filters could modulate the enhanced expression of defensive phytochemicals in secondary forests, 3) different defensive strategies can coexist in mature forests, where higher species richness could dilute the prevalence of pathogens/herbivores. 4) the spectral reflectance of the vegetation was useful to reflect both the taxonomic and functional diversity of the vegetation, the level of heterogeneity between conserved and disturbed habitats, and the action of internal and external filters that modulate intraspecific variation within communities. These results allowed us to infer, through functional and spectral leaf traits, the ecological patterns, processes and mechanisms that could modulate the nature of the plant communities in the anthropogenic landscapes of the BTS. Therefore, the ecological analysis of the leaf spectral data can provide very useful information in relation to the general patterns of richness and diversity of tropical tree communities, as well as in relation to the assembly of such communities. **Keywords:** Community assembly, phytochemicals, functional traits, spectral data, tropical forest

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Functional Ecology: From Traits to Ecosystems III

Interactions between Functional Leaf Traits and Foliar Endophytes in the Defense against Natural Enemies of Tropical Trees

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Leaf traits such as leaf chemistry, lifespan, toughness, and leaf mass per area (LMA) are a plant's first line of defense against foliar herbivory. Plants that invest more in leaf tissue with longer lifespans and higher LMA consequently need to invest in constitutive defenses (e.g., leaf blade toughness, thickness, density of cell walls) as well. In contrast, plants that invest little in leaf nutrients and have low LMA may have greater levels of induced defenses. Leaf traits, whether constitutive or induced, represent an environmental filter for leaf microbial communities, especially foliar fungal endophytes (FEF), which may in turn play a role in plant defense. Our overarching hypothesis is that FEF alter leaf defense (i.e., functional leaf traits) in tripartite interactions among FEF, leaf traits and plant enemies such as leaf-cutting ants (*Atta colombica*) and pathogens. Specifically, we predicted that (1) *A. colombica* would remove less plant material from leaves with higher endophyte loads (i.e., higher endophyte abundance and richness) compared to leaves with lower endophyte loads, once variation in leaf traits is taken into account, (2) pathogen damage will decrease in leaves with high (relative to low) endophyte loads, and (3) FEF-mediated defense against both herbivores and pathogens will be most important in short lived leaves, as long-lived leaves are expected to rely more on intrinsic defense. We inoculated seedlings from seven tropical tree species with natural and diverse endophyte communities. We confirmed endophyte inoculation and described endophyte community structure with culture assays and Illumina sequencing, respectively. We then measured leaf removal by *A. colombica* and leaf necrosis due to a generalist fungal pathogen (*Calonectria* sp.). Analysis of leaf traits revealed correlations among LMA, leaf toughness, and anthocyanin levels, and a gradient of leaf thickness and toughness. Leaves of all tree species with high FEF loads experienced significantly less leaf area loss to leaf-cutting ants relative to leaves with low FEF loads. However, pathogen damage did not differ meaningfully as a function of FEF load. Integrating data from endophyte community analyses provided evidence for variation that can be linked to leaf traits and foliar damage by leaf-cutting ants, with future work focusing on identifying the endophyte taxa or community traits associated with these differences. Together, our results illuminate how endophytes may be integrated into leaf defenses and the broader context of leaf traits. **Keywords:** Ecology, endophyte, mycology, leaf traits, plant-microbes, ant, pathogen, fungi

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The Impacts of Selective Logging on Traits of Recovering Seedling Communities in Bornean Tropical Forests

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Selective logging is a common form of disturbance in tropical forests, changing micro-environmental conditions and potentially the plant community composition of lowland tropical forests. Recruitment of seedlings is important for the recovery of logged forests, but we lack an understanding of how logging affects seedling

physiology, mortality and selection processes, which limits efforts to enhance the resilience and restoration of logged forests. We studied 14 traits (biomass allocation, leaf and root morphological and leaf chemical traits) of 399 woody plant seedlings from 15 common species growing in forests 27 to 39 years after selective logging (n = 204) in naturally regenerating and actively restored forest and compared them to traits of seedlings in neighbouring unlogged primary forest (n = 195) in Sabah, Malaysian Borneo. We also censused seedlings from 183 1 m^2 plots for ~1.5 years (4 censuses) immediately following a mast fruiting event to estimate species' annual mortality rates. Seedlings in logged forests had greater community-weighted means (CWM) of belowground biomass allocation and leaf thickness, but lower CWM leaf area per unit shoot area than those in old-growth forest. Species only found in both primary and logged forest, hereafter old-growth specialists, (n = 7 species) also increased belowground biomass allocation but had reduced foliar nutrient concentrations, higher leaf mass per area and lower specific maximum root length when growing in logged forest. Mortality rates did not differ significantly between logged and unlogged forests when compared across all censused individuals (n = 4970 individuals), but they were higher in logged forests for the seven old-growth specialists when comparing their mortality rates between primary and logged forests (n = 3436 individuals). In logged forests, species with higher foliar nitrogen concentrations displayed lower mortality rates. Species found in logged forests had a wider range of trait values, but because the dominance of pioneer species was spatially heterogeneous, local 1 m^2 functional diversity was lower in logged than unlogged forest. At the community scale, seedlings allocate relatively more biomass to roots and less to leaves in logged forest, which suggests that below-ground resources (water, nutrients) may be more limiting than light in this environment. Our results indicate that more pioneer species have a greater capacity to naturally regenerate than old-growth specialists. Consequently, active intervention may be required for old-growth specialists to successfully recruit and for functional diversity and long-term resilience to future environmental change to be maintained in selectively logged tropical forests.
Keywords: Biomass allocation, functional traits, mortality, selective logging, leaves, Roots.

Root Responses to Water Limitation in Seedlings from Dominant Tropical Andean Forest Species

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An increase in severity and frequency of droughts is one of the most pervasive manifestations of global environmental change that can result in protracted periods of water limitation for terrestrial ecosystems. The consequences of these effects have been analyzed mainly on adult trees of many ecosystems. However, previous studies have suggested the importance of studying the water limitation consequences on seedlings, because they represent forest turnover and exhibit a wide range of potential responses to water limitation based on the plasticity of their traits. These responses include adjustments in allocation patterns for morphological, physiological, and anatomical traits that can confer resistance to water limitation. Among the functional traits associated with the response to water limitation, root traits represent some of the most important, yet least studied traits, that relate to plant water uptake, nutrition, and growth. This type of assessment is particularly required in highly diverse ecosystems such as Andean Forests, where environmental change is projected to be intense, highlighting the importance of functional acclimation to water limitation. In this study, we are using a controlled water limitation experiment to evaluate the potential response of root systems in seedlings of selected dominant species on tropical Andean forests (Q*uercus humboldtii, Croton magdalenensis, Erythrina edulis, Meriania nobilis,* and *Clusia sp.*). This experiment includes four soil water content levels in the range of plant available water (PAW). Seedlings are subject to three successive drydown curves that start at (1) control (field capacity), (2) 80% of PAW, (3) 50% of PAW, and (4) allowed to drydown completely. We rewater all treatments (except in 4) to restart each drydown curve, and harvest seedlings to measure root functional traits related to soil space occupation, plant carbon storage, plant water acquisition, plant biomass allocation, and symbiotic relationships. Our preliminary results emphasize that interspecific differences in root architecture seem to determine seedlings resistance to water limitation. Species with thicker and deeper roots such as *Clusia sp.* and *C. magdalenensis* have a higher survival rate than species with thinner and shorter roots like *M. nobilis*. These results will be useful to unveil a specific information gap on the ecological vulnerability of highly diverse Andean ecosystems. Also, they can serve as a tool to inform strategies that incorporate water limitation resistance criteria for successful climate-resilient ecosystem restoration. **Keywords:** Drought resistance, root traits variation, climate change, native species

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Vulnerability of Andean Forest Tree Species to Water Limitation and Its Effect at Ecosystem Scale

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The vulnerability of ecosystems to climate change-related droughts is one of the most current environmental and societal challenges. Droughts have been among the main drivers of tree mortality in the last decades. However, the effects of droughts on tree species have not been systematically evaluated in tropical Andean forests, a highly diverse humid ecosystem that provides services for a large portion of the population in Andean countries including Bolivia, Perú, Ecuador, Colombia and Venezuela. Previous studies suggest that some plants from humid habitats can acclimate to atypical dry periods, opening opportunities to study the functional mechanisms behind drought resistance. For this purpose, we are conducting an experiment in which seedlings and juveniles of five plant species are exposed to water limitation treatments. These species are dominant trees from Andean Forest that are representative of a range of potential ecological responses. We are also measuring mortality rates and functional traits related to the trade-off between carbon assimilation and water conservation during water stress. Our experiment consists of four soil water content levels in the range of plant available water (PAW). Plants are subjected to successive dry-down curves that start at (1) field capacity (control), (2) 80% of PAW, (3) 50% of PAW, and (4) field capacity and soil is allowed to dry-down completely. Our preliminary results show that species can have response times in the order of weeks. Also, species have different mortality rates like *Merinia nobilis* that shows a higher mortality rate than others. Furthermore, we have found that successive soil drydown had intense effects on plants such as *Croton magdalenensis* and *Erythrina edulis* that exhibit wilting and loss of turgor on leaves, and higher mortality rate after the second drydown curve. In terms of plant functional traits, we found that water limitation has a strong effect on carbon assimilation, leaf area and growth rates. For instance, we have observed an evident decreased growth rate in plants exposed to water limitation treatments compared with the control group for all species. Nevertheless, that effect could differ among species because of their strategies such as physiological regulation, carbon storage, and carbon allocation. Our results provide general insights on the functional mechanisms that are relevant to project the overall effects of water limitation in the functioning of the Andean tropical forest. This information is key to improve management and restoration of ecosystems, land use planning and ecosystem-based adaptation programs in the region. **Keywords:** Climate change, drought, Andean Forest, vulnerability, plant functional traits

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Traits to Cope with Drought: Functional Responses to Water Limitation in Five Native Tropical Andean Seedlings

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Extreme drought events have modified the climatic conditions for the Tropical Andean forests, placing their diversity and ecosystem function at risk. The persistence of forests in the face of climate change depends on how trees at different ontogenetic stages respond to drought. The seedling stage is crucial for the population turnover of forests, for this reason, understanding the strategies to cope with drought is essential to assess the vulnerability of Andean Forests to climate change. However, little research has been done to evaluate those strategies in native species from the Andes, and even less with seedlings. Ecophysiological resistance to drought can be assessed through the measurement of aboveground plant functional traits (on leaves and stems), which are crucial to understand water use and regulation under water limitations. Here, we evaluate how five dominant native tropical Andean species respond to water limitation through the measurement of functional traits on leaves and stems on seedlings, to determine their functional response to water limitation. We conducted a controlled greenhouse drought experiment on *Quercus humboldtii*, *Croton magdalenensis*, *Clusia sp.*, *Erythrina edulis* and *Meriania nobilis* with four irrigation treatments based on different levels of plant available water capacity: Field capacity (control), 80% and 50% of field capacity, and complete water exclusion. Within each treatment, 30 individuals of each species were randomly arranged. We are measuring stems and leaves anatomical, morphological, physiological, and functional traits such as net rate of carbon assimilation, SLA, leaf water potential, and pit xylem density and survival rate of the species. Our preliminary results indicate that all species, but *Cluisa sp.*, accumulate less aboveground biomass under the 80% and 50% treatment than in the two extreme treatments. Net carbon assimilation shows different trends within each treatment and across

species, having its photosynthetic peak hours earlier in treatments that have some level of water limitation compared to the control treatment. Also, *C. magdalenensis* exhibited higher net carbon assimilation than the other four species across the 4 treatments. *M. nobilis* is the species with higher mortality rate in the three water limitation treatments, compared with the other species. These results are important to understand the different mechanisms that native Andean plants use to withstand water deficit and to cope with drought. This information is useful to project forests resilience under climate change, and in terms of conservation, this information can be used to strengthen climate change adaptation management. **Keywords:** Ecophysiology, drought, climate change, native species, greenhouse, functional traits

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Abiotic Drivers Have Shaped Trait Evolution and Trait-environment Matching in a Neotropical Radiation (*Swartzia, Fabaceae*).

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Introduction: Functional traits have major implications for plant fitness and directly affect ecosystem function and service. Leaf, fruit and petal size are important functional traits related to key ecological and physiological processes, but is remains unclear whether adaptive processes in response to the abiotic environment have shaped the macroevolution and distribution of those traits across ecological communities and abiotic gradients. We focus on the Neotropical *Swartzia* radiation, with approx. 200 extant species, to disentangle the macroecological and macroevolutionary drivers of trait environment matching. **Hypothesis:** We test the hypothesis that environments with extreme conditions (i.e., those with lowest rainfall, highest temperatures and poorest soil nutrient content) have shaped trait morphology by imposing strong selective pressures and / or ecological filters, resulting in traits matching the environment as a result of macroevolutionary, adaptive processes and others as a result of ecological filtering across communities. **Methods:** A novel trait database including leaf, fruit and petal sizes for approx. 80% of all *Swartzia* species was assembled from monographs and herbarium collections, and was integrated with distribution data, soil data, climatic niche modelling, and phylogenetic reconstructions. We used phylogenetic linear regression and correlated trait evolution models to assess to what extent trait-environment matching is affected by evolutionary history, and to identify whether transitions to extreme environments were conditional on the evolution of particular trait states. **Results:** We found that evolutionary transitions to relatively low rainfall and poor soil nitrogen content were conditional on the evolution of respectively small leaves and large fruits, supporting a pre-adaptation model (i.e., traits evolve before the environmental transition). However, the evolution of petalous and apetalous flowers was conditional on the presence of environments with respectively high and low annual mean temperatures, supporting an adaptive model (i.e., trait evolution follows the environmental transition). Furthermore, additional climatic variables (e.g., seasonality) have influenced the distribution of *Swartzia* species into ecological communities, independent from correlated evolution between the respective traits and the environmental niche. Significance: This study emphasizes the important role of deep-time, macroevolutionary processes in shaping trait-environment matching during evolutionary radiation, and illustrates how abiotic factors have shaped plant trait evolution and distribution in the Neotropics **Keywords:** Macroevolution, macroecology, functional traits, ecological filters, neotropics, legumes, *Swartzia*

Functional Distributions Patterns of Plants in Tropical Dry Forest of La Guajira, Colombia

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Studies on community assembly mechanisms of plant species in tropical forests have shown contrasting positions between the predominance of biotic and abiotic selection forces at local scales. We determined the influence of local topography variations and the effects of functional density-dependence on the functional distribution patterns in a tropical dry forest (TDF). For this, we measured leaves and wood traits for the most dominant species in a 10-h permanent plot and used the topographic information to define local variations in the environment. To evaluate the effects of density-dependence, we use the effective distance of the nearest neighbor and functional similarity index to determine the proportion of the biotic and abiotic filters influencing the community assembly. We found that environmental filtering dominates community assembly

locally because it determines the space where species survive, driving the aggregation of species with similar functional strategies. However, under less limiting environmental conditions, species with the same functional strategy have a competitive exclusion that leads to overdispersion. We found weak biotic competition between individuals with the same strategy and a facilitation between individuals with different functional strategies. We conclude that the abiotic filters determine the community assembly with environmental limitations, while the biotic filter acts when the environment ceases to be a limitation. In addition, this research gives guidelines to understand how plant species are assembled in the tropical dry forest, which will contribute to the design of strategies aimed at the conservation and restoration of this highly degraded ecosystem in Colombia. **Keywords:** TDF, assembly rules, functional traits, Functional distributions patterns

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Contrasting Community Assembly Mechanisms Drive Regeneration in Caribbean Tropical Dry Forest following Clearcutting and Fire

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Understanding how environmental and biological factors drive forest succession continues to be a primary focus for community ecologists. However, our knowledge of assembly mechanisms driving forest regeneration following different disturbance-types remains limited, especially in the dry tropics. We pay particular interest to resprouting, an important regeneration niche in tropical dry forests (TDF) that may alter or obscure assembly outcomes using a trait-based approach through its influence on demographic processes and the relative contribution of species post-disturbance. In a very dry tropical forest in Puerto Rico we asked: 1) How does functional recovery proceed in communities subjected to clearcutting and fire?, 2) What mechanisms of assembly drive succession in our two disturbance communities? We censused 44 tree species across a 47-yr clearcut and 34-yr fire chronosequence and collected data on ten physiological and morphological traits related to a species' resource economics and resprouting behavior. The community-weighted trait distributions were quantified including the community-weighted mean, variance and trait range to determine the relative contribution of different assembly mechanisms to recovery post-disturbance. We tested trait distributions weighted by abundance and basal area predicting each differed in their importance to different disturbance types. Over time, community-weighted means showed both clearcut and fire communities exhibited shifts in functional strategy from resource conservation to resource acquisition. However, fire sites showed a much greater rate of change consistent with higher resprout mortality in contrast to more gradual shifts in strategies following clearcut. Simultaneous multiple assembly processes may be driving succession in both our clearcut and fire sites. During early succession, we found functional similarity in drought tolerance (low ψ_{max}) and resource conservation (low SLA and $\delta^{13}C$) in clearcut and fire sites respectively highlighting the influence of abiotic filtering. However, in later succession, disturbance-types exhibited contrasting assembly mechanisms. Reduced trait range and variance in fire sites were linked to higher abiotic constraints imposed by poor canopy development and competitive hierarchies associated with exotic grass invasion. By contrast, gradual divergence of resprouting syndromes and resource acquisition strategies in later successional clearcut sites showed an increase in biotic interactions and concurrent decrease in the abiotic filter. Overall, whereas regeneration in clearcut communities more closely resembled 'natural' TDF successional trajectories, post-fire sites showed signs of arrest and limited functional recovery. Our study highlights the complexity of TDF assembly as resprouting niches can influence demographic forces structuring communities and multiple assembly processes may operate simultaneously. **Keywords:** Resprouting, Puerto Rico, abiotic filtering, functional traits, chronosequence, disturbance, fast-slow

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Habitat structure, fragmentation, connectivity I

Weak Edge Effects on Trees in Bornean Rainforest Remnants Bordering Oil Palm

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Background: Many tropical forests are highly fragmented and are dominated by edge habitat, with consequences for forest structure, carbon stocks and biodiversity. However, edge effects are highly variable and context-dependent, and are poorly quantified in oil palm landscapes, despite the widespread existence of these landscapes in many tropical regions. **Objectives:** We sought to quantify the effects of edge proximity on forest structure, aboveground carbon stocks, microclimate, and tree community composition and richness, in forest edges bordering oil palm plantations. **Methods:** We worked in 10 lowland rainforest remnants bordering mature oil palm plantations on Borneo, surveying 0.2 ha plots along transects running perpendicular to the forest edge (ten 1.6 km transects, 5-6 plots per transect, 57 plots in total). Within each plot, we measured forest structure (canopy cover, number and size of stems 10 cm diameter), aboveground carbon stocks, microclimate (air temperature and light intensity), and tree community composition and richness, and used mixed-effects models to analyse the effect of edge proximity on each variable. **Results:** The largest trees were significantly smaller (up to 21% reduced diameter) in plots near edges, and plot-level carbon was up to 30% lower (model-fitted average = 64.7 Mg ha^{1} at 50m from the edge, versus 92.3 Mg ha^{1} at 1600m), with the strongest effects within 300m of edges. However, these significant effects of edge proximity were relatively small in the context of existing variation, with distance-from-edge explaining $<$13% of the total variability in maximum tree size or carbon. Additionally, there were generally no effects of edge proximity on any other component of forest structure, composition or diversity, and only a weak effect on microclimate. Implications & Conclusions: If oil palm agriculture is to become sustainable as the industry continues to grow, it is important that edge effects on large trees and associated carbon stocks are taken into account when developing sustainability criteria, to ensure the long-term integrity of forest remnants that are protected within plantation landscapes. Overall however, our results suggest that mature tree communities in oil palm landscapes may be less vulnerable to edge effects than those in other agricultural landscapes. We conclude that limited edge effects in this system may reflect low structural contrast between forest and mature oil palm, and limited invasion of pioneer trees from plantations, which diminished edge influence in highly heterogeneous forest remnants. **Keywords:** Agricultural expansion, biodiversity, carbon storage, forest fragmentation, tropical trees

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Global Vs National: How Well Global Forest Integrity Products Represent Habitat Conservation in Colombia

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Forest integrity represents the degree of forest structure, composition, and function modification by anthropogenic activities. Robust assessments of forest integrity are critical for understanding patterns of ecological

forest condition and ecosystem services, as well as to design forest management strategies and establish platforms to monitor compliance to national and international environmental agreements (e.g., CBD, Aichi, SDGs, REDD+). Colombia's forest diversity hinders the development of robust integrity indices as it is unlikely that one solution will fit all. Recent global indices that take advantage of high resolution remote sensing data and thematic products of human pressures can help to address this challenge. These indices include the forest landscape integrity, human pressure and its trends, or forest intactness. However, the key question for many countries is how much they should rely on these global products and how much effort they should put on developing their own. Here, we adapt two global forest integrity indices (SCI from Hansen et al., 2019 and FLII from Grantham et al., 2020) for Colombia, using historical forest distribution data and mapping of canopy height calculated with the integration of LIDAR, multispectral and SAR data. Then, we test how national and global indices perform as a proxy of habitat quality by evaluating the mismatch among integrity values and biological records (mainly high-quality forest dependent species and exotic species associated with high levels of ecosystem degradation). Comparisons across scales indicate a regional signal on the mismatch between global vs national products that could be traced back to differences in data layers used for each one (e.g., prehispanic forest dynamics that are not represented in satellite imagery, morphological differences along altitude gradient and forest cover overestimation related to clouds). We detect that although most forest dependent occurrence data lie in areas with high integrity values for global and national indices, there are some mismatches associated with the spatial resolution of the underlying data, specially in those regions with particular forest features. For exotic species, we detect occurrences in areas with higher integrity values in global indices than national indices. The final forest integrity layer will be used to assess different features and processes in Colombia more precisely (e.g., structure, connectivity and dynamics), taking into account its high forest diversity and being supported with an interdisciplinary working group. We hope that this method could be a guideline to enhance future forest research and management in tropical forests. **Keywords:** Forest integrity, data combination, species occurrence, Colombia

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Using the Species Habitat Index to Measure Progress towards Goal-A of the Post-2020 GBF at a Country Level for Colombia

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The post-2020 Global Biodiversity Framework (GBF) seeks to achieve the future vision of the Convention on Biological Diversity of "living in harmony with nature by 2050". This builds upon the achievement of the Sustainable Development Goals by 2030 and aims to involve stakeholders at different scales. The Group on Earth Observations Biodiversity Observation Network (GEO BON) has developed several indicators to document biodiversity change and measure the achievement of these goals. The Species Habitat Index (SHI) measures the change in the quality of species (or a group of species) habitats, including habitat size and connectivity, and it is derived from the species population Essential Biodiversity Variable class. This index is handy to use because its measurement can be pretty straightforward and with the availability of global land covers, the IUCN range maps and data from GBIF, it can be calculated at a global level or, according to the availability of information, at a country or regional level. However, the connectivity measurement suggested for its calculation - distance to the edges, a structural connectivity measure - although it can be quickly calculated, can be more related to the fragmentation of the habitat than its actual connectivity. Therefore, this study evaluates how the proposed connectivity measurement and other connectivity metrics reflect the habitat condition for different species of the Tropical Dry Forest in the Caribbean Region of Colombia, a highly fragmented ecosystem in the country. However, in order to keep the index handy, usability metrics will be considered for the selection of the most adequate connectivity metric to use. Additionally, this study also compares how the SHI behaves when applied at a country level and using national official information vs. the global approach. According to the outputs of this study, if the other connectivity metrics capture better habitat conditions, the modified methodology to calculate the SHI will be proposed for the SHI calculation. **Keywords:** Conservation goals, essential biodiversity variables, connectivity, indicators, monitoring networks

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Tracking Detailed Tree Level Dynamics of Tropical Forest Landscapes Using Deep Convolutional Neural Networks and Multitemporal, Multimodal Remote Sensing Data Sources

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Tropical forests are an essential part of the global carbon cycle and home to two-thirds of terrestrial species. Improved monitoring of the growth, mortality and phenology of individual trees is essential to evaluating the resilience of tropical forests to climate change and other anthropogenic pressures. Identifying individual trees in tropical forest canopies from remote sensing data is challenging due to the diversity of species, the complex structure and spectral impurities from lianas and epiphytes. Modern convolutional neural network approaches can novel generate insights from aerial remote sensing imagery. Here we describe a new machine learning method which uses the Mask R-CNN algorithm to delineate tree crowns in tropical forest landscapes from RGB imagery. We deployed it to delineate 20,000 tree crowns in aerial images collected in Amazonian French Guiana and compared its accuracy to the AMS3D segmentation approach on LiDAR data. To assess its ability to identify tree species we compared its species identification of the delineated crowns to a machine learning approach (linear discriminant analysis with support vector machine) applied to hyperspectral imagery. To demonstrate an application of the methods, we tracked the foliar phenology of the species and individuals over an 18 month period. The skill of our automatic method in delineating the canopy tree crowns was high (F_1 score = 0.74) compared to the LiDAR clustering approach (F_1 score = 0.60). Its skill was further be improved when several time steps (12 dates) of imagery were used to locate the crowns ($F_1 = 0.82$). The hyperspectral machine learning was able to label the crowns of the 80 most common species with an average F_1 score of (F_1 score = 0.83). Our approach demonstrates that modern computer vision methods can automatically process abundant RGB imagery to characterise the dynamics of tropical forests. The spectral richness of hyperspectral data allows for identifying more species with greater accuracy than the RGB approach but further development of methods may close the gap. The methods could be scaled and applied to satellite based Earth observation data for global analyses of forest dynamics and resilience.

Habitat structure, fragmentation, connectivity II

Landscape Heterogeneity Can Compensate the Negative Effect of Habitat Loss on Biodiversity in Agroecosystems

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Agriculture promotes not only the *conversion* of native habitats but also the homogenization of landscapes – causing species turnover and biodiversity loss. However, in contrast to the well-documented negative effects of habitat loss, the potential of landscape heterogeneity – i.e. the diversity of land uses and of their spatial configuration – to prevent species loss is a pressing knowledge gap. This is mostly because of the dominance of the habitat/non-habitat perspective and the pervasive correlation between landscape homogeneity and habitat loss in available studies. Here, we analyze the relative importance, additive and interactive effects of habitat amount and landscape heterogeneity on mammal biodiversity to investigate whether heterogeneity can compensate for the loss of native vegetation in agricultural areas. We rely on an extensive landscape-scale field data, obtained through a sampling design across 55 landscapes that maximized variation, while minimizing correlation, between landscape heterogeneity and native vegetation amount. Our region is in a global conservation hotspot and a key commodity production area – the Brazilian savanna, Cerrado. We used a standardized protocol that included cameras-trap and transects to sample both native vegetation and agricultural land uses within each landscape. Then, we compared the plausibility of mixed-effects models of the richness and composition of native and exotic mammals as a function of single, additive, and interactive combinations of metrics of landscape heterogeneity and native vegetation cover. Both richness and composition of native mammals were best explained by the positive and additive effects of landscape heterogeneity and native forest cover, while the isolated and negative effect of native savanna cover best explained the richness of exotic mammals. Hence, we report strong evidence that – for native biodiversity – the positive effects of heterogeneity in land uses can compensate for the lack of native vegetation in agroecosystems, highlighting the conservation potential of policies centered on avoiding landscape homogenization in agriculture frontiers. Moreover, we report evidence on the role of native savannas as barriers to invasive mammals, suggesting the danger of ongoing degradation and afforestation of these habitats in promoting the spread of exotic species – such as the wild boar and European hare – that are known to cause relevant losses to agriculture. **Keywords:** Agriculture intensification, Cerrado, landscape homogenization, mammals

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Tropical Forest Typologies Distinction and Successional Stage Prediction Using UAV-lidar.

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Introduction: In order to mitigate the effects of climate change and ensure the future sustainability of tropical forests, it is crucial to restore degraded and previously forested lands. Field surveys still remain the most effective and efficient method of monitoring degraded forests and restoration areas but are labor-intensive and costly. Using Unmanned Aerial Vehicles (UAVs) and visual sensors, hundreds of hectares of forests can be monitored in a short period and the spatial data can be produced in high detail. Additionally, light detection and ranging (LiDAR) sensors on UAVs have made it possible to observe forest structural differences at the vertical and horizontal levels. **Object:** In a tropical forest restoration context in the Atlantic forest of Brazil, we explored the potential of UAV-borne LiDAR for distinguishing forest typologies and succession stages. **Methods:** This study covered 150 forest plots that included six forest types, which were also classified as natural forests and plantations. For our analysis, we extracted several metrics from the canopy height model and point cloud statistics from UAV-borne LiDAR data. **Results:** Natural and plantation forests were classified using a random forest model with 90% accuracy. Despite a lack of accuracy overall (58.7 %), monoculture plantation, restoration plantation, and natural regeneration could be classified with Producer's accuracy of 76.8, 70.0, and 54.2%. Among the most important classification metrics were the understory Leaf Area Index (LAI), and may help advance ecological understanding. Basal area (BA), a proxy for successional stage, was well predicted with $r2=0.9$, mainly by the recently developed metric called Leaf Area Height Volume. **Implications:** UAV-LiDAR data showed the potential to identify complex forest structures at a plot scale, and distinguish forest types and successional stages, widely distributed across different regions, with medium to high accuracy. Optical sensors will be further employed to characterize and differentiate forest types. **Keywords:** Remote sensing, forest restoration, forest ecology

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The Interaction between Ecological and Management Factors in Maintaining Net Primary Productivity in a Tropical Forest Landscape

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Protected areas (PAs) are effective in maintaining high species diversity and preventing forest loss within their boundaries. In landscapes with environmental variability, species diversity can buffer against change and increase the temporal stability of forest functioning. Net Primary Productivity (NPP) is a key ecosystem function that influences the contribution of forests to the global carbon cycle and is also associated with several regional ecosystem functions. However, NPP varies considerably through space and time, driven by several environmental factors. Disentangling the effects of ecological factors and protection on NPP is crucial to manage tropical forest landscape towards stable functioning in a changing world. We assessed the effectiveness of PAs varying in strictness in predicting interannual variability of NPP in the Andaman Islands, a biodiversity hotspot, through remote sensing, landscape ecology and machine learning. We accessed MODIS and LANDSAT imagery from 2000-2021 from the archipelago, used Google Earth Engine to derive annual maximum EVI (Enhanced Vegetation Index) at every pixel, and calculated stability as the inverse of the coefficient of variation (1/CV) across the timeseries. We sourced information on ecological predictors – island size, edge percent in the island, isolation, precipitation, elevation and slope from BioClim and SRTM. Since boundaries of PAs are not publicly available in GIS formats, we digitised maps from grey literature and assigned strictness values based on the Wildlife Protection Act, India (1972). We finally used random forest analysis to classify 1/CV at the 1km x 1km pixel level based on ecological factors and protection status. We found that forested pixels with higher precipitation and higher elevation were less likely to be protected (GLM with binomial errors, Hosmer-Lemeshow $X2=117.52$, $p<0.05$**). Moreover, we found that elevation is the most important factor in predicting the stability of EVI as well as mean EVI in forested areas across two decades (random forest $n=2534$, mean EVI, $R2=0.55$, 1/CV of EVI $R2=0.56$). Strictness of protection increased mean EVI of a pixel over the time series. EVI stability, however, increased only from the unprotected to low protection conditions, and did not increase with increasing strictness. Finally, we found negative interactions between protection and island area and precipitation in predicting EVI stability. Our results show that ecological factors rank higher than protection in maintaining NPP in tropical forest landscapes. Moreover, we find that negative interactions might constrain the ability of present-day PAs to ensure NPP stability. **Keywords:** Protected areas, NPP, stability, tropical islands, remote sensing

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Classification of Forest Degradation and Regeneration Based on LiDAR and Hyperspectral Remote Sensing

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One major challenge for integrating deforestation, forest degradation, and restoration as part of climate mitigation initiatives is to accurately differentiate forests under disturbance or regeneration processes and relatively intact forests. LiDAR (Light Detection And Ranging) and hyperspectral remote sensing provide complementary information that can improve the characterization of tropical forest classes based on processes of disturbance and recovery. In this study, we explore the combined use of airborne LiDAR and hyperspectral data and advanced machine learning algorithms for improving the characterization of tropical forest degradation/regeneration. We acquired data over 12 sites distributed across the Brazilian Amazon, spanning a variety of environmental and anthropogenic conditions. Four classes were identified (undisturbed forests, degraded forests, and two stages of second-growth forests) using Landsat time series (1984-2017) and field inventory information. To distinguish these classes, several metrics from LiDAR and hyperspectral remote sensing were obtained over 600 sample plots and used as input data to three machine learning classifiers (Random Forest - RF, Stochastic Gradient Boosting - SGB, and Support Vector Machine - SVM). The results showed that the combination of LiDAR and hyperspectral data improved the classification accuracy of forest degradation and regeneration by up to 9% over the use of a single data source. The use of multisensor data was more effective than the use of different machine learning algorithms, and the classification performance varied with the type of data and forest class. The LiDAR-based upper canopy cover and the hyperspectral-based absorption bands in the near-infrared and shortwave infrared spectral regions were the most relevant metrics for characterizing the four forest classes. LiDAR produced significantly fewer errors for discriminating second-growth from old-growth forests, while hyperspectral data had better performance to discriminate degraded from undisturbed forests. Models based only on hyperspectral data performed similarly to LiDAR-only models (mean F1 of 74% for both data sources). The results highlight the potential of integrating LiDAR and hyperspectral remote sensing for improving our understanding of forest dynamics in order to seek better solutions to mitigate climate change impacts. **Keywords:** Successional stages, multisensor analysis, LiDAR, hyperspectral, remote sensing

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Progress toward a National Map of Mountain Peatlands of Ecuador

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Introduction: Peatlands are globally important terrestrial carbon dioxide sinks and methane emitters, therefore, play a critical role in the global carbon cycle and climate regulation. Peatlands represent about 3% of the global terrestrial environment and store about 30% of global soil organic carbon stock. Moreover, peatlands play a critical role in the hydrological cycle and water supplies for vast ecosystems and people depending on this ecosystem. Successful conservation of peatland ecosystems requires innovative mapping approaches which identify and quantify the spatial extent of peatlands and facilitate their monitoring efforts. During the last years, lowland peatlands have been successfully mapped, however, peatlands located in mountain regions face challenges due to their commonly small spatial extend, rugged landscape, and cloudy conditions. **Objective:** The main objective of this study is to develop a methodology to detect and map peatlands and their condition, applying high spatial resolution remote sensing methods in the Andean region of Ecuador. **Methods:** Field sites were systematically selected across the Andean region of Ecuador. Sampled points above 3.000-meters above sea level were collected for training and validation purposes. High spatial resolution optical and radar remote sensing data combined with elevation data were compiled for specific regions. The multitemporal composites of satellite images were handled and processed using Google Earth Engine (GEE). A supervised machine learning algorithm, random forests, was applied to the remote sensing composites to classify land use/land cover classes taking special consideration on peatlands. Finally, confusion matrices were used to assess the accuracy of the resulting peatland maps. **Results:** Mapping mountain peatlands at a national scale is an ongoing process. At present we have successfully identified and mapped peatlands in subregions at high spatial resolution across the paramo of Ecuador. The accuracy of the classification ranges from 80% to 90% accuracy. **Implications/Conclusions:** This study presents for the first time a high spatial resolution map of peatlands across the Andean region of Ecuador. The map identifies the real extent and location of these huge carbon stores and guides the course of actions for ecosystem conservation and restoration. The map will significantly contribute to a better understanding of the implications of peatland disturbances in the land-atmosphere interactions and it will support monitoring of the effects of peatland disturbances on climate change processes. **Keywords:** Peatlands, mapping, remote-sensing, Andean-region, páramos, Ecuador

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Landscape Memory Is Mediated by Climate in Tropical Mountains - Implications for the Spatial Distribution of Landslides

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Background: Landsliding is a critical driver of change in tropical mountains. Recent work suggests that landscape memory - the extent to which past conditions influence recovery after disturbance - is critical to our understanding of ecosystem and community dynamics at large scales. Memory may act in non-disturbed areas by conferring resistance to future disturbance. Although there is evidence that topographic factors control the spatiotemporal distribution of landslides in these mountainous systems, little is known about the role of vegetation regrowth in modulating landslide recurrence. One corollary is that changes in the vegetation driven by global climate change may influence regrowth, thus forming memory linking past and future disturbance. If true, examining relationships between landslide co-occurrences and causational factors, both bioclimatic and topographic, will clarify the role of memory, bettering our understanding of future landscape trajectories. **Objectives:** In this study, we address three questions. First, how are landslides and landslide co-occurrences influenced by bioclimatic and topographic variables? Second, do the same factors influencing landslides influence co-occurrences, inhibiting memory? Third, where will memory function effectively and fail in anticipation of shifting climatic conditions? **Methods:** This work centers on the Sierra de Las Minas (SLM) mountains in eastern Guatemala which exhibit diverse climatic conditions. We processed remotely sensed data (1969 – 2020), creating seven landslide inventories in the form of vector shapefiles and used degree of landslide overlap between periods to represent co-occurrence and non-overlap as recovery. In ArcGIS Pro we extracted areas of overlap and non-overlap between contiguous years in our time series. Subsequently, we converted these polygons to points to model their relationship with bioclimatic and topographic variables using species distribution modeling (SDM). Finally, we predicted occurrence and co-occurrence distribution to identify areas resistant or susceptible to future land sliding. **Results:** Landslide occurrences totaled 972, 539, and 1,987 and impacted 424, 252, and 129 ha in 1991, 1998, and 2006 respectively. Less than 9% of the landslide-impacted area was affected by new landslides. Different sets of variables explained the occurrences and the two periods of co-occurrences. The first period of co-occurrences (1991-1998) retained one bioclimatic (positive relationship with precipitation during the wettest month) and one topographic (positive relationship with slope) variable. The second period (1998-2006) retained additional bioclimatic (positive relationship with isothermality) and topographic (negative relationship with aspect) variables. **Conclusions:** Our models suggests that in the SLM, memory is disrupted by bioclimatic conditions. This has the possibility to inhibit vegetation regrowth under conditions of increased precipitation and temperature variability associated with climate change. **Keywords:** Landscape memory, landslides, bioclimatic, vegetation, recovery, species distribution modeling, mountains

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Agents, Factors, and Indicators of Vegetation Anomalies in the Bolivian Amazonia

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Introduction: The Bolivian Amazonia is a region rich in timber and non-timber species such as the Brazil nuts trees, considered the cornerstone of forest conservation. Timber and non-timber products are the source of income for indigenous peoples, communities of forest dwellers, and timber and non-timber private concessions. Forest conservation is crucial for the region. Wildfires, land-use change, encroachment, and forest resource extraction are among the main factors inducing forest degradation. Additionally, drought is one of the environmental factors threatening Amazonian forests. **Objectives:** We assessed the variation of vegetation photosynthetic reflectance in Pando, Bolivia, from 2001 to 2021. The objective was to examine the relationship between the anomalies in the vegetation and the land-use categories and factors influencing such anomalies

to obtain indicators of vegetation stress. **Methods:** We use the Enhanced Vegetation Index (EVI) obtained from the product MOD13Q1 and MYD13Q1 of the MODIS optical images (250 m) to quantify the vegetation reflectance during the dry season. We derived the vegetation condition index (VCI) from EVI values. VCI shows the differences between the EVI for a given month, and year and the minimum EVI value of the whole series divided by the difference between the maximum and minimum values of anomalies of EVI over the 20 years of each MODIS pixel of analysis. **Results:** Our results show EVI values below -0,2 in 2007, 2019, and 2021 indicating greenness anomalies. We then applied VCI for 2021 and found lower values or severe to extreme vegetation anomalies concentrated in the central and north of the department of Pando, and roadside, coincident with settlements, and some timber concessions, whereas indigenous and protected areas have the highest percentage of areas in non-anomalous pixels. Preliminary field visits show that the detection of anomalies corresponds to processes of forest degradation due to wood extraction, fire events, and conversion of forest to pasture. Interestingly, in these areas, there has been evidence of the presence of bamboo (*Guadua* sp.) that becomes dominant after forest degradation. **Keywords:** Forest cover, land use, vegetation anomalies, EVI, Amazonia, Bolivia

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Mapping Forest Age And Characterizing Vegetation Structure And Species Compositition In Tropical Dry Forests Using Machine Learning Algorithms

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Introduction / Background / Justification: Land use changes generate a mosaic of forest patches with different ages of abandonment (i.e. succession) intermingled with other land uses. Mapping the successional age of vegetation is crucial to understand carbon accumulation patterns and the recovery of vegetation structure, diversity, and composition of forests over time. And because, secondary forests can also provide key ecosystem services and those ecosystem services can vary depending on the age of succession. **Objective(s):** Here we had two main objectives, 1) to produce maps portraying secondary vegetation age classes and 2) to assess how successional age classes can be related to vegetation structure, diversity and composition in two types of tropical dry forests (TDF) in the Yucatan Peninsula in Mexico. **Methods:** To generate the vegetation classification maps we used a two-stage image classification process. First, SPOT-5 imagery was segmented using the Python 3.6 RSGISLIB package and then classified using a Random Forests method in R. Second, the classified images were post-processed to rectify any classification errors. This process consisted of the reclassification of those polygons that showed some spectral confusion and zonal statistics of the polygons were used for a deeper visual inspection. Finally, the maps were validated after post-processing. To evaluate the differences between vegetation structure, diversity and composition, mean values and 95% confidence intervals were calculated for vegetation attributes such as diameter, stature, abundance, basal area, species richness and species composition in each forest age class separately for the two types of TDF. **Results:** We found that post-processing improved the accuracy of the Random Forests classifications by 14.19% and 16.28% for the tropical semi-deciduous and semi-evergreen forests, to attain final accuracy values of 91% and 88.37%, respectively. Vegetation structure, richness and composition were all strongly associated with successional age, accounting for 77.7% and 84.7% of the total variation among forest age classes for the tropical semi-deciduous and semi-evergreen forests respectively. **Implications/Conclusions**: The forest age maps obtained can be related to attributes of vegetation structure, diversity and composition that are useful for biodiversity conservation, forest management and climate change mitigation. The current and constant transformation of forests, mainly as a result of human activities, triggers structural and compositional changes within natural ecosystems. So, through the characterization of secondary forests it is possible to know in part the resilience capacity of forests and the recovery of biodiversity and its ecosystem services over time. **Keywords:** Stand age, land cover classification, secondary forest, chronosequence, species richness and composition, above ground biomass

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Habitat structure, fragmentation, connectivity III

Understanding the Impact of Habitat Transformations in Differential Landscape Structures on a Tropical Andean Epiphytic Orchid

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The tropical northern Andes region is considered a biodiversity hotspot, Orchidaceae family has species and endemic species concentrated in this region. In contrast little attention has focused on understanding the impact of habitat transformation on these native orchid species. Landscapes are highly heterogeneous in the Colombian Andes, and landscape structure may impact population and species conservation status. We aimed to explore the impact of different patterns of habitat transformation in the endemic Colombian twig epiphyte, *Rodriguezia granadensis* (Lindl.)Rchb.f.. This species has a wide distribution in the mid elevations of the three Colombian cordilleras (1,200-2,200 m.a.s.l.), and notably colonizes isolated trees within pastures. We compared population demography and genomic population structure between forest and pastures in two regions with contrasting landscape structures: with a dominant pasture matrix (Valle del Cauca) and with a dominant shade coffee matrix (Cauca). We undertook four censuses in 3 populations each in forest and pasture in each landscape over two years. Data from the postbreeding censuses were used to calculate the demographic transition matrix using asymptotic and transient models. Landscape genomic structure was assessed using ddRADseq. In the landscape with dominant pasture, we found lower population growth rates (lambda=0.65), with higher inbreeding (Fis= 0,040) and less genetically connected populations (Fst=0.0043). In the contrasting landscape, growth rates were higher (Lambda= 0.77), with no evidence of inbreeding (Fis= -0,035), and higher connected (Fst=0.003). Comparison between orchid populations in native forest habitat and in trees in pasture showed equivalent fruit set, however the populations in forest revealed higher fecundity (F=0.7, P=0.1), as wells as larger Ne (F=45, P=20) and higher genetic diversity (ForestHe= 0,385, PastureHe= 0,215). In pasture, orchids occurred in higher densities aggregations in isolated trees, although recruitment and survival were extremely low. Demographic and genetic patterns indicate the impact of habitat transformation on these populations of the orchid *R. granadensis* and their relative resilience in different landscape structure. The more connected landscape permits more connected populations and greater possibilities for growth and survival, interacting with pollinators, phorophytes, and microenvironment. We emphasize the need to integrate different approaches and organizational scales, using a "model" species to develop a detailed understanding of population and demographic processes in transformed landscapes. **Keywords:** Tropical epiphyte, population genomics, ddRADseq, demography, matrix models, *Rodriguezia granadensis*

Mapping Forest Structure and Tree Diversity in Colombia, South America

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Introduction/Background/Justification: Understanding spatial patterns of forest structure and diversity in tropical forests is indispensable for their sustainable use and conservation. National-scale mapping of forest structural characteristics (e.g., Canopy height-CH, Median Canopy height-MCH, Plant Area Index-PAI, Total Cover-COV, Foliage Height Diversity-FHD) is now feasible by integrating lidar measurements with continuous remote sensing imagery (e.g. multispectral and SAR). Recent studies have also reported robust relationships between forest structure measurements and tree α-diversity estimated from forest inventories, allowing the mapping of tree α-diversity in tropical forests. These studies relied on inventories with coincident lidar data to create tree α-diversity maps. GEDI (Global Ecosystem Dynamics Investigation lidar) has generated millions of high-quality measurements of forest structure in tropical forests from 2019, but GEDI data rarely coincide with forest inventories. However, GEDI's extensive sampling may allow wall-to-wall maps of derived forest structure to be used in place of coincident lidar surveys. **Objective(s)/Hypothesis(es):** Our objectives in this research were to (1) use GEDI and satellite imagery to create wall-to-wall maps of forest structure variables for Colombia (2) use these maps to create maps of tree α-diversity. We hypothesized that tree α-diversity would be related to forest structure and environmental variables at plot scales, revealing patterns at ecoregional scales. **Methods:** Methods were divided in two parts: (1) We created maps of five forest structure variables for Colombia (CH, MCH, PAI, COV, and FHD), relating over one-million GEDI footprints to 80 temporal and textural metrics of Sentinel-1, Sentinel-2 and PALSAR imagery using Random Forest regressions. ANOVAs were used to compare the resulting structure maps among Colombian natural regions. (2) We created three maps of tree-diversity (Richness, Shannon index, and Simpson index) for the Colombian Amazon, relating tree-inventory data to the five forest structural maps and 63 environmental variables. Mean absolute percentage errors (MAPE) were used to estimate modelling errors. **Results:** MAPE of the forest structural maps varied between 5% and 22%. Forests in the Amazon and Chocó regions, dominated by moist forest types, are taller, denser, and more complex than forest in the Caribbean and Orinoquía, regions heavily disturbed or dominated by dry forest (F-values > 292, p-values < 0.05). The highest concentrations of tree α-diversity are in non-flooded forests of the central and southern Amazon. Flooded forests and forest/savanna-transitions show lower diversities. **Implications/Conclusions**: Our mapping methods enable predictions of tree α-diversity where species inventories are available for calibration. Thus, they are a useful new tool to advance the sustainable management and conservation of tropical forests. **Keywords:** Forest structure α-diversity, forest inventories, spatial analysis, remote sensing GEDI, Amazon, Orinoquía, Chocó Andes

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How Does Landscape Structure Affect Mammal Species? a Case Study of Highly Fragmented Dry Forest Landscape in Ecuador

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Introduction/Background/Justification: Land-cover change is estimated to be the largest driver of biodiversity loss worldwide. Therefore, it is necessary to improve our understanding of how species respond to land-cover changes in their landscapes, especially in already highly fragmented landscapes such as tropical dry forests (TDFs). **Objectives/Hypotheses:** Evaluate how landscape structure affects mammal species occurence in a fragmented landscape of tropical dry forest in coastal Ecuador. We hypothesized that higher human impacts, indicated by the predominance of anthropogenic land-cover types, will negatively affect mammal species. We expected this effect to be different across species, with some species less affected or even benefiting from human impacts. **Methods:** We used camera traps to record mammal species over the course of one year and Sentinel2-derived land-cover classifications and forest seasonality metrics to estimate landscape structure in nested buffers around each camera. The effect of landscapes' structural characteristics on mammal species was evaluated using multi-species occupancy models. **Results:** Fifteen medium and large mammals were recorded. Our models indicate that species occupancy is related to low forest cover and high vegetation seasonality (i.e. high difference in Normalized Difference Vegetation [NDVI] between the wet and dry seasons). We believe the apparent negative effect of forest cover is an indicator of remaining species'

tolerance of disturbance. The effect of vegetation seasonality on our findings indicate that more seasonal forests tend to have higher mammal species occupancy. No seasonal or species level differences were detected. **Implications/Conclusions:** This research offers a first understanding of how mammal species that still persist in a highly fragmented TDF react to landscape structural characteristics. Careful attention should be paid to species not recorded in our data, including some large mammals and even small mammals, to understand well the response of the overall mammal community to disturbance. Future research should include similar assessments in non-forested land-cover types to better understand how species use and move across the landscape.
Keywords: Fragmentation, landscape, mammals, NDVI, occupancy, Tropical Dry Forests.

Birds beyond Borders: Hornbill Abundances, Resource Tracking and Nest Monitoring in Contiguous Rainforests and Adjoining Plantation Landscape in India

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Across the Asian tropics, hornbills are threatened by the habitat loss at alarming rates. They are known to forage and breed in fragmented rainforests and agroforestry plantations in human-modified landscapes adjoining contiguous forests. However, the factors influencing year-round hornbill abundance, demography and resource tracking such as wild fig Ficus fruits in modified habitats and protected forests remain poorly understood. We carried out monthly surveys of two species of high conservation concern, the Vulnerable Great Hornbill (GH, *Buceros bicornis*) and the endemic Malabar Grey Hornbill (MGH, *Ocyceros griseus*) for 15 months and monitored ripe fig fruit availability for 12 months along 11 line transects in shade-coffee plantations and adjoining continuous rainforests in a protected area (PA) in the Anamalai Hills, Western Ghats, India. Both hornbill species used both habitats year-round with higher densities in the PA in both nesting (GH by 57%, MGH by 50%) and non-nesting (GH by 53%, MGH by 144%) seasons. Relative to estimates from 2004 to 2005, mean GH density appeared stable or increasing, whereas MGH had declined by 39% in the PA and by 56% in plantations. Monthly encounter rate of both hornbills tended to be higher in the PA and that of MGH was also positively related to the density of fig trees with ripe fruit. Sex ratios of observed adult birds in the non-nesting season were relatively even (GH) or slightly female-biased (MGH), but became male-biased in both species during the nesting season when females were confined in tree-cavity nests. We used change in the adult sex ratio of observed birds from the non-nesting to nesting season to estimate an index of the proportion of adult pairs breeding at any point within the season, providing the first such estimates for any hornbill species. The proportion of breeding pairs was higher in the PA (GH – 56%, MGH – 64%) than in the plantations (GH – 33%, MGH – 30%). We also assessed 120 hornbill nests that were identified in the past for their current occupancy status. Out of 120 nest 65 (54%) of nests were active. Six GH nests identified twenty seven years ago and were found to be active in 2018. This highlights the importance of individual nest trees. Although hornbills use shade-coffee plantations year-round, partly due to fig availability, differences in hornbill density and breeding incidence, as assessed from the sex ratios of observed adult birds, indicate that plantations are sub-optimal habitats. **Keywords:** Habitat alteration, habitat fragmentation, breeding, Bucerotidae, distance sampling, food availability

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Habitat structure, fragmentation, connectivity: fauna

Habitat Fragmentation Increases the Probability of the Alien Wild Boar (*Sus scrofa*) Invasion in Agroecosystems

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The wild boar (*Sus scrofa*) is among the worst invasive alien species in the world because it usually destroys crops, hosts and transmits diseases, disrupts ecological processes such as ecosystem succession, and modifies species composition in patches of native vegetation. Understanding how landscapes patterns can favor wild boar´s invasion in tropical forests is key for planning control management programs in agroecosystems. To date, the influences of landscape structure on wild boar invasions in neotropical forests remain poorly studied. Here, we investigated how landscape structure influences the occupancy probability of the invasive wild boar in agricultural landscapes in southeast Brazil. We sampled wild boars using camera traps distributed in forest remnants in 42 agricultural landscapes. We used as predictor variables, composition, and configuration landscape metrics and the vegetation biomass productivity of the matrix (i.e. non-native areas), accessed by a normalized difference vegetation index, in 10 nested scales (2 to 20 buffer radii). To evaluate the effect of landscape structure on the species occupancy of forest patches, we fitted single-season occupancy models. First, we selected the scale of the effect of each covariate. Then, we built a set of concurrent univariate and additive occupancy models and selected the best models using Akaike Information Criterion (AIC). We found four plausible models (AIC 2) with similar support (i.e. model weight). All of them included the mean forest patch area at a 20 km scale, with a negative effect on the occupancy probabilities. These models indicated that the occupancy probabilities sharply increased as forest patches became smaller than 20 ha. Furthermore, the forestry cover at 6 km and the matrix productivity at 4 km had a positive additive effect with the mean patch size of forests, while the area covered by pasture seems to have a negative additive effect, although this effect was not clear. Our study indicates that the wild boar is benefited in fragmented landscapes with highly productive croplands and forestry in the matrix. These findings are in line with previous studies where the wild boar occurred in areas where there was shelter (forests) and abundant food items in croplands. Once highly productive and fragmented landscapes are common in southeast Brazil, the restoration of small forest remnants, such as many legal reserves and riparian forests of rural properties, could protect forest biodiversity in the remnants by reducing the occupancy probability of wild boar and possibly preventing crop damage, and economic losses to rural producers. **Keywords:** Invasive species, neotropical forests, fragmentation, landscape ecology, agroecosystems, anthropogenic landscapes

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Past Landscape Configuration at Different Scales Best Describes Current Distribution of South American Foxes

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Introduction: Changes to species distributions may not manifest immediately after changes to the landscape, resulting in a time-lagged response. These 'extinction debts' have been found across multiple taxa, and studies that look for evidence of these time-lagged responses typically look at species richness, and are concentrated in only a few systems. While biodiversity aggregates are useful for assessing/mitigating future losses, they ignore the variation in individual species response. We present evidence for short time-lagged responses for two mammal species in remnant patches of winter-rainfall temperate forests in an agriculture dominated system, using a framework that is commonly implemented to assess species distribution. Furthermore, we explore if the presence and magnitude of the time lag is dependent on the spatial scale of habitat metrics. While this study was situated in temperate forests in Southern Chile, it has wide applicability in any system where habitat destruction is a current or past feature of the landscape, especially tropical forests. **Hypotheses:** If time-lags are present, they will manifest at larger scales, with species responding to the present-day landscape instead at smallest scale. The magnitude of the time lag will depend on the level of habitat generality of each species. **Methods:** We determined if current occupancy of two generalist mesocarnivores (*Lycalopex griseus and L. culpaeus*) was better described by metrics from the present-day landscape, or past landscapes. For a five-year time series (1986, 2005, 2011, 2015, 2019), we collected habitat amount and configuration metrics at three scales to incorporate into single species occupancy models. Results: Culpeo and chilla occupancy both exhibited a time-lagged response to habitat configuration, with models with covariates from past years outperforming models with covariates from the same year the presence-absence data was collected. The scale and magnitude of the time lag varied by species, patch isolation (+) and edge/area (-) from 2015 at the 500m scale best described culpeo occupancy, while patch isolation (+) from 2011 best described chilla occupancy. **Implications/Conclusions:** We demonstrated that past landscapes better explained the present-day occupancy of two generalist carnivores, and that the scale at which past habitat metrics were important were nonintuitive given expectations for body size. Past landscape configuration may an important hidden driver of occupancy for some species, and given the widespread use of occupancy modeling in conservation.
Keywords: Extinction debt, time lag, fragmentation, habitat loss, landscape, Lycalopex, occupancy

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Ecologically Similar Lemur Species Are More Likely to Co-occur within a Fragmented Landscape in Southeastern Madagascar

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Land use change is a major threat to biodiversity globally. Forest loss due to land use change reduces the amount of habitat available for tree-living species, which may drive shifts in species distributions. Changing distributions may in turn alter how species interact with one another, funneling close competitors into shared habitat and limiting niche differentiation. Forest loss is especially prevalent in Madagascar, where nearly all lemur species are threatened with extinction. Here, we examine the influences of forest cover and ecological trait similarity on spatial aggregation (i.e., co-occurrence) among five threatened lemur species: the black-and-white ruffed lemur (*Varecia variegata*), greater dwarf lemur (*Cheirogaleus major*), Jolly's mouse lemur (*Microcebus jollyae*), red-bellied lemur (*Eulemur rubriventer*), and red-fronted lemur (*E. rufifrons*). We hypothesized that ecologically similar species would have low spatial aggregation, and that spatial aggregation would increase as forest cover decreased given that species would have less available habitat in their landscape. From May-August 2019, we used camera traps to sample species presence at 30 sites within five forest fragments in Kianjavato, Madagascar. Next, we generated a land use/land cover map to measure the proportion of forest cover surrounding each camera site. To measure ecological similarity, we calculated Gower's distance between each species pair using four traits: diet, body mass, home range size, and activity pattern. We then built two-species co-occurrence models and derived site-level species interaction factors (SIF) for each species pair to assess how forest cover influenced spatial aggregation. We found ecologically similar species were more likely to interact and co-occur at the same sites. Spatial aggregation varied across species pairs, with spatial 'avoidance' (SIF<1.0) being exhibited by three ecologically dissimilar species pairs (*V. variegata—M. jollyae, E. rubriventer—M. jollyae,* and *E. rufifrons—M. jollyae*), the other seven species pairs exhibited spatial 'attraction' (SIF>1.0). Forest cover had varied effects on spatial aggregation across species pairs, with 'attraction' in the four most ecologically similar pairs increasing or remaining unchanged as forest cover decreased. These results may reflect the similar habitat needs of ecologically similar species. Given the high degree of agriculturally-driven forest loss in Kianjavato, forest cover throughout the entire study system is low and species may be restricted in their use of space, even at sites with high forest cover in the immediate surrounding area. Our results indicate that shifting forest cover can be a major driver of primate co-occurrence patterns, substantially shaping spatial arrangements within tropical forest communities. **Keywords:** Primatology, primate conservation, landscape ecology, community ecology, camera traps

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Habitat Use by Jaguars (*Panthera onca*) at EARTH University, Costa Rica, in the Parismina River Biological Corridor.

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Banana and pineapple plantations occupy a large percentage of land use in the Caribbean lowland region of Costa Rica, along with cattle ranching and other crop production. The remaining forest reserves in the region, which include national parks and private reserves, harbor wildlife, but data are lacking about their populations and the connectivity among these forest patches. At the EARTH University campus, Guácimo, Limon, Costa Rica, commercial banana production and cattle ranching constitute important land use activities, but the largest percentage of the campus is dedicated to forests of different types (selectively logged old-growth, second-growth, plantations, riparian). The campus protects the largest forest patch outside of a national park in the Parismina River Biological Corridor. Land use management and agricultural practices on campus promote biodiversity conservation, for example, EARTH has maintained forested areas surrounding blocks of banana plantations, forest guards patrol the area to reduce hunting, and better agricultural practices including fallow areas increase habitat heterogeneity. In 2016, wildlife monitoring camera traps were first deployed at EARTH, since 2021, a more extensive monitoring project began using the Costa Rica PRONAMEC grid. During the five-year monitoring period, cameras have consistently documented jaguars (*Panthera onca*) on campus. In 2021, we explored jaguar habitat use on campus in three land-use types: old-growth selectively logged forest, mixed forest types (second-growth, riparian, advanced plantations), and forest bordering banana plantations. During 2364 camera trap nights at 14 camera stations, fifty-six jaguar detections were obtained on 28 sampling occasions (seven-day intervals) and the jaguar was detected at ten sites (naive occupation = 0.71). Jaguars were more relatively abundant in cameras in the old-growth, but there was no difference in use between the mixed forest and banana forest types. Occupancy models indicated that the jaguar detection probability ($p = 0.22$, 95% CI = 0.17-0.28) was not affected by any sampling covariates, therefore, a constant detection probability was defined for the campus. Thus, the proximity to banana plantations did not affect jaguar sightings on campus. The camera study continues and efforts are underway to work with neighboring landowners and other stakeholders in the Parismina River Corridor to monitor jaguars in the corridor and to determine connectivity routes and possible restoration areas. Restoration and education efforts within the landscape will be key to reestablishing connectivity for the jaguars that use the EARTH University campus. **Keywords:** Wildlife camera traps, biodiversity, forest connectivity, agricultural practices, Parismina River

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Host and Parasites/Pathogens interactions I

Disturbing Trends: Does Fragmentation Influence Pathogen Prevalence and Transmission in Small Mammal Communities?

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Background: Environmental perturbations are known to impact zoonotic disease risk. Recent studies have identified anthropogenic land-use change as one of the important drivers of zoonotic disease emergence. As the natural habitats get converted and fragmented, it modifies the natural community composition of organisms by affecting their local richness and abundances (positively or negatively). Small mammals (rodents and shrews), one of the major zoonotic reservoir taxa, often benefit from local-scale land-use modifications. Objectives: In this study, we investigate how land-use change alter small mammal community structure and consequently pathogen prevalence and transmission in the central Western Ghats. We predicted high reservoir abundance and prevalence in the forest plantation mosaic compared to undisturbed protected areas. Methods: We sampled small mammals using a capture-mark-recapture framework across five land-use types in a forest-planation mosaic and a relatively undisturbed protected area. In this community, we investigate species diversity, density and habitat associations. We used *Bartonella*, a gram-negative zoonotic bacterium, as a pathogen model and investigated its prevalence and transmission in this community. We performed PCR based screening to detect *Bartonella* in blood samples collected from small mammals. Sequence data generated from these samples were used to understand host association, haplotype diversity and phylogenetic ancestry. **Results:** We detected 406 individuals belonging to 11 species. In forested habitats, *Rattus satarae*, was predominant and showed similar density in forest-plantation mosaic and protected areas. *Mus cf terricolor* was only detected in grasslands and showed high density in the protected area. *Mus cf fernandoni* and *Mus cf famulus* were present in multiple habitats and showed strong signatures of population fluctuation across years. Among these four common species, *R. satarae* showed high *Bartonella* prevalence in both sites. No significant difference was observed in species-specific prevalence between sites. However, there was a high overall prevalence in the forest-planation mosaic which could be due to the large sample size of the host species. High haplotype richness of *Bartonella* was observed in *R. satarae and M. cf. fernandoni*. Our ancestral trait reconstruction analysis reveals a high probability for *R. satarae* being the ancestral host in the landscape. **Conclusion:** Taking all this evidence (density, haplotype diversity, and ancestral trait) together, we suggest that *R. satarae* could be the potential *Bartonella* reservoir that drives landscape-level prevalence and transmission. The high prevalence of pathogens in such species exist in high density in a rapidly changing landscape pose a significant risk of spillover to incidental hosts, including humans. **Keywords:** Small mammal community, land-use change, pathogen spillover

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Distribution of Bats Reservoirs for Beta-Coronaviruses

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Bats are found worldwide and are one of the most diverse groups among mammals. Previous research states that locally diverse bat communities could maintain more viruses and hence, a higher chance of being reservoirs of microorganisms that potentially be a risk for human health. But understanding cross-species transmission involves several factors, among which the relatedness of hosts (which can make the viral jumps easier between species), and the overall tendency of hosts within a locality to share viruses, which may limit viral diversity because of within-host competition. Therefore, an appropriate measure of viral risk should consider factors additional to host diversity and viral presence. Accordingly, the objective of our model is to estimate the spatial distribution of bat reservoirs for β coronaviruses with the highest viral and host diversity. Therefore, we overlapped three components: viral sharing, i.e. the chance that two bats will share viruses overall, Local Contribution to Beta Diversity, i.e. the fact that a bat community is compositionally unique compared to the average compositional similarity across the entire system, and phylogenetic diversity, i.e. how dispersed the bats in a location is within the tree of life. And we mapped the bat-β coronavirus interactions worldwide, using (i) a database of known β coronaviruses hosts, and (ii) range maps for the hosts according to IUCN. To reflect the fact that the risk posed by viruses has many ecological origins, we quantified the phylogenetic diversity of hosts, their compositional uniqueness, and the expected viral sharing. As a result, we composite a host risk map, where our result shows that hotspots were in Southeast Asia, Europe, and Sub-Saharan Africa. But Southeast Asia's importance lies from considering its bat's diversity and low viral sharing of beta-coronavirus. Our results provide valuable information about the spatial risk of viral outbreaks and lead to compare scenarios of high viral exchange vs low viral exchange, opening the discussion about scenarios where viruses easily adapted to multiple hosts but with low virulence or are easily ignored by the immune system of the host, or where we have viruses specialized to a specific host, but highly virulent when invade a new host. We conclude that understanding viral-host interactions from a taxonomic and phylogenetic point of view could contribute to improving zoonoses surveillance programs. **Keywords:** Bat, coronavirus, viral sharing, spatial risk

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Effects of Landscape Variation, Population Abundance, and Host Activity on the Rate of Asian Koel Brood Parasitism of Long-tailed Shrike

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Brood parasitism is a likely cause of decline in many bird populations globally, however impacts have rarely been studied in Southeast Asia, where biodiversity is already intensely threatened from human activities. This study is an ongoing investigation of the impact of Asian koel (*Eudynamys scolopaceus*) brood parasitism on Long-tailed shrike (*Lanius schach*). The Long-tailed shrike population, specifically subspecies *longicaudatus* which is *near* endemic to the central plains of Thailand, has been in apparent decline over the last thirty years. The cause of this decline remains unclear however, some potential stressors are brood parasitism, urbanization, and potential deterioration in prey quality. We investigated brood parasitism rate via nest checks during breeding season (March – August 2021) in Sukhothai province, Thailand. Susceptibility to parasitism was determined by observing host activity around nests during nest building and egg laying and conducting point counts to estimate abundance of parasites and all host species. Influence of habitat on parasitism and changes in landscape composition were determined by comparing habitat features at nest sites and random locations. Host foraging activity and prey consumption were monitored to determine prey size preference and potential variation in prey availability in habitats with differing levels of anthropogenic influence. Preliminary results suggest that brood parasitism is a significant issue in this population, with 69% of nests with identifiable eggs (25 of 36) being parasitized. Of the 11 non-parasitized nests, only 4 were successful. Of the 12 nests that were parasitized and also successful in producing fledglings, only 2 successfully fledged shrikes as well as koels. Additionally, there seems to be a difference in prey size consumption in park/garden habitats versus agriculture habitats. In agricultural habitats, the number of prey consumed of varying size (0.0-0.5x, 0.5-1.0x, 1.0-1.5x, 1.5-2.0x, and >2.0x bill length) is relatively equal. In contrast, shrikes in park/garden habitats consume smaller prey more often, with prey of 0.0-0.5x bill length making up more than 50% of food observed. The significance of this, especially in terms of reproductive success and shrike population abundance has yet to be determined, however, it suggests potential differences in prey availability between major habitat types within this shrike population's remaining range. Although data analysis is still ongoing, this project shows the negative influence of Asian koel brood parasitism on Long-tailed shrike reproductive success. This reproductive stressor, especially

when coupled with the variation in prey availability, could be the root cause of this population's drastic decline.
Keywords: Brood parasitism, Asian koel, long-tailed shrike, habitat variation, Thailand

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Rodent-ectoparasite Interaction through Anthropic Disturbance Gradients in a Tropical Forest Region at Yucatan Peninsula in Mexico

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The parasitism can significantly define patterns of diversity and ecological processes at different integration levels - from population to ecosystem level-, due to its influence on the species performance and in the way they interact with each other. This is especially true when host species are conspicuous, abundant and play critical roles in the ecosystems, such as the case of rodents. However, parasite-host interactions can be directly and indirectly modulated by anthropic disturbances, so we urgently need to understand how disturbance affects this interaction as natural ecosystems are experiencing an increasingly high rate of anthropogenic perturbations, especially in tropical regions. In this study, we characterized ectoparasites communities in rodent's species along anthropogenic gradients defined at different spatial scales, in a tropical humid forest region (Calakmul, Mexico), which is recognized by its extension and high biodiversity. Then, we analyzed how vegetation and landscape attributes may modulate the rodent – ectoparasite interaction in 13 study sites. Our sampling effort (4,680 Sherman trap nights) resulted in the capture of 258 rodent individuals, comprising 7 rodents' species: where the spiny pocket mice (*Heteromys gaumeri*) and the big-eared climbing rat (*Ototylomys phyllotis*) were the most abundant species. Indeed, the endemic pocket mice *H. gaumeri* showed the highest abundance of ectoparasites, with a notable number of mesostigmatic mites and fur mites (Listrophoridae), as well as hard ticks (Ixodidae) and lice. In addition, we found a high degree of specificity in the response of each ectoparasite groups: the prevalence of fleas was higher in disturbed sites, this also occurred with ticks in sites with an intermediate degree of disturbance, and lice in preserved sites. This variation corresponds to differences between the group of ectoparasite species in relation to their response to vegetation structural complexity and the associated environmental conditions (i.e., humidity, radiation, temperature) and resource availability (host species richness, abundance and physiological condition). Finally, we found the highest abundance and diversity of ectoparasites species in sites inserted in heterogeneous landscapes, where some remnants of native vegetation, with a moderate degree of connectivity between them, persist surrounded by anthropic land covers, allowing the coexistence of species that are favored in disturbed and preserved forest, as well as their dispersion across the anthropogenic landscapes. These findings constitute relevant information for the native faunal conservation, and for the health of domestic animals and humans and contribute to our understanding about how anthropic disturbances modulate parasitism and its effect on ecosystems. **Keywords:** Ectoparasitism, rodents, anthropic landscapes, anthropic disturbance, habitat loss, conservation

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Host and Parasites/Pathogens interactions II

Isolation and Identification of Fecal Bacteria in Aotus Lemurinus (Pijao, Quindío)

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Bacteria present in the gastrointestinal tract of mammals are important for the development of the organism, so in the case of Aotus lemurinus, the objective is to identify bacteria present in its feces. In order to analyze the bacterial differences between two groups of Aotus lemurinus located in Pijao, Quindío and determine if the bacterial community found has pathogenic significance. By collecting feces from the forest canopy to the bottom of the tree where they were collected in a blanket, for subsequent molecular study where a preliminary analysis of fecal bacteria was performed by DNA extraction, PCR and sequencing. To find a total of 5 bacterial genera from a total of 10 samples, all being from the Proteobacteria phylum. Suggesting that there may be bacterial differences between the two groups of Aotus lemurinus, because they did not share all the bacterial genera, so it can be inferred that this is due to their diet. **Keywords:** Andean night monkey, microbiota, gastrointestinal tract, molecular biology, feces, primates

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Functional and Taxonomic Relatedness of American Palms Drive Host Specificity Patterns in Parasitoid Beetles

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Plant-parasitoid interactions are intimate interactions and often host specific, meaning that a parasitoid species is usually dependent on a single or a few host plant species. Yet, some parasitoids can show a wide range of hosts, and it remains relatively unexplored what drives specificity patterns in plant-parasitoid systems. Herein I quantify different aspects of host specificity in interactions between American palms (Arecaceae) and their bruchid beetles (Bruchinae, Chrysomelidae). The study's goal is to understand the structure of these plant-parasitoid interactions, and to test if bruchid specificity is driven by taxonomical and/or functional relatedness of hosts. For that, I developed a novel species-level interaction dataset and conducted a compilation of functional traits of palm species to investigate use of host species by bruchid beetles. For each bruchid species and genera I calculate the number of host palm species and use a host specificity index that takes into account the taxonomic distance between host species to assess if palm-bruchid interactions are delimited by taxonomic constraints. I then perform a principal component analysis using multiple functional traits of palm species and assess if bruchid genera select for different palms in the trait space. A total of 100 palm species belonging to more than 30 genera are used as hosts by more than twenty bruchid species along the Americas. Interestingly, bruchid species recorded to interact with a low number of hosts tend to infest palms that are more distant taxonomically, while bruchid species with a broad host range interact with closely related palms. Nevertheless, results show that taxonomical relatedness among hosts of congeneric bruchids is high for most bruchid genera, regardless the number of host species recorded for each bruchid genus. In addition, congeneric bruchids interact with palms that have similar combination of traits while different bruchid genera diverge in functional trait space of hosts. Bruchids show a high interspecific variation of numerical and taxonomical host specificity, suggesting that different eco-evolutionary selective drivers shape palm-bruchid interactions in the Americas. Selection of different functional traits of palms by bruchid genera also suggests ecological adaptations by bruchids, which might have evolved to overcome defenses in palms, as in an 'arms race' coevolutionary dynamic. Besides,

specialization in these interactions is also likely to be influenced multi-trophic interactions, affecting host colonization abilities of bruchids, and ultimately determining the structure of palm-parasitoid interactions. **Keywords:** Arecaceae, Bruchinae, coevolution, functional traits, host specificity, plant-parasitoid interactions

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Ground Beetle – Fungus Interaction Networks in the Tropics

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Introduction: Ground beetles (Coleoptera: Carabidae) are valuable biological control agents, supporting sustainable agriculture. Microscopic fungi, which themselves often provide valuable ecosystem services by infecting and killing pest species, may reduce this benefit when they act as ectoparasites and/or entomopathogens of carabids. Fully understanding these processes and maximising the benefits of the ecosystem services each taxon provides is an important task for sustainable agriculture in tropical agroecosystems. Objectives: We aimed to gather a comprehensive dataset on the distribution of interactions between ground beetles and microscopic fungi and assess the completeness of this dataset. **Methods:** Global literature data of seven languages was overviewed and unique fungal associations were collected for a list of tropical and subtropical countries. **Results** : Here we gathered data from 114 unique literature sources covering 65 tropical countries and collated a dataset of 831 unique interactions between carabids and microscopic fungi. We investigated the differences in recording completeness, known network structure, and taxonomic distribution of the records among continents. The most records (318) originated from Central and South America (167 and 151, respectively), whereas Oceania (including Australia) was the least recorded (64). Three fungal classes, Basidiobolomycetes, Laboulbeniomycetes and Sordariomycetes, interacted reportedly with carabids from the investigated countries, with almost all interactions occurring with Laboulbeniomycetes within the order Laboulbeniales. The most recorded interactions were between the ground beetles belonging to the Harpalinae subfamily and Laboulbeniales fungi. **Conclusions:** Very few entomopathogenic interactions were recorded, thus, although Laboulbeniales parasites carabids, they normally do not cause substantial fitness decline, little fungal effect on ESs provided by carabids is predicted. Laboulbeniales –Carabidae networks from all continents were highly nested suggesting the presence of generalist species. The ratio of recent genera per parasitized genera compared to the same ratio in well-recorded areas (Western Europe and North America) suggest a considerable lag of recording fungal-insect interactions in the tropical and subtropical regions. Along with biodiversity discovery, a targeted research effort is needed to focus on exploring species' interactions in the tropics. **Keywords:** Fungal, ground beetle, interaction, Laboulbeniales, parasitism, ecosystem services

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Invasive species

Climatic Range Shifts of Invasive Woody Legumes

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Analyzing the shifts of the climatic space between native and introduced areas for invasive species is a powerful tool for understanding their distribution patterns and the factors influencing their spread into new areas. In this study, we explored the shift in climatic distribution between ranges for invasive woody legumes. We evaluated the global patterns of occupation of the climatic space for 107 invasive woody legumes on their native and introduced distribution ranges. We used trait probability density function (TPD) to estimate species probabilistic niches. We then classified species into four groups according to the climatic differences between the distribution ranges. The comparisons between the climate shift groups and the distribution ranges were evaluated with mixed linear models. Overall invasive woody legume species generally exhibited low to moderate climatic overlap between their native and introduced distribution ranges, and showed consistent patterns with previous studies showing differences in climate conditions between native and introduced areas. Invasive legumes were clustered in four groups (Conserved, Expansion, Dissociation, Unfilling), a majority of the legume species were classified in the Dissociation group (49 species) which includes species with differences in climate conditions between their native and introduced distribution ranges. However, our nestedness analysis indicates that, in a majority of species, most dissimilarity in climate niches between the native and introduced ranges are due to differential patterns of occupation of otherwise similar portions of the climate space. The high prevalence of Dissociation group is in agreement with authors that have postulated that invasion success may be related to the species ability to adapt to novel environmental conditions. Nevertheless, 58 of the studied species exhibited a different behaviour, which makes us think that environmental filtering influences the species distribution and that the environmental conditions of the native area can predict the potential areas of invasion of the species. In conclusion, our results showed no consistent climatic range shift across all invasive woody legume species from their native to their introduced distribution. However, some species tend to invade climatic conditions that are different to those in their native range, supporting the hypothesis that some invasive species are able to have high climate tolerance. **Keywords:** Climatic niche, climatic shift groups, functional traits, introduced range

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Biodiversity Increases Resistance to Invasion by Exotic Grasses in Neotropical Grasslands

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Degraded neotropical grasslands under restoration are often invaded by exotic grasses. Due to their acquisitive ecological strategies, invasive species rapidly accumulate aboveground biomass, which suppress native species and increase the likelihood and intensity of wildfires. Therefore, the success of restoration programs depends on establishing native communities that are resistant to invasions. One way to increase the resistance of restored communities to exotic species invasion is to build communities that fulfill the available niche spaces. In plant communities, invasion resistance may increase with diversity because empty niche space decreases simultaneously. However, it is still unclear how diversity and composition of species with different ecological strategies can increase resistance to invasion in tropical grasslands. In this study, we tested the hypothesis that plant communities with greater diversity will be more resistant to invasion. For this, we implemented a biodiversity experiment in the Parque Nacional da Chapada dos Veadeiros, Alto Paraíso de Goiás, GO. The

experiment has five levels of species richness: zero (control), one (monocultures), two, four and eight native grass species. In total, 302 plots (2x2 m) were sown along the diversity gradient according to the random partitions design, ensuring that all species were sown at the same density in all levels of diversity (totaling 1000 seeds/m^2). Six months before sowing, we manually removed all exotic species, as they germinated from the seedbank before the native species germinated. After the second growing season, we removed all individuals of *Urochloa decumbens*, *Melinis minutifolia* and *Andropogon gayanus*, which are the most problematic species in the region. The final dry biomass was used as a proxy for community invasiveness. Our results show that species richness was negatively related to the invasion by exotic species. Three species with distinct ecological strategies had significant negative effects on invasiveness. The annual species *Andropogon fastigiatus* had a positive effect on the invasion by exotic species, suggesting facilitation, since the biomass of exotic species in monocultures of this species was higher than in controls plots. These results suggest that niche pre-emption in more diverse communities may be an important mechanism increasing the resistance to invasion by exotic grasses. Furthermore, the ecological strategies of species can also contribute to resist or facilitate invasion. Future work should investigate how the functional diversity and composition of plant communities affect the invasiveness of tropical grassland communities. **Keywords:** Exotic species invasion, grasslands, Cerrado, restoration, functional ecology

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Marine Introduced Species in the Galapagos Marine Reserve – from Ports to the Natural Environment

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The marine ecosystems of the Galapagos Islands harbor unique biological communities with a high incidence of endemic species. Galapagos is a UNESCO world heritage site, renowned for its high biodiversity and extraordinary oceanographic features. Marine biological invasions have increased due to global trade and tourism. The Galapagos Islands are under continuing threat from marine non-native arrivals, given the connectivity and increase in marine traffic that exists across the Eastern Tropical Pacific, as well as the effect of extreme climatic events such as the El Niño. In 2019, 53 introduced and 33 cryptogenic species were reported in the Galapagos Islands (Carton et al., 2019). The current study reports how many of these species are known to occur in the natural environment of the Galapagos Marine Reserve (GMR). The Charles Darwin Foundation has been conducting long-term evaluation of subtidal communities in the GMR since 2000 focused primarily on recording the diversity, abundance and size of the species present in three major groups of macrofauna (fish, macroinvertebrates and sessile organisms) in subtidal communities. We are using these survey data to evaluate the status of bioinvasions in the GMR, testing for spillover of introduced species from anthropogenic habitats (e.g., docks and moorings) to natural habitats across the archipelago. More broadly, we aim to understand the risk (extent and impact) of non-native marine species already established in the GMR, as a model to evaluate invasion dynamics and management strategies for island ecosystems and Marine Protected Areas (MPAs).
Keywords: Biological invasions, climate change, marine protected areas, anthropogenic, natural

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Open to Invasion? Canopy Cover Determines Fruit Abundance and Fruit Removal of Invasive Lantana Camara in North India.

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The spread of invasive alien plants is among the leading threats to the persistence of native biodiversity. Tropics are at the perils from the alarming invasion of the fleshy-fruited invasive plant *Lantana camara* (hereafter, *Lantana*). Frugivores, especially birds consume its fruits and aid in the spread via seed dispersal. While its invasion is widely recognised to be more pronounced in open-canopy habitats (including deciduous forests, forest edges and gaps), it remains largely unknown as to how habitat features themselves may affect the key mechanism of spread i.e. vertebrate-mediated seed dispersal. We studied how patterns in fruiting and seed dispersal of *Lantana* varies across the habitat types including the open grassland-shrubland mosaic (open canopy habitat) and the Sal-dominated moist deciduous forests (closed-canopy habitat). The study was conducted in the Dehradun valley surrounded by Shivalik hills in the south and the outer Himalayas in north India. We monitored 45 *Lantana* shrubs in a gradient of canopy cover, fortnightly for 6 months until the end of the fruiting season. With equal effort in the habitats, we conducted focal watches on 80 *Lantana* shrubs in an effort of 240 hours of observation to identify patterns in frugivore visitations and fruit removal. We measured habitat and focal bush features to understand which features determined the visitations from effective seed dispersers of *Lantana*. We found that canopy cover was negatively influenced fruit crop size on *Lantana* shrubs. Open habitats had strikingly higher fruit abundance than the Forest habitats. Red-vented Bulbul, Himalayan Bulbul and Indian White-eye had higher visitation rates and fruit removal efficiency. Their visitation rates were negatively influenced by canopy cover. Together, our findings suggest that canopy openness will be associated with higher fruiting of and fruit removal from *Lantana* shrubs, thus leading to higher propagule pressure of the invasive. Our study stands to suggest that enhanced seed dispersal could be the potential mechanism leading to the widely acknowledged pattern of higher *Lantana* invasion in open habitats. Additionally, disturbances like lopping that create canopy openings and gaps in the forest habitats would as well put the surrounding areas in the intact forest at the risk of *Lantana* invasion. Thus, regular management and monitoring of such high-risk sites will aid in controlling the *Lantana* populations that act as sources of high propagule pressure. Considering monetary and logistical challenges involved in the management of the invasive Habitat-oriented strategies with prioritising on open canopy sites can thus prove to be beneficial. **Keywords:** Lantana, camara, invasion canopy, cover, seed dispersal, habitat-oriented, management

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Monitoring biodiversity I

AMAZONIA CAMTRAP: a Dataset of Mammal, Bird and Reptile Species Recorded with Camera Traps in the Amazon Forest

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The Amazon Forest has the highest biodiversity on earth. However, information on Amazonian vertebrate diversity is still deficient and scattered across the published, peer-reviewed and grey literature and in unpublished raw data. Camera traps are an effective non-invasive method of surveying vertebrates, applicable to different scales of time and space. In this study, we organized and standardized camera trap records from different Amazon regions to compile the most extensive dataset of inventories of mammal, bird and reptile species ever assembled for the area. The complete dataset comprises 154,123 records of 317 species (185 birds, 119 mammals and 13 reptiles) gathered from surveys from the Amazonian portion of eight countries (Brazil, Bolivia, Colombia, Ecuador, French Guiana, Peru, Suriname and Venezuela). The most frequently recorded species per taxa were: mammals - *Cuniculus paca* (11,907 records), birds - *Pauxi tuberosa* (3,713 records), and reptiles - *Tupinambis teguixin* (716 records). The information detailed in this data paper opens-up opportunities for new ecological studies at different spatial and temporal scales, allowing for a more accurate evaluation of the effects of habitat loss, fragmentation, climate change and other human-mediated defaunation processes in one of the most important and threatened tropical environments in the world. We also reference parallel projects currently being developed based on this dataset. **Keywords:** Data paper, Vertebrates, Tropical forest, Amazonia

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Acoustic Indices Limited in Their Efficacy of Quantifying Biodiversity in a Tropical Dry Forest in Central India

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Passive acoustic monitoring holds the potential for monitoring ecological changes across large spatio-temporal regions. The rapid development of easy-to-use passive acoustic monitoring tools and methodologies allows for collaborative and inclusive efforts in biodiversity research and monitoring efforts. The ease of computation of acoustic indices, which have been proposed as rapid biodiversity quantification measures derived from soundscapes, offers a novel solution for collaborative rapid biodiversity monitoring, especially to monitor socio-ecological systems managed by local communities. However, previous studies indicate inconsistencies in the performance of indices across different biomes, Previous studies demonstrate that the relationship between acoustic indices and traditional biodiversity proxies such as species richness and biotic activity varies over different biomes, with some indices poorly representing biodiversity in tropical humid forests but adequately in temperate forests, for example. In this study, we tested the potential of six commonly used indices, acoustic complexity index, acoustic diversity index, acoustic evenness index, bioacoustic index, total entropy and normalized difference soundscape index, for rapid monitoring of tropical biodiversity and consequently contributing

to forest management efforts in a community-managed tropical dry forest in central India. We calculated two response variables, avian species richness per recording and acoustic activity, a sum of the number of times an amplitude threshold was crossed in a given time frame. We measured the correlation of every index and a combination of indices with acoustic activity and avian species richness. We found significantly weak correlations ($-0.54 <= r <= 0.31$) between the indices and acoustic activity. We also found that no index showed significantly strong ($-0.08 <= r <= 0.36$) correlations with avian species richness. The indices, additively combined, also show a weak predictive ability to represent the acoustic activity ($R^2 = 0.4$) and avian species richness ($R^2 = 0.41$) in our sites. Our results indicate that the indices may not efficiently quantify biodiversity in tropical dry forests, a highly underrepresented biome in the field of soundscape ecology. We suggest gathering more evidence on the efficacy of acoustic indices from different tropical dry forests around the world and testing the combination of acoustic and human surveys for biodiversity monitoring. This study makes a timely contribution to understanding the limitations of acoustic indices as a widely-accepted biodiversity monitoring tool by presenting empirical evidence from a non-protected tropical dry forest that provides support for local forest-resource use. **Keywords:** Biodiversity, bioacoustics, soundscape, acoustic indices, tropical dry forest, socio-ecological system

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Paxilloboletus gen. nov., a New Lamellate Bolete Genus from Tropical Africa

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This study presents *Paxilloboletus* gen. nov., a new lamellate bolete genus represented by two tropical African species, *Paxilloboletus africanus* sp. nov. and *Paxilloboletus latisporus sp*. nov. Although the new taxa strongly resemble Paxillus (Paxillaceae), they lack clamp connections and form a separate generic clade within the Boletaceae phylogeny. The new species are lookalikes, morphologically only separable by their spore morphology. Descriptions and illustrations of the new genus and new species are given, as well as comments on ecology, distribution and morphological differences with other gilled Boletaceae. The current diversity of species in the genus Paxilloboletus representing African boletes is known to better participate in the in-situ conservation of fungal biodiversity in African forest ecosystems. **Keywords:** Boletaceae, Africa, lamellate hymenophore, morphology, phylogeny, taxonomy

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Bat Sonotype as a Novel Insight into the Congo Basin Rainforest Dynamic

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Tropical forest ecosystems are undergoing an exponential regression of their surface areas with subsequent habitat loss and fragmentation. The effects of such disturbances on bats are quite significant, even leading to a decline in populations. In order to ensure the maintenance of bat populations, it is thus important to preserve their habitats. This involves highlighting preferential habitats but also factors related to their foraging sites. We have combined acoustic surveys and capture-mark-recapture methods to study relationships between bats and their preferred habitats and also to identify functional role of bats captured or recorded in their habitat. A total of 42 bats were captured, belonging to 13 species, including 5 species of frugivorous bats and 8 insectivorous bats.The frugivorous bats - namely the species *Scotonycteris bergmansi, Casinycteris arginnis, Myonycteris torquata* and *Epomops franqueti* - were associated with dispersal of 16 plant species in the Yangambi Man and Biosphere Reserve (*Aidia micrantha, Allanblackia floribunda, Anonidium mannii, Barteria nigritana, Canarium schweinfurthii, Coelocaryon preussi, Dacryodes edulis, Mammea africana, Maranthes glabra, Microdesmis yanfungana, Musanga cecropioides, Pycnanthus angolensis, Staudtia gabonensis, Strombosia grandifolia, Strombosiopsis tetrandra* and *Panda oleosa*) while the species Megaloglossus woermanni ensures the pollination of the species Maranthes glabra. Acoustic monitoring revealed the presence of 11 sonotypes namely of the following species: *Chaerephon pumilus, Macronycteris gigas, Macrocycteris vittatus, Doryrhina cyclops, Rhinolophus fumigatus, Neoromicia nana/Scotophilus dinganii, Pipistrellus nanulus, Pipistrellus rueppellii, Nycteris arge, Myotis bocagii* and *Glauconycteris superba*. The type of habitat (primary forest) significantly increases the foraging activity of bats. A medium to high density of the understorey and a medium opening of the canopy have a significant influence on bat activity and call structure. There is a significant positive relationship between type of habitat and foraging activity of bats. Or Primary Forest was the habitat type with significantly more observations of foraging. complementarity of acoustic monitoring and

capture is crucial to understand the mechanisms governing aggregation of bats assemblages in order to assess their activity and the ecosystem services they provide **Keywords:** Sonotype, forest dynamic, bats, acoustic monitoring, Yangambi Biosphere Reserve, democratic

Monitoring biodiversity II

Does Low-carbon Footprint Mean Low-biodiversity Impact? Assessing Yucatan Peninsula Logging with Soundscapes

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Scaling reduced-impact logging for carbon (RIL-C) practices in the tropics could halve carbon emissions from wood production, however, few studies have assessed if RIL-C practices also benefit animal biodiversity across multiple taxonomic groups, such as by speeding up the biodiversity recovery after logging. Using autonomous acoustic recorders, we investigated how fast vocalizing diversity recovers after conventional selective logging practices and if this recovery changes with RIL-C in the Maya Forest, Mexico. We recorded one week of soundscapes at 30 forest sites, including never-logged sites and those that had been selectively logged at different times (1, 3, 5, 10, or 20 years ago), in 3 community-managed forests in Quintana Roo under different logging practices. Additionally, we recorded one year of soundscapes at 12 sites, half of them has been selectively logged during the recording period. We estimate animal biodiversity using soundscape indices over space and time and related changes to different logging practices. Preliminary results indicate that never logged sites in Quintana Roo follow a similar 24h soundscape saturation pattern to that found in undisturbed tropical forests in Southeast Asia, with a peak in soundscape saturation during the dawn and dusk. We will present if and how this pattern changes with different types of and time since selective logging. The results of this project will inform how wildlife-friendly current wood extraction activities are in Quintana Roo, and if RIL-C practices can benefit biodiversity conservation the same way that they tackle climate change. Our collaborating forestry communities will be able to use the results to communicate how well their practices support biodiversity conservation to their environmentally aware wood consumers. **Keywords:** biodiversity, monitoring, birds, logging, Mexico, acoustic, impact, soundscape, carbon, forestry

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Bioacoustic Monitoring Reveals an Increase in Illegal Logging within the Threatened Pacific Forest of Ecuador during COVID-19 Lockdowns

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The environmental effects of the 2020 COVID-19 lockdowns are still being documented. Many studies have focused on the positive impact of decreased human traffic on roads and in parks or the benefits to air and water quality, but the pandemic's impact on the global economy also has had negative repercussions on the environment–especially in developing nations. Ecuador's economy, which is heavily reliant on petroleum and ecotourism, experienced a rise in poverty in response to pandemic shutdowns. Although it is likely that the economic crisis has incentivized poaching and illegal timber extraction, these phenomena have not been quantified. Our objective was to compare chainsaw activity before and after the start of the pandemic lockdowns in two protected areas (Jama-Coaque Reserve [JCR] and Bosque Seco Lalo Loor [BSLL]) in the Pacific Forest of Ecuador. We visually and acoustically checked spectrograms for chainsaws and gunshots among the data collected by canopy acoustic recording devices from December 2019 to March 2020 and October 2020 to March 2021. We then used generalized linear mixed effects models to examine differences between pre-lockdown and lockdown hourly chainsaw activity and the influence of rainfall. Our results indicated lower hourly chainsaw noises before lockdowns ($\beta_{\text{pre.lockdown}}$ = -0.6666 +0.2685 SE, p-value = 0.013), although increased average rainfall also had a negative effect on hourly chainsaw activity ($\beta_{\text{avg.rainfall}}$ = -0.0023 + 0.0006 SE, p-value

= 0.0002). Gunshots were too infrequent to create statistical models, however, gunshot activity all occurred during the 'lockdown' period. Further, rangers from these protected areas noted an increase in poaching activities beginning July (at JCR) and November (at BSLL) of 2020 and persisting into 2021. These results add to the steadily growing literature indicating an increase in environmental crime–particularly in biodiverse, developing nations–catalyzed by COVID-19-related economic hardships. Identifying areas where environmental crime increased during pandemic lockdowns is vital to address both socioeconomic drivers and enforcement deficiencies to prevent further habitat/biodiversity loss and to promote ecosystem resilience. Our study also demonstrates the utility of passive acoustic monitoring to detect illegal resource extraction patterns, which can inform strategies such as game theory modeling for ranger patrol circuits and placement of real-time acoustic detection technologies to monitor and mitigate environmental crimes. **Keywords:** Anthropause, timber extraction, acoustics, biodiversity, SARS-CoV-2

Breaking Barriers of Knowledge through Monitoring a Tropical Dry Forest

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The persistence of tropical ecosystems depends on every day decisions made by both local communities and national legislators. Informing those decisions is critical to protect vulnerable ecosystems, yet the biodiversity of those ecosystems is sometimes poorly characterised and generally overlooked by society. With the aim to bring people from the local communities to become the main actors in the generation of biodiversity knowledge in their territories, in alliance with the private sector we launch in 2020 the pilot project "Fibras-Biomonitores". This project links researchers, life-science students (who receive monthly financial support), and local communities (who have a contract), are monthly monitoring plants, fungi and insects in a tropical dry forest (TDF) in the region of Huila, Colombia. In this joint effort we have collected and sorted so far ˜20.000 insects, 330 plants and 126 fungi. Sampled specimens are photographed and subsampled for subsequent generation of DNA barcodes. This project supports the bachelor's and master's theses of 19 students who, together with local communities, are generating significant data for the management of the TDF. For the local community, this project has represented an economic alternative of life and has become a means of empowerment, by building capacities around the knowledge and monitoring of the biodiversity of their territory. By linking this force to other sectors of society, we hope to impact everyday decisions that affect the sustainability of ecosystems
Keywords: Biological monitoring, tropical dry forest, local communities

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Using Soundscapes to Assess Impacts on Biodiversity in Nature Tourism Destinations of Colombia

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Conservation of tropical biodiversity should provide economic benefits to local people. Nature tourism has become an economic alternative for communities in many natural, well-preserved and isolated regions of post-conflict Colombia. Before the pandemic, Colombia had one of the highest growth rates in this sector worldwide. Our aim is to understand the potential effects of nature tourism on biodiversity and its implications for conservation and tourism based on the participatory monitoring of biodiversity in tourism sites. We evaluated the potential of using acoustic monitoring and generated a baseline with the collaboration of local environmental leaders, who helped installed Audiomoth recorders in 167 sites across several ecosystems in Putumayo, Cauca, Choco, Valle del Cauca, Meta and Casanare departments in Colombia, in places managed by 37 nature tourism organizations. We surveyed forest patches with different degrees of intervention and agroforestry sites. We

used the platform Arbimon to summarize acoustic activity patterns and soundscape metrics for every recorder. We applied a principal component analysis to assess differences between sites and determine the importance of different geographic and socioeconomic covariates on soundscapes. The analysis showed that soundscapes near urbanized sites, even with agroforestry or secondary forest habitats, were more similar to each other than the most isolated and well-preserved forest patches. We found that accessibility and ecosystem type played important roles in structuring acoustic communities. The number of visitors had no influence on soundscape variation, suggesting a potential low impact of the current tourism activity on biodiversity. However, visitors numbers are expected to grow exponentially in the coming years, which highlights the importance of developing visitor's carrying capacity models to minimize the potential impact of nature tourism on biodiversity. Acoustic monitoring may provide data to help guide the tourism industry towards more sustainable models for using tropical ecosystems and biodiversity. **Keywords:** Ecoacoustics, sound, development, monitoring, birds, industry

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The Complex of Cryptic Species Complexes: Adapting to a Changing Landscape in Citizen Science

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The Reptiles of India (ROI) citizen science portal has 116k website visits and 4900 contributed images for 341 species of Indian reptiles. An individual submits the photograph of an observation with relevant information (date, time, location, and suggested identification) which is reviewed by experts and made publicly available. Citizen science initiatives like ROI generally have two broad objectives: (1) collecting data across space and time to answer ecological questions, (2) improve accessibility and inclusivity of science, simultaneously using it as a tool for nature education. With advancements in taxonomic studies, there is an increase in the number of cryptic herpetofauna species being described, ie, those that are visually identical. Several of these cryptic species are sympatric and cannot be identified without capturing the specimen to study its features and/or analysing their genetics. This throws up a novel challenge for citizen science initiatives which have so far relied on identifying the species as a taxon unit. This increase in cryptic species disallows 'species' from being the taxon unit as participants may end up collecting incorrect data or not collect data at all. A coarser-scale identification, such as the genus of an specimen leads to a loss in information and is unlikely to be functionally relevant for the two objectives. This necessitates an urgent rethink on herpetofauna-oriented citizen science, and is likely to play itself across other taxa such as avifauna once genetic samples are more widely accessible. In managing ROI for five years, with 116k website visits and 4900 contributed images for 341 species of Indian reptiles, we have noted a distinct trend of an increasing number of cryptic species contributions, leading to the non-fulfilment of the objectives. Thus, we are considering the following two suggestions: (a) using 'morphotypes' as the units of identification, though this comes with its set of challenges such as defining the morphotypes, (b) shifting the focus from the densities/diversity of species to natural history observations. These could be in the form of morphological data (colour, size etc), and behavior. In this manner, citizen science could continue to be a powerful tool for engaging citizens in an ecological education and can contribute to wildlife science. These two suggestions are in addition to accurate identification of species when possible. At this conference, we seek further feedback and wish to undertake discussions with a larger community to preemptively plan the path forward. **Keywords:** Citizen science, natural history, reptiles of India

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Monitoring biodiversity: molecular techniques

IDNA in Dung Beetle Guts for an Improved Understanding of Dung Beetle Diets

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Dung beetles (Scarabeinae) are present on all continents except Antarctica, and provide many important ecosystem services such as, nutrient recycling, soil aeration, improved biodiversity of soil microbiome, improved nitrogen transport to soil, parasite and pathogen control, and they function as secondary seed dispersers. Scarabeaniae or the dung beetle subfamily has ˜6000 species and 200 genera, of those ˜1,200 species are found in the Neotropics, though this number will likely increase with more comprehensive biodiversity studies. Dung beetles are sensitive to both deforestation because of their sensitivity to microclimatic changes and to defaunation because they depend on some of the more vulnerable mammals' dung. Though the diets of dung beetles include dung, rotting fruit, carrion, among other things. The most common method used in dung beetle studies is pitfall trapping, which measures attraction but eliminates many natural variables, such as acceptance of dung, competition for dung, natural size of dung, and a limited number of bait types (e.g many fewer baits than mammal species in the forest). These limitations could be resolved with a more direct study of dung beetle diets. While pitfall trapping may not measure fine-scale diet it can be used to gain a rough understanding of the overall diet composition of dung beetles. We have measured the diet breadth of 12 dung beetle species, with baits of cow dung, rotten meat, rotten banana, and decomposing millipede in Ecuador. We also extracted mammal DNA from dung beetle guts to understand the role mammals play dung beetle diets more precisely. We wash and dissect the beetles then extract the DNA and amplify target mammal DNA from the guts using mammal specific primers for 12s and 16s mitochondrial genes. We captured a subset of the mammal community captured by a camera trap study, though there is a higher representation of terrestrial mammals. Dung beetles (Scarabeinae) are present on all continents except Antarctica, and provide many important ecosystem services such as, nutrient recycling, soil aeration, improved biodiversity of soil microbiome, improved nitrogen transport to soil, parasite and pathogen control, and they function as secondary seed dispersers. Scarabeaniae or the dung beetle subfamily has ˜6000 species and 200 genera, of those ˜1,200 species are found in the Neotropics, though this number will likely increase with more comprehensive biodiversity studies. Dung beetles are sensitive to both deforestation because of their sensitivity to microclimatic changes and to defaunation because they depend on some of the **Keywords:** iDNA, Dung beetles, networks, diets, DNA

Biodiversity of Eukaryotes in Large Tropical Trees: the Life On Trees (LOT) Program

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Introduction: Basic data on biodiversity, such as the variety of life forms coexisting on a single tree, are still lacking and prevent a full understanding of the complexity of interactions among organisms in a tropical rainforest. Filling this gap has recently become more achievable thanks to advances in canopy access methods and genetic tools. **Objective:** The main aims of the research program *Life On Trees* (LOT) are to generate baseline knowledge about the number of species a single tropical tree can support and to understand how these communities of organisms are assembled. **Methods:** Our first project is performed in one of the most biologically diverse regions: the Peruvian Amazon, in the Rio Abiseo National Park. We focus our sampling on a spectacular *Dussia* tree (Fabaceae), which is 50 m high and 45 m wide and covered with epiphytes. For safety reasons, the sampling is carried out by professional climbers, guided by experts of the different eukaryotic groups studied (plants, fungi, animals, protists). In order to better understand the contribution of different tree components (bark, leaves, fruits, flowers, dead wood) to overall tree biodiversity, we assign observations into communities based on height zone or microhabitat and examine similarities and nestedness in the composition of these communities. The complex architecture of the tree is studied using terrestrial LiDAR and the location of samples is recorded using a high precision differential GPS receiver (dGNSS). The collected specimens will be determined by classical taxonomy and genetic methods (DNA metabarcoding). An online tracking system for those specimens sent to taxonomists for identification, as well as a central database system, are already under development. Results: The first results of the LOT-Peru project from April-May 2022 and of the preliminary tests conducted in October 2021 will be presented. **Implications:** The scope of this program is not only scientific. Using the simple example of a large tree, we can reach out to the public and explain difficult concepts, such as what biodiversity is and how it is generated and sustained. In addition, the tree is a strong symbol that has an emotional impact. We hope that this program will build awareness about the impacts of deforestation, and conversely the value of conservation, by showing foresters, city dwellers or villagers that when a tree is cut down, a whole range of biodiversity disappears. **Keywords:** Biodiversity, Amazonia, canopy, LiDAR, Fabaceae, community assembly, Fungi, Fauna, Flora

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Richness, Diversity and Changes in the Composition of Marine Vertebrate Communities in Gulf of Tribugá, Colombia, Based on EDNA Analysis.

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In recent decades, advances in molecular techniques have given rise to a new biomonitoring tool known as environmental DNA (eDNA). With an efficient, non-invasive and replicable sampling approach, eDNA is currently posited as having great potential for the study of ecology and biodiversity, circumventing many of the challenges associated with traditional survey techniques. The Gulf of Tribugá, located on the Pacific coast of Colombia, is known for its high biodiversity and intact sensitive coastal ecosystems, such as mangroves and coral reefs. The gulf's unique hydrological characteristics, including extremely high rainfall and predominance of freshwater currents makes it an area of conservation importance, providing feeding and breeding grounds for large marine mammals such as humpback whales, dolphins, and killer whales, among many other vertebrate species. However, due to its geography (including the second deepest bay in the world), the gulf has been the target of pressure for the construction of commercial ports. Yet there remains a lack of data on the marine biodiversity and its importance in the region. Here, eDNA emerges as a valuable tool to reveal the marine vertebrate diversity in these ecosystems and detect possible temporal changes in community composition. With this in mind, we carried out the first eDNA project in the Gulf of Tribugá, to obtain baseline data on the species richness of the Gulf, and compare the results with existing records for the area. In addition, we plan to analyze the composition of the marine vertebrate community during the presence and absence of two migratory species: the humpback whale (*Megaptera novaeglidae*) and the Pacific sardine (*Sardinops sagax*), providing novel insights into co-occurrence or co-occupation processes. Using eDNA filter kits provided by NatureMetrics©, we carried out monthly sampling across two different periods of the year (Aug-Nov 2021, Feb-May 2022). Samples will be analyzed using two different primers (targeting 12S and 16S regions) to compare primer sensitivity and species detected. Preliminary 16S eDNA results detected a total of 31 taxa. The taxa belong to 4 classes, 12 orders, 22 families, and 23 genera of fishes, reptiles and mammals, including some notable detections such as *Carcharhinus falciformis* and *Megaptera novaeglidae*. We look forward to presenting the complete results and we hope this data will support local communities land rights and underpin conservation actions for the territory, highlighting the biological value of the Gulf of Tribugá. **Keywords:** eDNA, biodiversity, ecology, species Richness, community

Challenges of Monitoring Vast and Poorly Characterised Coastlines in Sub-Saharan Africa: an EDNA Prospect

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Introduction / Background / Justification: The coastline of Sub-Saharan Africa hosts highly diverse fish communities which are of high conservation value and key resources for local livelihoods. However, there is insufficient monitoring to support sustainable ecosystem management in many countries due to the vast extent of coastal habitats and severely limited conservation budgets. **Objective(s)/Hypothesis(es):** We evaluated the potential of eDNA-based techniques to alleviate chronic data deficiencies and surveyed fish communities in Mozambique using two 12S metabarcoding primer sets. **Methods:** Samples were collected by both scientific personnel, and trained local community members at 47 locations spread throughout the southern part of Mozambique at marine, brackish and freshwater sites. eDNA was amplified and sequenced using two 12S primer sets to survey tropical and subtropical fish communities in Mozambique. **Results:** Irrespective of the sampling approach, a high average fish species richness was recorded (38$\pm$20 OTUs sample-1). However, individual sections of the coastline largely differed in the occurrence of threatened and commercially important species, highlighting the need for regionally differentiated management and conservation strategies. A detailed comparison of the two applied primer sets revealed important methodological trade-offs. Whilst Mi-Fish primers amplified a higher number of species, Kelly primers performed much better in the detection of endangered fish species. This trade-off motivated us to develop a dataset merging approach that is critically evaluated here. **Implications/Conclusions:** Overall, our study provides promising results but also highlights that eDNA-based monitoring will require further improvements of e.g., reference databases and local analytical infrastructure to facilitate routine applications in Sub-Saharan Africa. **Keywords:** Sub-Saharan coastlines, environmental DNA, metabarcoding, diversity assessment

An Amazonian Perspective on Scaling Advanced Methods for Biodiversity Assessment

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Introduction / Background / Justification: The high species richness combined with the shortfalls in knowledge (Linnean, Wallacean) represent a major challenge for the conservation of Amazonian biodiversity. Modern techniques using molecular identification (metabarcoding) show promise in less diverse temperate systems, and show potential to massively scale up surveying and monitoring of biota to overcome the knowledge gap. **Objective(s)/Hypothesis(es):** Testing different methods for aquatic and terrestrial biodiversity with a robust spatio-temporal sample design should elucidate which sample types show most promise for mapping and monitoring biodiversity in Amazonia. **Methods:** Multiple types of bulk and environmental samples are being collected from a range of environments in Eastern Amazonia, including reference areas, impacted areas and areas undergoing regeneration and being tested with taxon specific and generalized primer combinations to assess the most cost-efficient samples and processing methods. **Results:** Results to date indicate the importance of good quality curated reference datasets to reduce noise in final ecologically informative datasets, while care must be taken to choose suitable markers for generalized amplification. Furthermore, it is important to provide adequate training in field sampling in order to guarantee data quality and confidence in results. **Implications/Conclusions:** Metabarcoding is still maturing as a technique and its reliable implementation in hyperdiverse systems requires careful consideration, balancing the demands for specificity and sensitivity in relation to the aims of the study. Cost-efficiency and data quality can both be improved by scaling up projects beyond specific target taxa. **Keywords:** Method evaluation, surveying, monitoring, cost-efficiency analyses

Specificity in Environmental DNA Surveys of Fish Communities in Amazonia

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Introduction / Background / Justification: Metabarcoding using environmental DNA from filtrates of water has been shown to be effective to survey fish fauna in diverse systems, but standard methods show some potential limitations in megadiverse systems. Specifically, congeneric species can be hard to distinguish using the short fragments of slowly evolving markers including standard 12S metabarcoding primers. **Objective(s)/Hypothesis(es):** We test the discriminatory power of different potential markers in publicly available and new reference datasets to determine how useful different markers are to reliably describe real communities of fishes found in Amazonia. **Methods:** Sequences for 12S, cytb and COI markers were either produced or obtained from publicly available data for species known to form real communities in eastern Amazonia. After alignment and delimitation of species using classical barcoding methods the sequences were then clipped to represent a range of different possible metabarcoding markers and retested to determine whether biodiversity indices were consistent or whether the inability to distinguish taxa based on shorter markers results in sub-estimation of biodiversity. **Results:** Some closely related taxa cannot be distinguished using shorter metabarcoding markers and this can result in lower estimates of diversity in real communities. However, some indices of diversity are less impacted by this loss than others. **Implications/Conclusions:** Metabarcoding requires not only a complete reference dataset but the careful choice of markers that adequately allow specific identification so as not to sub-estimate true diversity patterns. Previous knowledge on the likelihood of multiple congeners that represent large parts of the community of organisms studied should be considered when choosing appropriate metabarcoding markers. **Keywords:** Congeneric species, metabarcoding, markers, diversity, biodiversity

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Scaling DNA Barcode Generation of Insects from Malaise Traps in Colombia Using MinION Sequencer

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Introduction / Background / Justification: Insect diversity can be used as an indicator of the health of an ecosystem. Molecular techniques, such as DNA barcoding, are widely used to rapidly characterize species in highly diverse groups and are advantageous at big scales in comparison to traditional morphology-based characterizations. Emerging technologies in DNA sequencing, such as the portable sequencer MinION (Oxford Nanopore Technologies), are reducing costs and making it possible to perform sequencing experiments in simple laboratory conditions. Previous studies in massive DNA barcoding have been successfully developed focusing on certain insect orders (such as Diptera), nonetheless, they can also be adapted to include individuals from several orders to characterize insect molecular diversity in the tropics. Objective(s)/Hypothesis(es): To test and implement a laboratory workflow for massive DNA barcode generation of neotropical insects from multiple orders using Oxford Nanopore sequencing (MinION) and multiplexing several hundred individuals in a single run. **Methods:** Over 600 individuals from 16 insect orders collected in Malaise traps were selected for this experiment. Malaise traps were from different regions in Colombia (departments of Boyacá, Cundinamarca, Meta, and Santander), at an elevation range from 600 to ~3000 m.a.s.l. DNA was extracted using HotShot protocol, and a fragment of cytochrome oxidase I (COI) gene was amplified using LCO1490 and HCO2198 primers with different tags (13 bp) for multiplexing samples. PCR products were checked on 1.5% agarose gels and pooled together according to gel band intensity. Oxford Nanopore library was prepared using SQK-LSK109 kit and it was loaded on a FLO-MIN-111 flow cell (R10.3 chemistry) and ran for 48 hours. Raw sequencing reads were basecalled using Guppy basecaller and barcodes were reconstructed using ONTbarcoder software. The obtained barcodes were compared to NCBI database using BLAST to check its taxonomic classification at order level and compare it with the previous morphological identification. Results: We obtained over 550 barcodes, 85% of the total number of individuals. Over 450 were high-quality barcodes with no sequence ambiguities (80% of total sequences). After BLAST, 95% of barcodes coincided with the morphology-based insect order identification. Implications/Conclusions: Oxford Nanopore sequencing is a suitable method to produce large amounts of high-quality DNA barcode sequences from insects at low costs (<4 USD per sample, including DNA extraction, PCR, and sequencing). This study paves the road for rapid cost-effective biodiversity assessment of insects in the neotropics. **Keywords:** Insects, DNA barcoding, Nanopore sequencing, COI

Population Dynamics and Regulation I

Tree Species Demographic Trade-offs across the Seedling, Sapling and Larger Size Classes in Five Tropical Forests

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Life-history strategies of tropical tree species align along two trade-off gradients, one contrasting species with fast growth rates from those with high survival rates, and a second one contrasts species with both fast growth and high survival rates from those with high recruitment success. Research on those two trade-offs, however, is mostly based on trees of > 1 cm diameter at breast height (dbh), thus omitting demography at the seedling and sapling life cycle stages. It is thus unknown how early life-history stages relate to demography at larger size classes. In particular, we do not know whether those demographic relationships across the ontogeny of tree species are preserved or vary among forest communities that differ in species and environmental conditions. We used forest census data that includes seeds and seedlings in five large-scale, long-term plots in Ecuador, Malaysia, Panama, Puerto Rico and Taiwan. Using Bayesian hierarchical models, we calculated species average annual rates of seed-to-seedling transition as well as growth and survival of seedlings (< 20 cm height), saplings (20-50 cm height), and individuals > 1 cm dbh in sun and shade. We used correlation, principal component, and Procrustes analyses to explore the joint relationships among the demographic rates of > 700 tree species at different life-history stages across the five forest plots. Sapling growth was consistently and positively related to growth in larger size classes, but growth at the seedling stage was unrelated to the growth at larger size classes. At three sites, survival of seedlings and saplings was positively correlated with survival and negatively correlated with growth of larger size classes. In two hurricane-impacted forests, however, this trend did not hold. In the two forests where seed fall was recorded, seed-to-seedling transition was independent of growth and survival at larger size classes in one but not the other, where it was positively related to survival and growth of larger size classes. These results suggest that seed-to-seedling transition and seedling growth rates, but not survival rates might offer additional axes of life-history variation in tropical forest communities. Yet, these patterns in ontogenetic trade-offs might be altered in hurricane-impacted forests. **Keywords:** BCI, growth, life-history strategies, ontogenetic stages, survival, vital rates

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How an Emergent Tree Species Benefits from Being Struck by Lightning

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Introduction: Lightning strikes are among the most powerful phenomena in existence. A typical lightning strike carries 30,000 amperes of electric current and heats is path to temperatures hotter than the surface of the sun. Accordingly, lightning strikes are universally viewed as destructive, particularly in forests where they often kill groups of trees or ignite fires. However, scattered anecdotes suggest that some trees are not damaged by lightning and potentially even benefit from being struck. If some trees do benefit from being struck by lightning, that will likely shape their ecology, evolutionary history, and ability to coexist in a forest community. Here we evaluate whether certain trees benefit from being directly struck by lightning and explore the potential for lightning to shape a species' niche. **Methods:** We combine field surveys and drone imagery of systematically located lightning strikes to test whether a common canopy species, *Dipteryx oleifera*, benefits from direct lightning strikes. We evaluate whether the benefits of being struck by lightning, in terms of damage to competitors and parasitic lianas, outweigh the costs of being struck, in terms of mortality, crown damage, and trunk damage. We also use simulations to estimate the contributions of lightning survival to the longevity and reproductive output of this focal species. **Results:** Direct lightning strikes caused no mortality and minimal damage to *D. oleifera* trees while simultaneously killing neighboring trees and parasitic lianas. By contrast, among all other tree species, 64% of directly struck tress died within 2 years of the strike and 77% died within 6 years. During their long residence time as large trees (i.e., $>$ 60 cm in diameter), we estimate that an average *D. oleifera* tree is directly struck by lightning 5.6 times, killing 17.8 total lianas and 11.7 Mg of total competitor biomass. The ability to survive lightning is key to the life history strategy of *D. oleifera*, using detailed data on survivorship, growth, and seed production, we estimate that lightning facilitates ca. 50% of total seed production. **Discussion**: The association between *D. oleifera* trees and lightning likely facilitates the persistence of this species, expands its realized niche space, and influences its architecture. Similarities with other species suggest that this phenomena is widespread among large startured taxa. **Keywords:** Tree mortality, lightning, lianas, competition, parasitism, demography, fecundity, remote sensing

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Demographic Studies and Predictive Distribution Modelling Provide Baseline Data for Conservation Action for an Endangered Orchid Endemic to Tropical Dry

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Population ecology and potential distribution studies provide essential information for the implementation of conservation strategies for endangered species. Cattleya quadricolor Lindl. Is a highly endemic, epiphytic orchid, with a distribution restricted to the mid-basin of the Cauca River in Colombia. The species is categorized as 'Endangered' at the national level, a consequence of extensive degradation of its native tropical dry forest habitat, as well as severe historical and still ongoing illegal extraction of plants for trade. We aimed to generate baseline data on the conservation status of this species to inform future population restoration activities, through demographic studies in eight remnant populations, and predictive models of the species distribution. **Methods**: Demographic studies characterize the basic biology of a species by describing its life cycle, which constitutes the fundamental unit of description of an organism. This approach allows the estimation of the finite growth rate of the population (λ), the population structure by development stages, and the reproductive value of the different life cycle stages. The distribution models were elaborated in the MAXENT program, to predict the current potential distribution of the species. To do this, the occurrences found in the historical record were combined with the geographic coordinates of the populations in the sampled localities and with the climatic variables associated with each locality in different future scenarios. **Results:** Over the eight populations, N ranged between 100 and 200 individuals. Five of the eight populations showed negative growth rates, with λ from 0 to 1. The three populations with positive growth rates presented fertility rates 1, unlike the populations with negative growth rates. All populations had an abundance of seedlings less than 10%, which suggests a lower generational change. The maximum probability of distribution for the species was found to be concentrated towards the foothills of the western and central Andean Mountain range and in the northern zone of the Cauca river valley, between an altitude of 900 and 1500 meters above sea level. The vast majority of this predicted distribution has been transformed from the original tropical dry forest to livestock grazing and sugar cane crops. We undertook an extensive survey of all known remnant populations for this endangered species.

Updated predictive models of potential distribution together with population demographic data address the IUCN Red list criteria A y B. These data provide the baseline to now design and implement conservation strategies for C. quadricolor, prioritizing conservation areas and population restoration actions. **Keywords:** Demographic, distribution, orchids, conservation, population, ecology, epiphytes

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Estimating Jaguar Survival and Abundance Using Camera Traps and Tourists' Photos

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Abundance and survival estimates of large carnivores are scarce due to their elusive nature and low-density. The jaguar (*Panthera onca*) is one of such cases whose abundance and survival, especially on working lands, is poorly studied. We collected camera trap data over five sampling periods between 2014 and 2021 on a working ranch and ecotourism destination in the Colombia's Eastern Llanos and combined these data with tourist sightings during the same period to estimate survival and abundance using a Robust Design Model. We predicted that survival, abundance, and resighting probability would increase during the five studies. Results demonstrate an increase in jaguar abundance during the eight-year period, an increase in resighting probability, high temporary immigration—especially of males—and constant survival. However, there was a decrease in abundance and detection from the 2020-2021 study, likely because of small tourist numbers and therefore a low resighting probability. Our study demonstrates that responsible wildlife viewing can support large carnivore conservation on working lands while contributing to scientific studies. We suggest that further analysis is necessary to identify factors influencing jaguar survival and abundance at a larger scale due to rapid land use change from rice cultivation and retaliatory hunting in the region. **Keywords:** Panthera onca, robust design, ecotourism, camera trapping, jaguars, abundance, carnivores

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Demographic Response of a Range-limited Tropical Plant to Climatic and Geographic Gradients

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Introduction / Background / Justification: The center-periphery hypothesis predicts a decline in population density towards the periphery of species distribution range, reflecting a spatially explicit variation in environmental conditions. However, most demographic tests of this hypothesis failed to disentangle the role of geography from that of climatic or ecological niche. Because species density varies over time and space, using density instead of population dynamics to explain range limitation can lead to erroneous conclusions. **Objective(s)/Hypothesis(es):** We hypothesized that because species are expected to experience optimal abiotic conditions at their climatic niche centre, i) central populations will have better demographic growth, survival, and fruit production than peripheral populations. As a result, (ii) central populations are expected to have higher growth rates than peripheral populations, which are expected to show declining trends, limiting species range expansion beyond these boundaries. We also hypothesized that because ecological conditions are expected to worsen toward the periphery, (iii) population dynamics will be more sensitive to perturbation of vital rates in peripheral populations. **Methods:** To test these hypotheses, we studied the demography of *Thunbergia atacorensis* (Acanthaceae), a range-limited herb in West-Africa. We used these demographic data to parametrize an integral projection model to test how population dynamics, demographic vital rates, and the sensitivity of population growth rates to perturbation of these vital rates vary with increasing distance from the species' climatic versus geographic centers. Results: Demographic vital rates and population growth rates did not decrease significantly with distance from geographic or climatic centers contrary to CPH predictions. However, populations at the center of geographic range were demographically more resilient than those at periphery. Soil nitrogen was the main driver of population dynamics. The relative influence of plant survival growth on population growth rates exceeds that of fecundity across the ranges. I**mplications/Conclusions:** Our study highlights the need to use population dynamics instead of density as a metric in studies testing the center-periphery hypothesis. Our study also suggests that using geographic distribution in lieu of climatic or ecological niche to explain species center-periphery dynamics could lead to wrong conservations decisions. Thus, central populations are as valuable as peripheral populations for conservation. **Keywords:** Center-periphery hypothesis, integral projection model, peripheral populations.

Nonlinear Population Response of a Tropical Tree to Perturbation in Extreme Environments

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Introduction / Background / Justification: Theoretical studies on stage-structured population modeling suggest that population-level responses to perturbation of underlying demographic processes are nonlinear. However, most analyses of the responses of populations to chronic anthropogenic disturbance assume linear response and use classical sensitivity and elasticity analyses. Such assumptions can lead to misleading conclusions and suboptimal conservation and sustainable use strategies. Chronic anthropogenic disturbance can interact with climatic conditions to affect populations' ecological responses. These stressors can reduce the resources available for populations to respond to perturbation, trade-offs in demographic processes and can therefore influence the strength of the nonlinearity in these responses. However, theoretical and empirical studies failed to address these questions thus limiting our understanding of when and where nonlinear responses are expected or weak. Transfer function analysis is an exact perturbation method that relaxes the linearity assumption. **Objective(s)/Hypothesis(es)/Methods:** We used the transfer function analysis to test the effect of chronic anthropogenic disturbance and climate on the nonlinearity of the response of a tropical tree to perturbation. We expected strong nonlinear responses of asymptotic population growth rates to perturbation of stasis, particularly for such long-lived species that are often more sensitive to perturbation of survival. In contrast, we expected a linear response of population growth rates to perturbation of fertility. We also hypothesized that the strength of nonlinear response would increase with increasing stressors intensities due to the fast limitation of resources that can cause the quick onset of a response plateau. **Results/ Implications/Conclusions:** Population dynamics response to perturbation of stasis was nonlinear regardless of environmental conditions and linear for perturbation to fertility. Population growth rate response to perturbation of growth was mostly linear but become increasingly nonlinear in harsh environmental conditions. The nonlinear relationship between population growth rate and perturbation of stasis was convex. This indicates that classical sensitivity analyses, which assume linear response, underestimate the perturbation effort required to rescue declining populations, particularly for long-lived species whose sensitivities are often dominated by stasis. Our results illustrate that relaxing the nonlinearity assumption can lead to suboptimal management strategies and may explain the mismatch between modeling outcome and winning conservation strategies. **Keywords:** Population inertia, transfer function analysis, nonlinear mapping, sensitivity analysis, trees

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Population Structure of Three Threatened Timber Species in the Colombian Chocó Biogeographic Region

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Carapa guianensis Aubl. (Meliaceae), *Humiriastrum procerum* (Little) Cuatrec. (Humiriaceae) and *Minquartia guianensis* Aubl. (Olacaceae) belong to intermediate and climax successional stages in the rainforest of the Chocó biogeographic region. Those species are well known for the high quality of their wood, which has led to the overexploitation of this resource, both legally and illegally. Currently, these species are classified as threatened in the region. However, ecological aspects of the species such as spatial distribution, population structure, functional and genetic aspects are unknown. To improve the management and conservation of the species in this research 16 sites has been selected across the Colombian Chocó region to determine their distribution across the region, the population density, and the structure of the populations by classes. To date, 12 sites have been visited where 150 individuals of *C. guianensis* and 105 of *H. procerum* were sampled. *M. guianensis* was found only in 8 sites, there 22 individuals were sampled. 58% of *C. guianensis* individuals assessed have $<$ 20 cm dbh and 43% $<$12 m total height. 34% of *H. procerum* have $<$15 cm dbh m and 27% $<$ 12 m total height. 68% *M. guianensis* have $<$ 12 cm dbh and 64% $<$12 m total height. The number of individuals that exceed 50 cm dbh was, 19 for *C. guianensis*, 9 *H. procerum* and 1 *M. guianensis*. This project has recorded the double of individuals for each species in the region in relation to the present in the GBIF database. In addition, considering that these species can exceed 80 cm dbh and 40 m high it is evident that the selective and uncontrol logging has affected the presence of very well-developed trees in these forests. This can have an impact in the composition of the succession and in the interaction with other plant and animal species. Future studies in these species should be focused on the functional and genetic to understand

the impact of the lack of well-developed trees in the dynamics of the forests as well as the effect for the next generations. **Keywords:** Chocó biogeographic, rainforest, threatened species, conservation, illegal logging.

Population Dynamics and Regulation II

Distance and Density Dependent Regeneration, Seed Production and Biomass Accumulation of the Brazil Nut (*Bertholletia excelsa*)

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Conspecific distance and density-dependence is a key driver of tree diversity in natural forests, but the extent to which this process may influence ecosystem service provision by individual tree species is largely unknown. The amount of ecosystem services generated in a given area of forest by a tree species is governed by the combination of the number of individual trees in that area (population density) and the state and performance of the individual trees such as tree growth, survival, and reproduction. Each of these variables are differently influenced both by environmental growth conditions and drivers of distance and density effects such as pest and disease pressure, population genetics and intraspecific competition for resources. Drawing on transect sampling, population genetic data, and size and seed production information for >135,000 Brazil nut trees *(Bertholletia excelsa)* from the Peruvian Amazon, we assessed the manifestation of distance and density effects on regeneration, biomass accumulation and fecundity and aimed to identify the dominant underlying processes. Brazil nut seed is one of the cornerstone non-timber forest products (NTFPs) in Amazonia, sustaining multimillion dollar extractive economies in Bolivia, Brazil and Peru, and it plays a pivotal role in carbon sequestration. We found evidence for distance-dependent recruitment of Brazil nut trees but only in swiddens and not mature forest which may be related to the species gap-dependent nature. Further we found both negative and positive effects of conspecific proximity on seed production and above ground biomass at small and large nearest neighbour distances, respectively. Plausible explanations for negative effects at small distances are fine-scale genetic structuring and competition for shared resources, whereas positive effects at large distances are likely due to increasing pollen limitation and suboptimal growth conditions. However, both seed production and biomass accumulation of individual Brazil nut trees tended to increase with the genetic diversity of their conspecific neighborhoods, suggesting that genetic structuring might also contribute to explaining distance-dependent effects on biomass accumulation. These findings point to the importance of enhancing genetic diversity in enrichment planting and restoration or tree planting efforts using the Brazil nut. This is also important in the context of climate change, which is likely to reinforce trade-offs created by climate variables between recruitment, seed production and biomass accumulation. **Keywords:** *Bertholletia excelsa,* distance-dependence, density-dependence, genetics, Janzen Connel, climate

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Updating Distribution of *Magnolia calimaensis* (Lozano) Govaerts an Endemic and Critical Endangered Species

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Magnolia calimaensis (Lozano) Govaerts is an endemic species from the central Chocó biogeographic region in Colombia. It is thought to be restricted to 100 km2, because it had been observed only in the locality of Bajo Calima, department of Valle del Cauca. *M. calimaensis* is critically endangered (CR) and there is no ecological, genetic, or functional information about this species. Specific local uses, except spall wood, by locals have not been recorded either. All data available correspond to 2 old herbarium records. This lack of information limits any progress in their conservation and management. This research has carried out an inventory of *M. calimaensis* around the Tropical Forest Centre of this University located in the Bajo Calima region, as well as

in a small area of Bahía Málaga and Bajo San Juan. The aim was to establish a partial demographic study and provide management strategies for the conservation of the species. Were sampled more individuals than were expected, considering the alleged pressure of illegal logging and the lack of observations in the wild. The individuals were locted around 169 km2 in the Bajo Calima, and 5km2 in Bahía Málaga, no individuals were found in Bajo San Juan. In addition, later in 2021, one team member collected an individual of *M. calimaensis* 200 km out from the expected area of species. Those initial sampling showed that the species has a significant number of individuals in the wild in a wider distribution area than assumed by some authors.
Keywords: Magnolia, conservation, population, endangered species

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Population Dynamics and Regulation: Fauna I

Honest Signals in Food Competition: Crop Size and Age Influence Contest Rate but Not Its Outcome in the King Vulture

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Social species exhibit mechanisms to regulate competition to avoid dangerous and energy-consuming fights among individuals. Such mechanisms include asymmetries in resource holding potential (RHP) that distinguish competitors and may allow them to assess their chance of success in an interaction. Here, we test an honest signal that should reflect an initial asymmetry in satiety during competition for food: the satiety level exhibited by an individual holding the resource should be an important cue for a competitor motivated to acquire the resource to assess its chance of success. Our model species is the king vulture (*Sarcoramphus papa*), a large neotropical scavenger in which the level of satiety can be assessed visually through changes in crop size (from not visible to highly bulging). In this species, plumage pattern is also indicative of age and changes until individuals reach an age of 6-7 years. We investigated the role of crop size and age in the mechanisms regulating intraspecific competition in king vultures at feeding sites. Using video footage of the species at carcasses deposited in the Calakmul region of Mexico, we characterized the interactions among individuals at these feeding sites. Competitors were characterized according to their satiety levels (i.e., crop size), age (i.e., plumage pattern), and relative position to the carcass. We showed that individuals contesting the resource won in more than 90% of the interactions. As expected, the probability of initiating a contest increased significantly with age. However, contrary to our expectations, the probability of an individual initiating a contest increased significantly with the size of its crop up to a certain level that we might assume represented full satiety. None of these two variables had an effect on the interaction outcome. Our results suggest that both crop size and age act as asymmetries in resource holding potential in the context of competition at feeding sites in the king vulture. This research is also the first known to assess and confirm the role of bird crop size as an honest signal of satiety in intraspecific interactions and provides guidelines for further studies. **Keywords:** Ressource holding potential, satiety level, intraspecific interaction, asymmetries, king vulture

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Movement Ecology and Demography of Ocelots in Northern Pantanal

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Pantanal is the largest tropical wetland with well-marked cycles of wet and dry seasons. Such natural dynamics changes habitat availability over the year as most areas become temporary flood. Besides temporal dynamic, Pantanal is also spatially heterogeneous with a mosaic of open savanna, riparian forest and cattle pastures. Recent increasing in global temperature and reduced annual rainfall have resulted in longer periods of drought and higher frequency of large wildfires. Besides environmental heterogeneity, the majority of Pantanal is privately owned (95%) and historical dedicated to cattle ranching. In recent decades, ecotourism for wildlife observation has become an important income for the region, contributing to increasing people awareness of environmental conservation. In highly temporal-spatial dynamic landscape such as Pantanal, food resource and habitat availability change constantly forcing the animals to regularly adapt their movement behavior and forage strategies. Under such scenario, ocelots (*Leopardus pardalis*) are relative abundant small feline, which offers a great opportunity to understand how individuals adapt their life strategies across space and time in

response to natural and human-induced disturbances. This study has been conducted since 2020 in the Porto Jofre region, northern Pantanal, where Panthera Institution has established an ocelot monitoring program to uncover drivers of movement behavior and population dynamics for better plan conservation strategies of small cats. The study area is a 100 km^2 cattle ranch that follows wildlife-friendly best practices. So far, we have monitored the movement behavior of five individuals (3 males and 2 females) with radio-collar for 94 to 140 days during the dry season. Home-range size varied from a mean of 1.99 $\pm$ 0.36 for females to 6.82 $\pm$ 3.00 km^2 for males. Local population density was estimated in 48.3 individuals/ 100 km^2 from a camera-trap campaign with 36 stations spaced 1 km apart covering 78 km^2 (1514 trap nights). Next stages in our study include modelling resource selection based on animal movement using step selection analysis. Our study offers a great opportunity to study medium to long-term ecology aspects of ocelots. Understanding population ecology and animal movement in a multi-use landscape can help us to better design range-wide conservation priorities for small cats beyond protected areas, in an anthropogenic-context landscape. Due to its wide range distribution, ocelots may act as a key species in indicating habitat quality and priority areas for conservation. **Keywords:** Ocelot, movement ecology, Pantanal, demography

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Genetic Diversity, Phylogeny and Biogeography in the Tadpole Shrimp Triops Granarius (Branchiopoda: Notostraca) in Qatar

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The natural habitat of Qatar is characterized by a lack of standing freshwater and the tadpole shrimp *Triops granarius* (Branchiopoda, Notostraca) is the largest freshwater animal that inhabits the vernal pools. This study uses 28S rRNA, 16S rRNA and COI genes to examine the molecular diversity of individuals found in five vernal pools in Qatar and attempts to determine the origin of *T. granarius* in Qatar. Haplotype network was analyzed on the mitochondrial markers while maximum likelihood phylogenetic analysis was conducted on sequences from all three markers to determine the relationship of Qatari populations with those from other regions. Individuals showed a high level of sequence uniformity at all three loci. Both the haplotype network results and maximum likelihood analysis indicate that the closest relatives of *T. granarius* in Qatar are from northeastern Asia, including Mongolia, China and Japan. This pattern is consistent with the geological evidence that *T. granarius* expanded from its North African origin to Northeastern Asia through the Arabian land bridge. Given the great diversity within the species and low genetic variation in the populations in Qatar, it suggests that populations in this region could have experienced bottlenecks that led to their high genetic uniformity. **Keywords:** Triops, genetic diversity, phylogeny, biogeography, Qatar, COI, 28S, 16S

Recruitment Status of Sambar Deer (*Rusa unicolor unicolor*) in Horton Plains National Park, Sri Lanka

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Studying the calf survival and subsequent recruitment is essential to understand the population dynamics of sambar deer (*Rusa unicolor unicolor*) in Horton Plains National Park (HPNP), Sri Lanka, where sambar is considered a flagship species for conservation of the park. Sambar deer counts were conducted in HPNP over three years from January 2018 to December 2020, by road strip transects for three days a month, during which individual counts were recorded with information on growth stage and gender. A standard table of characters developed earlier was used to identify the life stage of sambar deer. Bucks were divided according to the number of antlers (three-point, two-point, and spike) they possess, while initial velvet antlers become hard during the peak of the breeding season, where three-point hard antlers indicate sexual maturity and dominance. The mean percentage of hard antlered bucks increased up to 96% in November- December, while mating-related behavioral units were observed from September to December. The highest number of newborn calves and adult hinds were recorded during July-August. The number of newborn calves per hind during the peak calving season was 0.51, while the highest mean number of newborn calves recorded for the same period was 170 $\pm$ 2.52, the highest mean number of six months old calves was 75 $\pm$ 2.96 in January- February, and when they

are one and half years old the number was decreased to 25 $\pm$ 1.53. Results indicate about 44% of newborn calves have survived to the age of six-month and only 27% survived to the age of 18 months. Results from this model suggest that approximately 56% of newborn sambar deer are not likely to survive beyond six months of age. Sambar deer population management in HPNP is recommended to take this annual calf survival into account when making their decisions. **Keywords:** Calf, Horton Plains National Park, population management, recruitment, Sambar, survival

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Chromosome Scale Genome Assembly and Historical Changes in the Effective Population Size of Two Marine Fishes from the Philippines

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One of the greatest challenges facing humanity today is our ability to understand the impact humans have on the natural resources we rely on for our existence. Overharvesting and environmental degradation have led to declines in fish populations of tropical regions, and yet there is little genetic evidence of this. Genetic diversity is critical for adaptation and evolution in response to perturbations, thus quantifying and describing the reduction in diversity can help us to better understand how to manage sustainable fisheries. Here, we utilize modern genomic tools, such as *in situ* Hi-C, to explore the previously unprecedented ability to evaluate genetic diversity and infer changes in it. We test for historical changes in the effective population size (N_e) of two marine fishes targeted by the NSF funded Philippines PIRE Project (PPP): *Salarias fasciatus* and *Sphaeramia nematoptera*. To test the null hypothesis of no change in N_e, we employ PSMC and the SNeP software packages to test for non-random patterns in historical N_e. Using our adapted *in situ* Hi-C protocol, we output a *de novo* chromosome-scale genome assembly for the *S. fasciatus* species using only Illumina short read 2 x 150 bp paired end shotgun and Hi-C libraries. To validate our approach, we compare the quality metrics of our *de novo* assembly to that of the published assembly available on NIH GenBank. By mapping contemporarily collected individuals of both targeted species to the reference genomes, we explore the population genomic underpinnings in which the previously described software are based - linkage disequilibrium, inbreeding, and genetic variance - over the past five centuries. Our research strongly suggests that the incorporation of *in situ* Hi-C libraries in *de novo* genome assemblies will improve the accuracy and validity of chromosome-scale assemblies and enable scientists to further their understanding of population genomics spanning many generations. Understanding anthropogenic impacts in ecologically important tropical regions to date will allow us to better conserve and protect vital resources for future use. Our research provides a platform for policymakers and resource managers to better choose a successful resource management strategy that ensures sustainability of resources for present and future generations. **Keywords:** Ecology, evolution, biology, population genomics, bioinformatics

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Habitat Suitability and Population Size Estimates for the Mongoose Lemurs of Madagascar and Comoros and the Implications for Conservation

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Tropical forests face alarming rate of loss driven by anthropogenic pressures exposing forest-dwelling species such as primates to extinction risks. Assessing knowledge such as population density and habitat selection by these species can allow gaining insight onto how these taxa respond to habitat fragmentation in order to assess effective conservation. In this study, we investigated the population density and size of the mongoose lemur (*Eulemur mongoz*), a Critically Endangered primate species from Madagascar and the Comoros Islands using distance sampling approaches through (1) conventional distance sampling, and (2) density surface modeling. We applied a species distribution modeling method (SDM) to assess the habitat suitability and geographic distribution of the species in the two regions. We estimated an average population density of 23.49 individuals/km^2 along 89.90 km of line transects for the population of Comoros and 15.23 individuals/km^2 along 65 km of transects for the population of Madagascar. We estimated a population size of 9,128 individuals in Comoros against 7,270 individuals in Madagascar. According to the SDM, mongoose lemur of Comoros has a relatively large geographic range (336 km^2, ˜47 % of the total area of Anjouan and Moheli, which is 714 km2) extending over low-elevation farmlands and in forests, while the population of Madagascar has limited distributions, restricted in the remaining natural forests (3,160 km^2, ˜17.5 % of the total studied area, which is 18,000 km^2). However, high levels hunting, habitat disturbance, and conversion of natural forest into agricultural lands render the species vulnerable to extinction. As population density and the distribution of primates are highly related to the habitat quality and vegetation availability and since the high level of habitat disturbance and lemur hunting (in Madagascar) are associated with high levels of poverty, we suggest (1) Enhancing livelihoods and well-being of rural communities that will allow them to be less dependent to natural resources and thus to reduce unsustainable natural resource use, (2) involving a broad community of local individuals and entities in the conservation and management, (3) Restoring forests and avoiding the conversion of secondary forest into agricultural lands. Our findings highlight how population density and distribution patterns are related to environmental factors. They also emphasize how species distribution modeling approaches are useful for primate's species conservation. **Keywords:** Comoro, Madagascar, conservation, density, *Eulemur mongoz*, habitat loss

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Population Dynamics and Regulation: Fauna II

Preliminary Evaluation of the Population of *Podocnemis unifilis* River Turtles within Matsiguenka Territory in the Manu Headwaters of Southwest Amazon

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River turtles have been very appreciated by indigenous and local populations as food, medicine and source of cultural traditions for a very long time since prehistoric times. However, high external consumption demands, lack of efficient wildlife protection policies, have led to intensive use, drastically reducing the population, the size of individuals, and the range of distribution for many species. *Podocnemis unifilis* (taricayas) is one of them. This study evaluates the population of taricayas in the upper Manu river area, jurisdiction of the Matsiguenka communities, an area with no restriction to the use of this resource for self-consumption, the "Special Use Zone" (SUZ), within the Manu National Park (MNP), in Madre de Dios, Peru. Two authors are Matsiguenka people whose names cannot be added as they do not use email accounts, they are Wilfredo Enrique and John Ahuanari, from Native community Tayakome. Our methodology followed established and adapted protocols for monitoring Amazonian River turtles. We monitored sun-basking adult individuals, nests, and the incubation process (including pre-eclosion mortality). The study was carried out from July - October 2019, at the MNP SUZ which runs along ˜ 111 kilometers of the main channel of Manu River. Taricayas produced 421 nests, distributed along 47% of beaches along the river. Main agents of mortality included human beings and diptera larvae. Interestingly, taricayas seem not to mind the proximity of the beach to native communities to choose a nest site, as long as the beach is long, wide and elevated (shown by a GLM analysis). Incubation term was longer, clutch size was smaller, and egg mortality due to Diptera larvae was relatively higher both in the SUZ and outside in the "Control" beach, when compared to records in the Tourism Zone from 2018. Could it be then a basin-scale shift in the incubation/development process of taricayas? A shift in response to global climate change and/or due to its own population dynamics? We cannot tell, monitoring should continue, and a basin scale approach used to re-design and capture both anthropogenic and environmental signals. The "Taricaya project" goes beyond monitoring goals, as it has reinforced a vital environment for a healthy cultural and non-formal training interchange among scientists, teachers, students, and the Matsiguenka, aiming to set the basis for an effective long term integral collaboration towards Food Security, Intercultural Education and a Resilient response to Climate Change. This story is to be continued. **Keywords:** Amazonian-river-turtles, podocnemis, matsiguenka, climate change, predation community-based-monitoring

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Introducing RangeShifter as a Tool for Landscape and Population Ecology in the Tropics.

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Introduction: Spatial ecological and evolutionary models provide important tools for understanding, predicting and ultimately informing the management of ecological systems. In this presentation, we will introduce the RangeShifter modelling software (and the new R version, RangeShiftR). RangeShifter provides a platform for developing spatially-realistic individual-based simulations. It has already been broadly used to address a range of questions related to landscape ecology and spatial population dynamics with a focus often being on habitat connectivity, population viability and population range expansions. **Objectives:** We will demonstrate how the

RangeShifter software can be used to simulate the dynamics of tropical ecological systems and to subsequently to test alternative management options. We will draw on a selection of recently published and unpublished studies that includes work on the landscape ecology of orangutan in Borneo, forest birds in Kenya, white-tailed deer in Ecuador and invasive plants in Argentina. **Methods:** We will introduce the key concepts embedded in the RangeShifter software (see https://rangeshifter.github.io) and demonstrate how simulations can be developed, and the simulation output analyzed to address a range of different types of ecological questions. **Results:** We will select results from a range of case studies to illustrate how the software can provide insight into spatial population dynamics, the impact of landscape management decisions on connectivity, population viability and rates of population range expansion, Implications: We will describe opportunities for using the software, highlight key challenges in using it effectively and discuss directions in which the software is being further developed. We will emphasize our ambition to support the development of capacity for using these spatial population modelling approaches in tropical regions as this type of modelling approach has, to date, been used far more frequently for temperate ecosystems. **Keywords:** RangeShifter, ecological model, dispersal, connectivity, population viability.

Genomic Analyses Reveal Loci Potentially Associated with Local Adaptation in the Endangered Black Lion Tamarin (*Leontopithecus chrysopygus,* Primates)

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Introduction: Improving our understanding of genomic mechanisms influencing local adaptation is essential in the context of rapid global climate and environmental changes. Small and isolated populations, as those of the black lion tamarin (BLT) *Leontopithecus chrysopygus*, tend to exhibit reductions in genetic diversity and consequently in adaptive and evolutionary potential. This arboreal primate is endemic to the Brazilian Atlantic Forest of São Paulo state, and is considered endangered mainly due to environmental disturbances caused by deforestation. **Objectives:** Here, we investigate putative signals of differential selection in seven wild populations of BLTs. **Methods:** We sampled eight groups from three fragments located in the Lower Paranapanema (westernmost region of São Paulo state) and two fragments in the Upper Paranapanema (easternmost region of São Paulo state), comprising two from the three regions where the species is currently distributed. Using Single Nucleotide Polymorphisms (SNPs) derived from Genotyping by Sequencing (GBS), we determined kinship and genetic structure, and employed Genotype Environment Association (GEA) methods for searching differential selection signatures. **Results:** We found strong population structuring and a significant isolation by distance, suggesting that geographic isolation is influencing the restricted gene flow among populations. Kinship analyses showed close relationships within each population. Despite this, none population showed significant inbreeding, instead, they exhibited heterozygote excess. GEA methods identified 18 loci under differential selection, which were associated with temperature, precipitation seasonality and/or fragment size, indicating that these environmental parameters are potentially drivers for local adaptation. Functional annotation showed these outlier-SNPs are within genes involved in relevant physiological processes, such as lipid metabolism, blood pressure regulation, fertilization, host-virus interaction and immunity. **Implications:** These findings are relevant in the context of habitat loss and fragmentation and its impact for rapid environmental and climate changes in the Anthropocene. According to recent studies, the tendency of latitudinal temperature increases over the next 30–60 years might promote the loss of most suitable habitat for BLT within its current distribution range. Indeed, climate and landscape-based niche modeling has shown that only 2% of its original geographic distribution can be considered suitable for the species. Thus, despite of the BLT ability to survive in disturbed environments, understanding genomic processes involved in the current population diversification become relevant to raise evolutionary and adaptive issues useful to help with conservation decision-making. In this sense, complementary studies should further investigate the potential adaptive role of the outliers identified here to guide effective conservation strategies for the species. **Keywords:** Local adaptation, conservation genomics, outliers, differential selection

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Restoration Ecology: Plants, Animals Ecosystems I

Intraspecific Variation along an Elevational Gradient Alters Seed Scarification Responses in a Polymorphic Hawaiian Tree Species

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Introduction: Physical dormancy in seeds poses a challenge in restoration efforts because optimal scarification conditions for germination and seedling vigor are often species-specific and unknown. For species that occur along wide environmental gradients, optimal scarification conditions may also differ by seed source. However, intraspecific variations in optimal scarification conditions are rarely considered. **Objective/Hypothesis:** Using a Hawaiian tree species (*Acacia koa*) that occurs across a wide range of elevational gradient, we examined intraspecific variation in optimal scarification conditions for germination and seedling performance. We hypothesized that seeds from lower elevation sources exposed to higher temperatures would have harder seed coats and would require more intense scarification treatments. Methods: To test our hypothesis, we repeatedly exposed seeds to hot water differing in temperature and time until seeds imbibed. We recorded imbibition percentage, germination percentage, germination time, seedling abnormalities, early mortality, seedling growth, and seedling survivorship, and developed a scarification index (SI), which integrated all of these measures simultaneously. **Results:** Supporting our hypothesis, seeds from lower elevation sources generally required more intense scarification, although substantial variation among sources existed. Koa seeds did not readily imbibe when exposed to hot water between 90°C and 100°C. Seeds that imbibed without any treatment germinated at the same level as manually-filed seeds (control) but produced poor seedling quality. Boiling seeds (maintaining at 100°C) was effective for imbibing seeds but it also substantially reduced germination percentages. Repeatedly exposing seeds to 90°C to 100°C water did not reduce germination percentage but increased early mortality and decreased seedling growth and survivorship. Abnormalities in seedling development due to hot water treatments were rare but increased with the treatment intensity. No seeds germinated when they remained unimbibed after six attempts of boiling although seeds that remained unimbibed after 15 attempts of exposure to 90-100°C water showed high germination percentages. Exposure to 100°C water (but not boiling seeds) for 1 minute overall generated the best SI values but the best treatment differed by elevation. Although many studies determine the optimal scarification condition based on germination results, the treatment with the best SI was rarely predicted from highest germination percentages. **Implications:** Variation in mother tree environments along an elevational gradient can lead to differences in seed coat characteristics, which may explain the different responses to treatments. Scarification treatments had effects on processes beyond imbibition and germination. Using an index such as SI may improve efficiency by identifying optimal scarification conditions while reducing seed waste. **Keywords:** Elevational gradient, forest restoration, germination, imbibition, mother tree, scarification, seedling

Monitoring Recovery of Tree Diversity during Tropical Forest Restoration: Lessons from Long-term Trajectories of Natural Regeneration

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Introduction: Tree species diversity is an important metric for assessing the recovery of forest ecosystems during natural regeneration and active restoration interventions. Assessments of assemblage-level species diversity still face major methodological challenges due to differences in plot size, stem abundance, and sample completeness. Despite many advances in understanding tropical forest regeneration, trajectories of tree diversity and evenness within sites remain poorly documented and poorly understood. **Objectives:** Our study addresses three main questions: 1) How effective are long-term monitoring plots of 1-ha for capturing complete information about species diversity of tree assemblages? 2) What are the best measures of species diversity for assessing change over time (12-20 years) during secondary forest succession or restoration? 3) How are estimates of observed, asymptotic, and standardized species diversity, sample completeness and standardized evenness affected by sampling effort? **Methods:** Based on annual surveys of trees (stems 5 cm dbh) in eight 1-ha plots (6 in second-growth and 2 in old-growth), we used diversity profiles to show successional trajectories over 12-20 years in observed, asymptotic, and standardized tree diversity, in evenness, and in sample completeness. We randomly subsampled 1-ha plot data at four scales (0.1 ha, 0.2 ha, 0.5 ha, and 0.8 ha) to evaluate whether smaller spatial subsamples could capture temporal trajectories in tree species diversity and evenness and reveal differences across plots. **Results:** Annual surveys in eight 1-ha plots missed substantial numbers of rare or infrequent species, but all abundant species were detected. Changes in species diversity in recovering forests do not show steady increases over time, which is the typical pattern portrayed in conceptual frameworks of succession. Rather, tree species diversity showed divergent and fluctuating patterns during the first 10–50 years of succession. Older second-growth sites showed consistent declines in tree diversity, whereas younger sites showed fluctuating patterns or increases. Standardized evenness showed increasing trends in young sites and decreasing trends in older sites. Subsample areas of 0.5 ha or greater were sufficient to infer the diversity of abundant species, but smaller subsamples failed to capture trajectories of species richness and yielded positively-biased estimates of evenness. Conclusions: In diverse tropical forest assemblages, species diversity and evenness from small sample plots should be assessed using methods that incorporate abundance information and that standardize for sample coverage. Recovery of species richness during forest regeneration may show periods of increases and decreases that correspond to shifts in dominance from pioneer species to shade-tolerant species. **Keywords:** Biodiversity recovery, diversity profiles, forest succession, natural regeneration, coverage

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Ecological Restoration in Semi-arid Africa: Comparing Strategies and Actions of the Great Green Wall Initiative in Senegal and Burkina Faso

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Desertification - defined as land degradation in arid, semi-arid and dry sub-humid areas, linked to the impact of climate change and human disturbance - causes habitat degradation, the disappearance of many species, and the loss of ecosystem services on which people living in these regions depend. The Great Green Wall (GGW) initiative is one of the responses to the challenges posed by desertification. The objective of this pan-African initiative, launched in 2007, is to restore the degraded landscapes of the Sahel, one of the most affected regions. There remains a critical need to articulate our understanding of restoration and protection of land, social and economic development, and conservation of biodiversity, to be able to properly document the various approaches, the significant outcomes they have achieved, and the lessons learned from each approach. Coordinating actions between restoration strategies and political decisions requires a detailed analysis of the context of the different biogeographical zones, countries, and ethnic groups, of the most abundant plant species in each territory, and of the various restoration practices applied. The objective of our study is to compare the actions undertaken since the beginning of this initiative in two neighbouring countries, Burkina Faso and Senegal, pioneers in the GGW initiative, in order to understand the advantages and limits of up-scaling restoration programs. Therefore, we will bring together different elements such as the criteria used in the selection of species planted and the distribution and abundance of indigenous plant species. We compare the

different restoration practices applied and study the influence of local activities and of access to land to highlight crucial elements for successful restoration in these countries. One of the conclusions is the need to have a systemic vision, which considers (i) the whole life history of the tree instead of considering actions focused only on one stage (e.g. planting), (ii) the variations in life history between species, showing the relevance of targeting restoration actions on different stages, depending on the species, and (iii) the interactions between trees and other ecosystem components. **Keywords:** Semi-arid lands, ecosystem restoration, GGW initiative, biotic interactions, indigenous plants

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Natural Regeneration in Post-gold Mining Landscapes in the Madre De Dios River Basin, Peru

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Background: Over the past three decades, thousands of hectares of lowland Amazon rainforest in the Madre de Dios river basin (MDDB) in southeastern Peru have been destroyed by gold mining operations that convert primary rainforest into a mosaic of bare sand interspersed with pools of stagnant water. Although primary forest continues to be destroyed at an alarming rate, mining activity eventually ceases, leaving behind a vast deforested landscape that could potentially recover over time. **Objectives:** The overall goal is the establishment of a long-term monitoring effort to track ecological recovery over time in post-mining landscapes across a gold mining corridor spanning the ~80,000 sq.km MDDB. Our research aims to document patterns of natural regeneration and examine the key factors driving these patterns. **Methods:** We set up a total of 47 plots measuring 50m x 20m (1000 sq.m) across a set of sites that represent key variables thought to influence the composition and trajectory of regeneration, including: proximity to primary forest, habitat type, mining technology, time since last mining activity, and number of times reworked. We sampled the canopy layer (stems 10cm dbh) and sub-sampled the understory (stems 1m tall, 1cm dbh) in each plot. **Results:** We documented a total of 9008 stems that represented 736 unique species or morphospecies. The canopy layer is dominated by a small number of classic pioneer species and genera including *Ochroma pyramidale* (Malvaceae), *Cecropia* (Urticaceae) and *Jacaranda* (Bignoniaceae). The understory is more diverse and dominated by shrubby species in the Asteraceae, Melastomataceae and Hypericaceae families. While wind-dispersed species predominate the canopy, the understory is well represented by small fleshy-fruited shrubs dispersed by small birds. Floodplain sites were more diverse than tierra fime sites, and sites subjected to heavy machinery were more diverse than sites worked with suction pumps. The effects of age and revisits were unclear based on the relatively small range of these two variables represented by the sampled sites. Implications: Our results indicate that post-mining natural regeneration in the gold mining corridor of the Madre de Dios basin is a very gradual process that is hindered by extensive hydrological, edaphic and geomorphological alteration of the original habitat. A key factor that accelerates the pace of regeneration is the replenishment of soil nutrients in floodplain sites that are flooded every 4-6 years in this region. Dispersal by bats and small birds appears critical to accumulating diversity in these early stages. **Keywords:** Gold mining, deforestation, natural regeneration, Amazon rainforest, Madre de Dios.

Restoration Ecology: Plants, Animals Ecosystems II

Tree Regeneration in Active and Passive Cloud Forest Restoration: Functional Groups and Timber Species

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As a result of tropical forest degradation and deforestation, forest restoration, which includes passive and active strategies, has gained relevance to achieving socio-ecological systems' resilience worldwide. Tree regeneration of late-successional, animal-dispersed and timber species in restored forests is key to recovering ecological functions and interactions and ecosystem services. We assessed whether active restoration (mixed plantation with native species) is more effective than passive restoration (natural regeneration) at increasing the recovery of these groups in the tree seedling community under similar historical and environmental conditions. We hypothesized a greater contribution of late-successional and animal dispersed species in the tree seedling community in the actively restored forest than in the passively restored forest by providing favourable conditions for dispersers and microhabitat for late-successional species establishment (closed canopy, soil and litter) and availability of seeds (as trees mature and attract wide-ranging animals that disperse seeds). We analyzed tree seedlings ($>$0.3 m to 1.5 m in height) over four years under three conditions in a tropical montane cloud forest landscape in Mexico: mature cloud forest (MF) as the reference system, active restoration (AR) and passive restoration (PR). The AR and PR were 24 years old and were established in abandoned grazing land located at similar distances to the MF (709 $\pm$ 67 m and 906 $\pm$ 66 m, respectively). We recorded ˜ 488 seedlings/year belonging to 51 tree species. Seedling density was higher in AR than in PR, but no differences were found in recruitment or survival rates between these restoration conditions. The density of late-successional, barochorous-synzoochorous and timber species was much higher in MF than in the restoration conditions. The seedling density of timber species was similar in AR and PR. Our results support higher recovery of the richness and density of late-successional and barochorous-synzoochorous functional groups in the tree seedling community in AR than in PR. However, the overall low seedling density and recruitment found in both restoration conditions highlight the need for additional intervention, even after 24 years, to overcome tree regeneration barriers. Direct seeding and enrichment plantings of late-successional, barochorous-synzoochorous and high-value timber species could contribute towards more ecologically and economically valuable forests. **Keywords:** Dispersal syndrome, tree recruitment, mixed plantation, landscape restoration

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Nucleation Techniques to Recovery a Heavily Impacted Area in the Brazilian Hotspot of Cerrado: What Is the Best Technique?

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Nucleation is a technique that uses small nuclei of habitat within degraded land as starting points of vegetation regeneration. This technique tends to facilitate natural successional processes since it can involves producers, consumers and decomposers, making it extremely effective. We performed an experiment to test which nucleating techniques better improve plant establishment in an area of Cerrado, Brazil. We compared the efficacy of the use of single and combined nucleation techniques including topsoil transposition, bird perches and brushwood. The study was conducted in an area that suffer a great amount of soil removal to the construction

of a river dam to generated energy. Due to the removal of the vegetation and soil layers, the C horizon and the remainder of the B horizon are currently exposed at various points in the study area, which was initially constituted by dystrophic reddish latosoil, with a clayed B horizon, and sandy and whitish C horizon. In this study, we sampled three modules, established 500 m apart from each other. These modules encompass the degraded area. To test topsoil transposition, in each module was established 12 sampling plots $4m^2$: four filled with 15 cm of red detached oxisoil plus 15 cm of topsoil with litter, four with 15 cm of red detached oxisoil and four used as control. Also, in each module we installed 12 bird perches: under six we installed plots of $1m^2$ filled with 15 cm of red detached oxisoil and soil under six were used as control. In each module we installed 12 brushwood made with dead wood of native trees. Six were installed over one plot of 4 m^2 filled with red detached oxisoil and six were used as control. During 18 months we followed seedling establishment in each plot of each experiment, recording seedling richness and abundance. Overall, we detected strong, positive, and significant effects of the application of nucleation techniques of restoration on seedling richness and abundance. Restoration techniques differed in their ability to improve seedling richness, but most effective results were found with the combination of topsoil transposition and bird perches. However, top soil transposition was the most effective with increased seedling richness and seedling survivorship compared to bird perches and brushwood. Our results suggest that the use of nucleation techniques in environmental restoration are an efficient tool to increase the richness and establishment of plants (seeds and seedlings) in soils that heavy been heavily impacted. **Keywords:** Biodiversity, restoration, ecological succession, anthropic impact

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Participatory Ecological Restoration: Guarumo's Experience in Sarapiquí, Heredia, Costa Rica

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The concept of ecological restoration is not always close to the public in fragile tropical zones such as Sarapiquí, Heredia, Costa Rica. In this locality rapid change in land use and low human development indices conflict with ecological restoration and sustainable initiatives. For this reason, a project named Guarumo was initiated in 2019 with the objective of promoting natural and social connectivity between community inhabitants and organizations with biological corridors, through ecological restoration. We started this organization with group students from San José del Rio High School, people from the community and organizations such as Tropical Studies, Lapa Verde Reserve, Macaw Recovery Network, Tirimbina Reserve, Associations for Community Development and the Casa de la Cultura. Activities were based on learning from experience, popular education and participatory methodologies. Activities include theorical sessions, workshops, the creation of communal nursery, collecting and care of plants, laboratories and creation of plans for ecological restoration for six farms. We collected 15 functional traits of seedlings in the nursery and growing plants in the field, of 30 species to understand if these traits could explain survival in order to determine final selection of species for restoration. After the sessions, participants showed greater interest in science, use of knowledge to stablished restoration processes in their lands, including replacement of exotic species with natives. Other participants improved their practices in their jobs, schools and in business to be more sustainable. For highschoolers was useful for their courses, they also developed an interest in university education and in the participation in local activities and associations. A regional ecological restoration network was created, which includes local organizations and landowners to promote other activities such a seed festival of species for restoration. This methodology demonstrated great potential of ecological restoration as a thematic line for the development of environmental and scientific education programs in schools and informal education, especially considering the lack of practical experiences in these subjects in the public education system of Costa Rica. It shows how this topic is related to common knowledge of people and with the synergy of local actors can improve the practices in farms and other jobs. The importance of making science more available outside of academia helps to make information more accessible and engage communities involved in conservation initiatives based on science, that may allow to reach regional restoration of ecosystems. **Keywords:** Community participation, informal education, applied science

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Effect: of Landscape Forest Cover on Early Forest Recovery on Abandoned Fields in Dry and Wet Mexican Forests

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Human-modified tropical landscapes consists of a mosaic of different land-use types and forests in different successional stages. In this study we investigated how surrounding forest cover affect forest regrowth on first year abandoned pastures and agricultural fields in dry and wet tropical forests regions in Mexico. We hypothesized that when landscape forest cover is too low, or the distance to the nearest forest patch is too far, recovery slows down because of a lack of seed sources and dispersal agents. We established forty 25 by 25 meter plots on abandoned fields that varied in surrounding forest cover to understand how basal area, density and diversity of adult trees and seedlings change in the first year after abandonment. To analyze the effect of surrounding forest cover on forest recovery, the percentage primary, secondary and plantation forest was evaluated at seven different radii, from 50 meters to 5 kilometers from the forest plot center. We used a random forest model to evaluate the most important radii explaining (change in) basal area, density and diversity of seedlings and adult trees. Using a generalized linear model, we evaluated how soil characteristics, previous land use, and different types of forest cover affect the change and presence of seedlings and adult trees in early succession. We found that after 1 year change in tree basal area, density, and diversity is larger in wet than in dry forests, and that most attributes were affected by surrounding forest cover. The results of this study are important for reforestation and forest conservation initiatives, as it sheds light on what type of forest is needed at which distance to facilitate natural regeneration. **Keywords:** Forest regeneration, tree diversity, secondary forest, primary forest, pasture, agriculture

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Restoration Ecology: Plants, Animals Ecosystems III

Assessing Mangrove Restoration Practices Using Ecological Networks

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Background: Mangroves are uniquely important ecosystems, for preserving biodiversity, sustaining livelihoods, and mitigating against climate change. However, they are degraded globally and are therefore a priority for ecosystem restoration. To date, the assessment of mangrove restoration outcomes is generally poor, and the limited studies that do exist are focused largely on forest area. Thus, more holistic ways of assessing the outcomes of mangrove restoration projects on biodiversity and associated ecological processes are urgently needed. Ecological networks are a useful tool for simultaneously examining both. **Objectives:** We assessed the utility of using species-interaction networks for evaluating mangrove restoration outcomes for the first time. We compared the structure and complexity of mangrove ecological networks in replicated "monoculture reforestation," "mixed species regeneration" and "reference forest" plots in two study areas in Sulawesi, Indonesia, an estuarine, and a coastal fringe mangrove system. We also combined and evaluated sampling methods, utilizing traditional plant–animal sampling while also integrating video recording data in a novel way. **Results:** We found significant differences in the structure and complexity of mangrove networks between restored and natural plots, with contrasting effects between the two sites. The inclusion of interaction data using different methodologies was found to be important. Implications: Our results show differences in the complex ways in which taxa interact in mangrove restoration projects, which would be overlooked if common biodiversity metrics, such as species richness, were used alone, with consequences for the restoration of ecosystem functioning. We also highlight the utility of video recording data collection for constructing species-interaction networks, overcoming the detrimental impacts of observer presence for some key species. **Keywords:** Camera traps, forest, marine, plant–animal interactions, Wallacea

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Living with Forest Valuations: Impacts and Lessons from 20+ Years of Government-led Forest Incentive Programs in Guatemala

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Guatemala has pledged to restore 1.2 million hectares or 11.2% of the country's total area under the Bonn Challenge. With high ambitions for forest restoration and one third of the country already covered by forests, Guatemala is poised to play an outsized role in international nature-based climate solutions. With the passage of its landmark Forestry Law in 1996, Guatemala instituted the first in a series of programs to promote forest conservation and restoration, which it relies on to meet its restoration goals. These programs have been championed as successful conservation and rural development initiatives, with recent programs targetting smallholders and promoting climate benefits. Despite these apparent successes, Guatemala continues to experience net deforestation. This study leverages an expansive dataset of over 50,000 government-funded forestry projects from 2004 - 2018 to determine the effect of programs on forest cover. A quasi-experimental synthetic matching analysis is used to estimate the impact of forest incentive programs on tree cover. This impact analysis is combined with a series of key informant interviews to provide qualitative insights into program design, implementation and administration. Results suggest that Guatemala's forest incentive programs increase forest cover when implemented, but forest cover declined after projects ended, demonstrating weak durability. Some project categories also raise ecological concerns, as timber and rubber plantations are common incentive recipients. Issues with program administration and funding are also major barriers to meeting long-term conservation objectives, as landowner demand continues to outpace supply. These findings suggest that Guatemala's forest incentive programs are impactful, but are likely insufficient to reach the country's ambitious forest restoration goals. Determining the ways in which incentive programs intersect with rural livelihoods and environmental consciousness is also necessary to better align programs with people and support climate-positive socio-ecological systems. **Keywords:** Forestry, natural climate solutions, Guatemala, PES, rural livelihoods

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Bee Diversity as Powerful Information for Conservation Strategies in Colombia

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Wild bees are considered among the most important pollinators of wild and cultivated plants. In addition to their ecological and economic value, this group has gained increasing attention and sympathy among people given their importance and the multiple threats they currently face. Therefore, information on wild bee diversity has the potential to be use as a measure for diverse conservation strategies, from informing territorial planning to environmental education. Here I illustrate this through some study cases in Colombia, which show how bee diversity is positively related to the amount of forest at the landscape scale, responds to restoration and connectivity efforts, is key for the production of a native fruit, supports the meliponiculture as a sustainable productive alternative and inspires the citizens. Multiple challenges remain to fully understand bee diversity in Colombia, including the limited taxonomic information and sampling efforts across the country. However, having an action plan for the National Strategy for Pollinator is an important progress and advancing it in a coordinate and collaborative way is key not only to protect bees themselves but to use their diversity to inform other conservation strategies. **Keywords:** Bee diversity, pollination, conservation, education, Colombia, restoration, landscape

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The Eco-evolutionary History of Madagascar Presents Unique Challenges to Tropical Forest Restoration

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Background: High biodiversity and endemism combined with persistently high deforestation rates mark Madagascar as one of the hottest of biodiversity hotspots. Contemporary rising interest in large-scale reforestation, both globally and throughout Madagascar itself, presents a promising impetus for forest restoration and biodiversity conservation across the island. However, Madagascar may face unique restoration challenges due to its equally unique eco-evolutionary trajectory, which must be understood to enable successful ecological restoration. **Objectives/Hypotheses:** We aimed to investigate whether published evidence supports the contention that forest restoration is intrinsically more challenging in Madagascar's terrestrial forest biomes, and to identify potential causative factors of slow regeneration. We hypothesized that regenerating Malagasy forests will demonstrate universally slower growth, lower survival, and lower dispersal rates than other tropical regions due to their unique, isolated evolutionary history. **Methods:** We conducted a systematic review of potential barriers to restoration for terrestrial forest biomes (rainforests, dry forests, subhumid highland forests) in Madagascar, extracting all available quantitative biomass recovery and sapling growth data, and comparing these data with biomass data available across tropical regions. We also extracted qualitative observations that may help identify factors affecting forest regeneration and restoration. **Results:** Our results indicate that aboveground biomass recovery of Malagasy forests appears slower than other tropical forests, and recovery of species diversity in regenerating areas is additionally stalled. However, we found that few rigorous studies exist investigating the potential mechanisms of low regeneration resilience in Madagascar, and thus, that no comprehensive assessment of major barriers was possible. Some research indicates native vegetation's vulnerability to shifting nutrient and fire regimes, which is likely amplified by Madagascar's inherently nutrient-poor soils, though current studies fail to effectively tease apart these two drivers. Invasive species may more readily outcompete native trees under new nutrient and fire regimes, leading to arrested succession, but very little research on invasive species exists in Madagascar. An extensive literature on seed dispersing animals in Madagascar suggests that primate-adapted dispersal strategies of most tree species and species-poor bird disperser assemblages may limit seed dispersal in degraded or regenerating areas, but little research on dispersal in these contexts exists. **Implications/Conclusions:** There is great opportunity and need for future research to disentangle drivers and interactions inhibiting forest restoration. These studies would enable reforestation practitioners to effectively capitalize on current global momentum to implement the large-scale restoration necessary to ensure future resilience of Madagascar's unique forests and the communities that depend on them. **Keywords:** Biodiversity conservation, biomass resilience, endemism, invasive species, natural regeneration, dispersal

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Restoration Ecology: Plants, Animals Ecosystems IV

Finding New Restoration Opportunities in Sugarcane Plantation Landscapes

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Mechanization of sugarcane harvest in Brazil has been increasing gradually over the years. One of the reasons for this increase was the approval of State Law nº 11.241/2002, which states the end of harvest using fire by 2031. The mechanization process of sugarcane harvesting represents from 30% to 35% of total production cost and also involves social impacts. The financial cost is linked to practical fuel consumption factors such as sugar cane field shape, obstacles and machinery maneuvering. Studies of economic and energy analysis of sugarcane harvest mechanization indicate that short planting/harvesting lines create zones of economic losses that make sugarcane production unfeasible. Given this scenario, this work sought to spatially locate these zones (here referred to as Inefficiency Regions – IR) in sugarcane plots of three agricultural landscapes (5 x 5 km), within the Piracicaba-Capivari-Jundiaí river basin, with more than 50% of sugarcane cover, characterize the landscapes according to land use, slope and probability of natural forest regeneration, and characterize the IR patches as to their proximity to watercourses and Permanent Preservation Areas (PPA). The IR were defined as the set of planting lines with length up to (a) 50 and (b) 100 meters. In this way, different scenarios of forest cover were simulated with the IR virtually reforested, and then the landscapes measured for increment of forest cover, core area, patch density, average patch size and proximity. Results show that the increase in forest cover contributes to the landscapes connectivity through both the incorporation of IR into existing forest remnants and also by acting as stepping stones. Landscape 3 presented the best aspects of spatial configuration evaluated by the metrics (higher vegetation cover and lower degree of fragmentation). Across all landscapes, the IR were close to watercourses and PPA (90 meters average), demonstrating that their ecological restoration can lead to economic and environmental benefits. Among them, we highlight the potential use of these regions as protected areas, environmental compensation, and payment for environmental services (PES), while also assisting with the economic and operational problems of sugarcane production. **Keywords:** Mechanization, landscape, ecology, metrics, ecological restoration.

Hydraulic Conductivity in Tropical Secondary Forests: the Role of New Forests in Soil Water Infiltration

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Understanding how forest restoration recovers soil water infiltration is important to promote water availability for the proper functioning of ecosystems and human well-being. The objective of this work is to understand soil water infiltration in tropical forests in different restoration processes. We expect hydraulic conductivity to vary across a gradient of land uses, in which lower values will be found in more intensive uses and higher values in more conserved remnants and restoration forests with a structure more developed. In this study, we evaluated different types of new forest cover, such as: abandoned monocultures (MonoAban), monocultures in use (MonoUso), natural regeneration (Reg), degraded forest remnants (RemDeg), forest restoration (Rest), agroforestry systems (SAF) and two references: conserved remnant (RemCon) and agricultural land uses (AgroPast). We analyzed 294 plots of the NewFor project which are distributed in the state of São Paulo, Brazil. Soil water infiltration was measured by the Beerkan Estimation of Soil Transfer parameters (BEST)

method, and its corresponding hydraulic conductivity. As these data do not have a normal distribution, the analysis of variance used between the typologies was the Kruskal-Wallis, which obtained a significant p value ($p<0.05$). The Wilcoxon test was used a posteriori to assess the difference between treatments. The main differences were between the areas of pastures and monocultures in use with the other types of forest cover. The agroforestry systems showed a significant difference for the areas of agricultural use and the areas of degraded forest remnants were significantly different from the areas in regeneration. The results corroborate with the hypotheses and with previous studies for the hydraulic conductivity in different land uses, of which areas with greater intensity of use, such as agricultural land uses and monocultures in use, presented lower values of hydraulic conductivity than areas of forest in restoration process. The comparison between the different forest areas (MonoAban, RemDeg, RemCon, Rest e SAF), which did not show significant differences, points to a possible rapid recovery of soil physical properties. This prior analysis needs to be integrated with other soil parameters, such as soil texture, bulk density and porosity, as well as the particularities of each analyzed site, for a better understanding of forest restoration processes. With more robust analyses, we believe that these results can contribute to the decision-making processes for land use and occupation. **Keywords:** Soil hydraulic conductivity, forest restoration, soil infiltration

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Understanding Ecohydrological Effects of Tropical Forest Restoration in Atlantic Forest Region

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Following Brazilian restoration goals, more than 1 million hectares will be restored at Atlantic Forest biome. Many sectors of society have high expectation about benefits on water provision and regulation by forest restoration, since there an association between native forest cover and quantity of clean water. Considering this context, it is necessary to increase our understanding the effects of forest restoration on ecohydrological processes and, consequently, on water resources and aquatic environment in tropical region. We used field data obtained by experimental catchments covered by native vegetation and forest plantations (Pinus and Eucalyptus) to understand effects of active forest restoration in the Atlantic Forest region. Effects of conversion to forest on hydrological dynamics vary according to forest growth rate and relative position of forest on topographic position. Forest cover establishment is not directly linked to hydrological processes recovery, but it depends on time lag, on the ecological condition of new forest, historical land-use and local natural physical characteristics. Positive effects of forest restoration on hydrological regime is expected over the long term, when stream flow regulation is achieved, compensating the short-term effect of stream flow reduction. A framework of forest restoration effects on water resources at catchment scale is proposed and discussed. FAPESP: 2019/25466-9 **Keywords:** Forest restoration, ecosystem services, water, stream ecology

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The Challenges of Natural Climate Solutions: Ecosystem Diversity and Ecological Restoration in the Colombian Andes

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Tropical alpine areas (paramos) and Andean forests have been transformed and degraded by agriculture and livestock. Human disturbances affect vegetation and hydrology and the carbon cycle, which could rapidly alter the key role that these ecosystems play in climate. While restoration is an effective climate mitigation solution, the extent in which restoration activities impact the concentration of Greenhouse gases (GHGis poorly known in tropical mountain ecosystems. Considering that ecosystem dynamics in the high Andean ecosystems is slow, we expect that active restoration, although more expensive, will have a greater cost-benefit effect on the reduction of emissions and carbon accumulation than passive restoration. The aim of this study was to evaluate the success of different ecological restoration strategies in the mitigation of climate changes in different high Andean ecosystems: Paramo, High Andean Forest and Wetlands. We designed restoration and monitoring activities on 10 different locations in the central cordillera in the Colombian Andes. Restoration activities were implemented after removing external stressors (extensive livestock farming and invasive species) from all sites. The main restoration technique for wetlands was hydrological restoration and for Andean Forest and Páramo

applied nucleation with different intensities and native plants arrangements selected by relevant functional characteristics. The contribution of carbon stored in vegetation and soil to GHG reduction was determined by calculating the difference between CO2eq emissions after the restoration implementation with respect to the site's emissions prior to the restoration. Our results were considered in a cost-benefit analysis to evaluate the expenses of the restoration activities and the gain of emission reduction and carbon accumulation per hectare for each ecosystem. The restored peatlands showed a rise in the water table regime that reduced the CO_2 and CH_4 emissions. On the Paramo and Andean Forest, we had a higher survival and growing rates on plants in the high-density arrangements, meaning a greater carbon accumulation. According to the cost-benefit analysis, the best cost-effective activity is the hydrological restoration activities in wetlands, due to its lower costs and greater reduction of emissions mostly due to reductions of CH_4 emissions. Paramo restoration showed a lower cost-benefit effect than Andean Forest, mainly due to the greater rates of biomass accumulation in the midterm shown by forest plants. We think that these results could help decision makers to determine the restoration activities desired to mitigate climate change with limited resources and a limited time frame in carbon rich ecosystems. **Keywords:** Andes, Paramo, wetlands, hydrological restoration, cost-benefit analysis, greenhouse emissions

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Restoration Ecology: Plants, Animals Ecosystems V

Effects of Forest Restoration on Recovery of Avian Habitat Use in Southern Costa Rica

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With ambitious forest restoration initiatives underway, it is critical to understand how different restoration methods influence biodiversity recovery over time. While species richness has been documented to recover relatively quickly for various faunal taxa during tropical secondary forest succession, recovery of species and functional composition for faunal communities may be slow or incomplete. We assessed how avian assemblages using forest restoration plots changed over twelve years in a replicated, long-term restoration experiment in southern Costa Rica. We surveyed birds at 11 sites where we had established 0.25-ha plots 3-5 years prior in a randomized block design to compare three restoration treatments: natural regeneration, tree plantations, and applied nucleation. To distinguish changes in habitat use attributable to restoration treatments from broader changes in the regional avifauna, as well as to assess changes in community similarity, we also surveyed remnant forests as reference sites and active cattle pastures as degraded sites. We found that within six years of monitoring, species richness of assemblages observed in planted restoration plots was comparable to that in remnant forests. However, species and functional composition showed disparate patterns among restoration treatments, with tree plantations most similar to reference forest communities, natural regeneration plots least similar, and applied nucleation intermediate. This work highlights the potential efficacy and the limitations of forest restoration for recovering avian assemblages and their associated ecological functions over a decade-long time frame.

Keywords: Biodiversity, restoration, avian communities, functional recovery, Costa Rica, habitat

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Community Engaged Research on Forest Restoration in Eastern Madagascar

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Introduction/Background/Justification: Increasing focus in on community engaged research aims to center local and Indigenous voices, interests and priorities in the research process. In this model, projects result from consultation and relationships built with community partners. Research questions emerge from ideas, needs and goals of community partners rather than from gaps in Western scientific knowledge, though they often fill gaps. This focus on social context of ecological and restoration work, in turn, can increase longevity and success of reforestation projects. **Objective(s)/hypothesis(es):** We present work in eastern Madagascar that centers local farmer voices and values, builds trust, works towards co-production of knowledge, and implements forest restoration that supports local Malagasy farmer goals. We present three projects that address these issues while enhancing biodiversity, knowledge of the ecology and life history of Malagasy trees, and community technical capacity. **Methods:** Community meetings and farm visits identify goals and needs. An iterative process is used to develop project specifics, such as type of project and species planted. Generally, farmers select from 85 Malagasy trees species and research team staff supplement farmer choices to increase diversity of plantings. Seeds are collected from forest fragments near project sites, trees are nursery grown in local soils, then outplanted. Site preparation includes removal of competing vegetation and juvenile trees receive yearly cutting of surrounding vegetation for three years. For several experiments, we implement plantings over 60

months during which we build relationships that enhance our work through knowledge sharing that integrates local and Western knowledges. Results: Core goals identified by local farmers included reducing land boundary disputes, growing more food, and controlling escaped fire. To address these goals, projects were designed that planted trees along property boundaries, on hilltops and slopes that are less desired for food production, and as fire breaks around food gardens and rice fields. First year tree survival was >75%. Growth was slower on hilltop plantings than lowlands, however, hilltop plantings didn't displace food gardens and thus may be more socially acceptable. Requests for projects from neighboring communities was high suggesting that our model of community-engaged research and restoration has been effective. Long-term implementation has led to knowledge sharing by community members. **Implications/Conclusions:** In conclusion, we argue that our approach that centers local people in all aspects of the research process, advances local and Western scientific knowledge. Moreover, our attention to the social context enhances success, longevity and spread of forest restoration in eastern Madagascar. **Keywords:**

An Experimental Test of Spatially-Patterned Tree Growing Approaches to Meet Ecological and Economic Tropical Forest Restoration Goals

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Introduction: Habitat restoration has emerged as a core approach for tropical rainforest conservation, yet there is little rigorous research about 'what works' and potential trade-offs between biodiversity, carbon and economic outcomes. Here, we report on an innovative reforestation experiment established in 2022 in the Chocó biogeographic zone, northwest Ecuador. Methods: Working in degraded pasture, we have planted 5,000 seedlings of 20 different species using an 'applied nucleation' restoration strategy. Applied nucleation is a cost- and labor-efficient restoration strategy that involves planting small islands of trees (15 m x 15 m) throughout the restoration landscape. This method replicates the patchiness of natural plant succession by establishing small plantings that expand and coalesce over time through facilitation with seed dispersal agents, providing similar results to traditional 'plantation' approaches with reduced cost and effort. Our experimental design evaluates how seed dispersal and forest regeneration vary in response to tree species selection by implementing four replicated 'island' treatments: (1) high diversity of tropical hardwood seedlings anchored by frugivore-friendly pioneer species, (2) high diversity of tropical hardwood seedlings with non-frugivore-friendly pioneer species, (3) balsa Ocrhoma pyramidale a locally important timber species, with frugivore-friendly pioneer species, and (4) balsa with non-frugivore-friendly pioneer species. Moreover, we implement each of these treatments with different spacings (10m, 20m and 30m) between 'islands' to investigate how density of plantings influences restoration processes. We combine this restoration work with a "Before-After, Control-Impact" (BACI) ecological and biodiversity monitoring in agricultural land we are restoring, neighboring agricultural land that will remain in production, and mature forest. Results & Implications: Results are expected to inform establishment of a landscape level corridor linking 6,000 ha of continuous priority habitat by FCAT, an Ecuadorian conservation NGO, and to inform tropical restoration approaches more broadly. **Keywords:** Applied nucleation, choco biogeographic zone, experimental reforestation, frugivory networks

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Restoration Ecology: Plants, Animals Ecosystems VI

Listening for Change: Quantifying the Impact of Ecological Restoration on Soundscapes in a Dry Tropical Forest

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Ecological restoration is crucial to mitigate climate change and conserve biodiversity, and an accurate quantification of the benefits of restoration is imperative to guide ongoing and future restoration efforts. In line with the theme of this conference - to understand the opportunities and drawbacks of achieving socio-ecological resilience- this study examines the impact of restoration of a socio-ecological system on soundscapes and avian diversity. Specifically, we study the impact of people-centric restoration of a community-managed tropical dry forest in the central Indian state of Madhya Pradesh. Here, the state Forest Department and a non-governmental organization work with local communities to remove an invasive shrub, Lantana camara. Such restoration is carried out to assist natural regeneration, primarily for the purpose of improving access to forest resources for forest-dependent people. We used acoustic technology to examine the bird species composition and the amount of acoustic activity across comparable restored, unrestored (with L. camara) and naturally low L. camara density (LLD) sites. Acoustic activity is measured by the number of acoustic events during a specific time period within the defined frequency range. We find no significant difference in the cumulative number of bird species detected across all sites (median in restored and LLD = 38, unrestored = 41), but a significantly higher proportion of forest- and woodland-affiliated species in restored and LLD sites (median in restored and LLD site = 46%, unrestored = 40%). Over a period of 24 hours, restored sites have, on average, marginally higher acoustic activity during approximately 77% of the 48 30-minute time bins in comparison to unrestored and LLD sites. Restoration is significantly correlated with higher acoustic activity than unrestored sites, which we interpret as a representation of greater insect diversity and populations rather than bird richness. Our results suggest that small-scale people-centric restoration efforts can also contribute to ecological goals in this landscape. We speculate that spatially upscaling such restoration efforts may result in small but observable biodiversity co-benefits in similar landscapes where a vast majority of people directly rely on natural resources for livelihood needs. However, given the small magnitude in differences in the acoustic activity, we are cautious in our interpretation of this result and find that it is necessary to monitor the impacts of such interventions, at small and large spatial scales, closely at several time steps in the future. **Keywords:** Tropical dry forest, bioacoustics, soundscape ecology, socio-ecological system, restoration

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Effects of Landscape Structure on Restoration Success in Tropical Premontane Forest

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Introduction: Reversing large-scale habitat degradation and deforestation goes beyond what can be achieved by site-level ecological restoration and a landscape ecology perspective is fundamental. Filling the knowledge gaps of how landscape structure effects biodiversity is essential to improve large-scale ecological restoration outcomes. **Objective***:* We examined the relative effects of tree cover and forest configuration (e.g., degree of fragmentation) on the abundance and diversity of late-successional tree seedlings and highly forest dependent birds across a 7-year timeline of vegetation recovery and bird surveys. **Methods***:* In southern Costa Rica, we surveyed 13 sites, where in 2004, we established 50 $\times$ 50 m (0.25-ha) plantation plots. Using 2014 aerial imagery, we determined landscape metrics for 17 progressively larger circular areas around each plantation plot (e.g., tree cover, corridor cover, live-fence cover, fragmentation, remnant tree density, patch aggregation index). We used the cumulative number of seedling and bird species recorded during seven years (2011-2017) to determine species richness. The mean number of bird detections per year for each species and the sum of new seedlings for each species across years were used as a proxy for abundance. We built generalized linear models (GLMs) between each landscape metric and each response variable to obtain the scale of effect and assessed the relative effect of each landscape metric on each of the four response variables using an information-theoretic and multi-model averaging approach. **Results***:* Abundance and species richness of birds increased in landscapes with larger corridors, higher tree cover, and lower fragmentation, highlighting the importance of riparian corridors for connectivity, and continuous tree cover as suitable habitat. Landscape variables had the same direction of effects on abundance and species richness of seedlings, but effects were weaker, possibly because seedlings face establishment limitation in addition to dispersal limitation. Moreover, the scale of landscape effects on seedlings was small, likely because proximal individual trees can have a large influence on recruitment in restoration plots. **Conclusion***:* Landscape structure effects have the same direction for birds and seedlings, but the strength of the effect varies. If we aim to implement a network of smaller optimal landscapes in an ever more resource limited world, we need to integrate landscape ecology and restoration science to effect better land-use practice. **Keywords:** Connectivity, fragmentation, Forest Landscape Restoration, landscape-scale, forest plantation, reforestation, seed

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Restoration Interventions Facilitate Tropical Tree Recruitment Dynamics over Time

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Introduction: Forest restoration is increasingly heralded as a global strategy to conserve biodiversity and mitigate climate change, yet long-term studies that compare the effects of different restoration strategies on tree recruit demographics and functional traits are lacking. Applied nucleation (i.e., planting trees in clusters or islands) has been suggested as an intermediate intervention strategy that helps to overcome common barriers to natural regeneration while simultaneously promoting a more heterogeneous ecosystem, but has rarely been compared to other forest restoration strategies. **Methods:** We measured tree recruit survival and growth annually in three restoration treatments – natural regeneration, applied nucleation, and multispecies tree plantations – replicated at 13 sites in southern Costa Rica, and evaluated the changes over a decade. We also measured a suite of leaf and stem functional traits to characterize recruit trait syndromes. **Results:** Early-successional seedlings had 14% higher survival probability in the applied nucleation than natural regeneration treatments. Early-successional sapling growth rates were >200% faster in natural regeneration and 127% faster in applied nucleation than plantation plots but converged across restoration treatments over time. Later-successional seedling and sapling survival were similar across treatments but later-successional sapling growth rates were 39% greater in applied nucleation than in plantation treatments. Community weighted means for functional traits of recruiting saplings appeared to converge across the three restoration strategies over time. When compared to nearby remnant forests, however, the overall functional richness of recruits in the natural regeneration treatment recovered by only 15% on average, whereas recruit functional richness in the plantation and applied nucleation treatment recovered by ~50%. **Implications/Conclusions:** Results indicate that applied nucleation was as or more effective in enhancing survival, growth, and functional diversity of naturally recruited trees than the more resource intensive plantation treatment, highlighting its promise as a restoration strategy. Tree-recruit dynamics also changed quickly over the 10-yr period, underscoring the

importance of multi-year studies to compare restoration interventions and guide ambitious forest restoration efforts planned for the coming decades. Finally, we briefly discuss ongoing work to evaluate long-term forest recovery in our experimental sites and our work with conservation organizations to scale up the implementation of applied nucleation in large-scale restoration projects. **Keywords:** Tropical, forest, restoration, succession, seedling, recruitment, applied nucleation

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Native Regeneration under Tropical Tree Monocultures: A Global Synthesis

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Tree monocultures are widespread across human-modified tropical landscapes, providing financial benefits to farmers and a large share of wood products to society. However, using monoculture tree plantations to promote forest and landscape restoration have been criticized for their potential damages to biodiversity and ecosystem services provision, accordingly it is crucial to understand whether and under what conditions these plantations can contribute to biodiversity recovery. In this research, we synthetized the current knowledge about native tree species regeneration under monoculture tree plantations across the tropics. We hypothesized that tree regeneration under tropical monoculture plantations can be substantial but is strongly modulated by management practices. We systematically reviewed papers about natural regeneration under tree monocultures in the tropics and conducted a meta-analysis with the studies that included a natural reference forest. This review included sixty studies carried out in four tropical biomes, thirty-seven ecoregions, twenty-two countries and five continents. We also explored a database that comprised eighty-eight studies about tree species regeneration under *Pinus* sp. and *Eucalyptus* sp. monocultures in Brazil as a case study to investigate the potential accumulation of woody species in tree monoculture understories. The woody species richness of plantations' understory showed high variability, suggesting the role of management in the regeneration potential. Monoculture tree plantations presented on average 39% of the richness and 24% of the tree abundance of the reference forests. Longer rotation, native species monocultures, and plantations adjacent to forest remnants harbored more species. In the case study, we found eight-hundred species regenerating in approximately twenty-five hectares. Our results suggest that monoculture plantations are not always 'green deserts' and can actually harbor diverse woody species regeneration. Management practices play a crucial role in determining their conservation value. Furthermore, diversity and abundance of woody regeneration under tree monocultures are not comparable with reference areas, emphasizing that protecting forest remnants is imperative for biodiversity conservation. **Keywords:** Plantation forest, monospecific plantation, woody plants, tree diversity, natural regeneration

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Restoration Ecology: Plants, Animals Ecosystems VII

Active Restoration Fosters Better Recovery of Tropical Rainforest Birds than Natural Regeneration in Degraded Forest Fragments

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Ecological restoration is a key strategy for conserving tropical forests and habitat specialists, and monitoring faunal recovery using indicator taxa like birds can help assess restoration success. But few studies have examined whether active restoration achieves better recovery of bird communities than natural regeneration, or how bird recovery relates species' habitat affiliation. In rainforests restored over the past two decades in a fragmented landscape (Western Ghats, India), we examined whether bird species richness and community composition recovery in 23 actively restored (AR) sites were significantly better than recovery in paired naturally regenerating (NR) sites, relative to 23 undisturbed benchmark (BM) rainforests. We measured eight habitat variables and tested whether bird recovery tracked habitat recovery, whether rainforest and open-country birds showed contrasting patterns, and assessed species-level responses to restoration. We recorded 92 bird species in 460 point-count surveys. Rainforest bird species richness was highest in BM, intermediate in AR and lowest in NR. Contrastingly, open-country bird species richness was least in BM, intermediate in AR and highest in NR. Bird community composition varied significantly across treatment types with composition in AR in transition from NR to BM. Bird community dissimilarity between sites was positively related to dissimilarity in habitat structure and floristics, and geographical distance between sites. Variance partitioning indicated that structural and floristic dissimilarity explained 90% of the variation in community composition. Indicator species analysis revealed significant associations of 34 species with one or more treatment types. Species associated with BM and AR treatment types were all rainforest species, while only 38% of species associated with AR and NR treatment types were rainforest species. We show that active restoration of degraded fragments benefits rainforest birds and reduces the infiltration of open-country birds, and highlight the importance of considering rainforest and open-country species separately. In human-modified tropical rainforest landscapes, active restoration of degraded fragments fosters partial recovery and complements protection of mature forests for bird conservation. **Keywords:** Bird community, ecological restoration, conservation, faunal recovery, rainforest birds

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Functional Seed Traits as Predictors of Germination and Seedling Growth for Species with Potential for Restoration in Caquetá, Colombia

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Deforestation in the tropics is one of the greatest biodiversity crises of the Anthropocene. Several tropical countries, including the 'megadiverse' Colombia, have committed to restoring degraded lands and reconnecting forest fragments. To contribute to this mission, we measured seven seed functional traits in 11 tree species native to the Andean-Amazon piedmont region and used cluster analysis to group them and evaluate how well the traits and groups predicted the optimal pre-sowing treatments, germination metrics (percent germination, velocity, and vigor), and seedling relative growth rates (RGRs). The pre-sowing treatments followed a 3x3 factorial design using the following variables: three light conditions (full, partial, and no light) and three

pre-germination treatments (hot water, abrasion and control). Species clustered into three groups, driven mainly by highly correlated variables of seed size and mass. Species within and among functional groups differed in their response to pre-germination treatments. Only small-seeded species responded with little-to-no germination in the absence of light. Because functional traits were highly correlated, we used Principal Component Regression (PCR) to predict germination metrics and RGRs. The multivariate trait axis of seed size and seed mass measurements (PC1) correlated negatively with germination metrics and positively with RGRs. Our results highlight the challenges associated with using easy-to-measure functional traits to deduce the most effective pre-sowing treatment. Other more relevant functional traits can be measured in lab, but a shotgun approach to testing pre-germination treatments may be more cost-effective. Higher germination in smaller-sized seed species highlights the early-successional niche these species occupy, but reduced RGR may represent a tradeoff associated with having fewer resources stored in seed. **Keywords:** Colombia, functional traits, ecological succession, germination, restoration

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Sounds of Restoration: Can Audio Recordings from Recovering Forests Tell Us How Animals Respond to Ecological Restoration?

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Today, much of our understanding of the faunal response to ecological restoration comes from studies focusing on a single indicator taxon at a time, and as a result, we do not have a complete picture of how animal communities as a whole are impacted by habitat recovery. Using passive acoustic monitoring, we aimed to quantify the impacts of restoration on all vocalizing fauna in a tropical biodiversity hotspot, the Western Ghats of India. Additionally, we also used the same low-cost, low-effort technique to study the impact of rainforest restoration on birds. Acoustic recorders were programmed to collect data for 24 hours for 7-15 days across 43 unique sites along a gradient of forest regeneration (consisting of actively restored (AR), naturally regenerating (NR), and mature benchmark (BM) sites). To examine the response of all vocalizing fauna, we calculated the acoustic space use (ASU) at each site. Here, we define ASU as a composite value representing the amount and pattern of vocalizations within each frequency bin from 0 to 24 kHz. AR and NR sites had an overall lower ASU compared to BM sites, and lacked vocalizations in the 12 kHz to 24 kHz bins, suggesting an absence of insect activity. When we looked at a single indicator taxon, birds, we found that generalist bird species richness was least in BM sites, intermediate in AR, and highest in NR sites, but rainforest specialists did not show any such variation between the three treatments. We highlight the need to study the faunal response to restoration in more detail by taking a multi-taxon approach and show that it is now possible to do so in tropical forests using affordable audio recorders. **Keywords:** Ecological restoration, bioacoustics, birds, acoustic space use, multi-taxon

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Optimizing Forest Restoration to Improve Water Resources Conservation in the Brazilian Atlantic Forest

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The need to preserve pristine ecosystems and restore degraded areas has never been greater. Restoration is crucial when conservation efforts are not enough to prevent environmental collapse and biodiversity loss. Forest cover loss in the tropics has been rising steadily over the past decades, and these areas hold great global restoration opportunities. Identifying priority areas for restoration increases restoration cost-effectiveness and avoids unintended consequences. In this sense, spatial planning is a critical strategy for achieving the ambitious global restoration commitments planned for the immediate future. Recent efforts to propose priority areas to be restored globally are focused mainly on biodiversity conservation and climate change mitigation. However, incorporating other benefits from restoration in prioritization approaches is instrumental in offering decision-makers multiple options to attend to local demands. Water resources conservation needs special attention as water is at the core of sustainable development. Also, forest restoration is considered an essential element for environmental policies focused on improving water security worldwide. Aiming to incorporating water resources

conservation into forest restoration spatial planning, we identified priority areas for restoration in the Brazilian Atlantic Forest – a global conservation and restoration hotspot – considering groundwater recharge, water quality improvement, and restoration costs. We developed a spatially explicit index to describe the variability of the groundwater recharge potential in the Brazilian Atlantic Forest. Also, we accessed the spatial variability of the human impacts on water quality in the biome, using the Water World policy-support system. Then, we developed spatial surfaces representing the potential of forest restoration in increasing groundwater recharge and water quality and the associated costs. Finally, these spatial surfaces fed the prioritization algorithm (based on linear programming) to identify the most cost-effective areas for restoration. Our results revealed that spatial planning could improve restoration outcomes for groundwater recharge up to 3.5 times and water quality up to 1.9 times. The Compromise solution (the most balanced solution, considering benefits and costs simultaneously) reduced restoration costs by 38%, while increasing the groundwater recharge potential 2.3 times and increasing water quality improvement 1.1 times. Scaling up ecosystem restoration actions is the challenge posed to the world by The United Nations Decade on Ecosystem Restoration (2021-2030). We believe the water narrative can boost restoration initiatives and provide a solid argument to scale up restoration. This work fills a critical methodological gap and offers valuable insights to guide the Brazilian Atlantic Forest's water resources conservation and forest management policies. **Keywords:** Forest restoration, water resources, spatial planning.

Dry Forest Restoration in Madagascar

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Berenty Reserve is a research site in the south of Madagascar, dedicated to the conservation of the dry forests and its lemurs. Severe droughts have contributed to the proliferation of invasive species along with a high tree mortality. Of particular concern is the lack of recruitment of the tamarind tree (*Tamarindus indica*), a keystone food resource for lemurs. Previous researchers in Berenty have suggested that drought hinders the growth and establishment of tamarind trees, but this hypothesis hasn't been tested. To ensure the persistence of this unique forest and its lemurs, restoring the forest with a particular focus on enhancing *T. indica* populations is pressing. In 2017 we set up three restoration plots in the reserve to (i) to determine an optimal planting strategy for forest restoration projects in the tropical dry forest and (ii) to determine which are the plant species that better perform in the planting assays of growth and regeneration of the tropical dry forest. In parallel, this year we set up a greenhouse experiment at the University of Minnesota, to evaluate the effects of drought on the early regeneration of *T. indica*. In the experiment, we imposed a drought treatment on 200 three-month old seedlings, and monitored their growth, mortality, and physiological responses to drought stress. We planted a total of 1354 seedlings of 24 species at two different planting distances (1 and 1.5m). Seedling height, canopy breadth, stem diameter, and mortality were measured for three years. We found that lower planting distance explained faster growth rates and enhanced survival in the first three years of the experiment, making planting distance an important variable to consider when planning and implementing future restoration projects in the dry forest. Our data also show which common native species thrive best. The tamarind experiment showed that watering levels but not watering frequency had a strong influence on T. indica early growth. Similarly, we found that there is an interaction between shade and watering on seed germination and seedling growth. Results of the greenhouse experiments and of the field trials will be used to guide future restoration projects in Berenty with the intention that they can serve as a model for the restoration of other dry forests in Madagascar. **Keywords:** Restoration, dry forest, Madagascar, drought, shade, tamarind

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Ecological Succession in a Restored Andean Forest: Lessons from Plant Recruitment

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Introduction: Forest restoration is an essential discipline for reducing the impact of current environmental challenges like climate change or biodiversity loss. In tropical countries, active restoration efforts are increasing, but we still have little information from long-term monitoring of these projects. In this study, we evaluate a decade-long restoration project with native species in an Andean montane forest located in Medellín, Colombia. We focus on woody plant recruitment and its relationship with environmental variables to assess ecological succession in this project and to extract lessons for future restoration projects in tropical montane forests. **Objective:** Identify the relationships between environmental variables and the woody plant recruitment abundance and taxonomic diversity in a forest restoration project in the tropical Andes. **Methods:** Woody plant recruitment information was obtained in 23 monitoring plots established one decade ago, where we sampled 1/3 of plot area (200 m^2/plot). Every individual with more than 80 cm height was included in the survey and identified to species level. Since land use before restoration differed among plots, we included the following environmental variables to account for the potential variation: soil nutrients, soil texture, pH, Cation Exchange Capacity (CEC) and slope. We also included information about planted trees in monitored plots: basal area per species and tree mortality. A Principal Component Analysis (PCA) was performed with soil variables to identify gradients and correlations between variables. Principal Coordinate Analysis (PcoA) and Redundancy Analysis (RDA) were performed to assess the relationship between environmental variables and recruit abundance (nº recruits per plot). PcoA and Distance based RDA (db-RDA) were performed to evaluate the relationship between environmental variables and recruit diversity. **Results:** PCA showed two gradients across soil variables, the first one related with soil texture, with clay negatively correlated with sand and silt. The second one showed a negative relationship between slope with CEC and nutrient concentration, except for aluminium. In woody plant recruitment survey 1973 recruits were counted, belonging to 50 species. Recruitment diversity and abundance of the recruits varied among plots. Compared with PCA, the statistical analysis performed selected similar environmental variables for explaining these differences in recruitment abundance and diversity. The most important variables were pH, sand content, Mg, Zn, and basal area of planted tree species (*Alnus acuminata* and *Quercus humboldtii*). **Conclusions:** Soil characteristics and species identity of forest canopy affect woody plant recruitment abundance and diversity, determining partly the ecological succession pathways followed in this restoration project. These results can help to improve the design of future restoration projects in Andean tropical forests. **Keywords:** Plant recruitment, restoration monitoring, tropical montane forest.

Restoring Tropical Dry Forests, Where? How?: a Global Overview

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Deforestation is the main threat to the tropical dry forest (TDF) worldwide, with agriculture and mining being the human activities with the greatest impact on this phenomenon. Rates of disturbance have reduced not only TDF areas, but also their ability to adapt and mitigate the effects of climate change. In some cases, natural regeneration is sufficient to reverse the effects of forest cover loss. However, when land use is intensive and chronic, soils deteriorate and sources of regeneration are depleted, then restoration efforts require greater interventions to promotes the recovery of forest cover and ecological functions. In this study we synthesize the published literature of over 30 years (January 1990 - February 2020) on the ecological restoration of TDF worldwide. We also conducted a meta-analysis to assess the effects of restoration strategies, previous land use and type of ecozone on restored sites and the soil properties, vegetation structure, biotic composition and ecological functions. We identified 196 studies that met our criteria, most of which took place in the Neotropic and Indomalaya ecozones. The most common restoration objective was the recovery of the vegetation structure, mainly after land-use-change for livestock, crops or mining. Planting seedlings was the most widely used restoration strategy and the evaluation of their success was generally based on assesing the survival of the plantings. Results showed that restoration treatments improved planted seedling survival (SMD = 0.51, 95%CIs = 0.15 to 0.87), with a significant effect in the Neotropics, Indomalaya and Oceania. Regarding the previous land use, no significant effect was observed on the survival of the planted seedlings. Derived from these results, it is necessary to highlight that survival, even though widely used to monitor restoration success, yield

very high variation in their results. TDF ecosystems have specific characteristics throughout their distribution related both to biodiversity and biophysical environment, as well as to their disturbances. In summary, through this synthesis we identified the main trends on restoration ecology of TDF at a pan-tropical scale, pointing out aspects that must be considered in order to comply with the international commitments in terms of forest restoration. **Keywords:** Ecological Restoration, Tropical Dry Forest, Restoration Strategy, Direct Planting

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Restoration Ecology: Plants, Animals Ecosystems VIII

Restoration Plantings: Forest Floor Conexions in the Dry Forest

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In degraded areas, soil does not have a mulch cover and planted or naturally recruited seedlings may die due to lack of humidity and nutrients. Restoration plantings not only provide cover to decrease soil erosion, they also may enhance further tree growth given the litter produced by them which becomes mulch. We want to test that higher mulch mass and quality produced in restoration plantings result in higher performance of trees in the following year because mulch mass help to keep humidity and provide nutrients. This study was carried out in restoration plantings established in a 40-year-old pasture in the dry tropics of central Mexico. Higher tree survival of the six planted species was realized when litter has higher concentration of Nitrogen while higher tree volume was reached under higher litter mass. Finally, higher values of the Integrated response index (IRI= survival probability $\times$ stem volume) were found when litter has higher phosphorous concentration. Combination of species in tree plantings may have different effects on recovery of soil attributes and further planting grow. **Keywords:** Tropical deciduous forest, maximal intervention, nitrogen, phosphorous

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Priority Areas for Forest Restoration in the Brazilian Atlantic Forest: a Multicriteria Approach

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Forest restoration is a nature-based solution to global challenges such as biodiversity loss, climate crisis, and water insecurity. The Atlantic Forest biome is a biodiversity hotspot of high priority for restoration since only 28% of its original vegetation cover remains, and only 30% of these are within conservation units. This biome also has a very significant socioeconomic importance, concentrating 70% of the Brazilian Gross Domestic Product and guaranteeing water, food supply, and energy generation for more than 145 million people. The Brazilian environmental legislation states that medium and large rural properties must have at least 20% of their area preserved as a legal reserve (RL). However, there is a debt of approximately 2.7 Mha, which represents an opportunity to scale up forest restoration since landowners are obliged to recover these areas. As there is no legal definition of where RLs should be allocated within properties, spatial planning approaches can be very useful to identify cost-effective locations to do so. In this study, a multicriteria spatial prioritization based on integer linear programming was performed to identify priority areas for restoration in the Atlantic Forest using the RL debt as the goal. Scenarios that optimized one or more criteria were developed, including a conciliation scenario that seeks a balanced solution between all criteria: biodiversity conservation, mitigation of climate change, water resources conservation, and reduction of restoration costs. By restoring the RL debt, it would be possible to reduce the risk of extinction of up to 588 species, sequester up to 5.6 million tons of carbon from the atmosphere, and increase the water quality by up to twice compared to the baseline. The minimum investment to restore the cheapest areas would be approximately R$ 62 billion (USD 12 billion).

The conciliation scenario stands out as the most viable solution if the objective is to find a more affordable solution and reduce conflicts with agricultural areas, ensuring a reasonable return for all selected benefits. It has the second-lowest total cost (only 2.9% more expensive than the cost reduction scenario), the second-highest potential for reducing the risk of species extinction (85% of the maximum potential), the second-highest potential for carbon sequestration (49% of the maximum potential), and the third-highest potential for water quality improvement (56% of the maximum potential). These results present a range of possible solutions that may better suit the implementation of restoration in the Atlantic Forest depending on specific objectives and local demands. **Keywords:** atlantic forest, climate change mitigation, restoration decade, spatial planning

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Responses to Climate Change of Dry Deciduous Forest Species along a Climatic Gradient in Mexico: a Translocation Experiment

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Ecological restoration projects focusing on species that in a few years will succumb to changes in climate can result in wasted efforts. Therefore, it is vital to use provenances of plants tolerant to climatic conditions expected in the future, and translocation to new places may be necessary. Aiming to find suitable species for restoring degraded tropical deciduous forests in a warmer climate, we first studied the germination and early growth of six Fabaceae shrub species along a climatic gradient (0-40ºC) in an incubator: *Mimosa luisana, M. polyantha*, *M. goldmani, M. rhodocarpa*, *Acacia constricta* and *Acaciella angustissima*. We also performed a translocation experiment, aiming to identify the populations of *Mimosa luisana* with potential to persist at different elevations now and in a future climate. We transplanted saplings to new elevations using seeds originating from the upper (1,550 m a.s.l.), middle (1,100 m a.s.l.) and lower (580 m a.s.l.) elevational range of *Mimosa luisana*. This species is endemic to the Valley of Tehuacán-Cuicatlán, Mexico, and has been highlighted as a good candidate for using in conservation and restoration actions. We transplanted saplings to both higher (˜1.5º and 3ºC colder) and lower elevations (˜1.5º and 3ºC warmer) compared to their origin, and compared transplants with saplings remaining in their native elevations as well as saplings adapted to the new elevation. We did this to test their tolerance to warming expected by climate change, and ability to survive and persist at higher elevations to assess the feasibility of using provenances adapted to expected future climatic conditions in restoration. We measured survival and growth of all saplings, as well as biotic (herbivory) and abiotic variables (temperature, soil conditions) at each elevation to determine what is driving the response of each population of *Mimosa luisana* at each elevation. To date we found that (1) *M. goldmani* does not germinate well at high temperatures (30 and 40ºC), making it sensitive to warming. (2) The rest of the species exhibited 100% germination in the first five days of warm treatments including dark conditions and mechanical scarification. (3) M. luisana survived and grew well at most of the elevations studied, the coldest and driest sites exhibited the lowest survival. This research will help to develop methods for ecological restoration of tropical deciduous forests to protect biodiversity and assist the livelihood of local indigenous communities in the face of expected climate change. **Keywords:** Reciprocal transplant, seed provenances, climate change, seed germination

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To Be or Not to Be a Forest: Implications for Forest Restoration in India's Forest-savannah Mosaic Landscapes

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The indistinctiveness of savannahs as an ecosystem and the puzzle of coexistence of forest-savannah mosaics takes centre stage in India, which has ambitious forest restoration targets and goals under the Bonn Challenge and the Paris Agreement 2015. This lack of recognition of savannahs as an ecosystem is due to two contrasting paradigms. The first is the tangled colonial narrative of deforestation and continued forest degradation caused by anthropogenic activities. The alternative outlook is that these ecosystems are ancient, formed and maintained by the complex interplay of fire regimes and herbivory pressures, over evolutionary time scales. Alternative Biome/Bistable State theory (ABS) has been used in African, Australian and southern American landscapes to explain the coexistence of savannahs and forests in the same climatic space. In this framework, the multimodality of tree cover is expressed across the rainfall gradient, with fire significantly differentiating tree cover in the two states of forests and savannahs. However, the ABS has not been tested to explain the pattern of forest savannah mosaics of India, which has a long history of fire suppression, but hosts remnants of guilds of wild herbivores and megaherbivores and domestic livestock. Here we explain India's forest savannah landscape using the ABS framework and test whether resource or disturbances drive tree cover. We use generalized additive models to explore multimodality in remotely sensed tree cover (MODIS derived), considering India's unique seasonality in terms of maximum climate water deficit and aridity. We included India's natural fire regimes, in terms of fire frequency (MODIS burn product) and fire radiative power (VIIRS derived, proxy for burn severity) and spatially processed dry matter intake of grazers, browsers and mixed feeders, considering population of domestic livestock, as determinants of tree cover modality. We found no evidence of alternative biome states of savannahs and forests in India. We found that seasonality significantly explained the wide range of tree cover, while fire and herbivory pressure had no significant effects on tree cover, contrary to findings from other savannah landscapes. We posit that India's fragmented and highly transformed landscapes has led to decoupling of the ecological signals from fire and herbivory, with no effect on tree cover in its forest-savannah landscapes. In the UN Decade on Ecosystem Restoration, we recommend caution about afforestation in savannahs and other open ecosystems. Instead, we emphasize further scholarship and restoration implementation focused on maintenance and reintroduction of natural disturbance regimes, as opposed to tree planting initiatives. **Keywords:** Forest-savannah transition, fire, herbivory, forest restoration, India

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Restoration Ecology: Plants, Animals Ecosystems IX

Priority Areas for Forest Restoration in the Brazilian Amazon Focusing on Terrestrial Biodiversity, Carbon, and Social Benefits

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The period from 2021 to 2030 has been declared by the United Nations as the Decade of Ecosystem Restoration. In Brazil, the national goal is to recover 12 Mha of native vegetation in all biomes by 2030, with 4.8 Mha in the Amazon. Multicriteria spatial optimization allows comparing a range of possible solutions to assist in decision making regarding forest restoration. Through this type of approach, it is possible to simulate scenarios optimizing the integrated management of landscapes, reconciling land use and nature conservation and its benefits for people through the recovery of native vegetation. The Amazon 2030 project, in which the present study is part, seeks to develop an action plan for the sustainable development of the Brazilian Amazon with a set of precise recommendations for immediate adoption by decision makers. In this context, the results presented here will contribute to the identification of priority areas for forest restoration that can optimize the cost-benefit relationship. We used Integer Linear Programming to simulate different scenarios to identify priority areas, including scenarios oriented to optimize a single criterion and others oriented to finding solutions that aim to optimize multiple benefits simultaneously at an optimal cost. The criteria considered were: (i) biodiversity conservation, (ii) climate change mitigation, (iii) socioeconomic return and (iv) reduction of forest restoration costs, considering both restoration implementation and land opportunity costs. Finally, we estimated the costs and benefits for each scenario, identifying trade-offs and synergies between them. The restoration of the top-ranked 10% of land areas, equivalent to 5.7 Mha, could generate revenue of up to R$132 billion. This would be possible through the commercialization of carbon credits based on forest restoration activities, which would lead to up to 2.6 billion tons of carbon sequestration from the atmosphere. Half of this amount could be allocated to farmers to cover costs associated with restoration, while the other half could be directed to public policies to finance sustainable initiatives in the Amazon. However, to achieve these benefits, it is necessary to follow the priority areas mapped. Restoring the same area randomly is much less efficient and can reduce cost-effectiveness by up to 10 times. Likewise, taking only cost into account can reduce results by up to 8 times. Our results provide an assessment of where land could be optimally managed for biodiversity conservation, climate change mitigation and social benefits, reinforcing the possible benefits of a large-scale restoration program. **Keywords:** Forest restoration, spatial planning, Amazon, scenario modelling, social impact

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Essential Science Advances for Effective Restoration of the World's Forest Landscapes

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Introduction: Despite their critical importance for biodiversity, carbon sequestration and national economies, the world's forests are under continuing threat. Furthermore, there are significant knowledge gaps for solving and reversing this potentially catastrophic trend. Objective: Inspired by the UN Decade on Ecosystem Restoration and an imminent Theme Issue in Philosophical Transactions of the Royal Society, Series B, we have identified eighteen essential science advances that will help achieve global goals for forest restoration. **Methods:** The advances were developed by considering where knowledge gaps in the restoration adaptive management cycle are most likely hindering practitioners. The importance of each advance was then ranked by 100 members of the ecological restoration community. **Results:** The advances comprise scientific contributions towards understanding restoration methods, planning and environmental and socio-economic determinants of success. All advances are most relevant for the downward, knowledge-gathering phase of the adaptive management cycle. The highest priority advances include 1-identifying and predicting site-specific socio-economic solutions for solving restoration challenges, and 2-collaborative strategic planning to determine where and what ecosystems and species should be restored under different objectives. **Conclusion:** In considering the advances we found disparity in the relative biases between the literature and practical application of forest restoration, with little evidence of truly holistic approaches or practitioner collaboration in science. We therefore call for greater collaboration and consideration of both biological and socio-economic implications, of both scientific and practical decisions, regardless of the initial incentives. **Keywords:** Adaptive Management, ecological restoration, forest, resilience, strategic planning, UN Decade

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Evaluation of Neotropical Trees and Shrubs Suitability for Soil and Water Bioengineering: Cuttings Survival and Growth

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Soil and water bioengineering techniques to control riverbanks erosion have recently experienced a new boom worldwide but their transfer to Caribbean Islands biodiversity hotspot is still lacking. The selection of suitable native species is critical to design successful riverbank soil bioengineering works and few data are available for Caribbean species. This study aims to characterize the performances and biotechnical traits of Caribbean native species potentially compatible with soil and water bioengineering. In a six-month greenhouse experiment, we measured the survival, biomass production and root growth of cuttings of ten native Caribbean shrub and tree species adapted to a diversity of riparian environments. All species appeared suitable for soil and water bioengineering but variation in species survival, growth performance and root system structure allow to evaluate their relevance regarding different techniques. Five tree species, Citharexylum spinosum, Cedrela odorata, Ficus citrifolia, Chimarrhis cymosa, Homalium racemosum, and three shrubs, Piper dussii Piper dilatatum and Phyllanthus mimosoides, presented survival, growth and root characteristics (i.e. high root biomass and length, root emission all along the buried section) compatible with a lot of soil and water bioengineering techniques. At the opposite, Tabebuia heterophylla and Cordia sulcata may be only compatible with few techniques. We proposed an innovative analysis to assess the species suitability with the common soil and water bioengineering techniques. These results allow to provide practical guidance for native species integration in soil and water bioengineering techniques, in the Caribbean and in Neotropics at large. **Keywords:** Riparian forest, caribbean islands, ecological restoration, growth, nature based solution

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Modeling Landscape Dynamics as a Tool for Identification of the Likelihood of Natural Regeneration in Cerrado and Atlantic Forest

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Changes in land use and occupation, especially in the agricultural sector, have been as a coadjuvant in the gain of naturally regenerated forests. In addition to the economic factors which conduct these changes in the agricultural and livestock sector, the Native Vegetation Protection Law with the establishment of the Environmental Regularization Program have intensified the demand for restoration of liabilities in rural properties in protected areas. In this sense, natural regeneration has been highlighted as a restoration proposal due to its low cost, however for its effective implementation it is crucial to know the limiting and conditioning factors of this technique. The present work aimed to investigate the probability of natural regeneration in the Alto Paranapanema Watershed with the purpose to understand the biophysical and anthropic variables that influenced the emergence of these areas, using as methodology the environmental modeling and generation of probability maps, and the study of the landscape dynamics focusing on the transition of the agriculture-pasture-native vegetation classes from 1992 to 2017 based on maps of land use and occupation. The results showed an increase of native vegetation of 5% compared to 1992, suggesting that the basin is in a forest transition process, since the native vegetation gain occurred mainly in the pasture and agriculture areas. Interestingly, much of the adoption of mechanization and technification of arable land occurred in the Cerrado biome, a territory where much of the livestock was shrunk and converted into agriculture, which showed that part of this increase in the native vegetation class is due to adequacy of large producers regarding environmental requirements of the foreign market. Regarding to the biophysical and anthropic spatial determinants selected for analysis by means of evidence weights, all show high values in the influence of natural regeneration and it has been found to act in synergy. Finally, about 25% of the municipalities that compose the basin showed areas with high synergy among the variables that positively influence the regeneration, concentrating these high probability areas in places with potential recovery in riparian zones. The understanding of the natural regeneration processes considering the particularities of the basin, clarified important information to enable the success of the restoration through natural regeneration, however, more in-depth studies are needed to consider such information raised in public policies to ensure that these regenerated areas are not deforested according to the new socioeconomic contexts which command land use change. **Keywords:** Natural regeneration, forest restoration, landscape ecology, landscape Modeling.

Birds as Important Species in the Restoration Process: an Integrative Approach

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While it is unquestionable that land degradation and water resources generates drastic impacts on biodiversity and ecosystem services, degraded environmental also represents possibility for ecological restoration. Measures such as the complexity in vegetation structure, species diversity and ecosystem process are parameters to indicate the success of ecological restoration projects. Vertebrates, especially birds, have been suggested as important species in restoration projects, especially due to the provision of ecosystem service of seed dispersal and associated functions in the establishment of plant communities. In this study we aimed to evaluate the effects of birds as important species in areas under regeneration. To this aim, we conducted an integrative systematic review, which consisted in the evaluation of published studies focusing on ecological restoration by birds. Only the articles found in the combination of keywords "Restoration Ecology" AND "Birds" were included in the qualitative database, since the objective of this qualitative review was to evaluate the role of birds in ecological restoration. From the reading of the titles and abstracts of the 1,369 articles initially collected, a total of 266 articles remained. These studies were published over the last 25 years (1993-2020), with emphasis on the last decade (2010-2020), which comprised more than 60% of the published studies. The studies were conducted in 85 different countries and the United States led the number of articles, with 39% of the studies published (n=104 studies). In 135 of the 266 articles (50.7%), the focus of the study was ecological restoration, where topics such as bird behavior and the positive effect on restoration, implications for seed limitation during initial forest succession and fire management. A total of 4,008 species of birds were recorded in all articles, distributed in 202 families. The recorded studies that exclusively addressed the role of birds in ecological restoration process proved the importance of this group for restoration. Review studies, such as the present one, are important because they bring information compiled on the subject in a single document, which may facilitate the understanding of global patterns and trends on eco-restoration techniques, as well as to allow better planning of future actions by pointing out important gaps in this theme. **Keywords:** Scientometric, ecological restoration, birds, seed dispersal

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Seed dispersal, seed banks recruitment I

Sowing Forests: A Synthesis of Seed Dispersal and Predation by Agoutis and Their Influence on Plant Communities

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Granivorous rodents have been traditionally regarded as antagonistic seed predators. Agoutis (*Dasyprocta* spp.), however, have also been recognized as mutualistic dispersers of plants because of their role as scatter-hoarders of seeds, especially for large-seeded species. A closer look shows that such definitions are too simplistic for these Neotropical animals because agoutis can influence plant communities not only through seed dispersal of large seeds but also through predation of small seeds and seedlings, evidencing their dual role. Herein, we summarize the literature on plant–agouti interactions, decompose agouti seed dispersal into its quantitative and qualitative components, and discuss how environmental factors and plant traits determine whether these interactions result in mutualisms or antagonisms. We also look at the role of agoutis in a community context, assessing their effectiveness as substitutes for extinct megafaunal frugivores and comparing their ecological functions to those of other extant dispersers of large seeds. We also discuss how our conclusions can be extended to the single other genus in the Dasyproctidae family (*Myoprocta*). Finally, we examine agoutis' contribution to carbon stocks and summarize current conservation threats and efforts. We recorded 164 interactions between agoutis and plants, which were widespread across the plant phylogeny, confirming that agoutis are generalist frugivores. Seed mass was a main factor determining seed hoarding probability of plant species and agoutis were found to disperse larger seeds than other large-bodied frugivores. Agoutis positively contributed to carbon storage by preying upon seeds of plants with lower carbon biomass and by dispersing species with higher biomass. This synthesis of plant–agouti interactions shows that ecological services provided by agoutis to plant populations and communities go beyond seed dispersal and predation, and we identify still unanswered questions. We hope to emphasise the importance of agoutis in Neotropical forests. **Keywords:** Frugivory, granivory, plant–animal interactions, scatter-hoarding, Neotropics, carbon storage, synzoochory, acouchy

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Complementarity in the Seed Dispersal Function of Three South American Primates

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Frugivorous primates play a unique role as seed dispersers, consuming and dispersing a high diversity of fruits, many of which require manipulation and are therefore inaccessible to other species. The level of redundancy (repetitiveness) or complementary (uniqueness) in the seed dispersal function of different co-occurring primate species is still unknown, although a loss of larger primates is associated with a decrease in dominance of large-seeded plant species. We compared inter- and intraspecific variation in the seed dispersal function of three sympatric South American primates: the large, frugivorous common woolly monkey (*Lagothrix lagothricha,* Atelidae), the large, folivorous Colombian red howler monkey (*Alouatta seniculus,* Atelidae), and the small, partially frugivorous (~50%) black-capped capuchin (*Sapajus apella,* Cebidae). In this comparison, we asked how the following aspects of seed dispersal vary in relation to body size and diet across and within species, the latter pertaining to age/sex classes: (1) overall seed dispersal function, (2) quantity of large seed (>7.5

mm wide) dispersal, (3) species richness of large seed dispersal. To answer these questions, we compared fecal sample data on these species from two neighboring sites (~23 km apart), Rey Zamuro and Santa Rosa, Meta, Colombia. KNE, JRO, and PRS collected and identified the seeds in the feces from one group of each species: *L. lagothricha* (adult males: 1, adult females: 2, juveniles: 1), *A. seniculus* (M:2, F:2, J:2), and *S. apella* (M:1, F:1, J:1). We compared among and within species: (1) the median seed size dispersed using the Fligner-Policello test, (2) the number of large seeds/fecal sample using the maximum likelihood of the Poisson parameter l, (3) the richness of large species dispersed using Bernoulli product sample-based extrapolation. We found the three species to be complementary in their seed dispersal function, with *A. seniculus* dispersing the largest median seed size, followed by *L. lagothricha,* and then *S. apella. L. lagothricha* was the main contributor to the dispersal of large seeds. This was expected given the larger size of *A. seniculus* and *L. lagothricha* and the higher degree of frugivory in *L. lagothricha.* Differences in seed dispersal among age/sex classes within species, however, could not be explained by body size. Our study supports previous findings of the critical role of *L. lagothricha* in the maintenance of large-seed dispersal and highlights the need to understand seed dispersal in the context of the community of dispersers due to high levels of complementarity among and within species.
Keywords: Capuchin monkeys, endozoochory, functional redundancy, howler monkeys, woolly monkeys

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Understanding the Relationship between Dispersal and Range Size

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Understanding what drives the vast variability in species range sizes remains an outstanding question in ecology. The theoretical expectation of a positive dispersal-range size relationship has received mixed empirical support, despite dispersal being one of the most prominent hypothesized predictors. Here, we synthesized results from 86 studies examining the effect of dispersal on range size for plants and animals in marine, terrestrial and freshwater realms. Overall, we found that dispersal had a positive effect on range size, but its effect was highly dependent on the clade and dispersal-related traits studied. Despite potential differences in habitat connectivity, we did not find an effect of realms. Moreover, the overall strength of the dispersal-range size relationship is influenced by how range size was measured, whether phylogenetic relationships were considered, and the taxonomic breadth of the study clade. Our synthesis emphasizes the importance of considering different aspects of the dispersal process -departure, transfer, settlement- and the traits associated with them. Furthermore, ecological niche, environmental tolerance and evolutionary components, such as time for range expansion and past geological-environmental dynamics, can additionally influence current dispersal-range size patterns. We therefore call for a more integrative view of the dispersal process and its causal relationship with range size. **Keywords:** Dispersal, range size, dispersal-related traits, evolutionary history

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Seed dispersal, seed banks recruitment II

Effect of Fruiting Neighborhood on Seed Dispersal Differs by Frugivore Functional Group and Spatial Scale

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Introduction / Background / Justification: Most tropical tree species rely on frugivores to disperse their seeds and provide escape from sources of high mortality associated with proximity to the maternal tree. The fruiting neighborhood, i.e., the density of conspecific fruiting trees surrounding a focal tree, may decrease seed dispersal through competition between trees for frugivores or facilitate dispersal by collectively attracting animal dispersers. Both these alternative outcomes have been observed in nature but the factors driving this variation are poorly understood, in part due to inadequate understanding of the relevant spatial scales at which the fruiting neighborhood may operate. Moreover, disparate functional groups of animal dispersers may exhibit distinct relationships to the fruiting neighborhood. To explore these questions, we examined relationships between the fruiting neighborhood and seed dispersal at a range of spatial scales by both flying and non-flying frugivores in a keystone canopy palm species *Oenocarpus bataua*. **Objective(s)/Hypothesis(es):** We hypothesized that fruiting neighborhood will asymmetrically influence dispersal by different functional groups at varying spatial scales. We predicted that flying animal dispersal rates will increase with fruiting density at the landscape scale and that small non-flying animal dispersal rates will increase with fruiting density at the local scale. Methods: We gathered four years of fruit removal data from motion-activated cameras deployed on fruiting adults of *O. bataua* in NE Ecuador. Using detailed phenology data from a large study population of *O. bataua,* we assessed the spatial scales at which the fruiting neighborhood impacts dispersal rates by each of two functional groups of dispersal agent, and what the direction and magnitude of these impacts are using GLMs. Results: We found that flying frugivores were most sensitive to fruit availability at the landscape scale while non-flying frugivores were most sensitive to local conditions. Interestingly, higher local fruit densities were associated with decreased dispersal by flying dispersers, consistent with competition among trees for flying dispersers at this scale and an increase in dispersal by non-flying dispersers, consistent with facilitation. In contrast, higher landscape fruit densities led to increased dispersal by flying frugivores (facilitation) but had no effect on non-flying dispersers. Implications/Conclusions: These results show how different combinations of spatial scale and frugivore functional group interact to generate opposing patterns of competition vs. facilitation for dispersal services among conspecific fruiting trees. Future work in this and other systems exploring impacts of fruit availability at the community level on seed dispersal are necessary to gain a more nuanced understanding of these dynamics. **Keywords:** Choco rainforest, competition, facilitation, *Oenocarpus bataua*, neighborhood effects, seed dispersal

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Investigate the Effect of Dispersal Limitation and Habitat Association on Intraspecific Recruit-adult Patterns in a Mixed-dipterocarp Tropical Rainforest

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Investigating spatial patterns and interspecific associations of plant communities can provide insights into processes and mechanisms that maintain species coexistence. We investigated mechanisms underlying the spatial association patterns of recruits relative to conspecific adults of 41 woody species in the Sinharaja Forest Dynamic Plot, Sri Lanka, using data from five censuses (1996, 2001, 2006, 2011, and 2018). We tested four hypotheses, including spatial independence (H1), habitat filtering (H2), dispersal limitation (H3), and joint dispersal and habitat filtering (H4) using point pattern techniques. Significant adult-recruit spatial associations (i.e., departures from H1) were detected using non-parametric pattern reconstruction. In a habitat analysis (for H2 and H4) we estimated the intensity function of recruits in dependence on six topographic variables, 17 soil variables, and bio-environmental index, mean and standard deviation of basal area of heterospecific and conspecific neighbors. We evaluated hypotheses H2-H4 by a heterogeneous Poisson process based on the intensity function of recruits to represent their habitat association and parametric and non-parametric pattern reconstruction (H2), a homogeneous bivariate Thomas process with known parents representing a dispersal kernel (H3), and an inhomogeneous Cox process with known parents (H4). Simulation envelopes of the point process models, Goodness of Fit tests and AIC were used to assess the fit of the point processes and to select the most parsimonious model. The majority of the species (87.8%) showed a positive association in the placement of recruits around adults. The habitat analysis showed that elevation, mean basal area of heterospecific neighbors, slope, and soil PCs were key environmental factors influencing the intensity of recruits. For 31.7% of all species we identified hypothesis H2 as the most parsimonious model, for 22% it was H3, and for one species (2.4%) it was H4, whereas the observed adult-recruit pattern of 31.7% of the species could not be explained by any of the four hypotheses and requires more complex models. Sinharaja shows strong habitat structure compared to other tropical rainforests, and previous studies found that the majority of the species show clustered spatial distributions due to habitat association and dispersal limitation. This was supported by our results that show that the dominant processes which drive the placement of recruits relative to conspecific adults were habitat heterogeneity and dispersal limitation. However, further work is needed to investigate additional mechanisms governing the adult-recruit spatial distributions of species that could not be well explained by any of the fitted processes. **Keywords:** adult-recruit spatial association, habitat filtering, dispersal limitation, point pattern techniques

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Potential Role of Rodents in the Secondary Dispersal of an Orphaned Baobab Species in Madagascar's Tropical Dry Forests.

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Introduction/ Justification: The loss of large-bodied frugivores might impact the survival of large-fruited plants that rely on them for their seed dispersal. The Malagasy baobab tree is one of the long-lived plants whose fruits might be adapted for seed dispersal by extinct megafauna. However, it is not known how this orphaned species can persist without its major seed-dispersers. The role of the extant ground-dwelling animals as secondary seed dispersers of this species also remains a mystery. **Objectives and Methods:** We investigated the potential role of rodents as secondary seed dispersers of a baobab species (*Adansonia grandidieri* Baillon) in western Madagascar's dry forests through seed-tracking experiments and camera trapping under 40 baobab trees in two sites. Additionally, we surveyed the communities of ground-dwelling mammals to identify the potential secondary dispersed dispersers of this species in these sites. **Results:** Using data from camera traps, we observed the native and locally endemic rodent, *Hypogeomys antimena*, interacting with the seeds of baobabs on the ground, consuming seeds on-site, and carrying seeds away. We also observed the introduced species, *Rattus rattus,* predating on the seeds. In our seed-tracking experiments, we found that some seeds were removed and secondarily dispersed away from the initial location in a scattered fashion. We also found the native rodent *Eliurus myoxinus* in these sites, although their potential role in the dispersal of baobab seeds is unknown. **Implications/Conclusion:** Our findings suggest that some native rodent species can play an important role in the secondary seed dispersal of Malagasy baobab trees through scatter-hoarding, indicating their potential to compensate for the loss of megafauna in baobab seed dispersal. However, the ongoing defaunation and fragmentation of dry forests in western Madagascar can have a dramatic impact on the persistence of the iconic Malagasy baobab trees. Therefore, conservation actions toward baobab habitats restoration should consider the animal species interacting with them. **Keywords:** Seed dispersal, plant-animal interactions, baobabs, rodents, anachronism, megafauna

Seed dispersal, seed banks recruitment III

Key Biotic-abiotic Processes Explaining Seed Bank Dynamics in Riparian Vegetation of Tropical Dry Forests

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Riparian ecosystems are very striking from an ecological point of view, they constitute ecotones where many physical, abiotic and biotic processes are continuously changing. They are key landscape elements regulating continental nitrogen transfer to the atmosphere and oceans and produce critical ecological benefits that help to mitigate the impacts of anthropic activities. Given that 65% of the world's fluvial habitats are threatened by land use change, it is important to recognize the factors that drive the dynamics of riparian plant communities. Based on our results from tropical dry forests (TDF) of central Mexico and northern Colombia, we present a synthesis of what we know about these driving processes, which may be useful to environmental managers and ecological restoration initiatives. We found that the frequent wet/dry cycles of river dynamics lead to constant change in the physicochemical conditions of corridors and create new and diverse ecological niches, leading to spatial and temporal heterogeneity in vegetation dynamics, species assemblages and abundance of dispersed seeds. Together, these results show that environmental variability in local conditions is a critical factor in this ecosystem. We also found that small fish species may have a role as seed dispersers of herbaceous species along the riparian corridor. They do this during the rainy season in synchrony with the flood cycle, when overflows release seeds accumulated as soil seedbanks into the water. We can thus differentiate between physical-chemical and biological determinants at large and small scales, and their influences on highly disturbed and less disturbed ecosystems. To further complicate the scenario, streams can be important groundwater-dependent ecosystems sustaining dependent plant species and important services in the TDF. In one such ecosystem, during the rainy season surface runoff erodes and removes seed banks and soil organic materials from the alluvial zone and riverbanks, increasing NO3-N concentrations and salinity, biasing the composition of the vegetation towards early successional species. Seed banks, mainly of herbaceous plants, are transient, allowing plant species to overcome hostile habitats, such as those with high salt concentrations. Although several previous studies have suggested that floods reduce spatial variability, such that rivers have a homogenizing effect on riparian plant assemblages, our results do not support this conclusion. These findings respond to the temporary and transitory conditions of riparian environments and deserve to be disentangled and understood in an integrated approach as part of TDF in order to highlight their functions and the importance of their protection. **Keywords:** Biodiversity, groundwater, ecosystem processes, riparian vegetation, community ecology, seedbank dynamics

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Effect of Seed Gut Passage of Birds and Bats on Seed Germination and Seedling Emergence in Deforested Bracken-dominated Areas

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Seed dispersers benefit plants by long-distance seed dispersal and they can also increase seed germination and seedling establishment probabilities by seed gut passage. The main seed dispersers in tropical montane forests are birds and bats. These dispersers are fundamental for forest regeneration in deforested areas. The main cause of deforestation in the tropical montane forest is human-induced fire. After fire, the bracken fern (*Pteridium*) dominates the vegetation for long periods and forest regeneration is hindered, mainly by seed limitation. Seed limitation could be surpassed by direct seed addition, but we still don't know the role of birds and bats on seed germination and seedling emergence in deforested habitats dominated by bracken. This knowledge is important to suggest restoration strategies as direct seed addition or the inclusion of bird perches and artificial bat roosts in deforested areas dominated by the bracken fern, to accelerate forest regeneration. In this study we evaluated the effect of seed gut passage of birds and bats on the velocity of germination and seedling emergence of tree species in the tropical montane forest in Bolivia. At eight sites, we set mist nets to catch birds and bats in deforested areas close to the forest edge. All frugivorous birds and bats were identified and held in cloth bags to collect fecal samples. We also collected ripen fruits in the surrounding vegetation in the forest interior and in the bracken dominated area. We then planted the digested and undigested seeds in Petri dishes, in a nursery and in a deforested area dominated by bracken. We found 16 species of plants in the feces: nine in bird feces, three in bat feces and four in both bird and bat feces. We found species-specific results in terms of germination velocity and seedling emergence. Three species digested by birds and one species digested by bats showed lower germination velocity than undigested seeds. Among the species that were digested by both groups, the seeds of *Piper elongatum* digested by bats had less germination time than those digested by birds and the opposite was found for *Cecropia* sp. Only seeds digested by bats of four species emerged in the deforested area. Our results highlight the importance of bat seed dispersal on seed germination and seedling emergence in deforested habitats. Our results also stand out the potential of direct seed addition and the inclusion of artificial attractants for birds and bats in bracken-dominated areas. **Keywords:** Seed dispersal, frugivory, tropical montane forest, bracken, Pteridium, forest restoration

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Frugivory and Seed Dispersal in the Cerrado: Network Structure and Defaunation Effects

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Tropical ecosystems greatly rely on seed dispersal for their maintenance and functioning. However, this vital ecological process is endangered by the rapid worldwide decline of large-bodied frugivores witnessed in the Anthropocene. The Brazilian Cerrado, the world's largest savanna biome, is a highly diverse and endemic biodiversity hotspot, facing several environmental challenges and still owning considerable knowledge shortfalls on seed dispersal. Investigating the topic in the Cerrado, thus, is appreciably important for its conservation. Our main objectives are (i) determining the structure of seed dispersal networks in the Cerrado, (ii) identifying the key species and their ecological contributions to it, (iii) evaluating the likely effects of defaunation of large-bodied frugivores on the biome network. Our initial hypothesis is that the Cerrado has a diverse and plural network, predominantly composed of generalist species. We also expect the effects of defaunation to be more prominent for large-fruited trees, whose alternative dispersers would be less efficient than the original large-bodied fauna. We performed a Systematic Literature Review using the PSALSAR framework and gathered secondary data to construct the seed dispersal network of the biome, employing a binary (presence/ absence) adjacency matrix of plant-frugivore interactions. The network was represented by bipartite graphs and characterized through analytical and ecological descriptors. We then calculated the defaunation index of the frugivore assemblage and made several comparisons between different fruit-sized plants and their respective dispersers. The seed dispersal network in the Cerrado is slightly nested and considerably modular, dominated by small to medium-sized generalist species, such as passerines, marsupials, and mesocarnivores. Nonetheless, large frugivores, such as tapirs, have a key role in the network due to their great foraging and network integration capacity. We found no correlation between fruit diameter and disperser mass, nor an increase in mean body mass according to fruit size. We also saw a low similarity between the assemblage of large-bodied frugivores and the actual dispersers of large-fruited plants. The Cerrado network has a heterogeneous structure, with a nested topology organized around a modular pattern. This architecture may confer some resilience to the biome's plant-frugivore interactions. Despite most interactions being performed by low body-size dispersers, larger dispersers are critical for the network's functionality. Our findings suggest the network is being impacted by the defaunation of large-bodied frugivores, with already perceivable effects in large-fruited plants. The Cerrado's defaunation and functional loss of large vertebrates deserve urgent attention to further understand the impacts on seed dispersal mechanisms and ecosystem functioning. **Keywords:** Brazilian Savannas, fruit size, functional-loss, seed dispersal network, large-bodied vertebrates

Socio-ecological Systems, Resilience, Sustainable Development I

Exploring the Socioecological Drivers of Deforestation in Mexico: A Machine Learning Approach

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Introduction: The quantification and prediction of forest cover (FC) loss, and the identification of the factors that influence this process, represent powerful tools for generating effective management and conservation strategies. However, understanding this phenomenon on a large scale is not simple. On the one hand, multiple biophysical, socioeconomic, and political factors can interact and spatially influence this phenomenon. In addition, modeling these data often presents several problems for traditional statistical modeling techniques, including unusual frequency distributions, nonlinearity, multicollinearity, complex interactions, and spatial autocorrelation. Recently, the machine learning (ML) framework has been proposed as a flexible and powerful tool for analyzing complex systems, generating more accurate predictions, modeling nonlinear relationships, and avoiding the need to make assumptions about data distributions or interactions among predictors. **Methods:** Using data from the MAD-Mex system on the land cover in the country and *ca.* 150 biophysical, social, and economic predictors, we quantified the rate of FC loss/degradation at the municipal level during the period 2010-2018 and generated predictive models. To generate predictions, we used base ML algorithms [random forest (RF)], ML algorithms considering the geographical dimension [random forest with spatial predictors (RFsp), and geographic random forest (GWRF)], and, as a benchmark, parametric algorithms [multiple linear regression (OLS), and geographic regression (GW-OLS)]. **Results:** During the analysis period, there was a country-level CF loss/degradation of 53,691 km2, representing 8.6% of the forest area present in 2010. Conversion to grassland, cropland and shrubland represented the most significant changes (39%, 37%, and 17%, respectively). ML models, in particular RFsp, showed consistently better fits than parametric models, reaching an R2=0.8. Both biophysical and socioeconomic factors were identified as the most important in generating predictions for transitions to cropland and grassland, while transitions to shrubland were dominated by the influence of biophysical predictors. **Conclusions:** The analysis of the phenomenon of CF loss at the municipal scale represents a feasible scale for integrating diverse sources of information. This study identified target areas where more attention should be paid to mitigate the loss of forests and their associated services. Our results show the potential of ML for the analysis of socioecological data providing predictions with greater accuracy and without geographic/spatial bias. **Keywords:** Deforestation, machine learning, random forest, artificial intelligence, decision support systems

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How Do Birds and People See an Ancient Agricultural Landscape in the Peruvian High Andes?

Liz B. Hurtado

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University of Florida, Gainesville, FL The tropical Andes have exceptional biodiversity that has been shaped by past climate history, topographic, and environmental heterogeneity. These factors coupled with the rich history of occupation including ancient civilizations have long shaped the region's landscapes and vegetation. As a result, today the Andean landscapes are dominated by a matrix of shrubs, remnant forest patches, and planted and fallow fields. This landscape conversion has greatly affected the wildlife communities of the region; however, the Andes are still considered a region rich in biological diversity and high endemism. This biodiversity has been studied in some sections of the High Andes (>4000 m elevation) but at lower altitudes where landscapes have been more intensively managed near areas with high human population density, there is no empirical information. Using an interdisciplinary approach, my study aimed to investigate: 1) the response of bird assemblages to landscape elements in a human-dominated landscape, and 2) perceptions of biodiversity among rural residents in Cusco. My results show that the heterogeneity of land cover types leads to high beta diversity in the site, but the remnants of native vegetation are the last refuge for specialist and endemic birds. Additionally, despite the rapid urbanization in the area, residents have a connection with wildlife and a willingness to collaborate with conservation actions. My research reinforces the view that retaining native plant species is important for biodiversity and should be a central consideration when developing conservation policies and management plans. This work also highlights the importance of understanding human perceptions of biodiversity in designing management and conservation recommendations. **Keywords:** Andes, bird assemblages, fragmentation, interdiscipline

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La Gestión Del Riesgo De Desastres Como Estrategia De Conservación De Ecosistemas. Caso De Estudio Reserva La Romera.

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La Romera reserve is located in the municipality of Sabaneta (Antioquia, Colombia), it has great ecological, social and cultural significance for the municipality and the Valle de Aburrá-Metropolitan Area. The reserve presents conservation conflicts caused by environmental problems such as the poor use of trails and ecological spaces, and risk, such as the occurrence of accidents, the presence of unsafe conditions, as well as geological and hydrometeorological hazards with their consequent impacts. This paper presents and discusses advances of a research project carried out by students and professors of the SICA study group at Institución Universitaria Colegio Mayor de Antioquia, in cooperation with social and institutional actors to identify weaknesses, opportunities and, strengths in the identification of risk reduction measures, sustainably prioritizing the capacities and existing resources with the conservation goals of the reserve. Risk analysis activities have been implemented through the use of participatory tools and environmental education strategies to build knowledge about the protection of the reserve from the perspective of risk and, above all, increase the awareness of individuals who visit the reserve. Risk reduction measures have been proposed as a starting point for carrying out the Risk Management Plan for La Romera reserve, articulated with the strategic planning exercises for development, land use planning and risk management existing in the municipality. Advances have made it possible to address the challenges of conservation from disaster risk management under an innovative approach of interdisciplinary work and active participation of the different actors present in the territory of the Local System of Protected Areas (SILAP), thus contributing to a sustainable management of the ecosystem and the ecosystem goods and services present therein. **Keywords:** Reserva natural, conflictos-socioambientales, gestión del riesgo, protección de ecosistemas.

Reconciling Policy Instruments with Drivers of Deforestation and Forest Degradation: Empirical Analysis of Stakeholder Perceptions in the Tropics

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The number and variety of programs for the protection of forests in tropical landscapes have increased substantially over the last decades worldwide (e.g. REDD+ or Forest Landscape Restoration initiatives). Despite the amount of policy strategies available, designing and implementing effective measures requires addressing the exact forces that drive deforestation and forest degradation in a particular context. This can be challenging, as these drivers act at different spatial scales and they are often dependent on the local context and stakeholder configuration. Cross-scale analyses of relationships between deforestation drivers and policy instruments in the tropics are scarce. In this study, we first aim to explore the spatial variability (cross-country and cross-scale) of stakeholder perceptions in the tropics on: (a) future drivers of deforestation and forest degradation, and (b) preferred protection measures. We further want to investigate the existence or not of a relationship between (a) and (b). We use quantitative data from a questionnaire conducted between 2018 and 2019 with 224 representatives of forest-related institutions in three tropical countries of Africa (Zambia), South America (Ecuador) and Southeast Asia (Philippines). Our sample includes respondents from local and central governments, national and international organizations, indigenous associations, private enterprises and academia. The methods used to analyze their answers include principal component analysis, k-means clustering and multivariate analysis of variance. Our results confirm the general importance of agriculture expansion and logging, timber and resource extraction as main perceived drivers of deforestation in the tropics. We further identified context dependencies in line with current continental trends (e.g. relevance of firewood and charcoal in Africa, importance of commercial drivers in South America and Asia, role of infrastructure and urbanization in Asia). We observed a general preference for mixed strategies conforming a bundle of different policy instruments, including spatial planning, economic and information measures. Surprisingly, our preliminary findings reveal less perceived importance of threats by stakeholders in Zambia, a country at an early stage of deforestation. Similarly, the perceived importance decreases gradually at local levels in all countries, revealing mismatches between the awareness of different stakeholder groups. We further analyze regional and scale variability of preferred instruments in relation to the actual perceived threats (e.g., logging ban in areas with high timber extraction or economic measures at the local levels). Hence, our study can help to understand what motivates these perceptions allowing conclusions on the coherence (or it lack) during the processes of policy design and implementation. **Keywords:** Drivers of deforestation, forest degradation, conservation, environmental policy.

Socio-ecological Systems, Resilience, Sustainable Development II

Indigenous Lands Are Better for Biodiversity Conservation than Colonizer-managed Agricultural Lands: A Case Study from South-eastern Peru

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The efficacy of core protected areas is often tied to the success of surrounding areas. Still, the importance of buffer zones for biodiversity conservation is often overlooked. Manu Biosphere Reserve is one of the most biodiverse places on earth, yet destructive land-use practices are degrading the ecological integrity of its buffer zone. To better understand the importance of different land-uses within the buffer zone for biodiversity conservation, we used amphibians as a model study system because of their sensitivity to environmental change and assessed changes to the amphibian community across a land-use gradient in the buffer zone of the Manu Biosphere Reserve, in addition to a reference site in its core protected area. We surveyed six sites to best represent typical land uses present within the Biosphere: complete forest clearance for agriculture by colonizer communities, two forest types used by Indigenous communities (secondary logged forest and hunted old-growth forest), regenerating protected forest, and old-growth forest within the core protected area. We sampled amphibian communities using visual encounter surveys and leaf litter searches during both dry and wet seasons. Overall, in only 2249 ha surveyed of the buffer zone, we estimated 79 amphibian species (64% of the 124 species ever recorded in the Manu Biosphere Reserve from the same elevational range surveyed within our study). Species richness, evenness, and diversity of amphibians decreased with habitat degradation and were lowest in the colonizer agricultural land. Conversely, the community composition of amphibians in the regenerating protected forest, the secondary logged forest and the hunted old-growth forest were similar to that of the old-growth forest in the core protected area, whereas the agricultural land contained more generalist species. Our results suggest that increasing degradation through expanding intensive agriculture traditionally adopted by colonizer communities could be a major threat to maintaining biodiversity within the buffer zone. However, our findings also underscore the high conservation potential of buffer zones managed by Indigenous communities for amphibian biodiversity conservation. Solutions to avoid extensive clearance and intensive forms of agriculture need to be available to local people to avoid biodiversity degradation that could end up reflected within the core protected area in the longer term. Therefore, a combination of sustainable livelihood activities, cultural practices and forest protection, as observed in the Indigenous communities, is critical to fulfilling the role of a Biosphere Reserve - to reconcile the conservation of biological and cultural diversity while improving social and economic development. **Keywords:** Buffer-zones, Biosphere-Reserve, land-use practices, agricultural land, amphibians, conservation, Indigenous-communities

Land Organization and the Effect of Rural Credit and Land Violence on Deforestation in Brazil

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Deforestation has been explained by a range of factors, from individual behavior to processes at large scale. Most of the time, economic factors both micro and macro are pointed to be the main drivers of deforestation, but also social and political processes, such as election incentives, affect vegetation loss in tropical countries. However, there is increasing evidence that low land governance may configure a first condition for high rates of deforestation. This leads to the idea that although economic, social and political factors certainly play a role on driving deforestation, their importance may be intensely mediated by the institutional context considering governance over land. We here hypothesize that such differences on land organization, this is whether land division is defined, formally assigned to landholders and land property is assured, combined with opportunity to deforestation, i.e., the extension of native vegetation areas, create distinct conditions in which different drivers impact deforestation. In this context, land organization and native vegetation extension are crucial dimensions. When landholders have a stable condition considering land property and there is still vegetation to be deforested then rural credit may influence the expansion of productive areas over forest. However, if landowners are not legally stated, government institutions are almost absent and there is pressure to new land acquisition, then deforestation occurs as a consequence of a non organized social process with frequently illegal strategies to obtain land tenure. In this case, violence is an expected outcome. We observe how drivers of deforestation such as rural credit, an economic factor, and land disputes, a social process evidenced by rural violence, are enhanced by different conditions of land organization. We combine deforestation, rural credit and land violence data into a longitudinal database and use a panel regression approach, controlling for municipality invariant characteristics (such as slope and elevation) and a set of control variables to investigate deforestation dynamics in these different conditions. We find that land organization differences significantly affect whether one of these observed processes predominates and whether the effect of such different drivers on the increase of forest loss is enhanced. Our results shed light on the fact that conservation strategies against deforestation must also be modulated taking into account land governance different contexts. **Keywords:** Native vegetation loss, land economics, governance, conservation

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The Burning Andes: Fires in the Colombian Paramos

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Paramos are highly biodiverse high mountain ecosystems that provide important ecosystem services such as carbon storage and water supply. However, the paramos are susceptible to disturbances derived from human activities such as forest fires, which are mostly associated with processes such as agriculture and livestock production. Although fires are the most significant disturbance agent within the paramo ecosystem, not much is known about their impact as they are generally relatively small in size and are therefore usually not detected within low-resolution satellite products. Here, we present the first database on fire occurrence within the paramos of Colombia from Landsat imagery at 30 m resolution over the period 2000-2021. We find that 5,632 Ha of paramo burns on average each year. Comparison with existing global burned area products (MCD64, FireCCI51) shows a structural underestimation in mapped burnt area of 4.5 times in these products across this ecoregion. We also found that the total annual burned area in the paramos of Colombia varies between 3,305 Ha in the year with the fewest fires (2010) up to 20,773 Ha in the year with the most burned area (2013). In the total number of years evaluated, the Sierra Nevada de Santa Marta paramo is the one with the largest burned area with 54,500 ha, while the Miraflores paramo presented the smallest total burned area with almost one hectare. On the other hand, the months with the highest number of fires in the Colombian paramos are December to April, which coincides with the dry season. Our results indicate that existing low-resolution burnt area products are unable to represent the fire activity in Colombian paramos. Our dataset allows for the first time to analyze the impact of fire on the paramo ecosystems at the national level, as well as an information source for decision makers to take measures for the conservation of the paramos. **Keywords:** Remote sensing, landsat, fire ecology, fire database

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Storymaps: A Virtual Tour to Promote Biodiversity Conservation in La Romera Reserve, Sabaneta – Antioquia, Colombia

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La Romera reserve is the connection point between the mountainous regions of Sabaneta, Caldas, Envigado and El Retiro municipalities in Antioquia. Hikers, cyclists and the general public prefer it for its accessibility characteristics to mountain trails, bird watching and other wildlife species, for the sound of crystalline waterfalls, and waterfalls with many branches that form the most harmonious whole with all the shades of natural green that predominate in the forest. Thanks to the role played by social actors and institutions, an environmental culture focused on the conservation and sustainable use of ecosystems and biodiversity has been promoted, in addition to improving communication and participation among researchers, educators, environmental administrators, and local communities. The confinement situation caused by the COVID-19 contingency caused several natural scenarios in the world to be closed to the public. In order to bring the general public closer to the La Romera Reserve, it was decided to create a virtual tour through a Story Maps of ArcGIS Online, as a strategic tool for the conservation of the ecosystem mediated by images, videos, short and interactive stories and free use technological tools to demonstrate the importance of its application in the social appropriation of knowledge and the promotion of research experiences such as this one, in projects that contribute to the conservation of local protected ecosystems. This type of initiative allows us to learn about our ecosystems and the biodiversity that abounds in these places, which despite being so close to urban environments, we do not know the importance of these types of spaces in our daily lives and in particular to understand the importance of the VOC (Value Object of Conservation) for the SILAP (Local System of Natural Protected Areas) of the municipality of Sabaneta, Antioquia - Colombia. **Keywords:** Protected natural area, biodiversity conservation, environmental education, native species

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Socio-ecological Systems, Resilience, Sustainable Development III

The Western Perspective of Nature and the Hurdles of Conservation

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In 1985, Michael Soulé published the foundational article in Conservation Biology, proposing the functional and normative principles guiding the discipline. Almost 30 years later, Kareiva and Marvier presented a revision of these principles, triggering – or rather renewing – a strong debate concerning motivational, ethical and applied dimensions of conservation, and prompting both criticism on the dominance of white, male, North voices and calls for pluralism within the movement. We here argue that we can strengthen dialogue to advance the field through a reflexive process of recognizing its roots as based on a western – and thus restricted – view of Nature. By exploring the historical roots of the conservation movement, describing its western framing of Nature and discussing the implications of both, we propose ways forward to create space for pluralism and increase the transformative potential of conservation actions. The initial environmental concerns in western societies started in the 19th century within aristocratic elites worried about the preservation of game species used in hedonic practices of hunting. These initial (western and elitist) motivations are the roots of modern mainstream conservation movement, although objectives and approaches have been diversified, reformulated and supported by science. Yet, the emphasis in avoiding species extinction still unifies the movement. This emphasis is evident in the key role the concept of biodiversity plays as the dominant scientific concept of Nature, and in the value given to "pristine" areas isolated from human disturbances (where biodiversity would be found in its complete form). Hence, we can describe the western framing of Nature within the movement as comprising a focus on: biotic components instead of the dynamics, feedbacks and emergences between components, strict separation of humans from Nature that serves humans (even if through the pleasure of being in Nature), and proximate causes of the socioecological crisis – those that affect biodiversity – instead of ultimate causes related to the way western society are structured. This limited framing implies the concealment of views of Nature of non-western societies and of their ways of living and reciprocally relating with Nature, erodes the legitimacy and efficacy of conservation actions, and helps maintain both apathy towards current socioecological crisis and the structure of western societies. Ways forward includes strengthening topics related to epistemology and science history and philosophy in education and fostering reflexivity to confront the myth of value-free science, and creating dialogue between science and the arts and indigenous cosmovisions. **Keywords:** Conservation science, conservation movement, human-nature relationships, global socioecological crisis

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The Biocultural Conservation of Epiphytic Orchids in Oaxaca, Mexico: Experimental Reintroduction of Prosthechea Karwinskii after Ceremonial Utilization

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The harvest of forest resources by rural communities puts pressure on the preservation of plant diversity, yet traditional land-use practices also generate cultural incentives for sustainable management. An example of social-ecological impetus for conservation is in Mexico, where 30% of the country's 1,300 native orchid species are wild-harvested for ornamental use in religious celebrations. In Oaxaca, the community of Zaachila harvests ~5000 *Prosthechea karwinskii* (Orchidaceae) to adorn local chapels during Semana Santa. The practice is a component of Oaxaca's biocultural heritage, but due to harvest pressure, climate change, and deforestation, P. karwinskii populations are in decline and under consideration for endangered species listing. We initiated

a biocultural approach to test the feasibility of reintroduction as a conservation measure, identify the micro-habitat preferences of *P. karwinskii,* and understand the cultural contexts of orchid harvest. Growth of *P. karwinskii* pseudobulbs after utilization was measured in a nursery experiment, 46% of harvested pseudobulbs displayed new root and shoot growth after three months, suggesting potential reintroduction success. Interviews with 15 traditional orchid-harvesters were conducted, transcribed, and coded, the distance traveled by harvesters has increased as orchid populations decline and forest access is restricted, and harvesters support conservation methods that do not discourage traditional practices. In collaboration with the Zaachila government and orchid-harvesters, we established an experimental reintroduction site to an effort to restore epiphyte-degraded forests, allow for the perpetuation of harvesting traditions, and prevent *P. karwinskii* extirpation. After harvest and use in Semana Santa 2022, ~3000 *P.karwinskii* pseudobulbs will be reintroduced to the pine-oak canopy of a nearby forested site where *P. karwinskii* populations have been extirpated due to excessive extraction. Monitoring will occur to answer the questions: 1) How do survival, growth, and reproduction rates of reintroduced *P. karwinskii* vary as a function of phorophyte species, elevation, and canopy microsite? 2) What is the feasibiity and efficancy of orchid reintroduction as a community-managed conservation plan for this culturally-valuable and at-risk species. The project holds potential to shift the pattern from extraction into a sustainable cycle of utilization, re-planting, and community stewardship, thus preserving the region's biodiversity while maintaining important cultural traditions. Results will be used to identify sustainable harvest limits and inform reintroduction protocols for orchids harvested by communities across Mexico. **Keywords:** Epiphyte, orchidaceae, reintroduction, conservation, biocultural, traditional harvest, NTFP

The Jungle Book Revisited: Combining Art and Storytelling for Impactful Conservation Science Communication

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As scientists who work on various aspects related to tropical biology and conservation, a lot of our study species, the landscapes, its people, and their interactions are extremely fascinating. Unfortunately, the way we communicate our science with peers or with the general public is often hampered by the means, methods, language, and platforms we use. India is a globally important country for several species of charismatic megafauna, which were popularized in The Jungle Book animated feature films. Many of these species, like tigers, elephants, sloth bears, and wolves are found at higher densities in India than elsewhere in the world, while also sharing spaces with a population of 1.3 billion people. But do we know anything about these species beyond The Jungle Book? For instance, how are wolf packs faring across India? What really are the simple 'bear' necessities? Why is the movement of Colonel Hathi's elephant herd being obstructed? Is Shere Khan the tiger still facing the wrath of man in the jungle? Recent research on these species has given us some incredible insights and generated knowledge about their ecology, behavior, interactions with people, and conservation requirements. As with most research conducted in countries of the global south, these findings are seldom celebrated, amplified, or effectively communicated with other scientists, local communities, wildlife managers, and the citizens– all of whom are important stakeholders in conservation. Given the projected rise in human populations, and the increasing interface between people and wildlife, effective and impactful science communication can be an important tool for garnering public support, building local stewardship for conservation, and achieving coexistence goals in shared human–natural ecosystems. Using six case studies from India, I will demonstrate how combining art, humor, popular culture, visual aesthetics, and storytelling with the way we communicate our research can amplify our scientific findings and broaden its impacts on society.
Keywords: Carnivores, elephants, vultures, conservation, tropics, science communication, social-ecological systems

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Quantifying Resilience of Socio-ecological Systems through Dynamic Bayesian Networks: An Application to High Andean Ecosystems in Colombia

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Background: Quantifying resilience of socio-ecological systems (SES) can be invaluable to delineate management strategies of natural resources and aid the resolution of socio-environmental conflicts. However, resilience is difficult to quantify and the factors contributing to it are often unknown in SES. **Objective:** We provide a theoretical and conceptual framework to quantify resilience in a long-term context. **Methods:** Our approach uses elements from interdisciplinarity and network perspectives to establish links and causalities between social and palaeoecological components and resilience attributes of SES. The evaluation and modeling of SES structure and function are established from the analysis of dynamic Bayesian networks (DBN). An advantage of DBN models is that they allow quantifying resilience through probabilities, but also offer a platform of interdisciplinary dialogue and an adaptive framework to address questions on ecosystem monitoring and management. The proposed DBN is then tested in Monquentiva, a SES located in the high Andes of Colombia. **Results:** We determined historical socio-ecological resilience from palaeoecological evidence (i.e. palynological diversity, forest cover, fires, and precipitation) and social factors (i.e. governance, social organization, and connectivity) between 1920 and 2019. We find the transformation processes in Monquentiva are mainly related to social change (e.g. high social organization) and have resulted in increased ecological diversity and SES resilience between 1980 and 2019. Differently, the absence of social organization has been related to low diversity and poor socio-ecological resilience between 1920 and 1980. **Implications:** The ability to predict the SES response over time and under cumulative, non-linear interactions across a complex ecosystem highlights the utility of DBNs for decision support and environmental management. We conclude with a series of management and policy-relevant applications of the DBN approach for resilience assessment. **Keywords:** Dynamic Bayesian Networks, Functionality, Interdisciplinarity, Participatory approach, Resilience modeling, Socio-ecological

Socio-ecological Systems, Resilience, Sustainable Development IV

Anthropogenic Tropical Forests in Global, Multidisciplinary Perspective: The Amazon, Asia, and Australia

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In popular discourse, tropical forests are synonymous with 'nature' and 'wilderness', battlegrounds between apparently pristine floral, faunal, and human communities, and the unrelenting industrial and urban powers of the modern world. Nevertheless, the last two decades of archaeological and palaeoecological research have revealed that tropical forests have actually been intensively managed by our species in many parts of the globe for over 45,000 years, something thatnecessitates re-evaluation of common ecological and conservation approaches to these environments. Here, we review how a diversity of multidisciplinary methods, including stable isotope analysis, dendrochronology, ancient plant genetics, and Geographic Information Systems techniques, have revealed detailed insights into the nature and intensity ofprehistoric impacts of humans on tropical forests. In particular, we discuss how the revolutionary discoveries enabled by these methods in the Amazon Basin have led us to apply them in diverse contexts ranging from the earliest arrival of Homo sapiens in the tropical forests of South Asia in the Late Pleistocene through to ongoing debates relating to the extent of Holocene pre-colonial human population and forest manipulation in the Australian Wet Tropics. We argue that it is essential to determine, in detail, these tropical forest 'prehistories' if we are to develop sustainable strategies to ongoing preservation of biodiversity hotspots. Indeed, we suggest that, rather than locking people out of these environments, more appropriate management approaches involve close collaboration with Traditional Owners 'on country', reconciling natural and cultural heritage for present and future generations. **Keywords:** Historical ecology, archaeology dendrochronology, tropical forest, amazon, South Asia, Australia

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Threats to Useful Plants in Colombia in the Light of Local Knowledge

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Colombia ranks second in the world for its botanical richness and is one of the most ethnically diverse countries in the world. However, the country is marked by social inequality and rural poverty. Following years of internal conflict, policies on bioeconomic development are being promoted to support people and biodiversity. This is reliant on the long-term sustainable use and conservation of natural resources. However, large gaps remain in understanding Colombia's 5,800 native plant species with known human uses. For conservation efforts to succeed, it is increasingly recognised that efforts need to go beyond scientific concepts and involve local communities. We took a case-study approach to investigate local knowledge on useful plant use, availability, and conservation priorities in three municipalities of Colombia. Workshops and semi-structured interviews were conducted in Otanche, Becerril and Bahía Solano to understand: 1. What are local perceptions on trends in useful plants? 2. What conservation actions would individuals prioritise? 3. How does local knowledge compare to national-level data and conservation priorities? Participatory activities and group discussions revealed that trends in the use and abundance of key useful plants are species-specific. Most of the plants discussed were perceived to have declined in both use and abundance in recent decades, but in each area, certain species have increased, often linked to cultivation and commercialisation. Participants showed overall optimism for the future, with conservation efforts and greater awareness expected to result in increased plant populations. This

presentation will summarise the methodologies used, results obtained, and next steps planned to compare local knowledge and use of plants with national-level conservation prioritisation. **Keywords:** Plant conservation, ethnobotany, socio-ecological systems, important plant areas, Colombia, botany

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Multiple Knowledges: the Diversity and Socio-economic Correlates of Local Knowledge on Climate-related Environmental Changes in Western Amazonia

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Global climate crisis affects social and ecological systems worldwide, posing a major threat to biological and cultural diversity. While global patterns in the atmospheric systems are increasingly understood, less is known about how climate change impacts socio-ecological systems, especially in Amazonia where local communities are strongly dependent on biodiversity-based resources. In that sense, the potential of bridging scientific and Indigenous and Local Knowledge (ILK) to thoroughly understand climate change impacts has increasingly been recognized. Here, we tap into the local knowledge of riverine communities within the Middle Juruá river, in the western Brazilian Amazon, to understand the diversity of climate-related changes according to their perceptions and to evaluate how local knowledge about these changes varies across different socioeconomic characteristics, namely age, gender and number of livelihood activities (i.e., fishing, agriculture, extractivism, etc). To do so, we used interview methods commonly used in social sciences, combining qualitative semi-structured interviews (42 community leaders and experienced farmers, fishers and gatherers) and quantitative questionnaires (171 interviewees randomly sampled) applied in nine communities. In preliminary analyses, we found that local people have a very diverse and detailed knowledge repertoire concerning climate-related changes, expressed in observations within atmospheric, physical, biological and socio-economic systems. Although some of these changes are widely perceived, there is substantial variation between individuals concerning level and type of knowledge. We show that part of this heterogeneity is driven by differences in gender, age and number of livelihood activities, with certain knowledge domains being mastered by specific groups of people. In general, gender and number of activities influence perception, with men and people involved with greater numbers of livelihood activities perceiving a greater number of environmental changes. More specifically, farmers and extractivists showed increased perception of biological and socio-economic systems, respectively, and older people perceived less changes related to the physical system. Our preliminary results emphasize the significant potential of ILK to understand climate-related changes and impacts over local people's livelihood and well-being. However, ILK concerning environmental changes is intertwined with socio-economic aspects, with different groups being specialized in specific ILK domains. In this regard, when leveraging the inclusion of ILK to support climate change mitigation and adaptation, it is crucial to ensure that knowledge holders from multiple groups, including the historically excluded such as women and youth, are thoroughly engaged and represented. **Keywords:** climate change, riverine communities, sustainable-use protected areas, socio-ecological changes

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Towards a Relational Understanding of Amazonian Fish Conservation

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Relational values encompass the diverse virtues and principles that emerge from human interactions with nature. The way we view and understand nature deeply influences the way we treat it, thus, worldviews have important consequences for the way we use and manage ecosystems. For at least 10,000 years, human communities throughout the Amazon Basin have shaped and been shaped by aquatic ecosystems, as evidenced by both historical and recent biocultural connections, including cosmological narratives, cultural heritage, and linguistic expressions, as well as settlement patterns and livelihood strategies. We argue that considering relational values in decision-making is critical to the sustainable use of natural resources and for protecting biocultural diversity of fish-people interactions in the Amazon. Through an extensive literature review of ethnographies, origin stories, and material culture, we explore relational values towards aquatic ecosystems of the Amazon, focusing particularly on the role of fish migrations in connecting people with nature and other entities. For example, for the Enawene-Nawe people of the Juruena River Basin, Brazil, annual fishing ceremonies to catch migrating Brycon amazonicus and other species is an important way to celebrate abundance and demonstrate gratitude towards fish spirits. It is also a chance to monitor fish populations and recall their origin story, as the Enawene-Nawe were once a part of the river themselves. Devotion or stewardship of aquatic systems are recurring modes of relationality in the Amazon, and in some cases, wetland spirits will mediate human interactions with aquatic organisms. These spirits are important figures among different Amazonian peoples, such as the Urarina people of the Ucayali River, Peru. In the Urarina cosmovision, some wetland spirits are benign, collaborating with humans to protect fishes and other creatures. Other wetland spirits predate on humans who trespass in non-human fishing grounds. Both oral histories and material culture objects keep these figures alive in Urarina culture, and their presence is essential to the management of fisheries. Diverse relational ontologies underpin the sustainable management and conservation of fish and aquatic ecosystems of the Amazon. As conservation scientists, we must value all aspects of Indigenous and local ecological knowledge systems, as a diversity of conservation strategies will be essential in the face of so many threats to aquatic social-ecological systems. Supporting biocultural revitalization and community-led efforts will be key to both the well-being of people and the conservation of migratory fishes of the Amazon Basin. **Keywords:** Relational values, fisheries, conservation, biocultural connections, Amazon

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Socio-ecological Systems, Resilience, Sustainable Development V

Modeling Pangolin Poaching Opportunity in Zambia

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Pangolins are considered the most trafficked wildlife species in the world with all 6 species listed as either threatened or endangered. The elusive nature of pangolins and the limited available data on pangolin ecology, especially in Africa, hinders our ability to adequately address poaching. We applied a Coupled Human and Natural Systems approach to assess poaching opportunity as a combination of human behaviors/motivations and pangolin behaviors/vulnerability. Here we present a conceptual framework of pangolin poaching opportunity through combining human and pangolin behaviors at multiple spatial scales. Our framework was designed for Zambia and incorporates variables at local, regional, and national scales. We applied the conceptual framework using a mixed-effects model of poaching opportunity and then displayed the model to map where poaching opportunity is highest. The model matched areas of high poaching (as revealed in key informant mapping exercises) with social and ecological variables such as proximity to roads, agricultural areas, waterbodies, temperature, precipitation, vegetation, landcover type, location of major markets for pangolin goods, chiefdoms, and population density. Our model reveals the areas where pangolin poaching is most likely to occur and we found the central and southeastern portions of the country had the greatest risk of pangolin poaching. While pangolins are highly desired for local and international consumption, their behavior makes them challenging to directly target for poaching. Therefore, modeling the intersection of humans and pangolins shows where poaching is most likely to occur and why. This framework and model can inform enforcement efforts throughout Zambia and ultimately help reduce pangolin poaching throughout the country. The model structure can also be adapted for use in other places where pangolin poaching occurs and can be continually improved as additional information about pangolins becomes available. Due to the sensitive nature of pangolin poaching we restricted our research to poaching opportunity and did not directly incorporate habitat models or enforcement data. **Keywords:** Africa, coupled human and natural systems, mixed-models, pangolin, poaching

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Traditional Ecological Knowledge and Patterns of Hunting in Vaupés, Colombia

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Introduction / Background / Justification: Defaunation in tropical forests is a major risk to the future health of forests, their capacity to store carbon storage, and the livelihoods of people depending on forest resources. A better understanding of the regulating role of cosmology in wildlife use in Indigenous multiethnic communities in Colombia is urgently needed to establish more sustainable uses of fauna and contribute to biodiversity conservation in Amazonian forest ecosystems. Indigenous livelihoods related to hunting practices are not properly considered in legal frameworks, government interventions, and discussions concerning biodiversity conservation strategies in indigenous territories. This research presents the traditional ecological knowledges (TEK) of East Tukano cultures from the Papuri River in the Colombian Vaupés and focuses on wildlife use reported by twelve local hunters. The presentation also describes an ongoing project on traditional ecological knowledges and forest fauna in the departments of Vaupes and Amazonas. **Objective(s)/Hypothesis(es):** Describing existing hunting patterns in indigenous communities of Vaupés and 2) how TEK is influencing

and regulating wildlife consumption in indigenous communities in Vaupes and Puerto Nariño (Amazonas). **Methods:** Six months of data collection: Ethnographic registration, participant observation, participatory workshops, hunting diaries. **Results:** A total of 82 species consumed by local people were identified, 32 fish, 22 mammals, 12 insects, 12 birds, 2 reptiles, and 2 amphibian species sum a total biomass of 2001.8 kg. Variation in biomass, species preference, and hunting locations among hunters, are mainly explained by ethnic distribution of hunting areas, related to community roles, and family history. Hunting is based on the knowledge of interdependence of living and non-living natural features and people in the territory. This knowledge is embodied by the Kumu, the local wise elder who interprets and teaches appropriate hunting practices. **Implications/Conclusions:** Wildlife consumption is an important dietary component and cultural activity in indigenous communities in the Colombian amazon region. TEK knowledge has real implication for hunting practices. Thus, it constitutes an important institution that regulates wildlife use and it is key to maintaining the ecological integrity of tropical forest ecosystems in the Amazon, including human diversity. This, however, requires the recognition and comprehension of the current TEK and its relation to local dynamics with formal an informal institution. **Keywords:** Hunting, Indigenous communitites, Colombian Amazon, traditional ecological knowledge, sustainability, conservation

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The Importance of Wild Plant Foods in the Food Security and Dietary Diversity of Forest-edge Communities in Southeastern Madagascar

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In rural societies, wild foods still play an important role in everyday diets as well as in coping with hunger during seasonal food shortages (e.g. famine foods). However, wild food collection and consumption may pose challenges to contemporary conservation efforts and some famine foods may have deleterious health impacts. Using data from a cross-sectional survey of 328 smallholder farmers and fisherfolk living in 15 villages surrounding Manombo Special Reserve on the southeastern coast of Madagascar, we examine the relationship between food security, dietary diversity, and consumption of wild plant foods (WPFs), specifically giant aquatic arrowhead or *via* (*Typhonodorum lindleyanum*) and the Polynesian arrowroot or *tavolo* (*Tacca leontopetaloides*), during the main hunger period for the region, as well as document traditional ecological knowledge and preferred choice of these two WPFs. Using multilevel modeling, we found that food insecurity and famine food consumption were significantly associated with inadequate nutrition, defined as consuming foods from less than four food groups within a 24-hour period. Wealthier households were less likely to consume WPFs as a coping strategy during food insecure periods, while larger and more food insecure households were more likely to consume these foods. These findings reaffirm the importance of local access to natural habitat such as forests, grasslands, and marshy areas, and supports conservation design strategies that honor traditional foodways, particularly taking into consideration more vulnerable populations and WPFs that serve as food safety nets. **Keywords:** Wild foods, food security, dietary diversity, nutrition, Madagascar, protected areas

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Disentangling the Volcanic Memory of Plants through Paleoecology and Art

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A large number of paleoecological records in the northern Andes of Ecuador and Colombia have provided a comprehensive understanding of the response of vegetation to past climates at different time scales. However, despite this area comprises more than 20 active volcanoes that have shaped landscapes and human societies for millennia, the impacts of volcanism on terrestrial ecosystems have been rarely addressed by paleoecologists in the region. Here, we illustrate how plants act as paleoclimatic archives that record and preserve information from past volcanic eruptions. Individual plants register in their tissue signatures of time, temperature, climatic variability, neighborhood, and other environmental conditions. On the other hand, plant communities may record successional trajectories, diversity patterns, networks of interactions, and connections with human societies. The time domains of some of these processes demand for integration of methodologies that allow disentangling short-lived events (months-years), intermediate variabilities (decades), and long-term trajectories (centuries). In our case, we propose a methodology to reconstruct successional pathways on volcanic substrates that is based on local knowledge, observational descriptions, and vegetation plots. This integrative view might serve to interpret palaeoeocological records in similar volcanic settings helping to reveal "hidden

eruptions" that are not conspicuous in the geological record. Furthermore, we explore the tensions between these geological and ecological forces through mixed artistic media that accompany and enrich the scientific approach. Concepts such as time, ecological succession, resilience, and recovery hinge between the artistic and the scientific languages, also acting as articulation elements between human perception and natural legacies.
Keywords: Tropical volcanoes, ecological succession, paleoecology, science & art, local knowledge,

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Are Indicators for Social-ecological Resilience Promoting Landscape Adaptative Management: A Mountain Social-ecological Landscape Study Case (2017-2022)

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Background: Our greatest challenge today is to return to the limits of safe operating space for humanity and to prepare ourselves to deal with expected and unexpected changes. Since biodiversity is the most vulnerable planetary limit, it is necessary to strengthen socio-ecological resilience in areas that conserve important reserves of biodiversity. The Las Cruces micro-watershed, located in the Serranía de Los Yariguíes in Colombia, is a mountain socio-ecological landscape important for biodiversity conservation and food production. The GEF-Satoyama project (2016-2019) proposed to strengthen this landscape resilience using the resilience indicators. Objective: Here we present and reflect on the results of the socio-ecological resilience assessments of Las Cruces landscape from 2017 to 2021. Methods: The GEF-Satoyama toolkit for resilience indicators consists of mixed participatory techniques that reflect participants' perceptions of their social-ecological landscape represented on a measurement scale of 1 to 5. Four assessment workshops were conducted over five years. The implementation team adapted and improved its application according to collective learning. Results : The resilience assessment allowed the researchers to quickly and effectively understand the dynamics of the territory and create a respectful and fruitful relationship with the community. It also provided the community with tools to reflect on the history of transformation, agro and biodiversity, traditional and innovative knowledge, governance capacity, and their well-being. However, when comparing the temporal evaluations, we found differences difficult to explain. Between 2017 and 2021 the perception of agrobiodiversity decreased (from 4.1 to 3.0) and wellbeing increased (from 2.8 to 3.8). This reinforces the fact that the indicators reflect the perception of the inhabitants and therefore, depending on the moment and the participants, the scores can be significantly different. Implications: The resilience assessment creates a space for dialogue that builds a valuable relationship of trust that allows organizations intervening in a territory to make a quick and rich reading of the landscape and to define actions that can be developed collectively. The success of its implementation lies mainly in the identification of the key actors of the landscape and the capacity of the research team to facilitate constructive dialogue and holistic understanding of the results, taking into account that the functionality of the methodology goes beyond quantitative results. Although the toolbox contributes significantly to adaptive landscape management and, therefore, to biodiversity conservation, indicators should not be used to monitore temporal changes in the landscape. **Keywords:** Socio-ecological resilience, adaptive management, mountain socio-ecological systems, social learning

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Conceptually Organizing Typologies of Human-nature Relationships

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In face of the current global socioecological crisis, the importance of human-nature relationships (HNRs) for conservation science has been increasingly recognized. HNRs are defined as the set of beliefs that people hold about their relationships to the more-than-human world, being embedded in individual and cultural contexts. Understanding them can contribute to conflict mediation, maintenance of biocultural diversity, and identification of leverage points for socio-ecological change. However, assessing conceptions of HNRs poses challenges, due to their multidimensional and often subconscious character. Typologies organize the complexity of social phenomena into distinct dimensions that in turn are combined into types, therefore being useful tools for conceptually organizing HNRs. Aiming at contributing to this conceptual advance, we reviewed HNRs typologies available in conservation science, comparing their context of development, scientific field of origin, method of development, and proposed dimensions and types of HNR. For each of the nine identified typologies, we recorded publication year, country of affiliation of authors, number of citations, and field in which they were

published and most cited. They were classified as deductive or inductive, quantitative or qualitative (if applicable), and anchored or not in a specific socio-ecological context. Dimensions and types appearing in more than one typology were codified and systematized. We found that most typologies were developed in the US and Europe, and those are also the most cited. Each typology is mostly cited within a specific subarea of conservation science. Deductive typologies tend to be quantitative and based on a generic idea of nature, while inductive typologies tend to be qualitative and anchored in a specific context. We identified eight common dimensions of HNRs and grouped them into four domains: conceptions about nature (positionality and understanding of nature), interactions with nature (goals and kinds of interaction), ethics (values of nature and responsibility/rights), and relationality (affectivity and identity). Ten types of HNRs were identified, eight of which are predominantly Western (domination, use, apathy, intellectual, aesthetic, stewardship, management, and affective participation) and two which are non-Western (devotion and active reciprocity). Our review shows that dimensions and types are reasonably consistent across distinct HNRs typologies. More importantly, it highlights a strong socio-geographic and methodological bias in the literature with most typologies focusing on Western views of nature. Finally, we argue that giving space to non-Western perspectives through contextualized inductive-qualitative approaches is a crucial step forward in the study of HNRs to foster multiplicity of views and transdisciplinarity. **Keywords:** Human-nature connection, visions of nature, relational values, social representation

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Community-based Fish Sanctuaries: Untapped Potential for Freshwater Fish Conservation

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Riverine systems and associated fish populations worldwide are threatened by human impacts from the proliferation of dams, pollution, destruction of riparian habitats, and unsustainable fishing. These threats are most pronounced in tropical countries with emerging economies, where extensive dam-building overlaps with high freshwater biodiversity and high dependence of local communities on the provisional services of aquatic ecosystems. For instance, despite over 10.8 million people being dependent on inland fisheries for their livelihood in India, national- and state-level laws and policies do not adequately protect river systems and freshwater fish species. Consequently, rivers and their biodiversity in India continue to face extensive threats from damming, pollution, sand mining, destructive fishing, and river modification projects. Community-based Fish Sanctuaries (CFSs) are among the only existing model of in-situ freshwater fish conservation in India. Despite the emergence of CFSs as a key tool for the conservation of vulnerable and endemic fish populations, they remain largely understudied in the scientific literature. In an effort to bridge this gap, we integrate primary field experience with a literature synthesis to define and classify CFSs in India. We identify three types of CFSs based on the motivation for their establishment and mode of management. We further present a novel, critical analysis of fish sanctuaries as social-ecological systems with a functional characterization based on the natural capital created, ecosystem services they provide, human wellbeing outcomes, and associated policy and governance structures. We find that such sanctuaries are shaped by complex social-ecological processes, including co-evolution of religious practices and ecological change, feedbacks created by retaliatory conflicts between river users, and diverse and dynamic governance strategies. CFSs hold great potential for the conservation of rare fish species in India, but they experience myriad threats from local, regional, and global scales. Given the complexity of these social-ecological systems, we outline their conservation potential and point to directions for future research. **Keywords:** Community-based conservation, fish sanctuary, participatory management, religion, social-ecological systems, temple

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Socio-ecological Systems, Resilience, Sustainable Development VI

Resilience Thinking: A Way to Promote Dialogue and Reconcile Different Perspectives in the Management of Productive Landscapes

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Under the Anthropocene scenario, Landscape Management must be able to cope with a changing world, especially in rural landscapes where ecosystems are highly interrelated with humans. In this context, the socio-ecological resilience approach should be considered a useful frame for analysis and action. The El Ramo micro basin is a productive landscape in the northeastern Colombian Andes, adjacent to the Serranía de los Yariguíes National Natural Park (Department of Santander, Colombia), where local stakeholders have faced great challenges in terms of sustainable landscape management. The aim of this study was to evaluate the effectiveness of the Indicators of Resilience in Socio-ecological Production Landscapes and Seascapes (UNU-IAS et al. 2014) in El Ramo micro basin, to create a dialogue among stakeholders, and to conciliate the different perspectives toward a more resilient future. To do it, first, we set a baseline of the territory functioning based on the community and institutional actor's perception, then we evaluate resilience at the veredal and micro basin scale, and finally, we evaluate the local and institutional actor's perceptions on their willingness to work together after the intervention. Through this methodology, we were able to identify temporal changes in terms of vegetation, production systems, and social dynamics, in the face of which the ecosystem and the community have shown a high capacity to cope with shocks and stresses and to innovate. In addition, we could understand the structure of the social organization and the relationships between local actors and stakeholders. The assessment workshops allowed participants to have a deep understanding of the landscape and created a space for discussion that effectively improved relationships within the community and among stakeholders. According to these results, the application of the Indicators of Resilience in Socio-ecological Production Landscapes and Seascapes (UNU-IAS et al. 2014) was useful to promote spaces for dialogue through the understanding of different perceptions of the landscape, which could lead to the improvement of relationships and communication between local actors, build local capacities that foster a holistic reading of the landscape and navigate towards scenarios of greater socio-ecological resilience. This suggests that the conceptual and methodological proposal can inspire transformation processes and build bridges among different backgrounds. Thus, the resilience approach could be applied to almost any Colombian rural area, and along with a broad kind of tropical landscapes worldwide, as a tool to initiate a process of adaptive management and participatory planning **Keywords:** Socio-ecological resilience, Landscape management, Resilience thinking

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Participatory Insights to Frailejon's Conservation Strategies at Colombian Paramos

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The frailejones are a complex of high mountain plant species inhabiting the Andes, in Colombia, Ecuador and Venezuela. They are strategic plants of the paramo ecosystems, mostly because of their ecological services related to the regulation of water quantity and quality in these Andean countries. Their adaptation strategies make them unique species living in extreme environmental conditions of low nutrients soils, low temperature and high radiation. Only 50% of the paramo land in Colombia is protected under some conservation designation. Therefore, promoting participatory measures to protect key species and ecosystems outside protected areas including local communities and their perceptions is imperative. High altitude socioecological systems are the topmost vulnerable areas on earth to climate change, and their species present many threats such as habitat loss due to fires, mining, agriculture and cattle ranching. Frailejones are a complex of species from genera *Espeletia*, *Espeletiopsis*, among others, 91 species have been reported in Colombia -78 endemic- and nearly 60% of them are under threat. 19 species have been described in the jurisdiction of the environmental Autonomous Regional Corporation of Cundinamarca (Corporación Autónoma Regional de Cundinamarca – CAR). This central region of Colombia represents one of the most transformed paramo areas, around 70%. During 2018, participatory observation tours were carried out in 13 municipalities of Cundinamarca and Boyacá departments, evaluating through 76 semi-structured interviews and 35 surveys the conservation strategies of frailejones species in place and proposed by local communities in the territory. Major findings identified that local communities interviewed recognize frailejones as key plants for the ecosystem but only 64% acknowledge their relationship with water quality or quantity, which shows a need for more community engagement not only in environmental education but conservation programs. Local communities participating in the study also mentioned different direct uses of frailejones and threats, and proposed conservation strategies towards frailejones, such as restoration and environmental education activities. Co-designing and implementing strategies with local communities are more likely to be successful over time and increase awareness of the impact of human activities to certain conservation values which will determinate primary slow feedbacks in socioecological systems affecting their resilience. **Keywords:** High land ecosystems, paramo, frailejon, participatory assessment, conservation strategies.

FCAT: Building Local Capacity in a Biodiversity Hotspot

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Many recognize the pressing need for more effective engagement and inclusion of women and youths in tropical biological research and conservation, yet achieving this goal has proved challenging. Here, we report on an ongoing project focused on building capacity among youth, particularly women, in a biodiversity hotspot in the Chocó biogeographic zone of northwest Ecuador. The overarching goal of the project is to develop a 'bottom-up' model for developing a diverse, highly trained workforce for research and conservation work in rural Latin America. The program is implemented by FCAT (Fundación para la Conservación de los Andes Tropicales), a grassroots Ecuadorian NGO with 20 years of experience in community engaged research. The first stage of the program consists of providing local high school age students with hands-on training in conservation biology research and theory and research via monthly, weekend-long workshops. The second stage provides tuition for a sub-set of participants to complete an undergraduate environmental engineering, or related, degree at a distance-learning university in Ecuador while concurrently providing 50%-time employment as staff biologists at FCAT, a local NGO. By providing a predictable, multi-year program for education, training and mentoring coupled with financial security, this program is intended to engage and retain youths and women that might otherwise be excluded from conservation programs. We summarize early successes and challenges from this program to date, and contextualize it within broader conservation and research programs by FCAT and other local stakeholders. **Keywords:** Ecuadorian Choco, local communities, conservation, FCAT

The Nexus between Democracy and the Environmental Issues: the Crisis of Democracy in Brazil and the Amazonian Degradation

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In Brazil, several indicators show that the democratization of the country, an event that was marked by the promulgation of the 1988 Constitution, expanded popular participation, favored the establishment of institutional arrangements for the direct participation of society and brought guidelines at the federal level for the protection of the environment. However, since the year 2016, with emphasis on 2019 and 2020, the country's democracy undergoes profound changes, in which systemic setbacks in the environmental field stand out. Academics are debating this conjuncture as a crisis of democracy. The Amazon region is at the core of political and socio-environmental debates in the country, giving rise to public policies, and social mobilizations around the theme of conserving and protecting the region. In this way, environmental indicators in the region, such as deforestation rates, are the upshot of the interaction of variables related to social and political aspects in a given conjuncture. This work aims to reveal evidence of the nexus between democracy and environmental issues in the context of the crisis of democracy in Brazil. We work with the research hypothesis that environmental degradation of the Amazon is correlated with the democratic setbacks. We performed an exploratory analysis of the quality of democracy in Brazil and deforestation rates between 1988 and 2020. We accessed quantitative databases about the quality of democracy (V-Dem), Brazilian Amazonian deforestation rates (Prodes and MapBiomas), and theoretical analyses in the field of Brazilian political science. The analyses proceeded in two steps. First, we investigated the existence of democratic scenarios using quantitative data. Second, we built and analyzed the statistical correlation of two historical data series: the quality of democracy and deforestation rate. We identified four scenarios that were related with theoretical debates of Brazilian democracy. Our analyses indicate that in a conjuncture of the crisis of democracy, Amazonian deforestation increases with each democracy setback. The results corroborate the perspective that the Amazonian degradation is one of the most prominent features of the current crisis of democracy in Brazil. Few studies have teased apart the importance of democracy to the Amazon, and no such study exists for the conjuncture of the crisis of democracy. **Keywords:** interdisciplinarity, deforestation, Amazon, crisis of democracy, democracy

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"Fruits Falling on the Ground": Flooded Forest, Arara Artisanal Fishing, and Belo Monte Dam's Hydrological Alterations in the Brazilian Amazon

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The Belo Monte hydroelectric dam started to operate in 2015 and has since then modified the Xingu River, an Amazon River clear-water tributary located in the Amazon, Brazil. By diverting the water flow from the Big Bend of the Xingu River, a 130 km stretch hosting a unique social-ecological system started to be dewatered, where the Arara, and other indigenous and riverine communities, lives. The floodplain forest (*igapó*) plays an important role as a source of food to the aquatic fauna, including a variety of fruit species, which provides 83% of the fish biomass. However, since the dam operation started, the fruit phenology that is synchronized to the flood pulse has been disrupted. This study aims to understand how hydrological changes caused by the Belo Monte Dam affects the igapó forest on the Big Bend of Xingu River and the Arara artisanal fishing. Our methods included Indicator of Hydrologic Alteration software analyses, literature review, and exploratory field research at the Arara da Volta Grande do Xingu Indigenous Land, through the conduction of semi-structured interviews and participant observation. Seasonal calendars of main fruits associated with artisanal fishing were compared with results of the hydrologic alteration analyses and the perceptions of the Arara and other Indigenous and riverine communities. We found that the reduction in the flood pulse magnitude, especially during rise and fall periods, provides a scenario of "fruits falling on the ground" (flooded areas that have dried up by the decrease in flood pulse magnitude) according to the local perception, potentially compromising fish nutrition. The rise of hydropeaking and abrupt river flow variations affects hydrochoric and ichtyochoric seed dispersal, phenology of tree species, raises the chance of fish traps increasing mortality, brings navigation insecurity and imperil access to fisheries. The drier future scenario in the Big Bend of Xingu River and the temporal asynchrony between the flood pulse and fruit phenology will have long-term impacts on the *igapó* forest, fishes and local livelihoods. We emphasize the need to build, through local participation, environmental flow requirements to manage the dam operation and guarantee minimum flood pulses that sustain the social-ecological system of the Big Bend of Xingu River. Finally, we argue that the knowledge held by Indigenous peoples and local communities is critical

to guide the management and monitoring of social-ecological impacts of dams. They need to be recognized as important knowledge sources and stakeholders and included in environmental decision-making processes. **Keywords:** Arara da Volta Grande do Xingu, Belo Monte Dam , Amazon , environmental flow, Igapó forest, fisheries

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Diversity of Traditional Useful Plants at Samper Mendoza Market, Bogotá, Colombia

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Samper Mendoza plant market is a great reservoir of biodiversity in the capital city of Bogotá (Colombia), being one of the most important in the country regarding medicinal and esoteric plants. Given the number of species and traditional knowledge associated with the uses of plants in this place and from different regions of the country, the purpose of this work was to know the richness of species and uses of plants commercialized in this market. For this aim, semi-structured interviews were conducted with local experts about uses and preparations, and collection and identification of specimens for 3 months were carried out, as well as the standardization of the categories of uses and the subsequent socialization of the results with local community. As a result, it was found that the largest number of species comes from rural areas, both cultivated and wild. Species richness is represented by 391 plant species, of which 201 are native to Colombia, five are endemic to Colombia and 163 are exotic. On the other hand, for 27 species there is no information on their origin. Regarding the uses reported in the market 137 species and five morphological varieties are edible. This list includes aromatic species, plants used as condiments, spices or as flour. There are 110 species of plants and four morphological varieties that have esoteric uses, 287 species and six morphological types have medicinal uses. There are 25 ornamental species, three species used for wrapping, 12 with cosmetic use, and 18 with other uses, including materials, animal food, medicines and environmental uses. Therefore, Samper Mendoza market constitutes an important sample of local biodiversity, especially of plants commonly used traditionally in rural areas but that are also used in the city and collected and used by the local population. Therefore, there is an immediate need to conserve these important species and traditional knowledege for the sustainable use in the future. **Keywords:** Medicinal, esoteric, edible, herbs, uses, traditional

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An Integrated Approach to the Study of Orphan Crops: towards New Conservation Strategies in Ethiopia and Guinea

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Indigenous food and agricultural systems (IFS, IAS) still sustain high levels of biodiversity and ecosystem services in several parts of Africa. They are rooted in local cultural heritages and have historically been key to create and maintain biodiversity-rich landscapes, as well as diverse and nutritious diets. Yet, over the past decades, the African continent has witnessed a progressive abandonment of IFS and IAS, as well as a significant cultural erosion, following the growing urbanisation, social transformations, and land use change. This has led to many local plant varieties and landraces becoming "orphan crops" (OC) and being replaced by a narrow range of commercial hybrids, usually highly input-dependent and unable to support balanced diets. With the present work, we combine taxonomical, ethnobotanical, and historical perspectives within a pilot interdisciplinary research methodology to study agriculture, crops, and food systems within selected agro-climatic zones. By focusing on case-study areas in two African crop diversity hotspots – the Ethiopian Highlands and Guinea – we aim to document traditional crop varieties grown by communities in different socio-environmental contexts, including endangered knowledge about their resilient traits, gastronomic use, and cultural role. We adopt participatory approaches for data collection (i.e., participatory mapping, seasonal calendars, temporal-change matrices) to deepen the complex relationships between local agricultural choices, environments, and cultural preferences, as well as to capture temporal changes and explore their drivers. The construction of such a holistic framework around agri-histories and heritage will help quantifying how cultural erosion and abandonment of IFS and IAS are affecting agrobiodiversity conservation. Additionally, the development of ethnobotanical inventories of local OC and traditional landraces will directly contribute to the preservation of the traditional ecological knowledge (TEK). Finally, the present findings provide solid evidence of the biocultural importance of IFS, IAS and OC, and can constitute a strong empirical basis for further

research and future tailored conservation initiatives to be effectively designed. **Keywords:** Agrobiodiversity, orphan crops, ethnobotany, indigenous food systems, land use change

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The Impact of Multilateral Forest Programs on Livelihoods of Forest-dependent Women in Semi-arid Forest Ecosystems in Brazil and Burkina Faso

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There is increasing recognition of women's distinct role in forest management and the unique benefits women receive from the collection, processing, and sale of non-timber forest products. However, many forest programs are still not designed in a gender sensitive way, and thus forgo benefits to both forest ecosystems and forest-dependent communities. Identifying and addressing challenges to women in forest management will help direct effective international aid to forest management projects. Women face unique obstacles in forest management, including lack of control in decision making over land use, exclusion from participation in meetings and consultations, undervalued skills and knowledge from men, and entrenched gender norms that may control women's daily tasks. In this work, individual and focus group interviews were conducted with women in fourteen project sites in Brazil and Burkina Faso. Results show that targeted forest initiatives designed and led by women have led to short-term tangible benefits for women in Brazil and Burkina Faso. These benefits include higher income, increased control over both household and forest decision making, increased cooperation with other women community members, and a greater sense of pride and agency. This research provides recommendations for gender sensitivity in the design of future Multilateral Forest Programs. **Keywords:** semi-arid forest, Brazil, Burkina Faso, gender, livelihoods, multilateral finance

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Socio-ecological Systems, Resilience, Sustainable Development VII

Wildlife Trade from Myanmar to China

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Wildlife trade in Asia is one of the most pressing threats to regional biodiversity. China is a major wildlife consuming country and is well known to heavily import wildlife from neighboring countries, while Myanmar is the largest and most biodiverse country in mainland Southeast Asia and shares a long, mountainous and porous border with China. At a global scale, the country has been found to be exporting the greatest number of threatened wildlife species to China. It is thus crucial to gain better knowledge of the state of wildlife trade from Myanmar to China in order to safeguard the country's exceptional biodiversity. Focusing on birds, mammals and reptiles, we analyzed data from scientific articles, NGO reports, local academic research, the IUCN Red List, CITES data and seizure reports in order to identify species involved, estimate volumes and prices, profile stakeholders and let spatial patterns of trade emerge. Legal trade of CITES-listed species is limited to 7 species only. By contrast, a total of 99 species have been found to be informally traded. Of traded native species, 56% are globally (near-)threatened and 76% are CITES-listed. 83% of species recorded are illegally traded. The border town of Mong La emerges as the most important point of entry into China. Myanmar also appears to act as a transit country for wildlife originating from India and Africa and destined for China. Rapid action is necessary from both countries in order to curb this devastating trade. **Keywords:** Wildlife trade, Myanmar, China, CITES

Decreasing Conflict with Wildlife by Improving Human Attitudes - a Cross-cultural Approach

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Anthropogenic pressure on the environment has been steadily increasing in the last centuries, often leading to an enhancement of conflicts at the human–wildlife interface, with consequences for human safety, disease transmission and biodiversity loss. Traditionally, one way to reduce the occurrence and/or intensity of conflicts between humans and wildlife is to improve people's attitudes, by for instance increasing their knowledge about wildlife and/or their tendency to attribute human mental or physical characteristics to animals (i.e. anthropomorphism), a tendency which has been hypothesized to increase with modernization (Manfredo et al. 2019, Biol. Conserv.). Here, we present the results of three studies we have recently conducted in Malaysia and other tropical countries rich in biodiversity, to investigate the link between attitude to wildlife, anthropomorphism, knowledge about wildlife and modernization. In particular, we predicted that both knowledge of wildlife and anthropomorphism would improve participants' attitudes, but that the link between modernization and participants' anthropomorphism would be culturally mediated. Overall, we completed 1294 interviews. Our results showed that better knowledge of wildlife failed to clearly predict better human attitudes, but it was linked to more positive behavioural intentions and behaviours (e.g., use of non-invasive methods to reduce the presence of primates). Moreover, the link between modernization and anthropomorphism was culturally mediated, with modernization being linked to higher anthropomorphism in some countries (e.g., Indonesia, Malaysia), but not in others (e.g., Brazil, Mexico). In turn, higher levels of anthropomorphism were linked to more positive

attitudes towards wildlife, independently of participants' country. Overall, these results suggest that, while the link between modernization and anthropomorphism is culturally mediated, higher anthropomorphism universally predicts better attitudes towards wildlife. In conclusion, our studies confirm that increasing specific knowledge about wildlife may be a powerful tool to mitigate conflicts between humans and other species, and call for caution when generalizing findings from western industrialized countries to inform conservation policies worldwide. **Keywords:** Conservation policies, primates, Malaysia, anthropomorphism, human-wildlife conflict, modernization, cross-cultural approach

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Indigenous Taxonomy in Papua New Guinea: Preserving Critically Endangered Language and Flora

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Background: New Guinea has the world's largest island flora and more spoken languages than any comparable geographic area. Many New Guinea languages are critically endangered, and the lowland forest is threatened with degradation through timber harvest and subsistence agriculture. A fifty-hectare Forest Dynamics Plot (FDP) was established in 2008 at Wanang, an Indigenous-owed reserve in Madang Province, Papua New Guinea. The customary landowners of Wanang speak a recently described language (Magi) at risk of extinction. Their 10,000-ha conservation area is situated in an active logging concession subject to extensive deforestation. **Objective:** Indigenous leaders and foreign botanists working in the Wanang FDP have recorded scientific names, Magi names, and ancestral knowledge of the tree flora. We compared scientific and Indigenous systems to study whether species traits or habitat associations related to cultural practices might account for gendered naming in the Magi language. Methods: Magi has a roughly comparable binomial system of naming in which the first part of a name is a noun referring to a general group (family, genus, or life form) and the second refers to a specific noun or adjective describing the species (large leaf, small leaf, of hilltops, of valleys). We examined how Wanang taxonomy employs gender to differentiate between similar species. Similar congeneric species in 22 genera are differentiated by maku (male) or ningi (female). At least four of these genera include two male/female pairs for a total of 26 gendered pairs. We investigated whether gendered naming is associated with differences among close relatives in ecology (habitat preference), plant traits (foliage, flowers, fruits, growth habit), or simply grammar as in Latin. **Results:** Many activities in Wanang society involve separate groups of men or women such as gardening, hunting, gathering, sleeping, and washing. We hypothesized that gendered naming could be associated with environments or stages of forest succession where a particular activity is carried out by either men or women. There could be some evidence for this but declining numbers of Magi speakers, gaps in knowledge, and potential bias of a scientific approach to interpreting Indigenous culture are limiting. **Conclusions:** The study supported the preservation of a critically endangered Indigenous language and improved taxonomic knowledge by associating Magi names with scientific names for the Wanang tree flora. This approach to recording traditional ecological knowledge has the potential to benefit future generations of landowners responsible for protecting natural and cultural resources. **Keywords:**

Large-scale Extractive Investments in Madagascar – Direct and Indirect Impacts on Nature and People

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The extractive industries sector is growing rapidly worldwide. The focus of scientific debate around extractive industries has shifted from the "resource curse" theory to concerns about "global environmental justice" and the unequal spatial distribution of benefits and burdens. Conflicts over large-scale extractive investments (LEIs) have been widespread and raise concerns about host countries' ability to achieve the 2030 Agenda's Sustainable Development Goals (SDGs). Madagascar is a key global biodiversity hotspot, but LEI expansion threatens many of its biodiversity-rich landscapes, from the rainforests along the Eastern coast to the dry forests in the West. In times of the COVID19 pandemic, a team of Malagasy researchers from ESSA-Forêts, virtually accompanied by researchers from the University of Bern in Switzerland, investigated land users' perception on land use and agricultural management changes triggered by LEIs, as well as their impacts on wellbeing around five LEI sites

(Ambatovy Moramanga, Ambatovy Toamasina, QMM Fort Dauphin, RREM Ampasindava, and Ranobe) in different regions of Madagascar. Our sampling design included a statistical matching approach to identify sets of villages affected by the LEIs, as well as non-affected villages serving as a counterfactual. Between August and November 2021, Malagasy enumerators conducted a total of 459 household surveys in 22 villages. Furthermore, around the Ambatovy Moramanga site, researchers from the University of Bern conducted a continuous assessment of forest disturbances from 2004 to 2020, using Landsat time series as well as a spatial mapping of urbanization trends using time series of high-resolution sentinel-2 satellite data. In this talk, we will present preliminary findings based on the households surveys and shed light on the direct and indirect impacts (spillovers) of LEIs in Madagascar, with a focus on land use and agricultural practices, but also regarding employment opportunities and other benefits. Zooming in on the Ambatovy nickel mine, we further highlight deforestation and forest degradation trends in several of the mine's extraction and conservation zones since the beginning of mining operations, and demonstrate how the aspect of forest degradation was underestimated in the mine's Environmental and Social Impact Assessment. We thereby contribute new scientific evidence to the debate about one of the major global drivers of biodiversity loss i.e., large-scale mining operations, and indicate pathways towards a more sustainable extractive industries sector. **Keywords:** Madagascar, mining, deforestation, well-being, environmental and social impact assessment

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Fighting Fire with Focus Groups: How Colombia's Wildfire Management Policies Can Benefit from Interdisciplinary Stakeholder Consultation

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Introduction: The arc of deforestation in Colombia's northern Amazon has faced increasing wildfire occurrence after the initiation of the peace process with the Revolutionary Armed Forces of Colombia in 2016. The region's complex socio-ecological dynamics and diversity of social actors present both challenges and opportunities for improving wildfire resilience and management in the long term. This project demonstrates the value of interdisciplinary research methods for developing collaborative policy solutions to wildfire reduction in post-conflict tropical ecosystems. **Objectives:** Elicit and understand the perspectives of diverse social actors around factors affecting wildfire occurrence, integrate these perspectives into participatory mental models to plan collaborative policy scenarios for the successful reduction of wildfires. **Methods:** We combined participatory mapping methods with semi-structured interviews to triangulate semi-quantitative and qualitative data on the factors perceived to interact with wildfires. Focus groups of stakeholders representing varied demographics including firefighters, former coca growers, gender-based community associations, and policymakers were guided through a mental mapping process to illustrate the interactions between different factors in Amazonia's social-ecological system. Participative scenario-building exercises were carried out to construct a set of distinct fire management approaches. Inferential modelling was then used to assess the potential impact of these scenarios on key outcome variables identified by stakeholders, including deforestation, cattle ranching, wildfire and illicit crops. Follow-up surveys and workshops validated the models and integrated stakeholder feedback. **Results:** Examining the different stakeholders' mental maps enabled their comparison across key and controversial issues such as the effects of institutional presence and government control. While stakeholders with closer ties to these two categories saw them as beneficial for reducing environmental damage, local participants questioned their effectiveness on-the-ground. Areas of agreement included the interactions between cattle ranching and land grabbing in perpetuating land clearance through fire. There was general acknowledgement that effective fire reduction policy should incorporate knowledge exchange with local communities. Participants also favored measures which address exacerbating structural factors such as land titling and speculation issues. **Implications:** The multiple and conflicting stakeholder perspectives illustrate the heterogeneous factors affecting wildfire across the territory. Fire management policies can usefully incorporate these diverse perceptions to move beyond reactive approaches of wildfire containment and towards pre-emptive management of the contributing structural issues. Participative stakeholder consultation can make use of interdisciplinary methods to integrate local knowledge into collaborative and resilient wildfire prevention policy. **Keywords:** Colombia, wildfire, social-ecological systems, participative, agriculture, land-use, resilience, illict crops,

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Economic Sustainability of Human-Elephant Conflict Mitigation Program

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Nepal experiences a severe human-elephant conflict (HEC) as 70% of the wildlife-caused human casualties and 2/3rd of the households in the elephant range area in Nepal are being impacted by elephants. Current mechanisms to mitigate HEC include compensation mechanisms, installing fences, and patrolling where financial sustainability of these programs is questionable. This study attempts to identify the residents' willingness to pay (WTP) to trust fund for HEC mitigation program in Nepal that can guarantee their economic sustainability. Structured questionnaires were carried out for household interviews in 11 districts in three regions with elephant subpopulation in Nepal to elicit the WTP by using seemingly unrelated regression. Over 85% of the respondents were highly interested to contribute to the HEC mitigation and elephant conservation program with an average monthly WTP of NPR 74.7 for current mitigation practices and NPR 117.6 (57.5% greater than for current practices) for better programs with economic transparency. Interest to trust fund was found to be significantly differed with regions, and associated with respondents' family structures ($p < 0.016$), family size ($p = 0.007$), gender ($p = 0.004$) and interest to visit natural areas ($p = 0.03$), and trust fund amount ($p < 0.001$). Respondents with higher annual income ($p < 0.001$) and lower education ($p < 0.001$) would prefer to increase the WTP amount by greater percentage for better programs. A government-public partnership to raise the funds to mitigate HEC in the region would be viable sustainably, ensuring elephant conservation in the high conflict regions. **Keywords:** Willingness to pay, seemingly unrelated regression, Nepal, Asian elephant

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Orchid Brigade Program: Sustainable Management of Mexican Orchids with the Communities of Oaxaca and Chiapas

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In Mexico, there is a great diversity of orchids, particularly in the south- east zone of the country being Chiapas and Oaxaca the most biodiverse states. However, in this region, orchids face several problems, which threat their survival including deforestation, expansion of the agricultural and urban frontier, illegal extraction, and complex social, economic and environmental issues. To counteract these negative effects on biodiversity, the Department of Biodiversity Conservation in Chiapas, in charge of Dr. Anne Damon, has worked for 25 years to develop the conservation of orchids in their habitat with the participation of local communities. The Mexican Brigade for the Conservation of Orchids emerged in 2017 as a project inspired by motivating young people to promote the diversity and beauty of the orchid flora in Mexico to prevent its extinction. This group has been dedicated to the knowledge of orchids, their habitat and the relationship with humans. The results of these efforts include living collections (orchid gardens in communities), research, and close collaboration with rural communities, courses, and workshops. We have worked within the legal framework of Mexican permit system called units for environmental management (UMA) that deals with the conservation and sustainable exploitation of flora and fauna endangered species. This permit model allows to communities to make a profit through sales of native orchids derived from the sustainable production. For example, in vitro propagated orchids, crafts with orchid flowers, and local coffee that promotes the conservation of Mexican orchid species. Working with local communities on flora conservation in Chiapas and Oaxaca has been formidable since they have been actively involved in the learning activities. In this way, we have helped raise awareness about the importance of native orchids and their sustainable use. This approach has generated new perspectives about community work and the development of collective strategies that can be replicated in other regions for the ecosystems preserving.
Keywords: Orchidacedae, conservation , communities , sustainable exploitation, enviromental management

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A Community Health Approach to Wildlife Conservation in the Western Ghats

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Introduction/ Background/ Justification: The Mudumalai Tiger Reserve (MTR) in southern India falls under a global biodiversity hotspot, the Western Ghats. It supports one of the largest populations of Asian elephants in the country and a sizeable population of tigers. However, severe anthropogenic pressures have resulted in drastic reduction and degradation of the forests. This has increased the interaction between humans, livestock, and wildlife, especially in terms of human-wildlife conflict and disease transmission. Conservation of its unique biodiversity, therefore, requires more invested participation by communities living in and around MTR, through the perception of tangible benefits provided by forests and biodiversity. Such benefits include better health outcomes (fewer diseases and/ or lifestyle-related health issues) for people and their livestock living in close proximity to forests and wildlife. **Objective(s)/ Hypothesis(es):** Our study, the first of its kind in India, investigates community perceptions, knowledge, and attitudes to animal and human health issues among people living in and around MTR. These include, but are not limited to, perceptions and knowledge of the diseases and other health issues that impact human and animal health in the communities surveyed, how forests and wildlife affect human and animal health, the importance of forests for human well-being, and the threats, if any, to biodiversity conservation. **Methods:** Semi-structured interviews and focus group discussions are used to collect information from the communities, which include indigenous tribes. Information collected from communities will be collated with data obtained from the local forest, animal husbandry, and public health departments on diseases and health issues in wildlife, livestock, and humans in the area. Data analysis uses mixed (qualitative, descriptive, and quantitative), and ranking and scoring methods. **Results:** Preliminary results indicate that traditional forest-dwelling communities are more aware of the benefits (health and well-being) of biodiversity and nature compared to the more recently settled (60-70 years ago) communities. They are, therefore, more invested in conservation than the latter, who need to see more tangible health and livelihood benefits to lend support to biodiversity conservation. **Implications/ Conclusion:** Understanding how communities perceive the health and livelihood benefits forests and wildlife provide them will help gauge their willingness to conserve the same. It will also provide a framework for strategies to improve community health, through better awareness of the issues and factors that affect the same. Ensuring better health and well-being outcomes for the local communities and their livestock might help garner long-term local conservation support and participation. **Keywords:** Wildlife disease, animal health, human health, community, one health, conservation

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Soil ecology I

Drought Decreases the Prevalence of Root-associated Mutualists in Tropical Dry Forest Tree Seedling

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Tropical dry forests (TDF) occur in regions that experience strong seasonality in rainfall, with the dry season typically lasting 3 to 10 months. Climate models predict that these hot and dry conditions across TDF regions will further intensify by the end of the 21st century, however, little is known about how TDF plant species will be affected by this changing climate. In this study, we tested whether drought affected the strength of plant-soil feedback formed between plants and their associated soil microbial mutualists and pathogens. We grew seedlings from 4 TDF tree species: two N-fixing legume species (*Pseudosamanea guachapele, and Pithecellobium dulce),* a non-fixing legume species (*Hymenea courbaril*) and a non-legume (*Hura crepitans*) with and without soil microorganisms in a two-stage experiment. In phase 1, plant species were inoculated with whole-soil microbial communities from a TDF in Valle del Cauca (Colombia), while in Phase 2, each individual plant species was inoculated with soil microbes "cultivated" by itself, or by each of the other three species. In both phases, plants were grown under two water treatments: control (C), and reduced precipitation (P). Plants in the control treatment received the equivalent of precipitation in a dry forest (160 ml/week), while plants in the reduced precipitation treatment received half the water of the controls (80 ml/week). We found no evidence that the soil community if of sufficient specificity to drive feedbacks in these dry forests. However, we did find that reduced precipitation not only reduced growth of all plant species, but also nodule formation in N-fixing bacteria, and root colonization by arbuscular mycorrhizal fungi (AMF) in all species. Thus, predicted changes in climate may significantly impair not just plants, but also their soil symbionts, in ways we are only beginning to understand. **Keywords:** Drought, mycorrhizal fungi, N-fixing bacteria, soil microorganisms, tropical dry forest

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Root Fungal Communities Reflect Host Phylogeny and Differ among Adults and Seedlings in a Neotropical Forest

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Introduction / Background / Justification: The extent to which root-associated fungi shape plant communities depends on their variability amongst hosts. In tropical forests, hosts range from basal angiosperms to recently evolved eudicots and from seedlings in the understory to canopy trees in full sunlight. **Objective(s)/Hypothesis(es):** We tested the hypothesis that host phylogeny predicts root-associated fungal communities by comparing these communities across angiosperm tree species from seven orders. Within each species, we also compared communities between understory seedlings and canopy adults. **Methods:** We collected root samples from adults and seedlings of thirteen tree species at two premontane forest sites in southern Costa Rica, and amplified and sequenced the fungal ITS2 region of ribosomal DNA using ITS4 and 5.8SR primers and high throughput sequencing. We identified fungal sequences and assigned them to probable guilds using the UNITE and FUNGuild databases, respectively. We tested the predictive value of host phylogenetic relatedness and life stage for root fungal community composition using PERMANOVA. **Results:** We found that community composition of root-associated fungi reflected phylogenetic distance among host tree species, with root fungal communities of the two hosts in the Magnoliales, *Annona pittieri* and *Virola*

sebifera, being most similar to each other and most distinct from two hosts in the Sapindales, *Protium panamense* and *Tapirira mexicana*. Relative abundance of arbuscular mycorrhizal and ectomycorrhizal fungi also differed between adults and seedlings for three of the twelve tree species. **Implications/Conclusions:** The strong association we observed between root fungal communities and evolutionary history of plant hosts suggests that these communities may evolve in tandem with their hosts and that relationships between plants and their root-associated fungi exhibit phylogenetic conservatism. Differences between seedling and adult life stages in prevalence of arbuscular and ectomycorrhizal fungi for some tree species suggests that adjacent host species and host light environment may influence mycorrhiza formation and connectivity between adults and seedlings. **Keywords:** Root fungi, community, ecology, host, phylogeny, life stage, mycorrhiza, forest

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Stressful Conditions Alter the Resistance and Resilience of Soil Microbial Communities in Colombian High Mountains Ecosystem Soils

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Soil is one of the most valuable resources in terms of climate regulation. On the other hand, it is one of the most threatened resources due to the rapid advance of its desertification generated mainly by human activities. Soil microorganisms perform ecological functions that can vary when changes occur, either due to climatic fluxes or anthropogenic effects that can modify the soil's physicochemical properties. It has been shown that soil microorganisms have a greater capacity to resist stress (resistance) and have a greater capacity to recover later (resilience) when subjected to high temperatures, but they do not present a noticeable improvement when exposed to copper, which is present in most fertilizers. Studies focused on determining the resistance and resilience of microorganisms in short periods find that there is a recovery of microbial communities when they are subjected to different types of stress. This study focuses on understanding the degree of resistance and resilience of microbial communities in soils present in Colombia, specifically in a high mountain ecosystem, where climate change (increase in temperature) and agriculture (use of fertilizers) can affect their health. Three different types of ecosystems were used in this experiment: primary forest, recovery forest, and pasture. The soils collected were subjected to temperature stress of 40°C for 16 hours and exposed to a concentration of 1 mg Cu per g of soil to see the response of microorganisms through respiration. In this study, we found that conserved forests had consistently a higher respiration rate compared to the other soils. In the conserved and reforested forest, we found that the heat treatment has a decrease in the respiration rate immediately after the treatment start. The treatment of copper has a retarded effect on respiration rate and its effect occurs later during the experiment. These studies are necessary to understand the effect of different factors on soil and to understand in a better way the effect of climate change and agricultural land use in soil and microorganism's dynamics. **Keywords:** Resilience, microbial soil , respiration, colombian ecosystem

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Contrasting Patterns of Soil Biodiversity along an Elevational Gradient

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Biodiversity change along elevation is a widely documented pattern for most biological groups, but not for microorganisms. The soil harbors a huge unseen diversity of bacteria, fungi, insects and other eukaryotes, that directly affects aboveground diversity. Even when soil biota importance is recognized, its characterization is laborious, time-consuming and requires multiple experts, hindering large-scale community studies. Seizing advances in molecular techniques, we characterized the biodiversity patterns for bacteria, fungi, plants and eukaryotes from the soil, along an elevation gradient from 110 to around 4000 m, in the Northern Andean mountains. Using molecular units (OTU) obtained with metabarcoding, we compared changes in the diversity, richness, and composition across 59 samples, and analyzed their relationship with land-use and soil physicochemical properties. We find contrasting patterns among the four groups, with a significant relationship between the OTU richness and elevation for bacteria and fungi. Likewise, communities clustered by elevation, according to their composition, only in these two groups. Finally, we did not find an association between OTUs richness or composition and land-use variables. Our results shed light on the complex systems of soil communities and demonstrates the usefulness of molecular tools to address ecological questions for microorganisms at large scale. In addition, it highlights the need to strengthen genetic databases for tropical systems to achieve more accurate conclusions. **Keywords:** Microorganisms, Andes, mountain, metabarcoding

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Soil ecology II

Non-Rhizobia Partners in Neotropical Legume Nodules Are Associated with Higher Rates of Nitrogen Fixation

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The mutualism between plants and nitrogen (N)-fixing bacteria, symbiotic N fixation (SNF), is the pathway in which the majority of N enters many tropical forests. Thus, SNF can have a significant influence on tropical ecosystem productivity, as forest growth is linked to N availability. Much of our understanding on what controls SNF in natural tropical forest ecosystems thus far is from the plant-partner perspective with very little understanding of the role specific N-fixing bacteria play in SNF rates. Here, we pair identified N-fixing bacteria communities from DNA metabarcoding with measured SNF rates from root nodules of three wild legume species experimentally grown in a Neotropical forest in northeastern Costa Rica. Symbiotic N fixation rates were estimated using $^{15}N_2$ enriched gas incubations for the nodules from each seedling. Among the three legume species, we found there was some overlap in nodule bacteria community composition, but that there were significant differences among these legume species. Further, some bacteria, like *Bradyrhizobia*, were found in more than half of all our study seedlings but were only significantly associated with higher-than-average N fixation rates in one legume species, *Zygia longifola*. This suggests there are species-specific pairings between legume species and N-fixing bacteria that may lead to differences in SNF efficiencies. Finally, legumes that form this mutualism are generally thought to primarily associate with N-fixing *Rhizobia*. Surprisingly, we found a consistent novel pairing between a legume, *Pentaclethra macroloba*, and *Actinobacteria* (a bacteria in the same Order know to also form this symbiotic mutualism with non-legume N-fixing plants). The presence of this particular *Actinobacteria* strain was associated with higher-than-average SNF rates when present in the root nodules of the *Pentaclethra macroloba* seedlings, but this bacteria strain was not present in the nodule bacteria communities of the other two legume species. This novel pairing between a legume and non-*Rhizobia* suggests a needed reframing in our conception the two major types of SNF (legume-rhizobia and Actinorhizal plants-Actinobacteria) to improve our understanding of what regulates SNF. Further, our data suggest there is no "optimal" nodule bacteria community for high SNF rates, but rather legume species-specific nodule bacteria communities that likely include non-N fixing bacteria that facilitate differences in SNF rates. **Keywords:** Symbiotic nitrogen fixation, legume, N-fixing bacteria, species-specific, mutualism, Neotropics

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Root Traits and Soil Characteristics Provide Predictive Relationships with Root Phosphatase Activity in the Luquillo Experimental Forest, Puerto Rico

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Background and Objectives: Tropical forest productivity often is limited by the low availability of inorganic phosphorus (P) in old, highly weathered soils. Root phosphatase activity provides an important mechanism whereby plants acquire sufficient P from P-limited soil. Our objective was to investigate P dynamics at the root-soil interface in forests in Puerto Rico on soils with contrasting P availability. Our goal was to elucidate relationships that could be sufficiently generalized to inform models of tropical forest productivity. **Methods:** Initial studies investigated relationships between edaphic factors and phosphatase enzymatic activity in the Luquillo Experimental Forest. We measured root phosphatase activity of four abundant tree species on sites differing in parent material and topographic position. Subsequent studies with additional species focused on relationships between root phosphatase activity and seven fine-root functional traits, as well as stand-level variation in soil and root phosphatase activity throughout the soil profile. **Results:** The greatest root

phosphatase activity in the initial studies was observed in *Cyrilla racemiflora* on the soil with the lowest available P of our study sites. The least phosphatase activity was observed in *Prestoea montana*, the only species present on all sites. Subsequent studies showed that roots of pioneer species (*Spathodea campanulata* and *Cecropia schreberiana*) with high colonization of fungi but less branching had high phosphatase activity. Non-pioneer species, however, exhibited a different P acquisition strategy as evidenced by a high branching ratio. After the major disturbance to the forest caused by Hurricanes Irma and Maria, there were no significant changes in most root trait expression except that root phosphatase activity was significantly higher. Phosphatase activity at these sites was measured in relation to soil and root characteristics (bulk density, soil texture and moisture, organic P content, available P, root mass density, and specific fine root length) that vary throughout the soil profile. Although there was no significant species-level relationship between phosphatase and specific root length, a significant site-independent relationship was described at the stand level relating root phosphatase activity as a function of specific fine root length and available P. **Implications:** Given the high species diversity of tropical forests, representing species-specific variation in phosphatase in models is an impossible task, so discovery of relationships between phosphatase activity and observable or predictable soil or plant traits should advance model development in this critical area if those relationships are found to be robust across a broader range of tropical forests. **Keywords:** Phosphorus, phosphatase activity, root traits, soil characteristics, tropical forest

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Biological Soil Crusts Favour Nucleation-driven Regeneration by Water Redistribution in a Human-disturbed Tropical Dry Forest

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Biodiversity persistence and ecosystem services provision by tropical dry forests under continuous human disturbance rely on the forests' ability to regenerate (i.e., forest resilience). In this process, biological soil crusts (biocrusts) play an important role on water and nutrient availability, especially during primary succession in water-limited dry forest scenarios. They can create small-scale source-sink patterns within the landscape by driving matter fluxes from vegetation-free spots (e.g., old fields) to deposition spots where higher/vascular vegetation benefits from the lateral resource redistribution. This study investigated the impacts of cyanobacteria-dominated biocrusts on water infiltration, aggregate stability, and soil organic carbon (SOC) content in a human-modified landscape of the Caatinga dry forest (NE Brazil), which experiences high levels of forest degradation and increasing aridity. By trapping dust and by swelling of cyanobacterial filaments, biocrusts can seal soil surfaces, which slows down infiltration, consequently increasing surface runoff after rain events. To quantify hydraulic conductivity, water repellency and aggregate stability, we used minidisc-infiltrometry, raindrop-simulation and wet sieving at two sites with different disturbance levels: an active cashew plantation (grazed by cattle) and an abandoned field experiencing forest regeneration. Both sites are characterised by sandy soils. Biocrusts roughly doubled the SOC content within the first cm of soil (increased by 77 % and 128 % in the disturbed and undisturbed site, respectively) and drastically decreased hydraulic conductivity and sorptivity by 38 % and 42 %, respectively. Undisturbed biocrusts further reduced infiltration by increasing the soil water repellency. Despite reducing the infiltration rate, biocrusts formed water stable aggregates. Interestingly, the biocrust-induced differences in infiltration parameters were largest in the disturbed site, indicating a stronger ecosystem impact for that habitat. Summarizing, biocrust presence increased SOC content, with positive impacts on aggregate stability and water repellency, consequently reducing infiltration, which likely leads to an increased runoff. Our results confirm that biocrusts covering bare interspaces between vascular plants in human-modified landscapes play an important role in surface water redistribution towards suitable microsites, where they can favour nucleation-based regeneration of the Caatinga. Biocrusts have the potential to reduce land degradation, although their associated ecosystem services can be depleted by disturbance such as trampling and grazing. Considering an average biocrust coverage of 8.1 % of the Caatinga landscapes, further research should aim to quantify the contribution of biocrusts to forest recovery. **Keywords:** Biological soil crusts, aggregate stability, anthropogenic disturbance, water redistribution, erosion

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Microbial Community Response Is Decoupled from Increased Respiration in Warmed Tropical Forest Soil

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Introduction: Soil microbes form some of the most diverse biological communities on Earth and are fundamental in regulating the terrestrial carbon cycle. Their response to climate warming could therefore have major consequences for future climate, particularly in tropical forests where high biological diversity coincides with a vast store of soil carbon. **Objectives :** We used an *in-situ* soil warming experiment to test the response of tropical forest soil microbial communities, growth, enzyme activities and respiration to two years of soil warming. We first determined the response to warming of the microbial community composition and asked whether community change was related to a change in the intrinsic sensitivity of microbial growth. Second, we asked whether the response to warming of microbial growth sensitivity could explain the response of heterotrophic soil CO_2 emission under in situ warming. **Methods:** The experiment, SWELTR (Soil Warming Experiment in Lowland TRopical forest) consists of five pairs of circular control and warmed plots (whole-profile warming, using buried resistance cables) distributed evenly within approximately 1 ha of semi-deciduous moist lowland tropical forest on Barro Colorado Island, Panama. Each warmed plot is heated across the full soil profile, resulting in a total of 120 m^3 of warmed soil for the experiment. For this study we established two subplots per treatment plot that differed with distance to the heating source, thus providing two treatments of, on average, 3ºC and 8ºC warming of surface soils and performed field campaigns during the wet season (when soil moisture was not limiting to microbial activity). **Results:** Microbial diversity declined markedly, especially of bacteria. As the microbial community composition shifted under warming, many taxa were no longer detected and others, including taxa associated with thermophilic traits, were enriched. The activity of 7 out of 10 measured soil enzyme activities increased with warming. The community shift resulted in an adaptation of growth to warmer temperatures, which we used to specify a microbial model to predict changes in soil CO_2 emissions. However, the observed *in situ* soil CO_2 emissions increase exceeded the rates predicted by our model three-fold. **Conclusions:** Our results suggest that the soil microbial community and growth response to two-years of soil warming was decoupled from large increases in CO_2 emission, which was potentially boosted by an abiotic effect of warming on soil enzyme activity. Our results suggest that warming of tropical forests will have rapid, detrimental consequences both for soil microbial biodiversity and future climate. **Keywords:** Biogeochemistry, enzymes, microbes, tropical forest, respiration, soil carbon, warming

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Soil ecology III

Vegetative Stakes Nuclei: Alternative to Restore Soils Eroded by Extensive Cattle Ranching in Bello (Antioquia, Colombia).

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Large soil extensions in Latin America and the Caribbean are being overexploited to the point of degradation, in some cases irreversible. About 12.2% of the Colombian territory is used for cattle raising, 2.3% has adequate conditions for its use and at least 40% of the soils present some degradation due to erosion. The most recurrent types and those that cover the largest area are the combinations: laminar-groove, terrace-laminar and terrace-groove. The impact on the soil is due to the reduction and almost all vegetation cover disappearance, clearing and compaction caused by the livestock load, which in turn limits the carbon reserves in the surface horizons. One of the productive activities and main causes of deforestation and soil erosion in Bello municipality (Antioquia, Colombia) is extensive cattle raising for milk and dairy products. This work deals with soil recovery eroded by grazing and excessive fodder consumption at San Felix (Bello) and is a small-scale (pilot) experience of successful ecological restoration activities. The National University of Colombia at Medellín and community members verified soil erosion after five years in three areas: (a) degraded by cattle ranching and intervened with ten restoration cores with plant stakes, (b) degraded, without intervention (natural regeneration) and (c) pastures. Areas (a) and (b) showed less structure degradation but higher nutrients and organic matter content than (c). Area (b) suffered greater soil loss compared to (a). The restoration method with plant stakes can be applied to control soil erosion in areas with conditions similar to those of the study. Ecological restoration should be approached from different subject areas, including work on soils. Soil restoration by biological methods takes longer than other methods. Plant stakes provide faster root growth and accelerate soil restoration, increase infiltration and reduce runoff, compared to natural restoration and pasture, making them a useful but not sufficient tool to achieve some recovery. **Keywords:** Erosion control, livestock load, vegetative propagation, Andes.

Effects of Land-use Change and Disturbance on the Fine Root System at Mt. Kilimanjaro

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Tropical forests including savanna ecosystems are threatened by anthropogenic activities such as agroforestry and conversion into agricultural land, logging and fires. Land-use change and disturbance affect ecosystem properties not only aboveground, but also belowground. The alteration of the fine root system functioning leads to marked consequences on the ecosystems' carbon (C) and nitrogen (N) cycle, as fine roots are one of the physiologically most important tree components. We studied the impact of different types of land-use change and disturbance on the fine root biomass, dynamics, morphology and chemistry as well as on the C and N fluxes to the soil via fine root litter across a variety of natural (forest) and disturbed ecosystems distributed into different elevational zones at Mt. Kilimanjaro (Tanzania). We found a decrease in fine root biomass (80%), necromass (80-90%), production (50-60%) and on C and N fluxes to the soil via fine root mortality (60-80%) with land-use change in almost all the elevation zones. In the lower montane zone, the traditional agroforestry 'Chagga homegardens' showed enhanced fine root turnover rates and similar stand fine root production, C and N fluxes and leaf litter quality compared to the natural lower montane forest. The decrease of C and N fluxes with forest disturbance was in particular strong in the upper montane zone (60 and 80% decrease respectively),

where several patches of *Podocarpus* forest had been disturbed by fire in the previous years. We conclude that changes on species composition, stand structure and land management practices resulting from land-use change and disturbance have a strong impact on the fine root system at different elevational position. These factors modify the fine root C stocks, fine root production and the C and N supply to the soil from root litter, which strongly affects the ecosystems' C and N cycle. **Keywords:** Agroforestry, fine root dynamics, fine root morphological traits, land-use change

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Nutrient Controls on Soil Archaeal and Bacterial Communities and Soil Trace Gas Fluxes in Tropical Montane Forests of Southern Ecuador

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Tropical forests play an important role in the global carbon and nitrogen cycle and are increasingly affected by elevated atmospheric nutrient inputs and shifts in nutrient availabilities due to forest degradation. Unfortunately, there is only little information about nutrient controls on microbial communities and trace gas fluxes in tropical montane forest soils. Therefore, we assessed the five-year impact of moderate nitrogen (N) and phosphorus (P) additions on soil archaeal and bacterial communities, soil carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) fluxes and their environmental drivers across an elevation gradient of tropical montane forests in southern Ecuador. A nutrient manipulation experiment was established in 2008 with control, N (50 kg N ha^{-1} $year^{-1}$), P (10 kg P ha^{-1} $year^{-1}$) and N+P additions in old-growth forests at 1000, 2000 and 3000 m elevations. We hypothesized that N and P controls on microbial communities and soil trace gas fluxes will change with elevation and depend on forests' nutrient status. Soil archaeal and bacterial communities were characterized using Illumina MiSeq sequencing and soil trace gas fluxes were measured monthly from 2008 to 2012 using static vented chambers. Soil archaeal and bacterial community composition was best explained by edaphic properties at each elevation. Soil archaeal and bacterial diversity and soil trace gas fluxes decreased with elevation. Nutrient additions showed differential effects on soil archaeal and bacterial communities and soil CO_2, CH_4 and N_2O fluxes at each elevation and duration of nutrient addition. Our results show that projected increases of N and P depositions may change microbial community composition and soil trace gas fluxes in tropical montane forests but the direction, magnitude and timing of the effects will depend on forests' nutrient status and plant-microbial competition for N and P. **Keywords:** Forest soil, Ecuador, nutrient manipulation, trace gas fluxes, microbial communities

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Species interactions I

A Case for Studying Biotic Interactions in Epiphyte Ecology and Evolution

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Introduction/Background/Justification: Biotic interactions are widely accepted as important drivers of ecological and evolutionary patterns, contributing to the structure of systems as diverse as tropical tree seedlings, intertidal barnacles, and wildflower-pollinator networks. One system in which biotic interactions are not well-explored is epiphytes, or structurally dependent, non-parasitic organisms. This is a topic of broad interest because epiphytes—including vascular plants, bryophytes, and lichens—exist in practically all terrestrial ecosystems throughout the world and make substantial contributions to theory, biodiversity, ecosystem services, and the global economy. **Objectives/Hypotheses:** Here, we report quantitative results from a systematic review of existing epiphyte biotic interactions literature, with the aim to stimulate further research and inspire cross-disciplinary collaboration. **Methods:** We collected data from 304 articles on biotic interaction direction (positive, negative, neutral), interaction mode (e.g., pollination, epiphyte-epiphyte competition), broad taxonomic group of epiphytes (vascular plant, bryophyte, lichen), and growth form of vascular epiphytes (hemi- or holo-epiphyte). We highlight areas where different groups of epiphytes and ecosystems have contrasting patterns, and fit those into predicted expectations from theory. We provide a conceptual framework distilling open questions in the field, expand our findings to the community and ecosystem level, and summarize the biodiversity conservation implications of ignoring biotic interactions in epiphytes. **Results:** Overall, our understanding of epiphyte biotic interactions has grown in recent years, with total number of publications increasing over time. However, biotic interactions, in their various forms, are still not a major point of attention in the field. Our collective research effort is uneven both taxonomically and across biotic interaction modes. For example, while over 100 of our 304 reviewed articles focused on vascular plant-pollinator interactions, fewer than 10 publications exist for any type of biotic interaction within the nonvascular epiphyte system. In lichens, herbivory was the most-studied interaction (16 publications), but herbivory was one of the least-studied interactions in both vascular epiphytes and bryophytes. We only found one publication that focused on the effect of parasites or pathogens on any type of epiphyte. **Implications/Conclusions:** Epiphyte biotic interactions have several implications for ecosystem-level characteristics, including bird diversity, nutrient cycling, and insect-mediated habitat cascades. Excitingly, epiphyte biotic interactions have been used in conservation and agroforestry, signaling opportunities for progress in applied ecological fields. Our synthesis brings together currently disparate literature from tropical and temperate systems on vascular and nonvascular plants and lichens, and argues for more consideration of biotic interactions as contributors to epiphyte ecology and evolution. **Keywords:** Epiphytes, lichens, bryophytes, species interactions, mutualism, parasitism, competition, facilitation, pollination

Markers of Competition between Three Puerto Rican Anole Species

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Resource competition is hypothesized to be one of the critical processes driving adaptive radiations. Anoles (genus *Anolis*) of the Greater Antilles are considered a prime example of adaptive radiation in a higher-order taxonomic group, yet there remains little empirical evidence for competition occurring directly between Greater Antillean anole species. We conducted a set of manual removal and manual addition experiments between three species of Puerto Rican anole over a three-month period to identify possible markers of competition. The experimental design of our study allowed for identifying markers of both intra- and interspecific competition. For each captured anole, the species, sex, stage, morphometric measurements, body condition, and location, were recorded. Each anole was also given a unique tag ID using visible fluorescent implant tags. In addition to quantifying any experimentally-induced changes in abundance between the three species, we also sought to quantify possible changes in pregnancy rates, individual-level growth rates, and movement patterns. Due to relatively low GPS accuracy with respect to plot size (~225m^2), location data was collected for each captured specimen using trilateration, where the distance of each specimen to three fixed points within a plot is used to calculate the individual's relative position in the plot. The results of our study indicate that competition between these three anole species is relatively intense regardless of species identity. With respect to individual-level growth rates, interspecific competition was greater than intraspecific, however, this distinction was less apparent in pregnancy rates. As is expected, the two anole species of the same ecomorph (*A. gundlachi* and *A. cristatellus*, trunk-ground ecomorph) exhibited stronger signals of interspecific competition than between anoles of differing ecomorphs (e.g., between *A. gundlachi* (trunk-ground) and *A. evermanni* (trunk-crown)). Additionally, markers of competition were more significant when individuals were added rather than removed. This study provides direct evidence of both intra- and interspecific competition between species where competition has been theorized to play a role in shaping community structure. **Keywords:** Species interactions, competition, Anolis, community structure, adaptive radiation

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Partitioning of Acoustic Space among Sympatric Terrestrial Birds in Lowland Amazonia

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Acoustic signals are the basis for avian social interactions who depend on effective communication spaces to optimize signal transmission and detection. In Amazonian forests, multispecies choruses, and abiotic noise often overlap in frequency and time, increasing the likelihood of acoustic competition and masking interference. This is particularly relevant among sympatric closely related bird species, such as tinamous, where errors in conspecific recognition may have detrimental consequences to their fitness. Thus, vocal species that compete for acoustic space will likely respond by adjusting either the structure or the timing of their signals to minimize overlap. The few studies conducted in the Amazon addressing this idea have targeted dawn choruses of bird multispecies assemblages. Yet, we know little about how multispecies of dawn and dusk choruses utilize the acoustic space. Here, we focus on tinamous songs, considered some of the most characteristic voices of the Amazon. Specifically, we assess how ten sympatric tinamous inhabiting lowland Amazonia partition the acoustic space along the spectral and temporal (specifically diel partitioning of calling time) dimensions. We test whether possible spectral differences could be explained by habitat or body size variation, two other main drivers of song evolution in birds. Using passive acoustic recorders, we (1) quantify how song structure varied between species and by habitat types and (2) compare if vocal activity patterns overlap or segregate between species sharing the same habitat and between species with spectral similarities. Our main findings demonstrated that most tinamous diverge in vocal frequencies, and those species with spectral similarities were largely segregated by habitat. Differences in vocal frequencies are partially explained by the role of ecological selection for body size, but they also provide evidence of acoustic competition in signaling communities. Finally, species sharing the same habitat and with similar vocal frequencies segregate the timing of their vocal activity, which likely reduces the effect of masking interference or minimize potential interspecific competitive interactions. These results provide support for the hypothesis that sympatry of closely related species enhances divergent selection on acoustic signals, partitioning the acoustic space and facilitating co-occurrence patterns in tropical bird assemblages. **Keywords:** acoustic competition, acoustic drivers, Crypturellus, spectral partitioning, Tinamus

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Niche Evolution in South American Trees and Its Consequences

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Background: Patterns of species diversity and the processes that created them have long intrigued biologists but are still surprisingly poorly understood. In particular, there are conflicting findings about the importance of niche evolution during plant diversification. Phylogenetic evidence for a few clades suggests a pattern of niche conservatism in tropical dry forests. In contrast, wet forest lineages have switched to drier environments frequently, suggesting lesser niche conservatism. **Objectives:** To address this debate, our aims are twofold: (*i*) quantify the climatic niches of adequately sampled species of tropical plants, and (*ii*) assess trends in climatic niche evolution over evolutionary time. Methods: We bring together a comprehensive database on the composition of tree communities across lowland tropical South America, and a phylogenetic hypothesis for the Leguminosae (Fabaceae) that occur in these ecosystems. **Results:** Our preliminary results show that rates of climatic niche evolution seem to be correlated with rates of diversification across legume genera, so clades that shift their climatic niche more often may contain more species. **Implications:** Because legume lineages are unevenly distributed across climatic gradients, we argue that the destruction of ecosystems harboring unique climatic conditions would result in a greater loss of evolutionary diversity than expected by chance. **Keywords:** Phylogenetic niche conservatism, climate, dry forest, rainforest, savanna

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Host Plant Niche Partitioning as a Mechanism for Species Coexistence between Hummingbirds and Their Phoretic Mites

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Phoresy, the use of other organisms for dispersal, evolved as a strategy by small organisms to reach suitable habitats. Although phoresy is assumed to be a commensalism, in some cases phoretic organisms share the same diets of their phoretic hosts. Such interactions may become antagonistic, leading to resource-based competition. We propose that one of the equalizing mechanisms promoting species coexistence in these parasitic interactions is niche partitioning. Hummingbird flower mites (Family Ascidae, genera *Proctolaelaps*, *Rhinoseius*, and *Tropicoseius*) complete their life cycle inside the corollas of hummingbird pollinated flowers. Mites disperse to new flowers by hitching rides on hummingbirds. Previous studies determined that both flower mites and hummingbirds feed on nectar, and this diet overlap generates resource-based competition. We performed this study at La Selva Biological Station, a tropical lowland rainforest in Costa Rica. In this study we used machine learning methods to estimate host plant niche breadth and overlap. Analyses included ten host plant species, each representing a niche dimension, and interactions among ten species of hummingbirds and 18 species of flower mites. If competition for nectar is a driving mechanism of host plant use, one possibility is that mites and hummingbirds may reduce competition through niche partitioning. If the effect of competition is weak, and mites mostly benefit from the phoretic interaction, we would expect a generalized niche overlap among hummingbirds and mites. We reconstructed interactions between mites and plants using DNA barcoding methods, and identified hummingbird-plant interactions using video. We quantified niche overlap among hummingbird and mite species using multidimensional niche space analysis. Mite and hummingbird host plant niches are segregated, with some plant species mostly interacting with mites, and others with hummingbirds. This result suggests that while mites rely on hummingbirds for dispersal, they don't simply use any host plant that the hummingbirds take them to. Our results support the hypothesis that niche partitioning potentially reduces resource-based competition and promotes species coexistence between hummingbirds and flower mites.
Keywords: Niche partitioning, competition, flower mites, hummingbirds, tropics, phoresy

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Consequences of Host-switching in Panamanian Fig Wasps

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Background: High Specificity characterizes many pollinator host interactions. Pollinator specificity is thought to potentially promote diversification by restricting gene flow and contributing to reproductive isolation of both host and pollinator populations. However, pollinator and host sharing in ecological time and host-switching at larger time scales are increasingly recognized, and the extent and mechanisms of this process are not well studied. Long-term surveys in the Barro Colorado Natural Monument (BCNM) in Panama have demonstrated that along with many cases of high pollinator to host specificity, both host and pollinator sharing characterize some fig wasp mutualisms, and at least two fig pollinators have switched hosts over the past 20 years. **Hypotheses:** We experimentally quantify the fitness consequences of pollinator wasp switching among fig hosts. We ask: What are the consequences of host-switching on pollinator fitness and hybrid seed fertility and viability? Specifically, are fig wasps more likely to visit and more successfully reproduce in fig species that are more in closely related to their "usual" fig species relative to phylogenetically more distantly related species? **Methods:** Large-scale fig phenological census in the BCNM permit pollen-carrying pollinator transplant experiments. Pollinators that naturally emerged from their usual fig hosts (the figs species in which a given wasp species usually pollinates and develops) were artificially transplanted to receptive figs on different host species. They were given the choice to enter figs (and pollinate and reproduce within the figs) or leave. Choices were recorded, and pollinated figs were allowed to develop and then collected. Wasp offspring and seed production were counted. Hybrid seeds were later germinated, and their viability tested. The same method was used on usual hosts for control. **Results:** Preliminary results show that exceptions to host specificity in the fig-fig wasp mutualism are more numerous than previously thought. At least five pollinator species were observed repeatedly switching hosts during experimental transplants. While host-switching seems to be most common between host figs that are phylogenetically close relatives, it does not only happen among sister fig species. The consequences for pollinator fitness and hybrid seeds viability given experimental host-switching will be discussed. **Implications:** This work is consistent with growing evidence that fig and fig-wasps are not a strictly a one-on-one mutualism, and that hybridization is an important part of the evolution of *Ficus*. It also shows how large-scale phenological surveys can be combined with experimental transplants to reveal the factors that affect specificity in plant–insect interactions. **Keywords:** Host specificity, mutualism, Ficus, ecology

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The Pantropical Co-variation of Frugivore and Plant Fruit Trait Syndromes

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Introduction / Background / Justification: Tropical rainforests are the most diverse ecosystems in the world, but the underlying drivers of this diversity remain debated. Mutualistic interactions between fruits and frugivores (i.e., fruit-eating and seed-dispersing animals) are prominent in tropical rainforests, and may influence diversification and diversity. These interactions are facilitated by functional trait matching between plant and frugivore traits, such as fruit size and frugivore gape width. Therefore, the frequency and diversity of matching traits of interacting species may influence how plant and animal communities vary in space and time. **Objective(s)/Hypothesis(es):** We hypothesize that regional plant species richness is primarily explained by the regional richness of frugivorous animals, and that the hyper volume of frugivore traits is the strongest predictor of the hyper volume of frugivory-related plant traits, but that additional variation in species and trait richness is explained by abiotic environmental variables, such as climate. **Methods:** We integrated global distribution data with novel trait data for three vertebrate-dispersed, pantropical plant families (i.e., Annonaceae, Arecaceae, Moraceae), and two major frugivore lineages (i.e., birds and mammals). To correct for abiotic effects on species and functional richness, we also assembled environmental variables, such as temperature, precipitation, and forest structure. We constructed trait hyper volumes based on principle coordinate analysis at different spatial resolutions for both plant and frugivore lineages, and used structural equation models (SEMs) to investigate the direct and indirect effects of biotic (i.e., frugivore) and abiotic (e.g., climate) variables on plant species and trait richness. **Results:** SEMs indicated that regional species richness in all three plant lineages was best explained by bird and mammal frugivore richness, but environmental variables such as climate (first two PCA axes based on temperature, altitude and precipitation), net primary productivity, and area size explained additional direct (except area size in Annonaceae/Moraceae) and indirect variation in plant richness. Additionally, we show that biogeographical realms occupy different partitions of the global functional trait space of plants and frugivores, and regional, community-level plant trait hypervolume variation is best explained by frugivore trait hypervolumes, species richness, climate, and area size. **Implications/Conclusions:** These results support the theory that plant-frugivore communities are strongly shaped by co-diversification and reciprocal selection pressures on co-evolving traits, and these may thus be important mechanisms explaining species and trait diversity of plant-animal mutualisms more generally. This study sheds novel light on how plant-animal mutualisms contribute to the extraordinary species and trait diversity in tropical rainforest biomes. **Keywords:** Functional diversity, macroecology, seed dispersal, species richness

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Species interactions II

Impacts of Climatic Variability and Hurricanes on Caterpillar Diet Breath and Plant-herbivore Interaction Networks

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Introduction: Climatic variability and meteorological extreme events are known to impact insect and plant populations, ecological processes and ecosystem services. Available evidence suggests that variations in temperature and precipitation and extreme events such as hurricanes or acute droughts can affect nutrient cycling, species abundance and composition of biodiverse insect communities, the strength of species interactions, and the resilience of their networks**. Objetives:** We describe how the most abundant oligotrophic caterpillars of a tropical dry forest show variability in their diet breaths in a 11-year study period, as a function of interannual variation in climatic variables and the incidence of two hurricanes, influencing in turn the parameters of plant-herbivore interaction networks. Methods: We sampled herbivores in permanent plots for 11 years in the tropical dry forest of Chamela, Mexico. We verfied trophic relationships between herbiores and host plants and chose the most abundant species to assess their diet breath. **Results:** We report that lepidopteran diet breath was variable across years, and this variation is partially related to some climatic factors such the coefficient of variation in maximum temperature, variation in annual rainfall and the duration of the preceding dry season. Plant-herbivore network parameters were affected by the same climatic variables, negatively influencing network size, H2, and the number of compartments, while it positively affecting the number of links per species. In addition, years with high variation in precipitation during the rainy season with high precipitation events promoted larger and more specialized networks. Regarding the impact of extreme meteorological events, herbivore's diet breath increased after the stroke of two hurricanes, increasing the number of links per species and network connectivity. In contrast, plant-herbivore network size, their specialization degree and the number of compartments was negatively affected by these extreme events. **Conclusions**: Understanding the relationship between climatic variability and caterpillar diet breath leads to open questions on the evolution of herbivore foraging behavior and phenotypic plasticity in plant host use and plant-herbivore network topology, influenced by climate and land-use changes. **Keywords:** Diet breath, herbivores, tropical dry forests, climatic variability, hurricanes

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Seasonal Variability of Plant-hummingbird Interaction Network in a Tropical Rainforest of the Colombian Darien

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Introduction: The study of plant-pollinator interaction networks allows us to quantify the dynamics of communities and their importance for the ecosystem, as well as to understand their structure and function, as well as how susceptible they are to disturbances. This is particularly relevant in tropical forests, where there is a high diversity of species and interactions, and alterations mediated by anthropogenic pressures can negatively affect ecosystems. Despite the current knowledge on plant-pollinator interaction networks in aspects such as species richness and abundance and their importance within the interaction networks, there are still very few studies focused on their dynamics and seasonal variation in tropical rainforests. In this study, we seek to define the structure of a plant-hummingbird network and its seasonality in two contrasting seasons in tropical forests of the Colombian Darien. **Methods, Results and Conclusions:** In particular, based on the analysis of pollen loads of hummingbirds, collected during the dry (April) and wet (October) seasons of 2003, we determined the structure of the communities and compared the networks in both seasons. We used parameters estimated at the species and network levels, as well as diversity and abundance indices. We found 16 and 23 plant morphotypes carried by 8 species of hummingbirds during the dry and wet seasons, respectively. The constructed networks tended to be generalist, nested and, most importantly, robust. In general, during the wet season the interaction network showed greater connectance, thus evidencing more complex and stable networks. Understanding these variations in interaction networks can provide information on emerging patterns or fauna and flora species relevant to the long-term stability of communities. We highlight the idea that forest conservation, especially in scenarios of global climate change, should not be thought of as a process isolated from the associated faunal communities. **Keywords:** Interaction networks, plant-hummingbird, seasonal variation, tropical rainforest.

Using Citizen Science Data to Study Animal Movement: Implications for Ecological Connectivity of Hummingbirds in the Andes

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Understanding how animals move between habitat fragments or in mixed land covers is key to estimate ecological connectivity. By assessing connectivity across a landscape, conservation and management efforts may be guided to avoid population declines, decreased genetic diversity and local extinctions. In the case of the tropical mountains of the Andes, historical land degradation and fragmentation still threaten animal movement between habitat remnants. However, functional assessments of ecological connectivity are hindered by a general lack of movement data for most animals in the region. Given the economic and technical difficulties of large-scale tracking studies, we explored the possibility of using citizen science data to quantify population-level movement of hummingbirds across the Andes Mountain Range. We chose hummingbirds as a study system because ensuring connectivity for these animals signifies protecting their ecological role as plant pollinators in tropical ecosystems. Furthermore, the small body size of hummingbirds poses a challenge for tracking individuals with most existing technologies, but they are frequently observed and reported by citizen scientists. Using data from eBird to construct monthly species distribution models, we quantified hummingbird movement and habitat associations throughout the year. Our results suggest marked altitudinal movements and seasonal habitat use, possibly in response to the fluctuation of flower nectar availability. These findings reveal previously undocumented hummingbird movement between tropical mountain ecosystems, with the implication that ecological connectivity models should allow for seasonal habitat use. Such models will be essential to understand how the movement of hummingbirds may be impeded by landscape barriers and altered with future changes in land use and climate, therefore providing information to promote present and future connectivity for hummingbirds and protect pollinator-plant networks. **Keywords:** Hummingbird-plant pollination networks, eBird, species distribution models, animal movement

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Mechanisms of Mutualism Disruption between *Khaya senegalensis* (Meliaceae) and *Oecophylla longinoda* (Formicidae).

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Ecological interactions between species are central to maintaining biological diversity. Particularly, plant-weaver ant interactions are mutually beneficial interactions that contribute to the maintenance of plant biodiversity. Plants benefit from the protection of ants (*Oecophylla longinoda)* that defend them against external attacks related to the harvesting and insects. Weaver ants weave the leaves of these plants to make their nests that serve as shelters. The disruption of this mutualism would lead to the extinction of the plant species with which they are associated, in particular Khaya senegalensis which is the main host species for *Oecophylla longinoda.* This study investigates the effect of repeated pruning by Fulani on the probability of colonization of Khaya senegalensis by weaver ants in the drier Sudanian and wetter Sudano Guinean regions of Benin. In each region six populations of *K.senegalensis* were selected. Ten individual trees were randomly sampled in each population. On each chosen tree, we measured the height and the diameter at breast height (Dbh). The debarking and pruning intensities were also estimated for each individual. On each of these individuals, 10 ordinary leaflets were sampled, and their length, width and surface were measured. To understand the mechanisms by which repeated pruning affects the probability of colonization of Khaya senegalensis individuals by weaver ants, up to 5 nests were then sampled on each tree to measure nest length, and the length, width, and area of the leaflets that were used to construct the nest. We found that tree harvesting decreased the probability of

colonization of Khaya senegalensis individuals by weaver ants, *Oecophylla longinoda.* Leaflets used by the weaver ants to build their nests were larger and longer than those that were not used. We found a bimodality in the distribution of the size of weaver ant nests, although this was not associated with the effect of pruning. Weaver ants on harvested individuals of Khaya senegalensis and in small nests tended to be more aggressive than those on unharvested individuals and from large nests. This study highlights how anthropogenic activities, even non-lethal, by modifying the ecological interactions in which plants are involved can change their ecology.
Keywords: Ecological interactions, disruption, mutualism, *Khaya senegalensis, Oecophylla longinoda,* host species

Species interactions III

Long-term Suffering: Drought Duration Limited Ficus Defensive Traits but Increased the Herbivory of Caterpillars

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Background: Drought alters plant-insect interactions by altering plant growth, nutrient quality, and defense traits. Tropical regions are particularly at risk of severe drought and are home to a variety of insect species that depend on plants. However, little is known about how drought affects tropical plant-herbivore interactions. *Ficus* is a dominant tropical plant genus involved in numerous interactions. Figuring out how drought affects *Ficus*-herbivore interaction is vital to understanding how climate change alters tropical plant-insect interaction. **Objectives:** The main objective of this project is to compare the impact of drought gradient and duration on *Ficus* nutrient quality and defensive traits and consequently on the herbivory of caterpillars. **Methods:** To study the response of plants to droughts, we introduced four *Ficus* species to a drought gradient, consisting of three different water regimes: control (soil moisture 100%), mild drought (soil moisture 50-60%), and severe drought (soil moisture 20-30 %). After 2, 3, and 4 months of treatments we compared growth, Carbon/Nitrogen ratio (C/N ratio), trichome density, leaf water content, leaf toughness, alkaloids, and phenolics concentration. We measured leaf characteristics on the newest, fully expanded leaves of each of the 105 plant individuals. Additionally, we ran caterpillar food-choice trials and herbivory assays to evaluate the impacts of treatment on herbivores. **Results:** Caterpillar herbivory positively increased with drought duration in *Ficus benjamina* and *Ficus carica* due to decreasing concentration and diversity of alkaloids, as well as leaf water content and latex outflow. In contrast, leaf water content but not drought duration increased herbivory of caterpillars in *Ficus lyrate*. No factors could explain the herbivory in *Ficus elastica*. **Conclusions:** Our results suggest that the impact of drought on tropical plant-insect interaction is long-term progress, and vulnerable plants species are more sensitive to drought than resistant species. The strength of plant chemical defense has a stronger impact on herbivory than nutrient quality. This project first establishes the link between drought and insect performance on tropical tree species. **Keywords:** Drought, Ficus defense, caterpillar herbivory

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Top-down Regulation on Daily Activity Patterns across Tropical Forest Mammal Communities

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Most animals follow distinct daily activity patterns reflecting their adaptations, requirements, and interactions. Specific communities provide specific opportunities and constraints to their members that further shape these patterns. Here, we ask whether community-level diel activity patterns among long-separated biogeographic regions differ or converge and whether the resulting patterns indicate top-down (predation risk) or bottom-up processes (prey availability)? We estimated the diel activity of ground-dwelling and scansorial mammals in 16 protected areas across the tropics, using an extensive network of camera traps, and examined the relationship to body mass and trophic guild. We found that mammalian guilds exhibited consistent diel activity patterns across regions, indicating similar responses to similar evolutionary and ecological opportunities and constraints. Larger herbivores tended to be more nocturnal than smaller herbivores, whereas carnivores and omnivores showed the opposite pattern. Insectivores were exceptions, revealing regional differences in which larger insectivorous species were more nocturnal than smaller ones in the Afrotropical and Indo-Malayan regions, while the pattern reversed in the Neotropics. The consistent contrast between predators and prey suggests that diel activity within

these communities is primarily determined by large predators and the associated risk of predation. **Keywords:** Mammals, activity patterns, biogeographic regions, feeding guilds, protected areas

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Evolutionary and Ecological History of Allopatric Avian Populations in Two Neotropical Dry Forests: the Caatinga and the Chaco

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The South America Dry Diagonal, a continuous corridor of open landscapes from NE Brazil to N Argentina, represents a natural laboratory to test hypotheses of evolutionary and ecological diversification. The Caatinga and the Chaco are both part of the Dry Diagonal and although they present similar phytophysiognomies due to their adaptations to draught, they are currently separated by the more humid Cerrado. Despite this separation, biogeographers have recognized the presence of several plant and animal lineages with allopatric populations, suggesting an ancestral connection. The presence of multiple allopatric pairs of closely-related taxa was considered evidence of vicariant-driven diversification, a model postulated under the Pleistocene Arc Hypothesis. Building on the early work of Short (1975) and Prado (1991), we identified 12 avian lineages with allopatric populations in the Caatinga and the Chaco and evaluated their evolutionary and ecological levels of divergence to shed light into the history of this biological connection. We used genomic data to evaluate population structure and to estimate time of divergence of these populations. Then, we used climatic and topographic data, coupled with ecological niche models and multivariate analyses, to evaluate hypotheses of niche divergence. Finally, we used biogeographic and phylogenetic data to estimate the putative ancestral biomes of these populations. Preliminary data of five avian lineages indicate that the allopatric avian populations investigated are indeed geographically structured. Population divergence was either quite recently (i.e., 50,000 yrs for two pairs) or date to about 1 Myr (three lineages). These figures suggest that pairs of avian taxa with similar distribution patterns became isolated during different periods, either during different climatic cycles or following species-specific dispersal events. Our niche analyses indicated that, in general, pairs represent cases of niche conservatism, suggesting that their current allopatric niches are more similar than expected at random, indicating that these lineages have likely not endured niche evolution to adapt to live in either the Caatinga or the Chaco. Finally, our ancestral biome reconstructions indicate that these lineages are either from xeric of mixed (xeric and mesic) origin, pointing out to a long history of adaptation to dry environments. Our results highlight the idea that these pairs represent dry-adapted lineages that continue to occupy relatively similar niches. However, given the disparate levels of gene divergence it seems unlikely that these pairs are the result of a single common vicariant event. **Keywords:** Dry diagonal, dry forests, niche conservatism, genetic divergence

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Insular Lizards as a Model to Study the Importance of Marine Subsidies in Islands of the Gulf of California, Mexico

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The hot and arid islands of Gulf of California, have very low productivity but are surrounded but a rich colder ocean. This circumstance converts the ocean-island ecotone in an ideal place to study the effluence of marine inputs into the terrestrial food webs. Such marine resources spread into the insular systems increasing the abundance and richness of flora and fauna populations especially small vertebrates as insectivorous lizards and rodents. According to previous studies those resources are particularly important in the North, for the smaller islands and in those that host seabird colonies. But less attention has been paid to the importance of marine resources on bigger, southern and less arid islands, or to their effect on herbivorous reptiles. The objective of this work was to study the importance of marine nutrients on those islands and species. For that we compare the trophic niche of herbivorous (genus *Sauromalus, Ctenosaura* and *Dipsosaurus*) and insectivorous (genus *Uta*) lizards inhabiting islands that differ in latitude, aridity and size as well as with and without seabird colonies in the Gulf of California. We used the composition of ^{13}C and ^{15}N stable isotopes from tail tissue samples of small lizards from each island. Our results showed a gradient of marine subsides from the south to the north, as well as a strong relationship with the aridity and the size of the islands. The existence of seabird colonies was also very important. For the herbivorous the importance of marine resources is more notorious on very small islands and those that host seabird colonies. **Keywords:** Marine subsidies, lizards, stable isotopes, islands, trophic niche

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Insect-mediated Pollen Movement of an African Canopy Tree: Gene Flow and Potential Pollinators of *Cylicodiscus gabunensis* Harms

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Introduction: Sustainable Forest management requires a good understanding of the natural regeneration of tree species. A decisive reproduction phase in flowering plants is pollen dispersal as it affects gene flow and inbreeding. In Central Africa, Cylicodiscus gabunensis is a very large timber species currently heavily exploited although showing a natural regeneration deficit in dense forests. **Objectives:** This study aims to characterize pollen dispersal patterns in C. gabunensis and to identify its potential pollinators. **Methods:** Adults, juveniles, and seeds were sampled in three plots of 400 to 900 ha in natural forests of Cameroon and Gabon, and were genotyped using 24 nuclear microsatellite markers to perform parentage analyses and describe their fine scale spatial genetic structures (SGS). Three IoT cameras and four insect trapping methods (passive and active) were used in front of the flowers of one tree to identify pollinators. Results: We found that C. gabunensis is mainly an outcrossed species (s = 3% selfing rate) for which pollen disperses over much larger distances (mean distance dp= >1km, mp = 71% immigration rate) than seeds (ds= 32m, ms = 65%). The SGS showed contrasting patterns between the three populations studied, probably reflecting different colonization histories and/or population dynamics. In total, 81% of arthropods trapped (N=68) were identified at the family level, corresponding to 24 families and 7 orders, with an overall dominance of Diptera, Hymenoptera, Coleoptera and Lepidoptera (90% of the visitors). They visited flowers diurnally and nocturnally but mostly in the morning (6am-11am). **Conclusions:** To achieve sustainable exploitation, pollen dispersal distance and generalized pollinator assemblage did not appear limiting but the low natural regeneration of C. gabunensis and patterns of SGS suggest other limiting factors such as seed dispersal. This innovative approach to study pollen movement allows an interpretation of gene flow in an ecological context and can ultimately help inform sustainable management decisions to maintain sufficient potential for regeneration. **Keywords:** African rainforest, gene dispersal, pollen movement, insect pollinators, sustainable management

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Sexual Selection Meets Resource Ecology: the Relationship between Fruit Distributions and Male Mating Success in a Lekking Manakin

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Lek mating systems, in which males form display aggregations that females visit solely for the purpose of copulation, are frequently characterized by high levels of male reproductive skew. Given that lekking males provide no direct benefits to females, theory predicts that the evolution of female preferences in these systems is primarily driven by indirect genetic benefits associated with mate choice. However, this "good genes" view of sexual selection overlooks the potential importance of ecological factors in shaping individual variation in male trait expression and fitness. We tested the overarching hypothesis that spatial and temporal variation in fruit density influences male mating success in the white-bearded manakin (*Manacus manacus*), a widely distributed frugivorous bird. Males of this species perform energetically costly courtship displays at long-term, individually defended courts situated within larger leks. Working at five leks in the Chocó region of northwest Ecuador, we: (1) assessed spatiotemporal variability in fruit biomass at both the landscape scale and in the immediate vicinity of individual male display courts, (2) recorded male vocalization and display behavior, (3) quantified predictors of male reproductive success (e.g., time on the lek, body condition, display rate, and female visitation), and (4) used radio telemetry to assess foraging ecology and habitat use in relation to resource availability. We found considerable spatial variation in local fruit density among individual courts and between leks, and the relative density of these resources varied over time. Local fruit availability did not correlate with male home range size or time on the lek, but fruit density at both the lek and court levels robustly predicted individual display activity. These results suggest a potential role for ecological resources in shaping condition-dependent male display performance, which may contribute to the variation in individual mating outcomes at leks. Genotype-environment interactions across spatially or temporally heterogeneous resource landscapes may play a key role in the maintenance of genetic variation in systems with strong sexual selection.
Keywords: Lek mating, sexual selection, frugivory, radio telemetry, gene-environment interactions, foraging

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Biotic Interactions and Abiotic Factors Structure Vertical Seed Movements and Seedling Survival: Can Animals Help Tropical Plants Outpace Climate Change?

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Most tropical plants rely on animal seed dispersers to colonize new environments they will face as the climate changes. In a warming world, lowland tropical biota rely on elevational migrations to locate habitats that fit their ecological and physical requirements. The objectives of our study were to determine if upslope biotic or abiotic barriers currently exist to prevent plant range expansions along two tropical mountains: (1) Volcán San Martín Tuxtla (Los Tuxtlas) in Mexico and (2) Volcán Barva in Costa Rica. We investigated if pre- and post-dispersal barriers exist to delimit the ranges of low-elevation plants. Using upslope transplant experiments of seedlings at multiple elevations, we assessed seedling survival in native (lowland) and novel (upslope) habitats on both mountains. In Los Tuxtlas, the three focal plant species showed different levels of success in colonizing upslope habitats. In Barva, all nine transplanted species suffered complete mortality at high elevations (2000 m a.s.l.) but had highest survival at middle elevations (1000 m a.s.l.). In Barva, we supplemented field experiments with laboratory work, using temperature-controlled incubators to assess seed resilience to novel temperature environments. We tracked seed germination success for 12 large-seeded lowland species and found that, overall, lowland species germinated well, even at an artificially high temperatures they do not currently experience (35° C). For both mountain ecosystems, some plants do not face post-dispersal barriers to upslope migration and may be able to colonize novel habitats to outpace global warming. However other species face strong pre-existing biotic barriers to survival at high elevations. This allows for potential upslope mobility, if animal seed dispersers deposit seeds as they move up mountains. The results of this study have implications for understanding and predicting plant ranges as mediated by seed dispersers in a changing world. If plants are unable to colonize novel highland habitats as biomes shift upward, these barriers will prevent successful elevational migration, resulting in lowland biotic attrition. Altered plant-animal interactions, especially seed dispersal and predation, will play major roles in redefining tropical plant and animal communities as the world warms. **Keywords:** Elevational transplant, mammal, seed elevator, seed fate, species migration

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The Interaction between the Bacterial Communities Associated with an Arboreal Dominant Ant and the Tropical Canopy Phillosphere

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Ant-associated microbiota influences how an arboreal ant species interact with its host plants, and even may define how large a colony might be in a forest canopy. There is evidence that the high density of ants in a foliage habitat can substantially affect the leaf microbiota and its relationship with the plant. This work aims to determine to which extent the microbiota associated with dominant and abundant ants in the tropical forest canopy could act to inhibit potentially entomopathogenic microorganisms. In three ecotone areas in the Brazilian Atlantic Forest, we verified the influence of the interactions between the bacterial communities of *Azteca chartifex* workers bodies, and bacterial communities of *Byrsonima sericea* leaves surface. We hypothesized that (i) The diversity and composition of bacterial communities of ants from main nests are different from satellite nests ants, and (ii) There is a difference in the diversity and composition of bacterial communities from leaves without ants and from leaves foraged by them. We used 16S rRNA gene amplicon sequencing to analyze the bacterial communities of ants (n=22), from main and satellite nests and leaves (n=32) in both groups of plants that have and have no interaction with ants. Variations in diversity components between ant colonies generated more dissimilarity than these variations between different areas ($p<0.01$). In addition, by decomposing the beta diversity, we observed that the heterogeneity between the nests is mainly explained by the exchange of species ("turnover") instead of nesting, which is the loss or gain of species. Compositional analyzes showed that bacterial communities differ between satellites and main nests. Similar to the leaf surfaces of different plants, the diversity analysis showed that alpha and beta do not vary between plants with and without ants. However, we saw that there is a higher abundance of OTUs in leaves that were foraged by the ants. Beyond that we have found a difference in the composition between plants with ants and plants without ants. Thereby, we concluded that there are differences in the bacterial communities of different type of nests, which may be related to the presence of the queen. There is an influence caused by the ant microbiota on the plant microbiota, in a way that these bacteria, apparently, are replaced in a short period of time. Hence, we still seek to understand how these interactions between bacterial communities can influence the health of the colony, host plant fitness and their associations. **Keywords:** Ant–plant–bacteria interaction, Atlantic Forest, canopy, 16S rRNA gene amplicon

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Threats on Biodiversity, Species Conservation Status I

Anthropogenic Threats May Cause Vulnerable Andean Condor Extirpation in Northern South America

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The total population of the Andean Condor (*Vultur gryphus*) does not exceed 6.700 mature individuals and is rapidly declining throughout its range. This species is therefore listed as Vulnerable. Local population extinctions and declines are particularly worrying in northern South America, where no more 400 condors may exist at present. Despite this, in Venezuela, Colombia and Ecuador, there are no quantitative assessments about their population threats. The aim of this study is to analyze effects of anthropogenic threats and natural causes of mortality of Andean Condors in northern South America during the last 43 years. We compiled information from records of adult and immature condors poisoned, shot, electrocuted, colliding with vehicles, illegally captured, attacked by dogs, traumatized, fallen from the nest, or dead by other causes between 1979 and 2021. We obtained records of 164 condors that were affected by these causes of mortality, of which, 17% were adults and 28% immature, for 55% of the individuals, it was not possible to determine the age. 28.6% of the condors were males and 14% were females, for 57.3% it was not possible to determine the sex. 83.5% of the condors were reported in Ecuador, 15.2% in Colombia and 1.2% in Venezuela. 84.7% of the condors died. Only 4.8% of the individuals suffered natural causes of mortality, the rest of the birds suffered from anthropogenic threats: 62.8% were poisoned and 13.4% were shot. Other10 birds were illegally trafficked, five were injured, three were electrocuted on high-tension wires, two fell from the nest, two were illegally captured, two starved, one collided with a vehicle, one was attacked by dogs, and one suffered from a gastrointestinal infection. It is quite worrying that in this study period, at least 103 condors were poisoned and other 22 were shot in Venezuela, Colombia and Ecuador, which represent between 32% and 80% of the current total population estimated in northern South America, where also a reduction of its historical range has occurred. Effective conservation planning for Andean Condors needs to go further than the protected areas system, and include the human dimensions in conservation practices applied at landscapes scales that are dominated by people. Education programs, socio-ecological research, application of environmental laws, and management strategies based on scientific evidence to improve human-wildlife interactions, along with participatory work in local communities are key to the conservation of the Andean Condor in northern South America. **Keywords:** Conservation, efficient management, extinction risk, poisoning, *Vultur gryphus*

Site-occupancy Modelling for Two Threatened and Endemic Birds of Colombia: a Case Study from Southwestern Colombia

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Site-Occupancy Modelling have become a useful tool of increasing use in conservation biology, due to provide information about probability of occupancy of one or several species, taking account quantitative associations between the occurrence of biota and the surrounding landscape. Between October 2019 and January 2022 (n=10) and using bird point counts (80 points over 10 months), we estimated the probability of habitat occupancy of two globally threatened and range-restricted bird species (<50,000 Km²), endemic from Colombia: Chestnut Wood-quail (*Odontophorus hypeyrthrus*) (NT) and Red-bellied Grackle (*Hypopyrrhus pyrohypogaster*) (VU), in the Bota Caucana region (Department of Cauca), Colombian Andean-Amazon foothills.

We used the statistical package "unmarked" in R software to analyze the occupancy data from covariates on occupancy (landscape elements) and detection probability (environmental conditions and human presence), across eight sampling stations distributed along 1636 and 2980 m. All detection ($\boldsymbol{p}$) and occupancy (Ψ) covariates were standardized and the level of correlation between them was assessed (r 0.6 were correlated). We obtained 22 detection models, 25 occupancy models and a null model (detection and occupancy were constant). We ranked models with less than two AIC units using Akaike's Information Criterion (AIC) and we explored the estimated coefficients, standard errors, significance of the intercepts and significance of detection and occupation covariates for the best model ($p<0.05$). A parametric goodness-of-fit test was performed to assess whether the prediction values obtained for the covariates were greater than those expected by chance (without overdispersion), after, occupancy plots were drawn. The results showed that cover forest of "fragmented forest" and "distance to rivers" had a positive and significant effect on the probability of occupancy of *O. hyperythrus* ($p<0.05$), while the cover forest of "fragmented forest" and "wooded-pastures" had a positive and significant effect on the probability of occupancy of *H. pyrohypogaster* ($p<0.05$). Our results showed the state of occurrence and occupancy of two bird species priority for conservation in a scarce explored region and with few or no studies, so, our findings may contribute to describe new behavioral or ecological aspects related to the biology of both species and strengthen regional and national conservation strategies. **Keywords:** Avifauna, range-restricted, habitat, Andean-Amazon foothills.

Systematic Review on Impacts of Water Pollution on Avifauna

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The impact of water quality reduction in both marine and terrestrial water bodies has caused significant changes in behaviour, breeding success, mortality rate, malformations in physiology, and habitat loss of avifauna. This systematic review focuses on the studies done in the most recent five decades (1971- 2021) relating to water pollution and its impact on avifauna. The method PSALSAR (Protocol, Search, AppraisaL, Synthesis, Analysis and Reporting results) and the PICOC (Population, Intervention, Comparison, Outcome and Context) framework were used to conduct the review. A number of 151 publications from four different databases (Google Scholar, ScienceDirect, Springer Link, and Journal Storage) were chosen, including original research articles, reviews, books, book chapters, reports, and conference proceedings. The highest number of publications were between the 2011- 2021 years. The highest number of publications (99) are journal articles. The majority (52) of publications were from ScienceDirect. Only a few studies focused on the global scale, while nine coastal regions, five continents, and 35 countries were covered in the selected publications. Seventy-nine publications were based on the primary data sources, while 72 were used secondary data sources. The most utilized mode of assessment in the literature was the qualitative method. The majority of publications' purpose was based on expanding awareness towards conservation. The literature based on the rapid increase of polluting sources in water bodies and its direct impact on avifauna is rapidly rising. The results of avifaunal model studies are widely used to understand and estimate the influencing parameters on bird survival. The greatest extent of the publications was contrasting the impact relating to organochlorines, heavy metals and marine litter in water bodies. The contribution of long-term data records in studies and projections through models were highlighted with supportive data. In conclusion, birds rapidly adapt to constructive and adverse alternative sources for survival due to the rapid decline of habitats. However, exposure to these threats at some point in the avian life cycle has caused an immeasurable impact on avifauna as many incidents have been reported despite age. Therefore, implementing conservation measures is essential to mitigate this global issue. **Keywords:** Water pollution, avifauna, review, PSALSAR, PICOC

Bioaccumulation of Petrogenic Compounds in Amazonian Wildlife from Oil Extraction Areas in the Peruvian Amazon

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Oil has been extracted from the northern Peruvian Amazon since the 1970s, resulting in severe pollution by heavy metals and hydrocarbons from the dumping of produced waters (the main waste product of oil extraction operations) and the regular spills from oil extraction operations. In this area, redirected geophagy from mineral licks to oil-polluted sites has been recently documented as a widespread behaviour of herbivores and omnivorous Amazonian wildlife. In here, we study the concentration of Al, Fe, Be, V, Cr, Mn, Ni, Cu, Zn, As, Se, Cd, Ba and Hg in livers of *Cuniculus paca* that were obtained from wild game that was hunted for food by indigenous populations from four different remote areas of the northern Peruvian Amazon, two in an oil-extraction areas —the Pastaza and Corrientes River basins— and, two in areas without oil-extraction —the Pucacuro Protected Area and the Yavarí-Mirin basin—. Significantly higher levels of nickel, cadmium and barium have been found for specimens from oil-impacted areas compared with those from control areas. We conclude that oil extraction is an important source of oil-related contaminants for Amazonian wildlife and, that the consumption of wildmeat, in particular *Cuniculus paca*, one of the most important game species for subsistence-hunting communities, a potential important route for oil-related contaminant exposure for indigenous people that rely on subsistence hunting. **Keywords:** Extractive industries, petroleum pollution, environmental health, subsistence hunting, geophagy

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Threats on Biodiversity, Species Conservation Status II

Tracing Pangolin Trade Origins and Revealing Illegal Trafficking Networks through Next-generation Sequencing

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Introduction: Illegal wildlife trade poses significant challenges to biodiversity conservation and global health monitoring, as its illicit nature leads to a lack of reporting and difficulties in regulation. With the emergence of COVID-19 and the discovery of SARS-2-like coronaviruses in Sunda pangolins (Manis javanica), the rampant illegal trade of the Critically Endangered species has received significant attention. This has highlighted the severe lack of information on the trade itself, including geographic origins of traded pangolins and underlying trade networks, impeding conservation action and the monitoring of potential pathways of zoonotic emergence. **Objective(s):** Determine whether Sunda pangolins seized in Hong Kong are of single or multiple origins within its range and uncover characteristics of the Sunda pangolin trade network through seizure origin information **Methods:** From 89 Sunda pangolin carcasses seized in Hong Kong (88 from a single seizure in 2018 and one seized in 2013), DNA was extracted and sequenced using ddRADseq to obtain genome-wide neutral SNPs from each individual. The SNPs were then analysed with Principal Components Analysis, STRUCTURE analysis, and fineRADstructure to form genetic clusters and inform population structure. Cluster identity was determined by including known wild references of Sunda pangolins from Singapore, Borneo, and Java regions. **Results:** Through SNP data quality filtering, ultimately 33,951 SNPs from 85 individuals were used for subsequent clustering analyses. The first two principal components of the PCA revealed three distinct genetic clusters associated with the three available reference regions. STRUCTURE results indicated that there was most likely two distinct genetic clusters, while fineRADstructure showed further subdivision within the two groups delineated by STRUCTURE. Ultimately, results from all three analyses show three distinct clusters from each region, while indicating possible population substructure in Borneo. **Implications:** From the presence of pangolins from two separate genetic clusters in Borneo, it is likely that there is expansive poaching effort on the island. Pangolins of multiple origins trafficked in Hong Kong also indicates this city as an important intermediary in the trade. Multiple origins captured in a single seizure reveals the organised, international nature of the trade, pointing to a complex underlying trade network. Transnational cooperation will therefore be required for effective design and implementation of mitigation and conservation action. By characterizing the general structure of Sunda pangolin trade in Hong Kong and Southeast Asia, this study provides an important first step to population genomics research of the species and efforts to curb its illegal trade within Southeast Asia. **Keywords:** Pangolins, illegal wildlife trade, population genomics, global health monitoring

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IMMINENT THREATS: The Role of Fire and Cattle Presence in a Natural Evergreen Forest Archipelago

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Natural forest island systems in tropical mountains are home to an exceptional percentage of the world's biodiversity, providing additional resources and conditions for species. Yet they are largely ignored and undervalued even though under constant threats. We aimed to determine how impactful is the occurrence of fire and the presence of cattle on both local and landscape scale over time for the natural and evergreen forest islands associated with the Espinhaço Range. Our main predictions are that the presence of cattle and the occurrence of fire influence the canopy cover variation over time and also lead to a greater spatio-temporal variation of the landscape characteristics in which the forest islands are inserted. We performed this study over a six-year period along 14 forest islands of various sizes and shapes within a natural mountainous forest archipelago in southeast Brazil. We evaluated the variation of the canopy cover four times over the 6 years through hemispherical photos that were taken from five vertices of each patch. We also measured the patch and landscape variables based on high-resolution satellite images. We used linear models to relate both cattle presence and fire occurrence to canopy cover variation and landscape characteristics. The occurrence of fire had a positive effect on canopy variation, especially when there were no cattle around, where forest islands that presented both fire occurrence and cattle presence at the same time showed less variation in their canopy cover. On the other hand, the variation observed in landscape metrics did not show a direct relationship with the presence of cattle or with the occurrence of fire. Our results emphasize fire as the greatest threat to the forest islands and highlight the complexity of the outcomes of large herbivores and forest patches, indicating a potential benefit of grazing in the protection of the fire-sensitive forest islands. However, we recommend caution in cattle grazing management in these environments, especially as we do not know yet to what extent this association is beneficial. We also draw attention to the need for the establishment of permanent plots dedicated to the documentation and monitoring of long-term data in this system, with a timeframe of decades. It will be the most reliable way to really track how global-change drivers and anthropic disturbances are affecting natural ecosystems over long time series, and to determine what strategies are needed to effectively mitigate such impacts. **Keywords:** Anthropic disturbances, Atlantic Forest, campo rupestre, forest islands, tropical mountains

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Hotspots of Threatened Plant Species in the Americas

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Setting priority areas for conservation is a fundamental step in the challenge of protecting global biodiversity, particularly in face of the anthropogenic-driven modification of natural systems. Recent studies, however, highlight that the current global networks of conservation areas are ineffective to protect all dimensions of biodiversity (taxonomic, phylogenetic, and functional), especially for the most threatened species. Beyond that, while we have seen much progress on the identification of areas of conservation concern for charismatic groups such as birds and mammals, plants have been largely neglected, despite constituting the fundamental support for all terrestrial ecosystems. This situation is even more alarming in megadiverse regions undergoing accelerated conversion of natural habitats such as the Americas, where more than one in five plant species are predicted to be threatened with extinction. To ensure conservation of plant species that are more at risk, extension of conservation areas network should target the highest density of threatened species. Our work aims to use publicly available data on the distribution and extinction risk in the legumes (family Leguminosae or Fabaceae). Because legumes are among the most species-rich, economically important, and ecologically dominant elements of flora of the Americas, they can serve as a proxy for all flowering plants. Here, we (i) identify areas of highest conservation concern (those with greatest density of threatened species) across the Americas and, (ii) evaluate the extent to which these areas overlap with the existing protected areas. The key areas identified here can be used at political, social, and economic scales as a foundation to inform future conservation planning, assisting in the expansion of conservation areas networks. By providing relevant conservation information at a continental scale, our results may ultimately lead to more reasonable and effective conservation actions, helping policymakers to reach Target 7 of the Global Strategy for Plant Conservation aimed to protect at least 75% of threatened plant species *in situ*. **Keywords:** Conservation, extinction risk, IUCN, New World, predictive modelling, prioritization

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Red List of Ecosystems as a Tool for Decision Making

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Background: In light of the 6th biodiversity mass extinction, there is a need to unite and standardize global efforts to assess biodiversity loss and promote sustainable management of the planet's resources. In that regard, the IUCN Commission on Ecosystem Management (CEM) brings together 1.195 experts from around the world. Its mission is to provide expert guidance on integrated approaches to the management of natural and modified ecosystems to promote biodiversity conservation and sustainable development. CEM Working Groups produce, compile and transmit scientific information to facilitate decision-making and the implementation of international agreements. **Objective:** In the framework of the United Nations Decade on Ecosystem Restoration (2021 - 2030), CEM seeks to clarify what ecosystem restoration entails, why many restoration efforts have been only partially successful, and what needs to change to motivate a common vision that encourages groups of people (non-specialists) and public and private organizations to develop effective restoration actions. To that end, The IUCN Red List of Ecosystems (RLE) aims at providing a global standard that tells us how to assess the risk of ecosystem collapse at a given point in time. **Methods:** The Red List of Ecosystems (RLE) provides a new unified global standard for assessing the status of all the world's ecosystems at risk, and can be applied at global, regional, national or local levels. The methodology is based on criteria for assessment based on evidence of risk of ecosystem collapse, measured through reduction in geographic distribution or degradation of key processes and biotic components (Keith et al, 2013). **Results:** The Red List of Ecosystems (RLE) provides a new unified global standard for assessing the status of all the world's ecosystems at risk, and can be applied at global, regional, national or local levels. RLE assessments provide inputs for land-use planning, implementation of conservation and restoration actions, among others. To date, studies have been carried out in about 100 countries, including Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Uruguay and Venezuela in Latin America. **Implications:** RLE allows assessments of the risk and economic costs associated with the loss of ecosystem services and, conversely, the potential economic benefits of. This set of tools reflects the thematic priorities of the Commission and how its Working Groups have become world authorities and references in the topics they develop. **Keywords:** LRE (lista roja de ecosistemas), IUCN, ecosistemas, Latinoamérica.

Threats on Biodiversity, Species Conservation Status III

Chemical Tracing of Timber Origin: From Global to Regional Scales

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Illegal logging poses a serious threat to tropical forest conservation. Independent methods to verify timber origin are needed in addition to current enforcement based on checking paper permits. A completely novel method for timber origin verification is the analysis of elemental composition, which has shown high potential for commodity tracing at small spatial scales. It is often applied in combination with stable isotope analysis, which has already shown potential for timber tracing. As the establishment of chemical reference datasets is costly and time-consuming, there is need to find associations between chemical wood characteristics and environmental data, as well as similar patterns across timber species. Our aim was to investigate the potential of two chemical tracing methods: elemental composition (ICP-MS, 60+ elements) and stable isotopes (IR-MS, C, O, H, S) in West Africa. We established an extensive geolocated reference dataset of wood elemental composition and stable isotope ratios as part of the TIMTRACE project. We studied two major timber species, Azobe (Lophira alata, Ochnaceae) and Tali (Erythrophleum sp., Fabaceae), from over 20 sites across Cameroon, Gabon and Congo. A Random Forest classification model was developed and assignment accuracy was compared across the sampling area and between the species. Additionally, we developed the first pantropical isoscape for tropical wood $\delta 18O$ including 24 commercial tree species to evaluate the potential of stable isotopes for coarse-scale timber tracing. Accuracy of the regional classification model was over 90% at 100 kms. Furthermore, combining the two species in one model improved classification accuracy, thus implying a shared chemical profile across species. Stable isotope analysis – on the other hand – may help verifying provenance at larger spatial scales. Our pantropical isoscape showed increasing isotopic differences up to 2000 kms and revealed pronounced isotopic shifts in South America and Asia. We provide the first test of elemental analysis for tropical timber tracing. We indeed find regional differences in elemental composition that can be used for elemental tracing, providing a resolution down to 100 kms. The method has a high potential in areas where soil clay and organic matter content vary at small spatial scales. Additionally, our isoscape provided a proof of concept for isotopic tracing at large spatial scales. Our results help to guide the application of the different methods and are the first to reveal the potential of multi-element analysis for timber provenancing. **Keywords:** Illegal logging, wood chemistry, provenancing, ICP-MS, IR-MS, isoscape, random forest classification

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The Vulnerability of Freshwater Fishes to Expanding Oil Fields in the Amazon

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Oil exploration is a major source of pollution across several regions of the Amazon, with the western portion of the Basin being an area of particular concern. Events of fish kills, contamination and disease outbreak (e.g., tumors, birth defects) have been reported in areas of intense oil exploration and after spills. Although these reports suggest that oil contamination may have strong negative effects on freshwater fish communities, it is still unclear how different species respond to oil exposure and which have the greatest vulnerability to oil spills in the Amazon. Here, we examined the existing scientific literature and available spatial databases to identify which fish species are most vulnerable to oil contamination in the Amazon based upon their ecology, physiology and geographic distribution. Our search revealed a total of 15 papers examining the effects of crude oil on fishes of the Amazon, of which 10 are based on laboratory experiments, one on a field experiment, and

the other 4 on reviews and descriptions of case studies and policies needed. Our spatial analyses identified hundreds of fish species vulnerable to current and future oil exploration like the 747 fish species that occur in the Marañon Basin in areas covered by extensive oil blocks. Overall, our results highlight that oil contamination is an issue of high concern for freshwater fish conservation in the Amazon and that hundreds of species may be considered vulnerable to oil exposure based on a variety of factors examined. **Keywords:** Ecotoxicology, petroleum exposure, disturbance, freshwater fish, toxicology, Amazon

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Biological Correlates of Extinction Risk in Resident Philippine Avifauna

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Introduction/Background/Justification: The majority of the world's biodiversity occurs in the tropics, but human actions in these regions have precipitated an extinction crisis due to habitat degradation, overexploitation, and climate change. Understanding which ecological, biogeographical, and life-history traits predict extinction risk is critical for conserving species. The Philippines is a hotspot of biodiversity and endemism, with 258 endemic birds. However, it is also a region that also suffers from an extremely high level of deforestation, habitat degradation, and wildlife exploitation. While the country ranks 58th in the world for total number of bird species, it has the 8th highest number of globally threatened birds. **Objectives/Hypotheses** : We investigated the biological correlates of extinction risk based on the IUCN Red List threat status among resident Philippine birds using a broad range of ecological, biogeographical, and life history traits previously identified as correlates of extinction risk in birds, comparing the effects of multiple traits simultaneously. We predicted that species at greater risk of extinction in the Philippines would be endemic, restricted elevationally, large-bodied, have limited dispersal ability, be ecologically specialized, and have sensitive nesting habits. We especially focused on species that have either been split within the last decade or have been proposed to consist of cryptic populations that may warrant species-level status. **Methods:** We compiled a dataset of the 446 resident Philippine bird species and then collated data on nine ecological traits: endemism, elevational range, average elevation, body mass, hand-wing index, forest dependency, trophic level, ecological specialization, and nest type. We then created a series of generalized linear mixed-effects models and then dredged these models to simultaneously compare every possible subset of ecological traits to indicate correlates. We also predicted threat status for every species and compared with IUCN rankings. Results: We found strong support across competing models for endemism, narrower elevational ranges, high forest dependency, and larger body size as correlates significantly associated with extinction risk. We found fourteen species that are not currently recognized by the IUCN as threatened that may be more threatened than currently believed and therefore warrant heightened conservation focus. We found 12 species that are the products of recent taxonomic splits that have a fitted threat status more severe than their IUCN-designated ones. **Implications/Conclusions :** Our findings provide a framework for avian conservation efforts to identify birds with specific biological correlates that increase a species' vulnerability to extinction both in the Philippine Archipelago and elsewhere on other tropical islands. **Keywords:** Cryptic species, deforestation, island biogeography, bird conservation, endemism, elevational range, forest dependency, body size

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Urban ecology: animals

Species-specific Responses of Psittacidae across an Urbanization Gradient in the Aburrá Valley, Antioquia-Colombia

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The urban green spaces are emerging habitats for biodiversity, which respond to changes in urban landscapes. Psittacidae (parrots, parakeets, and macaws) represent a family of charismatic and conspicuous birds that are common in tropical cities, where they use anthropogenic resources and emerging habitats across the fragmented urban green spaces, they might offer information about landscape changes, allowing the detection of possible impacts on biodiversity and the improvement of urban ecosystems. We aimed to evaluate how local distribution and the abundance of Psittacidae species change across an urbanization gradient in a city of northern Andes of Colombia (6°15'N, 75° 34'W, ca. 1400 - 2000 m.a.s.l), we determined the urban gradient from the percentage of impervious surfaces based on supervised classification methods with satellite imagery (10 x 10 m of resolution). We counted birds at 10 sites in four to five visits along a 1 km transect during 1 hour each, between 06:00-10:00 h, total sampling effort was 45 h (4-5 h per site) from September 2021 to February 2022. We recorded 181 birds of 11 species of Psittacidae using urban green species along the gradient, with *Brotogeris jugularis* (65, 46.9%) and *Forpus conspicillatus* (42, 23.2%) being the most abundant species. *F. conspicillatus* was less abundant towards sites with more percentage of impervious surfaces, whereas *B. jugularis* was most abundant towards sites with less percentage of impervious surfaces. Other species such as *Amazona amazonica* also showed a positive response to an increasing percentage of impervious surfaces. *Ara spp.* were rarely detected and *A. ochrocephala* and *Eupsittula pertinax* showed ambiguous responses across the urbanization gradient, with records and relative high abundances in sites with contrasting percentages of impervious surfaces. In conclusion, *F.conspicillatus*, *B.julugaris* and *A.amazonica* by showing a clear and differentiated response to the percentage of impervious surfaces (compared with other Psitaccidae) as well as also being easy to recognize visually and by hearing, may be useful in the future as bioindicators species in community science exercises. In further studies, we suggest a visiting schedule for each sampling transect that includes both morning and afternoon hours, in view of the fact that macaws and parrots hat less representation in this study since they are more active between 15:00-19:00 h. **Keywords:** Psittacidae, urban ecosystems, impervious surfaces, green spaces.

Bird Diversity along an Urban Gradient in a City of Northern Andes of Colombia: Community and Species-specific Response

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Urban landscape transformation represents pressures on biodiversity, which might have different responses at community and species-level. Birds, with high species richness and detectability, could be useful bioindicators in urban ecosystems. We evaluated the bird community and species-level responses to an urbanization gradient in a city of northern Andes (6°15'N, 75° 34'W): four sites with less than 20% of built surfaces, three sites between 20-50%, and three sites with more than 50%, percentage of built surfaces was estimated from supervised classification methods using Landsat-8 satellite images. We sampled birds at each site 4-5 times (in different days) for one hour along a 1 km transect (1400-2000 m.s.n.m.), from September 2021 to January 2022 (between 06:00-10:00 h). We evaluated the community-level responses using Hill numbers,

and the species-level responses using abundance changes of 31 "easy-to-identify" bird species with different habitat use and foraging strategies. We found 139 bird species (median 63 species per site), with the highest species richness ($q = 0$) (84 species) at the less urbanized site and the lowest at the more urbanized site (31), nevertheless, the number of common ($q = 1$) and very common species ($q = 2$) were higher at sites with intermediate urbanization percentage. Species such as *Ortalis columbiana* (Cracidae), *Saucerottia saucerottei* (Trochilidae), and *Sporophila nigricollis* (Thraupidae) showed abundance decreasing towards more urbanized sites, whereas *Zenaida auriculata* (Columbidae), *Phimosus infuscatus* (Threskiornithidae) and *Pitangus sulphuratus* (Tyrannidae) showed the opposite pattern. Other species such as *Myiozetetes cayannensis* (Tyrannidae), *Picumnus olivaceus* (Picidae), and *Amazilia tzacatl* (Trochilidae) showed the highest abundances at sites with intermediate urbanization, whereas *Stilpnia vitriolina* (Thraupidae) and *Thamnophilus multistriatus* (Thamnophilidae) showed the highest abundances in sites with low and intermediate urbanization percentage with larger green spaces (e.g. regional protected parks in the city center and peri-urban areas). We found different bird responses across the urbanization gradient, especially comparing the extremes (i.e. most urbanized vs less urbanized sites), but both community and species-specific levels showed no linear patterns at intermediate urbanized sites, suggesting that other variables such us the size of urban green spaces, habitat type or fragmentation might also have influences on bird biodiversity. Understanding these patterns, especially focusing on birds with predictable responses to urbanization that are easy to identify, could improve biodiversity monitoring in Andean cities, with the potential of improving social engagement and the use of this knowledge on urban planning and conservation efforts. **Keywords:** Biodiversity, urbanization, bioindicator, conservation

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Opportunities for Ecological Restoration of Exotic Grass Areas: Potential Impact on Avian Biodiversity in Urban Conservation Units of the Cerrado

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The Cerrado is the most biodiverse savanna on the planet, the second largest biome in Brazil and in South America. It has been the most devastated of the Brazilian biomes, impacted by the unstoppable expansion of commodity agriculture and cattle ranching. Among many critical problems, the massive invasion of exotic Poaceae, severely compromises its biodiversity - generating losses of native avifauna and its foraging niches. Rare and endemic bird species have their habitats deprived, registering local extinctions and expanding the list of critically endangered species. The objective of this study was to evaluate: i) the importance of native vegetation in urban parks of Brasília for the maintenance of bird species richness, ii) the potential increase in bird species richness if exotic grass areas of these parks were restored. We applied a semi-log model to establish the relationship between native cover area and bird richness in nine urban Conservation Units (CUs) of Brasília with up to 40ha. We used the relationship found and the areas occupied by exotic grasses to calculate the potential increase in avifauna richness if restoration took place in these areas. Vegetation cover data was extracted from MapBiomas and species lists data from iNaturalist, e-Bird and Management Plans of these CUs. We selected the iNaturalist research-grade observations, while EBird data is verified by algorithms and specialists. QGIS and R software were used to extract the vegetation cover values and perform the semi-log model, respectively. This model is $y = 38.47\ln(x) + 20.21$ ($R^2 = 0.44$, $p = 0.05$) The model explained 44% of the species richness variation, showing that despite the tendency for an increase in richness with the increase in native area, other variables also affect this variation, especially in protected areas with less than 10ha of native cover. In the nine parks analyzed, the total native cover was 115.70ha, an average of 12.86 ha per park. On the other hand, the total areas occupied by exotic grasses and susceptible to restoration summed 413.23ha, an average of 45.91ha per park. We calculated that the Ecological Restoration in viable areas of these UCs would generate an average increase of 51 bird species per park, with small parks having greater increase per hectare restored. In conclusion, recovering the native cover in urban conservation areas, thus restoring specific bird niches, significantly increases bird species richness in anthropized fragments, especially in small ones, contributing to the conservation of the Cerrado. **Keywords:** Restoration Ecology, urban ecology, brazilian savanna, bird diversity, species-area relationship

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Urban Avifauna: 18 Years of Christmas Bird Counts in Three Colombian Cities.

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A significant gap in understanding biodiversities' responses in urban areas is the lack of long-term studies, with most of the information on urban birds coming from studies carried out in the northern hemisphere and data not exceeding five years. Although short-term studies show communities' diversity and spatial distribution, they could be biased towards more conspicuous and abundant species with higher detection probability. This could limit registering rare, discrete, or species with specific occurrences that can only be recorded at specific times. One of the few global multi-temporal datasets on urban birds available in tropical areas is the Christmas Bird Counts (CBC). In Colombia, since 2001, counts have been carried out in urban and rural environments. Using annual CBC count data available between 2001 and 2018 from 21 urban and peri-urban sites assessed in the main cities of Colombia (Bogotá, Cali, and Medellín), we identified and analyzed the diversity and cumulative and annual distribution of the bird communities. Supported by GLM, NmDS, and NDOF analyses, we estimate comparative trends in richness, abundance, similarity, and complementarity of avifauna for each city and site and the communities structure based on their response to urbanization and dietary guilds. Cities and sites with a higher degree of urbanization showed lower richness, mainly due to the loss of those species considered avoiders related to a frugivorous and insectivorous diet. The peri-urban sites of the three cities seem to help maintain the most sensitive species, promoting higher dissimilarity and complementarity for those cities with bird counts within the urban areas. In Medellín and Bogotá, intra-urban wetlands and urban parks were the most important refuge for birds, maintaining the highest avoiders and utilizers richness and abundance. Although richness and abundance follow patterns found in other Latin American cities, we found significant spatial and annual variation in these trends in the abundance of dwellers species and those with granivorous diets. Long-term inventories are fundamental in determining consolidated bird diversity and distribution patterns. Likewise, the information establishes a baseline for decision-making and applying recommendations that allow reconciling the growing demand for urban with the need to preserve the native avifauna in megadiverse Neotropical countries such as Colombia. **Keywords:** City, utilizers, richness, abundance, avoiders, dwellers, native avifauna

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Urban ecosystems

The Drivers of Lightning Enhancement over Cities

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Introduction: Urbanization creates climatological feedbacks that influence regional weather patterns. Among these changes is a tendency for cities to increase local lightning strike frequency (i.e., the urban enhancement effect) with corresponding economic and human costs. Despite varied evidence of lightning enhancement, the prevalence of these effects is unknown, and the drivers underlying these patterns are poorly tested. **Methods:** Here we test whether the likelihood and magnitude of lightning enhancement vary with climate, pollution, topography, and urban development across 607 cities with more than 300,000 inhabitants. We tested for lightning enhancement by assessing whether each urban area had elevated lightning strike frequency (i.e., the number of strikes reaching the ground) relative to natural areas within 150 km. We then combined data from 10 global geospatial datasets to explore the drivers of lightning enhancement and tested both the direct (e.g., average temperature) and indirect [e.g., urban heat island effect = urban temperature divided by natural area temperature] effects of each potential driver. **Results:** The likelihood of exhibiting lightning enhancement increased with proximity to marine water bodies and higher total lightning strike frequency but was not associated with latitude. Among cities with significant lightning enhancement, the strength of this effect increased with decreasing latitude, proximity to marine water bodies, and increasing heat island effects (i.e., the ratio of urban temperature to temperature in surrounding natural areas). Total aerosols were associated with a smaller proportion of lightning strikes reaching the ground but had no effect on total lightning strike frequency. **Implications/conclusions**: These patterns suggest that coastal cities in tropical regions experience the strongest effects of lightning enhancement. Additionally, although pollutants are frequently hypothesized as the primary anthropogenic cause of the urban lightning enhancement effect, we find stronger evidence that this effect is controlled by urban heat island effects. These findings shed light on how and where cities influence the local lightning frequency with implications for damage to local ecological systems and human structures.
Keywords: Urban ecology, weather, pollution, lightning enhancement, strikes

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Variations in Human Perceptions, Attitudes, Biophilic Values and Interactions Towards Bats at Three Urban-Rural Locations in a Neotropical City

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Bats have historically interacted in different ways with human societies. These interactions have been expressed in the cultural manifestations and the cognitive and affective links that humans have on bats, which arise from the beliefs, knowledge, and perceived and real impacts that include them, and generate affection, attachment, relevance, dislike, and misconceptions about many bat species and their habitats in urban and rural settings in Western civilization. We examined human perceptions, attitudes, and biophilic values toward bats in three urban-rural locations in the Neotropics and assessed how these aspects impact human-bat interactions. 210 people in Cali, Colombia completed a questionnaire. Perceptions, attitudes, biophilic values towards bats and interactions with them varied along with urban-rural locations. Our findings indicate that gender and age influence attitudes and biophilic values towards bats. Most of the values, perceptions, and attitudes towards bats were positive and are influenced by the recognition of their ecological role as well as by the respondent´s sense of identity as part of nature. Rural people seem to exhibit a higher number of human-bat interactions

because of their direct implications as vectors of zoonotic diseases, fruit crop consumption, and livestock blood-feeding. These results significantly show that the human-bat relationship is complex and may be the result of multiple social and cultural factors that must be understood and addressed in the development of actions and instruments the conservation. **Keywords:** Human-wildlife interactions, urban biodiversity, biophilia, Chiroptera.

Contaminants Play a Key Role in Understanding Ecosystem Function in Tropical Urban Estuaries

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Tropical urban estuaries are understudied and researchers often apply conceptual frameworks of ecosystem function developed for temperate systems to tropical ones. But it is becoming increasingly clear that the ecosystem dynamics driving tropical estuaries are different from temperate systems. Given concerns about human impacts on urban coastal waters and the dearth of tropical biogeochemical research, this study looked for indicators of human influence on the biogeochemistry and productivity of the San Juan Bay Estuary (SJBE) in San Juan, Puerto Rico. We observed a mismatch between high counts of fecal indicator bacteria (fecal coliform and *Enterococci*) but low dissolved inorganic nitrogen (N) concentrations and stable isotope values in SJBE waters. Sucralose and caffeine concentrations also indicated high human sewage loads. Very low N stable isotope values in the most urbanized stretches suggest that, despite bacterial and chemical indicators of extensive sewage contamination, the microbial community may be adding new N. Sewage N contributions may support only a small portion of the net ecosystem production and urban carbon contributions may be indirectly fueling ecosystem production in the most impacted regions of the estuary. **Keywords:** Ecosystems ecology, urban, coastal, estuarine, nitrogen, stable isotope, estuary, tropical

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Part III

Posters

Bioinformatics, Modeling

Analysis of the Propagation of Moko (*Ralstonia solanacearum* Phylotype II Race 2) in Plantain Crop (Musa AAB Simmonds) with Mathematical

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Plantain crops is of great socioeconomic importance in Colombia and in the department of Quindío, since it is part of the family basket of different social strata, due to its nutritional content and also because it has been established as the economic livelihood of many families, however, it has been affected by re-emerging diseases throughout history that have reduced the availability and quality of planting material. Moko is a disease caused by the bacterium *Ralstonia solanacearum* phylotype II race 2, it has caused great economic losses and, unfortunately, it still continues without adequate management. So far there is no treatment to control the disease and the best control mechanism and/or solution is to prevent the arrival of the bacteria in healthy crops through management strategies and eradication of infected plants, since the bacteria have the ease of propagation by different means, such as water, wind, animals, among others, and the main form of dispersion is through infected planting material. For this reason, population simulation models were built with nonlinear ordinary differential equations, which allow interpreting the dynamics of the Moko disease of plantain, these models include 1) the analysis of the optimal conditions that control the disease and reduction of the costs of production, 2) the analysis of the reseeding with conditioned planting material and, finally, 3) the analysis that includes the development cycle of the plant with disease prevention and population of susceptible and infected plants and associated economic losses over time. It was found that the reseeding of infected hills in only 30%, has a noticeable effect in increasing the incidence of the disease and in production costs, in addition, it was established that in order to avoid greater economic losses, both prevention strategies should be implemented in a medium proportion (f 60% - g 70%), in order to sustain a reasonable number of susceptible plants over time and, thus, ensure that the plants infected tend to be controlled and stabilized, in such a way that the effects and economic losses are less. **Keywords:** Simulation models, Moko, plantain, *Ralstonia solanacearum,* prevention.

Co-evolution between Heliconius and Passiflora: A Search for Evidence from Its Geographic Distribution and Species Richness

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The adaptive diversification of plants and their herbivorous insects is potentially influenced by coevolutionary processes. The morphological, physiological, and behavioral aspects of the biotic relationship between Heliconius butterflies and their host plants Passiflora is well documented. However, whether the degree of geographic correlation between their distributions and richness is informative regarding their coevolution is poorly known. To explore this, we modelled the richness and distribution of 165 *Passiflora* and 34 *Heliconius* species in Colombia using four different algorithms. Isothermality and seasonality of precipitation were the environmental variables that best explained the observed distribution patterns of *Passiflora* and *Heliconius*, respectively. Furthermore, we found a low degree of geographic overlap between both genera. In addition, we compared the distributions of a monophagous (*H. eleuchia*) and an oligophagous (*H. cydno*) species with each of their host plants. *H. eleuchia* had a higher correlation with its host plants than *H.cydno*, which is consistent with their larval dietary preferences. Other ecological factors such as toxicity of plants deserve more attention as potential drivers of coevolution. On a geographical scale, it can be concluded that the pattern of diversification of both

genera is likely to be different. Furthermore, since they do not share species richness hotspots, our results are not compatible with a strict coevolution scenario. **Keywords:** Heliconius, passiflora, species richness, coevolution, spatial analysis, species distribution models

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Method Development for Paleoclimate Estimation Using Anatomical Characters of Neotropical Woods

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Introduction: Until today, various correlations have been made between the physiognomic traits of plants and the climate, in order to estimate the paleoclimate. For example, from leaves margin, pollen fossils, and wood. Nevertheless, in these previous studies about wood and climate, phylogenetic analyzes have not been carried out with the data, so there is a great gap between the data and the evolutionary characteristics of the species from which the data is obtained. Furthermore, despite the fact that the Neotropics is one of the areas with the greatest diversity of plants, it remains one of the most unexplored. **Objectives:** To elucidate correctly which characteristics of the wood that correlate in a better way with precipitation and temperature to know if similar characters are due to shared evolutionary inheritance or due to the environment where they are found **Hypothesis:** Evolutionary history has an effect on prevailing adaptive interpretations of the relationships between wood physiognomy and climate. Methods: This work proposes to improve previous studies through new methods, such as the use of global data obtained from databases such as *Inside Wood, WorldClim* and GBIF (*Global Biodiversity Information Facility*), taking into account phylogenetic relationships and with a focus on tropical areas, using R packages as "V.PhyloMaker", "GEIGER", "raster", "Picante", "ape", "phytools", "nmle" and others. **Results:** It is expected to find that evolutionary history has an effect on the relationships between wood physiognomy and climate. Additionally, we will deliver to the scientific community the method for paleoclimate estimation based on anatomical characters in wood. In order to do this, to find out some equations that could explain any particular climate variable as MAT (Mean Annual Temperature) and MAP (Mean Annual Precipitation) Conclusion: Evolutionary history has an effect on prevailing adaptive interpretations of the relationships between some wood functional traits and climate. **Keywords:** Wood anatomy, physiognomic traits, climate, paleoclime stimation

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Conservation, Restoration

Cattle Pastures as Carbon Sinks: Evaluating Carbon Storage of Non-forest Tree Cover classes in Dry Tropical silvopastoral systems

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Introduction: Land conversion, particularly for agricultural purposes, is a leading cause of ecosystem degradation in the tropics and projected to increase under growing global demand. While there are many consequences due to this conversion, the loss of tree carbon storage is one of the most urgent under the climate crisis. Alternative farming practices such as silvopasture, offer underutilized opportunities to restore tree carbon within pastoral landscapes. Landowners with silvopastoral systems utilize trees in multiple ways, resulting in variation amongst non-forest tree cover classes within farms, as well as potential variations in carbon storage. However, these variations remain to be quantified. Furthermore, the relationship between the total tree carbon stored within a sustainably managed pasture and the diversity of woody species incorporated in the farms is also unclear. **Objectives:** The aims of this study are (i) to assess the relationship between tree carbon storage and woody species diversity on silvopastoral farms and (ii) to evaluate differences in carbon storage amongst non-forest tree cover classes within these farms. **Methods:** The total aboveground carbon storage of tree cover classes within five silvopastoral farms in the Los Santos province of Panama were determined remotely using ArcPro and verified by field inventories. The resulting carbon storage estimates will be compared to the total cattle per hectare within the farms to determine if a threshold exists at which tree carbon compromises production. **Results:** Data analyzed remotely indicate that the highest carbon storage in megagrams (MgC) per hectare (ha) is found in riparian gallery forests (200.01 MgC/ha), followed by forestry plantations (52.401 MgC/ha), and clustered pasture trees (34.975 MgC/ha). Further, higher woody species diversity positively predicted average MgC/ha ($R2 = 0.32$). **Implications/Conclusions:** These findings improve our understanding of how specific practices alter environmental characteristics like carbon sequestration and woody species diversity, which are particularly important for threatened ecosystems like dry tropical forests. In addition, they support the consideration of silvopastoral management as a mechanism for climate mitigation in national carbon credit plans, thereby improving funding availability and reducing barriers to implementation for farmers. **Keywords:** Climate change, restoration, agroforestry, silvopasture, carbon sequestration, sustainable agriculture, forestry

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Selection of Species for Ecological Restoration in Moorland Ecosystems Present in the Department of Quindío, Colombia

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The Páramo is one of the high mountain ecosystems with the greatest biodiversity in the world, home to a significant number of species that are generally exclusive to each Páramo. The moors are considered fragile and complex environments, in recent times they have been degraded by anthropic factors, including pollution, agricultural expansion and climate change, driving shifts in their natural limits, habitat and species loss, as well as the ability to provide key ecosystem services. To mitigate this problem, there is a need to implement ecological restoration processes, which lead to a selection of species with functional potential, so that they assist the natural dynamics tending to restore some of the historical trajectories of the moor, the factors that influence the failure of these processes is undoubtedly the incorrect selection of plant species, since the success

of these processes depends on the capacity of said selection. For this reason, the objective of this study was to determine the composition and floristic structure of the moor "El Campanario" Calarcá, Quindío, Colombia, as well as contribute to knowledge in the selection and prioritization of plant species that should be used in future restoration processes in paramo ecosystems. The composition and structure of vascular plant species associated with two vegetation covers (Páramo and High Andean Forest-Páramo transition). 194 individuals and 46 species were registered, distributed in 37 genera and 25 families. For the selection and prioritization of those species that showed potential to assist ecological restoration processes, an analysis of the importance value index was carried out and from this, those species with the highest percentage of relative abundance were obtained. The relative abundance showed that, of the 46 species, 11 presented values higher than 70%, showing potential for ecological restoration processes. The most representative species were *Espeletia hartwegiana* and *Gaultheria myrsinoides*. These data agree with the literature, which indicates that the Asteraceae family together with Ericaceae, are an important ecological and floristic component of the high Andean forests and moors, since they participate as water regulators and, in addition, are a great source of food (leaves, fruits, seeds, nectar) for birds (ornithophily), insects (Entomophily) and different species of mammals present in these ecosystems. **Keywords:** Composition, structure, ecological restoration, Moorland, Quindío.

Species of Cyatheaceae Kaulf., Polypodiopsida, Present in the Herbarium University of Quindío -HUQ-, Colombia

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Tree ferns are part of the "pteridophytes", they present arboreal growth and form an erect stem of up to more than 12m. These plants are key in the floristic diversity of the tropics, where they present their greatest number of species, in Colombia they are more representative in the Andes and between 1200-2500 msnm. Cyatheaceae is the largest family, with 643 species in the world and three genera: *Alsophila* (275 sp), *Cyathea* (265 sp) and *Sphaeropteris* (103 sp). Colombia has 140 species, 46 with some degree of threat. The present work is part of the taxonomic review that has been carried out on the species of tree ferns of the Cyatheaceae (Polypodiopsida) family present in the department of Quindío, Colombia. For its development, 56 specimens deposited in the Quindío University Herbarium -HUQ- were reviewed, grouped as follows: *Cyathea* (50 specimens), *Alsophila* (5) and *Sphaeropteris* (1). These specimens correspond to 9 of 12 municipalities that make up Quindío (75%). Filandia recorded 14 samples, followed by Circasia and Salento (13) and Armenia (10), while the municipalities of Montenegro, Córdoba and Pijao do not have any records. For its determination, keys, descriptions, Colombian publications on the family, international databases and the classification system of the Pteridophyte Phylogeny Group - PPG I (2016) were used. Regarding the results, it was obtained that the most representative genus within the studied family was *Cyathea* with 11 species, followed by *Alsophila* with 2 and *Sphaeropteris* with 1 species. Additionally, there were records of other arborescent/subarborescent type ferns, such as *Lophosoria* (Dicksoniaceae), with 7 specimens and one species identified, and *Culcita* (Culcitaceae) and *Plagiogyra* (Plagiogyraceae), with 1 specimen and one species. In total, 6 genera and 17 species of tree ferns were found in the collection. At a specific level, it was found that *Cyathea horrida* is the most widely distributed species, while there are several species such as *C. divergens* and *C. nigripes*, restricted to a single municipality, so their presence is clearly limited. On the other hand, only one species (*S. quindiuensis*) was recorded in *Sphaeropteris*, *A. erinacea* and *A. imrayana* in *Alsophila*, *C. coniifolia* in *Culcita*, and *P. semicordata* in *Plagiogyra*. The work included descriptions, keys, photographs and distribution maps for the Cyatheaceae species present in Quindío. The data agree with the literature, where it is stated that the genus *Cyathea* is the best represented in Colombia and the department of Quindío. **Keywords:** Tree ferns, taxonomy, cyathea, alsophila, sphaeropteris, quindío.

Conservation Status of a Set of Potential Useful Endemic Plants from Colombia

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IUCN Red Lists represent a comprehensive and worldwide framework used for biodiversity conservation planning, providing information about extinction risk for species and ecosystems. Despite its relevance for designing conservation action plans, prioritizing sites for conservation, and designing sustainable use practices, by the end of 2020 less than 10% of plant species had been assessed for the global Red List. Colombia is recognized as one of the richest countries in plant species in the world, with 6500 endemics of about 28,000 species registered to date, but it has less than 50% of its endemic flora assessed for the red list. As a contribution to conservation planning for the plants of Colombia, we present here the results of Red List assessments of a set of 866 endemic plant species with potential use. In collaboration with Red List Unit from IUCN, we selected endemic species from taxonomic families traditionally and broadly used by humans that lacked assessments. The species belonged to the families Arecaceae, Asteraceae, Fabaceae, Heliconiaceae, Orchidaceae, Passifloraceae, and Solanaceae. We used herbarium specimens from the seven largest herbaria of Colombia (COL, COAH, CUVC, FMB, HUA, JAUM, PSO), to compile and to georeference a species-occurrences database. Using a protocol to estimate standardized risk extinction parameters from IUCN, we assigned the corresponding Red List categories. Of the 866 species assessed, almost a half (45%) were categorized as threatened (CR, EN, VU), most of them belonging to the families Orchidaceae (212 species) and Asteraceae (92 species). The most common threat was habitat destruction and degradation, and in a few cases by overexploitation, especially in the case of orchids. Human uses for Colombian plants are poorly documented, therefore we found information on use for only 21% of the selected species. Nevertheless, of the species with reported uses, almost half were categorized as threatened. Of the non-threatened species (388 species in the Least Concern category), 62 had a wide geographic distribution. We declared 55 species as Data Deficient, however, Arecaceae, Fabaceae, and Solanaceae did not have species in this category, given the more detailed knowledge of these taxonomic groups. This study represents an important contribution towards understanding the conservation status of plant species in Colombia. Nevertheless, it is necessary to continue documenting species distributions, population and habitat viability, and potential threats for all plant species, and to better integrate scientific and traditional knowledge for adequate conservation planning in the country. **Keywords:** Plant-Human relation, risk extinction, red list assessments, IUCN

Pregerminative Tests of Promising Species for the Restoration of the Iguaque Flora and Fauna Sanctuary (Boyaca, Colombia). Analysis from Literature.

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The identification of the most efficient pre-germination process for native species that are promising for the restoration of protected areas contributes to the optimization of the propagation and establishment of said species. Through pre-germination treatments, the dormancy type of a particular species can be identified in order to optimize its germination process. Since each plant species responds differently to pre-germination treatments, which can accelerate germination in one species and slow down this process in another, the ideal treatment for each species of interest must be identified. This is of vital importance in restoration processes where one of the greatest limitations is the scarcity of pioneer species propagules that initiate succession, and species of advanced successional stages that allow the recovery of the ecosystem composition. To evaluate different pre-germination tests of promising species for the restoration of the Iguaque Flora and Fauna Sanctuary (Boyacá, Colombia), 10 species of plants from the Sanctuary were selected of which the favorable pre-germination treatments published in the literature are known (for example mechanical scarification, imbibition, inter alia). Free access databases such as google scholar, research gate, Microsoft academic, among others, were used. As search criteria, filter expressions such as 'dormancy in -species-' and 'germination in -species-' were used. Based on this information, these treatments will be applied to other native species that occur in the protected area, considering the taxonomic groups of the species previously studied (E.g. Fabaceae, Melastomataceae, Asteraceae). One of the expected results is gaining a piece of greater knowledge about the physiology and morphology of the native and vulnerable seeds from the Flora of the Sanctuary. Some of the most relevant results to date are those found in two of the species of interest. The first is *Varronia cylindrostachya,* for which no conclusive information was found in the literature and when it was subjected to pre-germination treatments, the best result was obtained by immersing the seeds in hot water for 40 seconds, obtaining 12% of the germinated seeds vs. the control (where 10% was obtained). The other species *Alnus acuminata* was subjected to

pre-germination treatments, with which a higher percentage of seeds was obtained by submerging the seeds in corn water with 8% of the germinated seeds, and in the control, 5% of germination was obtained. These findings will improve the seedling's propagation processes, by establishing a germination protocol, that will be applied to multiple nurseries in the community, it will be promoting the use and management. **Keywords:** Seeds, dormancy, restoration ecology, pre- germination test.

Importance of Degraded Dry Forest Fragments for Javan Mongoose (*Herpestes javanicus*): Abundance and Spatial Ecology.

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Tropical small carnivore species frequently lack basic ecological data. Forests that provide habitats for such species are increasingly degraded due to landscape changes, such as deforestation. This makes collecting data within remaining forests important for accurate conservation planning. The Javan mongoose is a small generalist carnivore with a wide distribution through Southeast Asia, and could potentially provide ecosystem services such as pest control in degraded habitats which lack larger predators. However, despite this the species still has an unknown population, home-range size and micro-habitat selection. We investigated each within a protected degraded forest fragment located in Thailand, by analyzing camera trap and radio telemetry data, as well as availability of prey and den sites. We found mongoose abundance was positively associated with open canopy dry forest habitat, with mean abundance three times higher in dry dipterocarp forest than closed canopy forest. Our telemetry data indicated that males have larger home-ranges, with mean home-range size for our two males being 1.86 km2 and for one female 0.27 km2. Availability of termite mounds with entry holes was our top den site model, showing a clear utilization of mounds for shelter by Javan mongoose. Prey availability did not affect micro-habitat selection by mongoose, presumably due to an even distribution of small mammals across our tracked individual's chosen habitat. Radio tracked mongoose selected for areas with low numbers of small trees, and camera trap data showed a negative association of mongoose abundance with basal area of small trees. Our findings indicate that Javan mongoose select for open dry forest over closed canopy forests. We suggest that future camera trap surveys focus on habitats other than traditional closed forests to provide a more complete knowledge on this species population throughout its range. A better understanding of the reliance of Javan mongoose on open dry forests is urgent, as these habitats are under threat and are often considered of lower conservation importance in tropical areas. **Keywords:** Small carnivores, dry dipterocarp forest, home-range, abundance, habitat selection, Thailand

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Ants: Bioindicators of Ecological Restoration Processes at Zapatoca (Colombia)

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The Zapatoca Nature Reserve Network (RENAZ) includes areas neighboring the National Natural Park of La Serranía de los Yariguíes, Santander, Colombia. In particular, the Civil Society Reserve "La Montaña Mágica-El Poleo" started in 2017 an ecological restoration with support from the Universidad Nacional de Colombia Sede Medellín (UNC) through nuclei with stakes and seedlings (˜10,000). In surrounding areas, agricultural activities predominate, so ongoing monitoring on the evolution of conservation and restoration also provides helpful information to gain the interest of the communities. Because of their rapid responses to changes in land use, ants play significant roles in ecosystems, are sensitive to environmental disturbances, and have been recognized as bioindicators. The UNC identifies changes in ant diversity caused by restoration and conservation processes in the RENAZ. Samples were collected from three environments (a secondary forest under passive restoration for the last 20 years, an area under active restoration for the last five years, and a disturbed forest) using four capture methods: (i) drop traps, (ii) Winkler bags, (iii) baits, and (iv) direct collection, with three repetitions in six months. The disturbed forest showed the highest diversity, dominated by generalist and hunter functional groups, recorded in very fragmented environments (Camponotus, Crematogaster and Odontomachus). The passive restoration process showed more specialized functional groups, indicators of conservation, and the actively restored forest showed both lower diversity and fewer individuals, with species typical of disturbed sites (i.e. Camponotus). Drop traps and Winkler bags were the best capture methods, while baits quickly attracted the dominant ants in the disturbed environment. Because of the size of the ants ($<$3 mm) and their subterranean habits in the passively restored forest, direct trapping was inefficient. The restoration processes

generate a tree cover and an understory, but there was no clear relationship between ants and vegetation, nor was there in the disturbed environment. All species captured showed edaphic behavior and nested in leaf litter. At Zapatoca, Odontomachus and Camponotus can be considered disturbance indicators genera. Passive restoration allows the conservation of specialist ants who could not survive in disturbed ecosystems, however, long-term monitoring is necessary, especially where active processes have been practiced. This work confirms that ant species can be restoration and conservation processes bioindicators in the neighboring area of the Serranía de los Yariguíes National Natural Park, and generate information for eventual conservation measures.
Keywords: Entomology, biomonitoring, conservation, ecology

Conservation, Restoration

Rapid Assessment of the Distribution and Population Characteristics of *Eulemur mongoz* and Its Congener, *E. fulvus* across Northwestern Madagascar

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The persistence of endangered species in disturbed landscapes partly depends on their capacity to occupy a wide breadth of biogeographic conditions and their ability to find conspecifics. Species that exhibit a narrow preference of habitat conditions are often more vulnerable to extirpation when facing the threats of habitat loss and fragmentation. Under these disturbed habitat conditions, species may also experience additional difficulties finding conspecifics when they disperse from their natal group. Little is known about the distribution and population ecology of the Critically Endangered mongoose lemur (*Eulemur mongoz*). In comparison to its sympatric congener, the Near Threatened common brown lemur (*E. fulvus*), population densities of *E. mongoz* have severely declined over the past 30 years across their geographic range in northwestern Madagascar. However, despite the severe conservation issues *E. mongoz* is currently facing, this species has received considerably little attention. In this study, we present current estimates of the distribution and relative population structure of *E. mongoz* across two of the largest forest landscapes present in NW Madagascar, with comparison to populations of *E. fulvus* found in sympatry within the same landscapes. To examine the distribution and population ecology of these two species, we conducted a series of rapid surveys for a 6-month period in 2019 along the western portion of Ankarafantsika National Park (ANP) as well as the Mariarano Forest Complex (MFC). In each of these two landscapes, we collected GPS data on the occurrence of *E. mongoz* and *E. fulvus* as well as information on their group size and the age-ratio of each group. We combined the GPS data with vegetation datasets from each landscape to estimate the distribution of these two species via kernel density mapping. Moreover, we also compared variation in the average group size and age-ratio of the two species in each forest landscape. Our results show that in contrast to *E. fulvus*, *E. mongoz* is primarily distributed in a river valley located in the western portion ANP. Outside this valley, the species is rarely observed. Similarly, our results show that at MFC, *E. mongoz* more commonly occurs in smaller group sizes with no infants or as solitary individuals. While preliminary, the results of this research stress the importance of immediate conservation action for *E. mongoz* across its home range. Our research shows that in the immediate future river valleys in ANP stand as the best stronghold for the survival of this Critically Endangered species. **Keywords:** Rapid surveys, habitat loss and fragmentation, sympatry, conservation, Eulemur, Madagascar

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Diversity and Endemism of the Brazil Nut Family Lecythidaceae in Colombia

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Lecythidaceae (Ericales) is a pantropical family of trees with ca. 232 of 278 species restricted to the Neotropics. The family is characterized by its diverse flowering morphology and woody fruits. The global center of species richness and ecological importance is in the Amazon basin and Guiana Shield, where most Lecythidaceae research has been focused. To better understand the diversity and endemism of Lecythidaceae in Colombia, we performed a phytogeographic study based on herbarium specimens in Colombian COL, HUA, CUVC, FMB, and the U.S. herbaria MO, NY, and F, using specialized bibliography and the databases of IPNI, Global Plants JSTOR, and Plants of the World Online, prioritizing the groups less studied. The species reported in the Catálogo de Plantas y Líquenes de Colombia were revised and compared with the records from GBIF,

local herbaria: COL, COAH, HUA, FMB, CHOCO, CUVC, and international herbaria: UMICH, STRI, MO, NY, F. The records were compiled, cleaned, and mapped using CordinateCleaner and ggplot2 in R.v.4.1.3. Additionally, based on the ranges of distribution of the species, there were estimated potential areas of endemism for the family in Colombia. Despite finding almost 15000 records, we compiled 8824 georeferenced records corresponding to 10 genera and 115 species (13 endemic) of the family, where the most diverse genera found were Eschweilera and Gustavia, with 48 and 26 species, respectively. Although the family is widely distributed throughout the Amazonia, Guayana and Serranía de La Macarena regions, with dominance of Eschweilera, there are other important genera like Gustavia and Grias which are dominant in the Pacific coast and in the Magdalena Valley, occurring between 0-1800 m of elevation, that include most of the endemic species in the family. Furthermore, we found 27 species reported as vulnerable, 11 endangered and two critically endangered (according to the IUCN), with most of these species occurring in the Andes and in the Pacific regions. Due to these results, we conclude that it is important to study the widespread groups in the family, given their gaps in taxonomy and ecology that are important to understand their diversification, and necessary to identify and prioritize areas for conservation in regions like the Andes and Chocó in Colombia. **Keywords:** The Andes, choco biogeographical region, distribution patterns, prioritized areas

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CALORIC SUPPLY OF FRUITS ASSOCIATED WITH THE MOST REPRESENTATIVE FLORA SPECIES OF THE MOORLAND "EL CAMPANARIO", CALARCÁ, QUINDÍO, COLOMBIA

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The moorland are considered strategic ecosystems due to the innumerable ecosystem services they provide, however, due to agricultural expansion, climatic variation and other aspects derived from anthropic factors, the natural limits of said ecosystems have been affected and/or transformed, the area of plant covers and, consequently, the displacement of species, among others. For this reason, it is essential to carry out ecological restoration processes, which throughout history have been poorly implemented, mainly due to ignorance about the ecosystem functions of each of the species used. In this sense, it is important to make a correct selection of species to assist these restoration processes in moorland ecosystems whose attributes tend to potentiate and promote the natural dynamics of these biomes. An example of a functional attribute that should be taken into account could be the interaction of plants with birds, for this reason, the objective of this study was to determine the caloric supply of fruits associated with the most representative flora species of the moorland "the Campanario", Calarcá, Quindío, Colombia, in addition to contributing to knowledge in the selection and prioritization of plant species that should be implemented in future processes of ecological restoration in moorland ecosystems. For this purpose, permanent plots were established, and the fruits of those plants that were found within the plots were collected, Subsequently, the determination of the specimens to which these fruits corresponded was carried out. Then, the caloric content, in brix degrees (percentage of sugars), of each of the harvested fruits, was evaluated using a portable refractometer. It was found that the most representative families in terms of caloric content were Solanaceae with *Saracha quitenesis*, Berberidaceae with *Verberis sp,* Rosaceae with *Hesperomeles ferruginea* and Melastomataceae with *Miconia gleasoniana*. These data agree with the literature, where it is stated that Ericaceae, together with Melastomataceae and Rosaceae, are important ecological and floristic components of high Andean forests and moorland, since they provide food resources (fruits, seeds, nectar) to different kinds of birds, insects and mammals present in this type of ecosystem. **Keywords:** Ecological restoration, páramo fruits, interactions, Quindío

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Viability and Germination of *Vochysia duquei Pilg* as a Conservation Strategy in the Departament of Quindío

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El papelillo (*Vochysia duquei)* es una especie de importancia ecológica para el departamento del Quindío incluida en el documento de especies focales de la flora, que brinda una amplia gama de beneficios ambientales, económicos y sociales. Sin embargo, su uso indiscriminado, la deforestación provocada por el cultivo extensivo y su dificultad para propagarse en condiciones naturales han provocado la disminución de sus poblaciones en el departamento. Por ello, como estrategia de conservación y para futuras propagaciones, las semillas fueron presentadas a pruebas específicas para tener una perspectiva más clara de los posibles problemas fisiológicos que puedan tener la especie al momento de su propagación.Se realizaron pruebas de calidad de semilla para determinar el porcentaje de humedad, viabilidad y germinación. Los frutos fueron recolectados en diferentes municipios del departamento del Quindío, seleccionando solo las maduras que se encontraron en mejores condiciones físicas, envasándolas en bolsas herméticas hasta transportarlas al laboratorio de biotecnología vegetal de la Universidad del Quindío, donde se realizó su debido proceso de registro y limpieza. Además de la extracción de las semillas, las cuales fueron expuestas a pruebas de viabilidad con cloruro de tetrazolio en diferentes concentraciones (0.5, 1 y 1.5%), bajo diferentes tiempos de exposición y con dos temperaturas diferentes las cuales mostraron un alto porcentaje de viabilidad ,así como pruebas en cajas de petri con papel filtro esterilizado a las que se les agregó agua destilada para garantizar la hidratación de cada embrión y ácido giberélico para estimular la germinación, el resultado de esta germinación fue bastante alto puesto que *en 8 de los 10 embriones sometidos a la prueba completaron su desarrollo , dándonos como resultado el 80% de germinación en las semillas evaluadas para esta especie. la gran mayoría de semillas* adicionalmente se realizó un control de humedad donde se evaluó el embrión recien extraido y el embrión después de 24H a 40 °C donde al someter las semillas recolectadas a las pruebas iniciales de calidad aplicando la formula CH= ((peso inicial – peso seco) /peso inicial) x100se obtuvo un contenido de humedad del 25%. **Keywords:** Conservation, "papelillo", Quindío, germination.

Comparing Mosquitos and Carrion Flies to Survey Mammals in a Semi-controlled Area Using IDNA and Metabarcoding

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Introduction: Monitoring the occurrence of species in human-modified habitats is crucial to infer on how species are responding to these modifications. For some groups, such as mammals, because of their elusive habits and low densities, monitoring them is not an easy task. An alternative to detect mammal species is using invertebrates that feed on animals for sampling vertebrate DNA (invertebrate-derived DNA, iDNA), since invertebrates are easily sampled, cosmopolites, and can feed on all terrestrial vertebrates. However, the use of iDNA is still little explored in high biodiversity areas, especially in the Neotropics. **Objectives:** The objectives of this study were focused on (1) surveying mammal species in a semi-controlled area using iDNA, (2) comparing the effectiveness of carrion-flies and mosquitos as iDNA samplers, and (3) verifying the reach of each sampler group through the distance between the insect traps and the mammal locations. **Methods:** Invertebrates were collected in the "Parque Ecológico de São Carlos" (PESC, Brazil), a Zoo located within a Cerrado remnant, that houses local fauna and Zoo's exclusive species. Mosquitos and carrion flies were collected during five consecutive days from eight sampling sites distributed across the PESC area, using, respectively, light traps and bottle traps baited with meat. DNA was extracted using the DNeasy Blood and Tissue kit (Qiagen). Two mini-barcodes for both 12S and 16S regions were amplified employing specific primer pairs. Metabarcoding sequencing was carried out on an Illumina platform. The obtained OTUs were compared against sequences from the GenBank database. The locations of sampled insects and exclusive species were retrieved to infer distances between them. **Results:** A total of 46 carrion flies and 20 blood-engorged mosquitos were collected. iDNA from carrion flies and mosquitos recovered 48 (1.04 species/carrion fly) and 41 mammal species (2.05 species/mosquitos), respectively. The iDNA from both insects recovered local and exclusive mammals, but also domestic species. The longest sampling distance was 300 m for mosquitos and 230 m for carrion flies. The 12S and 16S mini-barcodes showed different species detection efficiency, reinforcing that they are complementary. **Conclusions:** The employed methodology was efficient to detect mammals, mainly by using mosquitos as samplers, which

allowed us to identify a higher number of mammals per insect and with longer sampling distances. These results will be helpful to guide the sampling design and effort to survey mammals in high biodiversity areas, aiding to monitor species in human-impacted areas and supporting conservation strategies. Financial support: FAPESP (2017/23548-2). **Keywords:** Conservation, species monitoring, biodiversity, neotropic, environmental DNA

Taxonomic Agreement and Inventory Completeness of Bird Species at the Great Escarpments of Angola and Namibia

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Introduction: Despite centuries of biological exploration, information about the world's biodiversity remains largely incomplete. While some regions and biological groups attract public and scientific attention, others lack basic studies such as field inventories or taxonomic assessments. **Objectives:** The overarching goal of this study is to quantify 1) spatial biases in inventory completeness and 2) the degree of species-level taxonomic agreement for bird species of the Great Escarpment region of Angola and Namibia. We focus on this region because it hosts remarkable levels of biodiversity, which seems to be poorly reflected in global biodiversity databases, such as the GBIF. **Methods:** We retrieved and screened GBIF occurrence records of bird species collected after the 2000s, and calculated inventory completeness for each 10 x 10km grid square within the study area. We also developed a metric of taxonomic agreement based on the concordance of species names among six world Birds checklists. We then calculated the median taxonomic agreement for each grid cell, and tested whether there is a spatial correlation between completeness and taxonomic agreement. **Results:** We found marked spatial biases in inventory completeness in the the Great Escarpments. Biodiversity of the Escarpment in Angola is largely underrepresented in GBIF. Conversely, biodiversity in Namibia is better sampled, particularly near main cities. Of the 827 bird species of the Great Escarpments observed at least once among the six world Birds lists, 516 (62%) agreed across all lists. The western border of the Great Escarpments of Namibia was the region containing the lowest taxonomic agreement upon species. We also found a low, but significant positive correlation between median taxonomic agreement and inventory completeness ($rho = 0.12$, $p<0.001$), showing that areas with higher inventory completeness also show higher taxonomic agreement. **Implications/Conclusions**: Our results emphasize the urgent need for i) new surveys across the Great Escarpments, and particularly for Angola and the extremes North and South of Namibia, and, ii) resolve disagreements across Birds checklists for a more comprehensive knowledge of the biodiversity of the Great Escarpments. **Keywords:** Bias, biodiversity data, sample effort, taxonomy, bird checklists

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Contributions of Urban Linear Green Infrastructure to the Maintenance and Use of Habitat of Bird Communities in a Neotropical City

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There is a growing interest in understanding and mitigating the effects that growing urbanization processes on a global scale can have on wildlife. Faced with the effects of urbanization on birds and other groups of fauna, multiple responses have emerged associated with the development of policies and tools for the conservation and maintenance of biodiversity in cities. However, in practice, little is known about aspects related to what species are occupying different types of linear green infrastructure in a city? What use are birds making of this type of green infrastructure? And what determines the type of species found there? This study seeks to address some of these gaps through three scales of analysis to determine the diversity and distribution of species related to different types of corridors, their use and selection, and to quantify the influence of various urban factors that describe Bogotá at the site scale. landscape and urban matrix have on a) patterns of total richness and abundance, b) patterns of richness and abundance registered for ecological guilds in which the species were classified according to their diet and tolerance to urbanization and c) patterns of abundance for a group of specific species (control species) recorded in ecological corridors in the city of Bogotá. It was obtained that the border and round corridors were the corridors that presented a similarity in their wealth, compared to the road corridors and the control corridor. The bird assemblages between types of corridors have an important dissimilarity, especially due to the difference between the bird species found in the edge corridor and those in the control corridor, registering the same trend found in relation to their tolerance to urbanization and diet. The border corridors are the main receptor for urban evasive birds, the corridors for urban user and adapter birds, and the urban adapter bird vials. The factors that condition both the presence and the selection of habitat of the corridors by the avifauna, was the vehicular traffic, which had a negative impact on the species composition, on the contrary, the site variables such as the Simpson general diversity index, the diversity index of native species and the height of plant species had a positive effect on the composition. The results of this study are expected to contribute to the environmental planning of green areas in the city, for the maintenance and conservation of urban birds. **Keywords:** Urban birds, ecological corridors, tolerance to urbanization habitat selection, urban disturbance, environmental planning city, urban ecosystem, conservation, biodiversity

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Conservation, Restoration

Edge Effect On The Diversity Of Spiders Present In Severely Fragmented Tropical Dry Forest Remanants In Southwestern Colombia

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The edge effect is considered the most serious threat to biological diversity in fragmented tropical forest. The Tropical Dry Forest in Colombia has been seriously reduced to less than 8% of their original extension and is severely fragmented, and in the Cauca river valley is less than 3%. The present study aim is to evaluate the effect of fragmentation on spider communities in TDR. The edge effect was evaluated on spider diversity in six TDF fragments in the Patía (Cauca) and Cauca (Valle del Cauca) river valleys. Those fragments ranged from 6.3 to 116 ha and were the largest in the region. Spiders were collected at stations placed in radial transects from the centroid to the matrix surrounding each fragment. Sampling points in the fragments were the centroid, and 100m, 75m, 50m, 25 m and 0m from the edge, and a surrounding matrix sampling point for comparison. Spiders of 3525 individuals belonging to 126 species in 25 families were collected. The most abundant families in this study were Theridiidae, Salticidae, Thomisidae and Araneidae. The results show that the most similar fragments in terms of species composition are those found in the Patía Valley, followed by those found in the north of the Cauca Valley and finally El Hatico (Valle del Cauca) and La Pachuca (Cauca) were the less similar. Regarding the similarities of species between the distances, a greater similarity was found between the centroid, 100m and 75m, followed by another group of 50m, 25m and 0m, the matrix was the one that showed the greatest difference with the other sampling points. It is concluded that the assemblage of species at the regional level in the fragments presents similar diversity patterns but not by geographic proximity. The spiders present in the matrix are different from the fragment, some with a strong preference for this area, while most species are exclusive to the interior. The diversity of species is greater and different from the edge towards the interior of the fragments, increasing towards the centroid, showing that there are different species near the edge, compared to the interior, evidencing the edge effect on spider diversity. Spiders are a sensitive group to fragmentation and could be used to assess the fragmentation and possible restoration programs.
Keywords: Edge effect, spider communities, distance, diversity

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A Decade of Studies on Forest Recovery after Mining in the Eastern Amazon: What Have We Learned?

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Mining contributes to global socio-economic development but also increase land degradation. There is a growing concern about this activity, especially for Eastern Amazon. About 270,000 km^2 (40%) of forest cover in Pará has been lost, 100,000 ha due to mining. Although the Brazilian law obliges reparation of areas disturbed by mineral exploration, the ecological resilience vary, and there much to learn on methods for ecosystems' restoration in post-mined areas. In this context, BRC – Biodiversity Research Consortium - has for nearly ten years conducted projects on forest recovery, restoration of biodiversity and soils, biomonitoring and bioindicators, and greenhouse gas fluxes related to mining, both in terrestrial and aquatic systems. The study area is a bauxite mine at Paragominas – PA, owned by the company Norsk Hydro. The three major techniques applied to reestablish vegetation are: seedling planting (PL), natural regeneration (NR), and nucleation (NU). The area also contains a large patch of altered primary forests (FO). Species diversity was higher for most taxa in FO, although some insect groups were more abundant in the restoration areas. Most ground-living mammals occurred across all habitats, suggesting some level of tolerance. However, some species showed

distinct habitat preferences. For example, Giant anteaters and Giant armadillos preferred disturbed habitats, whereas White-lipped peccary showed the least preference. Diversity of birds was much higher in FO, even after eight years of recovery. In aquatic systems, concentration of metals was influenced by mining activity and seasonality, and fishes residing near the mine had reduced antioxidant and detoxification capacity. Within restoration areas, regenerating plant species were most efficient to occupy and cover the soil in NR, as well recovering important soil attributes. It's recommended, though, introducing early and late-secondary species to increase diversity and ensure restoration. Biomass accumulation was higher in NR, with NU showing the lowest values. CO_2 fluxes were highest in NU, followed by PL, NR and FO had the lowest. Several taxa were recommended for potential use as bioindicators, especially aquatic insects. Results showed that restoration should be addressed at ecosystem's scale, and that biological responses to techniques for ecosystem's recovery are distinct and complex. We expect that BRC may work as a laboratory to understand ecosystems' restoration in areas impacted by mining, and provide low-impact alternatives. **Keywords:** Amazon, restoration, mining, biomonitoring, bioindicators, forest succession, biodiversity, regeneration

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Occurrence of Albino Seedlings of the Species *Eschweilera micrantha* (Lecythidaceae) and Comparison of Survival with Green-leaf Seedlings, Central Amazon, Brazil

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In South America, including the Amazon region, protection areas have accelerated human population growth at their edges that cause imminent threats to biodiversity conservation due to deforestation. The seedling phase that begins after seed germination is the period of the initial life cycle of the trees most vulnerable to mortality in the face of a disturbance. For an effective conservation of species in areas vulnerable to destruction, prior knowledge of their development is necessary and there is still a large gap on the seedling phase of several Amazonian species. Albino or chlorophyll-deficient mutants are rarely found in tropical forests and may be a result of inbreeding that may be related to habitat fragmentation. There are still few records of albino seedlings in the Amazon, such as *Carapa guianensis* Aubl. (Meliaceae), popularly known as Andiroba. Thus, the aim of this study is to disseminate the occurence of albinism in seedlings of the species *Eschweilera micrantha* (O. Berg) Miers (Lecythidaceae) in an urban forest fragment. During the months of May to June 2019, two groups of seedlings were sampled: 20 albino seedlings and 20 seedlings of green-leaves (between 6.5 and 26 cm high) of the species *E. micrantha*, identified by the parataxonomist Paulo Apóstolo Costa Lima Assunção (*in memoriam*) at the sampling site: the upland forest of the Central Amazon (Adolpho Ducke Forest Reserve, Amazonian Museum, Manaus, Brazil). The seedlings were located within a radius of approximately five meters away from the mother plant. The number of leaves of each individual and survivors of each group over eight weeks was counted. In the group of green-leaf seedlings, the number of leaves of each individual remained constant and there was no record of death during the sampling. While in the group of albino seedlings, there was a decrease in the number of leaves in 90% of individuals and an increase in mortality between weeks 6 and 8 sampling, reaching 65%. In this way, the present study can be used as a basic research to better understand the early stages of tree species in the Amazon, as well as encourage in-depth studies that relate the inbreeding of species in habitat fragments with the occurrence of albino seedlings in order to assist in the conservation of biodiversity in the Amazon region. **Keywords:** Conservation,tropical forest, fragmentation, Lecythidaceae, forest regeneration,survival.

Identification of Wood Species from Selva Central, Peru

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The Central Peruvian Jungle is characterized by having a wealth of forest species that are used for various purposes. It is estimated that around 2,000 species are described in Peruvian forests, however, 200 species are used commercially, which generates pressure on some groups/families of wood-producing plants. In addition to that, the species have similar general characteristics such as color, smell, even the anatomy are very similar, which generates confusion at the time of identification at control posts. Added to that, there is a trend for the tropical timber trade around the world to grow with the resumption of economic activities around the world after the Covid-19 pandemic. So there is an urgent need to correctly identify the commercialized species not only in the Central Jungle, but also in all Peruvian territory. The objective of the study was to identify, through the macroscopic anatomical structure, 20 species commercialized in the Central Selva, Peru. The wood samples were collected in 13 sawmills located in the Central Selva, located in the provinces of Chanchamayo and Satipo (Junín) and Oxapampa (Pasco). Subsequently, the samples were brought to the Wood Anatomy Laboratory at the Universidad Continental in Huancayo, Peru for further anatomical analysis and identification of species that will follow the standards and available bibliographies. As a result, 20 forest species were identified at the specific level that are distributed in 12 botanical families, including Podocarpaceae (2), this family is characterized by not having the presence of conductive vessels, in addition to that, the identified species do not mark very well their growth rings and were differentiated by the presence of different axial parenchyma in the species Retrophyllum rospigliosii. The other representative families were Fabaceae (5), Moraceae (3) and Lauraceae (2) with more numbers of identified species. With only one representative are the families: Apocynaceae, Calophyllaceae, Caryocaraceae, Chrysobalanaceae, Juglandaceae, Meliaceae, Rhizophoraceae and Rubiaceae. In general, the species have diffuse porosity, without a defined arrangement, with solitary and multiple vessels and poorly demarcated growth rings. Three of the identified species presented ray stratification, which is extremely important in identification (*Amburana cearensis, Myroxylon peruiferum and Myroxylon balsamum*) and only one presented cambial variations such as phloem (*Sterigmapetalum obovatum*). The identification of forest species is essential for the conservation and sustainable development of tropical forests. In addition to that, for the development of technologies that can later support the fight against illegal carving. **Keywords:** Identification of wood, Peruvian forest, Ilegal trade, Peru.

Looking for Tropical Dry Forest Mammals in a Southwest Region of Colombia

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Introduction and Background: Colombia's tropical dry forests (BsT) have been threatened by anthropic transformations to the point of near extinction, affecting the functioning and structure of the biome and causing a decrease in biodiversity richness. These ecosystems are of great interest for the conservation of wildlife threatened by the convergence of endemic species, because currently approximately 60 species of mammals have been reported, of which three are unique to this biome. **Methods:** In agreement with the Humboldt Institute, Ecopetrol and the Universidad Surcolombiana, a mammal survey of one of the largest BsT relicts in Huila, carried out during the year 2021 in the Ecoreserva La Tribuna. Sherman traps and snap traps for terrestrial mammals and mist nets for flying mammals were used, as well as nine camera traps installed during the two seasons of the year (dry and rainy) in strategic transects of the Ecoreserva. Using traditional taxonomy together with molecular tools, the species found in the area were identified and confirmed. **Results:** Eight genera of chiroptera were found by trapping methods (*Artibeus, Platyrrhinus, Dermanura, Sturnira, Carollia, Glossophaga, Pternotus, Myotis)* from three families (*Phyllostomidae, Mormoopidae, Vespertiniolidae*) and a marsupial (*Marmosa sp*). On the other hand, photo-trapping technique, we found the presence of *Tamandua mexicana* rare species within the biome. In addition, 42 sequences of the COI gene belonging to the chiropteran species captured were obtained, which were deposited in databases such as BoldSystem, which do not have much information on these species for the country. **Conclusion**: It is possible to say that this project identified the mammals of the La Tribuna Ecoreserve BsT using invasive and non-invasive techniques, obtaining a total of 196 records and information on species rarely recorded in the area. Thus, It should be mentioned that, for

identification, traditional taxonomy and molecular tools provide greater efficiency and accuracy, although they are the most costly. This survey represent the first assessment using traditional taxonomy and molecular tools to describe fauna diversity in Tropical Dry Forest, allowing understand better the composition of this Biome.
Keywords: Dry tropical forest, ecoreserve, molecular biology, Huila.

Evaluating Temporal and Spatial Trends in Roadkill Frequency in Central Panama: A Baseline Study

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Urban expansion around Panama City and the Panama Canal has increased dramatically in recent decades. To accommodate a fast-growing region's needs, new roads and highways have been built. This has caused fragmentation of protected tropical forests that are essential for connectivity of animal populations between North and South America and the functioning of the Canal. In addition, research has shown that roads that intersect forest fragments have a higher impact on wildlife roadkill than those that avoid them. Due to this urban growth and the lack of research on the impact of wildlife-vehicle collisions in Panama, we undertook an initial assessment of wildlife roadkill in this region. Specifically, we recorded all terrestrial vertebrate roadkill in order to determine which group was the most affected, the time of day when more collisions occurred, and the location of potential roadkill hotspots to inform future mitigation strategies. Two visual surveys were conducted daily for 62 days along two roads built through national parks adjacent to the Panama Canal: Centenario Highway and Gamboa Road. The location, time of day, and highest taxonomic group were documented for each registered animal. A total of 1,074 individuals from 55 different species were collected across both sites. Nocturnal collisions were significantly more common than diurnal ones on both roads, consistent with the findings of other studies in the region. There were differences in the most impacted taxonomic group in each road, with amphibians most affected on Gamboa road and mammals most affected on Centenario Highway. The species found in Gamboa were behaviorally diverse, whereas in Centenario they were mostly nocturnal and arboreal. This could be related to the difference in distance between forest fragments in each road and the presence of underpasses. Forest fragments in Gamboa were closer than in Centenario, which could cause a variety of species to attempt crossing the road. In Centenario, distant forest fragments are connected by underpasses built for river flow, and non-arboreal animals may be using these spaces to avoid the highway. No hotspots were identified in Centenario due to the smaller sample size, whereas in Gamboa two were identified. Both were adjacent to small creeks, which could explain the higher mortality of amphibians. Further studies are needed in Panama to assess impacts of roads on wildlife and provide insight into the types of structures and strategies needed to mitigate these collisions. **Keywords:** Roadkill, Panama, fragmentation, hotspots, underpasses.

Environmental Compensation in Costa Rica: Disparity between Commitments and Actions

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Background: Development projects often generate irreversible impacts that severely affect ecosystems, especially those already reduced or threatened. *Environmental compensation* is a legal-administrative instrument that governments of tropical countries increasingly use to compensate for these irreparable losses. Compensation is usually framed in ecological equivalence, which seeks proportionality between the losses due to the impact and the compensatory actions that result in a net environmental gain. However, one limitation is that it is not always clear how to make proper assessments for the correspondence between habitat or biodiversity loss and the expected gains from offsets. This study evaluates the implementation of environmental compensation measures in Costa Rica, a country with a strong reputation for protecting the environment. **Methodology**: We analyze the technical records of projects that have merited an environmental compensation plan registered by the National Environmental Technical Secretariat (SETENA) between January 2018 and June 2020. **Results:** Seventy-four projects required compensation. Over 75% of them relate to infrastructure projects for housing, services, energy, or agro-industry, while the rest carry out activities to exploit materials and resources. The main impacts reported were: deforestation and destruction of riverbanks (13%), earthworks (15.5%), poor water management (15.5%), administrative faults, and non-compliance with environmental commitments (62%).

The main compensatory actions requested were: support for school infrastructure (20% of the projects), environmental education programs (17%), and reforestation programs (>15%). Actions such as the purchase of school supplies, equipment donation to community associations, and the arrangement of roads and causeways were also recorded. In only three cases, the replacement of the impacted habitat was used as compensation for projected damage. Most compensation measures were requested after the environmental license, responding to impacts that had not been contemplated during the preliminary evaluation or administrative faults. **Conclusions:** Although the compensatory measures observed benefit sectors of society, it is clear that they do not endorse the spirit of return on components equivalent to those impacted. These measures try to repair infractions of an administrative nature, which explains their incompatibility with the elements of the natural environment and their ineffectiveness in ensuring a net environmental gain. This situation results from an ambiguous regulation on environmental evaluation in the country and the confusion of concepts of mitigation and compensation in practice. We propose measures to resolve these inconsistencies and provide SETENA with a more appropriate strategy to achieve equivalence in the requested environmental compensation actions. **Keywords:** SETENA, environmental impact, environment offsets

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Silviculture with Native Species: The Case of *Retrophyllum rospigliosii* in the Southwest of Colombia

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Tropical forests provide ecosystem services that ensure the maintenance of ecological functions and guarantee the quality of life for all. However, illegal logging of tropical timber, results in the loss and degradation of millions of hectares of forest leading to an increase of anthropogenic emissions, and the number of endangered species. *Retrophyllum rospigliosii* is one of the few native coniferous species that growths naturally in the Andean forests of Colombia. The intensive exploitation of *R. rospigliosii* during the last century has progressively decreased its natural populations, and it has become classified as vulnerable. Smurfit Kappa Colombia, in 1993, established several research studies (in-situ and ex-situ such as plantations) to determine the ecology and silviculture of *R. rospigliosii* in the southwest of Colombia. Researchers and students from University of Cauca have accompanied and monitored these studies in the last years. Overall, we found that under natural conditions the seeds of *R. rospigliosii* germinate poorly and take long (approximately 160 days) to complete the germination process. Under nursery conditions, the germination substrates, as well as the pre-germination treatments significantly influence the percentage and mean germination time. Thus, under mechanical scarification and the application of growth hormones the maximum germination value is 84.84% and the mean germination time is 51 days. In terms of management, fertilization with nitrogen, phosphorus, boron, and trace elements significantly increases the annual increment in diameter, height, basal area, and volume. This is probably because early fertilization allowed the early crown closure and weed reduction. However, the findings of the growth rates of *R. rospigliosii* showed that these plantations did not perform as well as expected in terms of growth for commercial reforestation compared with exotic species that are commonly planted in the Andean zone. In terms of wood quality, the mechanical properties of 20-year-old logs were inferior compared wood species commonly used in the milling and paper industry. Given the vulnerability of *R. rospigliosii*, this research provides relevant information for the establishment of restoration and conservation programs that should be a priority to maintain the few remaining relicts of forests where this species grows. Given its slow growth, it is likely that trees of this species are the few and oldest individuals in tropical montane forests, so they may store valuable information about past conditions of the tropical Andes. **Keywords:** Colombian pine, Montane forest, Propagation, Tree growth, Wood use

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Ecosystem Function, Ecosystem Services

Exploring the Functional Traits of Frailejones (*Espeletiinae, Asteraceae)*

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Introduction / Background / Justification: The subtribe Espeletiinae is a well-known example of adaptive radiation in the ecosystem of páramo. With over 100 species described, there is still much debate about their delimitation, given that there is no molecular support for most of the taxonomically recognized species. Additionally, not much is known about the diversity of functional traits in *frailejones*. The variation and distribution of functional traits within a community are one of the main topics to understand the performance of an individual in a given environment and ecosystem functioning. Traits could also be used as a source of data to test for species delimitations. By sampling functional traits of different morphospecies of *frailejones* we aim to test if these traits are coherent with our perception of morphospecies or if new groupings are suggested. **Objective(s)/Hypothesis(es):** What is the diversity of functional traits of *frailejones* in six different páramo complexes in Colombia, and what can it tell us about the species delimitation? **Methods:** Five functional traits (specific leaf area, leaf dry matter content, leaf area, leaf thickness, root specific length) were assessed in at least five individuals per morphospecies occurring in sympatry at each sampling site. Based on these traits, Normal Mixture Models (NMM) were used to test for the existence of different morphospecies in the six páramo complexes, without a priori information about the groups. Then, the Bayesian Information Criterion (BIC) measured the empirical support for different NMMs. Finally, to address the influence of external and internal filters on the community assembly of each páramo complex, we used the Trait statistics (T_IP.IC, T_IC.IR, T_PC.PR). **Results:** Several species of *frailejones* coexist in each of the páramo complexes. Furthermore, based on taxonomy and species lists, we collected ca.20 different species. However, based on our sampling and the functional traits measured, the best BIC score for the NMMs suggested only 11 species in total for the six complexes. There was support for nine species coexisting in sympatry in the complex of Guantiva-La Rusia. Also, there is a strong internal filtering for leaf thickness and leaf area (lower values of T_IP.IC, compared to the null models), while no traits showed a significant pattern for the other T statistics. **Implications/Conclusions:** *Frailejones* are an example of an adaptive radiation and are a key component to the páramo ecosystem. Functional traits are an additional source of data to understand the species diversity, especially using a method such as NMMs, which offers a new perspective on the phenotypic structure of biodiversity. **Keywords:** Colombia, leaf traits, páramo, root traits

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Unrevealed Plant Food Sources for Stingless Bees: The Potential Use of Pollen and Honey DNA Metabarcoding

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Introduction: Stingless bees (Meliponini) are among the most important pollinators in tropical regions. However, little is known on the breadth of their diet, that is, how many different plant groups they use as food source. **Objective:** In this study, we give a first step towards filling this gap in knowledge by providing a preliminary assessment of their diet using pollen and honey DNA metabarcoding. **Methods:** We analyzed 191 samples of pot-pollen and pot-honey from three commonly managed stingless bee species in the neotropics (*Melipona rufiventris*, *Scaptotrigona postica* and *Tetragonisca angustula*) collected every other week during five months in a biodiversity hotspot in Brazil, the Cerrado. The ITS2 region was matched against a reference library built with GenBank sequences of species previously recorded in the area. **Results:** Our results show that the three analyzed bee species together may visit over 300 species in 55 plant families, a much broader spectrum than pointed out by previous studies based on analyses of pollen morphology, including several species that are not strictly classified as melitophylous. The analyses also reveal that c. 20% of bee food sources (honey and pollen) are from non-native species, including food plants, providing data for conservation planning and food security. **Conclusions:** We point out challenges in conducting pollen-metabarcoding studies in tropical regions including incomplete plant inventories and the lack of adequate DNA-barcode reference libraries (c. 40% of the metabarcoding sequences were identified only to generic level or above), lack of taxonomic review of some groups of bees (even those commonly used for beekeeping). These challenges must be overcome in order to better understand the diets of tropical stingless bees, for both domestication and conservation purposes. To our knowledge, this is the first assessment of the diet of stingless bees in the Neotropics, and one of the first in tropical regions in general, using pollen metabarcoding. **Keywords:** DNA barcode, pollination, Meliponini, Cerrado, plants, ITS2, food security

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Bark Water Vapour Conductance as an Indicator of Water Stress Conditions in Tropical Ecosystems

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Hydraulic traits are widely used to assess vegetation resistance to drought, focusing mostly exclusively on xylem measurements. On the other hand, bark traits are usually related to the tree insulation and resistance to wildfire occurrence. However, recent studies showed that bark traits are also likely relevant to predict tree vulnerability to droughts. Bark water vapour conductance (g_{bark}), for example, is a rarely studied functional trait, but has already been shown to be associated with drought performance in tropical trees. In this sense, we tested whether more access to water is associated with 1) higher bark conductance, and 2) less variation in bark conductance within tree communities. We selected two endmembers along a topographic gradient at Chapada dos Veadeiros National Park (CVNP), to simulate contrasting water stress conditions: on the highest end, savanna communities (SAV) and at the lowest, gallery forest communities (GF). After measuring g_{bark} for the dominant species using the mass loss method, we found, on average, higher g_{bark} in GF, indicating the expected association among the degree of water stress and the investment on bark conductance as a protection against water loss, i.e. the higher the water stress, the lower the bark conductance. Our findings highlight the need to consider bark traits not only as a protection against fire but also as part of plant water use strategies, regulating water loss even when other drought avoidance mechanisms (e.g., leaf senescence, stomatal closure) are in place. **Keywords:** Water vapour bark conductance, tropical savannas, tropical forests,water stress.

Global Problem, Local Impact: Could Cultural Uses of Amazon Trees Be under Climate Threat?

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The Amazon is the greatest tropical forest in the world, sustaining about 30 million people who depend on the resources that the biome provides. In that forest, where biological and cultural diversity go together, the so-called Ecosystem Services (ES) can flow between material and cultural aspects. The Amazon ES might include material products, such as stem barks used for cooking or leaves used in traditional medicine, that also reflect and sustain the local mores and cultures. However, this cultural, social and economic interdependence could be threatened by the effects of ongoing climate changes. Therefore, if modifications in the distribution patterns of species that provide locally important ES occur, so will important social, cultural and economic dynamics. Based on different scenarios of climate change, we aim to identify possible distribution shifts of

plant species connected to Amazon people by the following ES: feeding, medicinal inputs and raw material. A list of 407 plant species from central Brazilian Amazon provided by AmazonFACE, guided a literature review through the keywords "Amazon", "use" and "ethnobotany" at Google Scholar and Web of Science databases. A total of 155 references between peer-reviewed (145) and grey literature (10) gathered 220 species identified as an ES source, with only 29 corresponding to all the three Services. As a final selection, we will consult the GBIF database to check the occurrence of each of these 29 species and gather those that are associated with Brazilian Amazon Protected Areas for Sustainable Use. R language will be used to simulate future climate scenarios and visualize the new distribution of these species. The results will allow us to better understand how climate change can affect relevant species for ES, helping to guide political measures that seek to conservate the Amazon biome while also taking into account the well-being of often overlooked populations. **Keywords:** Amazon Forest, climate change, ecosystem services, niche modeling, brazil, amazonface

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Peatlands of the Amazon Basin: Distribution, Vegetation Types & Conservation Status

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Substantial peat deposits are known to exist across Amazonia. The peatlands of the Pastaza-Marañon Foreland Basin in Northern Peru have received increasing attention from researchers in the past decade, however, peatlands found in other Amazonian countries remain relatively unstudied. Most notably the peatlands of Brazil and Venezuela, which are predicted to cover 260,000 km^2 and 39,000 km^2, respectively. Peatlands are known to be the most carbon dense terrestrial ecosystem, once soil carbon is accounted for, and due to the remote and inaccessible location of many Amazonian peatlands most of them are believed to remain relatively intact. Thus, these ecosystems are likely to harbour large stocks of carbon, which need to be protected. We undertook a systematic review of published literature to assess the current state of knowledge of Amazonian peatlands with the aims of 1) testing the current predictions of peat distribution and extent, 2) identifying different peat forming ecosystems and assessing their ecological and social importance, 3) determining the potential threats to peatlands and 4) evaluating the current conservation status and policy frameworks and how they may help or hinder peatland protection. Based on our systematic review we identified specific regions of conservation concern where current land use change processes could lead to peatland degradation and we identify key areas where further research is needed and make recommendations for policy makers, to help improve our knowledge of this important ecosystem. **Keywords:** Peatlands, Amazonia, peatland conservation, M*auritia Flexuosa*, carbon, land-use change

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Time Series of Analysis of Sentinel-1 and Sentinel-2 Reveals Phenological Shifts in Leafing Dynamics in the Atlantic Forest of Brazil.

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The phenological behavior that many plants exhibit in response to environmental cues is useful for monitoring ecosystem-scale change. Although seasonality in tropical forest canopy leafing has been documented in forests with and without a consistent dry season, mapping the latter over large areas has been more problematic. Furthermore fine scale characterization of responses is required when the objective is to uncover subregional growth patterns and to improve predictions of forests' response to climate shifts. Microwave remote sensing techniques such as C-band and L-band radiometry present key strengths for phenological studies of tropical forests as they are robust to varying atmospheric conditions and sensitive to the high relative permittivity of liquid water in living plant tissues. When used in concert with multispectral data, microwave image time series of canopy leafing reveal differences in timing across forest types, as well as changes in periodic characteristics of seasonal pattern within forest types. In this study, I asked whether phenological leafing patterns can be reliably reproduced to distinguish between two forest types present in the Atlantic Forest: seasonal semi-deciduous and broadleaf evergreen forest. For that I used Google Earth Engine to assemble and process a high temporal (15-day) and high spatial (20m) resolution archive of Sentinel-1 and Sentinel-2 imagery spanning a 6-yr period (2016-2021). I derived seasonal parameters (season length and amplitude) from modeled VH and VH/VV ratio backscatter ($\sigma°$) in Sentinel-1 imagery and Enhanced Vegetation Index (EVI) values derived from Sentinel-2

imagery over 20 1-ha sampling plots in each of the two forest types. Forest type was verified using IBGE and MapBiomas 2019 landcover maps. I then calculated the phenological phase shift p (days) between two curves (σ°-EVI) by both difference in seasonal maxima and difference in the mid-point of the season length. We tested the hypothesis that p can consistently describe semi-deciduous and evergreen broadleaf forest and that number of rainless days (from GSMaP time series) is an adequate meteorological determinant of forest type. We also show how multi-year regional shifts in rainfall patterns can result in significant trends in p for these forest types, suggesting that major forest types of the AF are in a process of significant redistribution. Continuous monitoring of tropical ecosystems with respect to growth and resource use are critical components of global carbon balances and this method may provide significant enhancements to estimates of forest function and its vulnerability to climate-related perturbations. **Keywords:** Leafing phenology, rainforest, c-band radar, regional climate change, ecosystem function

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Fungal Root Endophytes of Tropical Pioneer Plants from a Premontane Forest in Colombia

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Introduction / Background / Justification: It is well-known that leaf fungal endophytes are hyperdiverse in tropical ecosystems, however, little is known about the root endophytes inhabiting tropical tree species. Based on the diversity of hosts and microclimates, a high species diversity of root endophytic fungi associated with tropical tree species is also expected. The interactions between root endophytes and their host as well as with other microorganisms are considered as important as those of relationships established by mycorrhizal fungi. Objective(s)/Hypothesis(es): We aim to document the diversity of root endophytes and to develop a preliminary theoretical framework, tested in a small set of species, that could help start a conversation about potential tradeoffs present in root associated fungi. We expected hyphal color to be negatively correlated with growth rate, since it is believed that the darker the isolate, the slower the growth. We also expect fungi with thinner hyphae to have a higher growth rate and lower biomass, since the construction of thinner hyphae is less energetically costly. **Methods:** We used culturing and molecular identification to characterize the community and functional traits of root fungal endophytes associated with three pioneer plant species (*Bambusa* sp, *Cecropia* sp. and *Oreopanax parviflorus*) in an early successional tropical forest in the Cundinamarca, Colombia. For each fungal species isolated, we measured growth rate, hyphal diameter, and culture coloration. Growth rate assays were performed using Potato Dextrose Agar media. Three replicates per isolate were grown at 25 °C for 23 days and photographed to monitor their diameter. Pigmentation and cytoplasmic contents were described under a light microscope. **Results:** A total of 41 fungal isolates, representing 25 species, were obtained from the roots of the three plant hosts. For *Bambusa* sp. The most abundant genera were *Penicillium* and *Fusarium,* and for *Cecropia* sp. and *Oreopanax parviflorus* was *Diaporthe*. We found different growth patterns among species suggesting a potential role of growth rate in determining fungal hyphal diameter. We also found a significant negative relationship between relative growth rate and hyphal pigmentation and colony color. **Implications/Conclusions:** Ecological substitution is driven by plant pioneer species, which have high colonization capacity but a low capacity to compete. It has been suggested that biotic interactions with pathogens and herbivores can alter successional patterns. Therefore, this is a first step in understanding the functional ecology of root endophytes associated with tropical pioneer plant species that is crucial for understanding succession in tropical forests. **Keywords:** Endophytic fungi, ecological succession, molecular biology, ecology

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Functional Traits of *Quercus humboldtii* across an Environmental and Disturbance Gradient in the Tropical Andes

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Introduction / Background / Justification: High mountain forests in the tropical Andes are ecosystems of great biodiversity and endemism. In Colombia, the Andean oak *Quercus humboldtii* is a characteristic element of montane ecosystems and the only representative of this genus. The wide altitudinal and climatic gradient as well as the ability to tolerate disturbances, makes this species an interesting object of study. However, these forests have high levels of deforestation, fragmentation, and biodiversity loss. Climate change also represents a real threat to the natural distribution of *Q. humboldtii*. Therefore, we ask how environmental and disturbance gradients reflect in the functional traits of the Andean oak. This to determine if habitat pressures have generated a differentiation of functional traits in individuals of the same species, in addition to providing an idea of the limitations and opportunities that plants face depending on the characteristics of their environment. **Objective(s)/Hypothesis(es):** We examined how functional traits in this species vary across an environmental and disturbance gradient in four locations in Colombia. **Methods:**Seven functional traits (specific leaf area, leaf dry matter content, leaf area, leaf nitrogen and carbon content, leaf thickness, specific root length) are assessed in 15-20 adults and 15-20 juveniles at the three sampling sites. We compared functional trait values between adults and juveniles, between sites and analyzed them in the context of temperature and precipitation. **Results:** So far, we have found differences between juveniles and adults in the three sampling sites. There are also differences between adult individuals and among young individuals in each of the sampled sites. **Implications/Conclusions:** Functional traits influence the performance of organisms in a community, therefore, they reflect plant adaptations according to their physical environment and physiological and/or evolutionary trade-offs. Our results indicate that there are functional differences that depend on the climatic characteristics and on the level of disturbance in the sample sites. **Keywords:** Colombia, leaf traits, precipitation, root traits, temperature

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Edaphic Control of Neotropical Grassland Community Assembly

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In many tropical areas, the conversion of native vegetation in pasture involves the chemical modification of the soils. This common management aims to improve pasture productivity by increasing soil nutrient availability. In areas of the Cerrado – the Brazilian savanna –, soils are typically acid and native Cerrado plants are well adapted to these conditions. In these areas, soil liming of pastures inhibits a passive establishment of Cerrado native plants adapted to low nutrient availability. Conversely, the acidification of the soils should mimic the low nutrient edaphic conditions of Cerrado, which could improve the chance of native plants' establishment relative to exotic species. To test this hypothesis, we established a soil manipulation experiment with the main objective of controlling the herbaceous community assembly in grasslands. We deployed 14 blocks, each one with four plots of 5 m x 5 m (25 m2). Each plot within the blocks represented a specific treatment: "control", "acidification", "topsoil removal" and "acidification + topsoil removal". Acidification was undertaken by the addition of iron sulphate to plots. Topsoil removal consisted of the removal of the top 5 cm layer of soil. The "acidification + topsoil removal" treatment had topsoil removed and was acidified with the same iron sulphate solution used in the "acidification" treatment. The acidification treatment had a significant impact on the soil's chemical properties and decreased the amount of some nutrients in the soil relative to control plots. Soil treatments with higher nutritional status have a lower diversity of species and are mostly dominated by exotic species. The proportion of native species cover also varied according to soil chemical features. Acidification seems to benefit native species along the study area by decreasing the dominance and height of exotic species. Furthermore, acidification has a significant effect on species composition. Acidification treatments ("acidification" and "acidification + topsoil removal") showed similar composition in relation to no acidification. We show unprecedented significant patterns in terms of soil nutrient status effect on native plant herbaceous communities in neotropical grasslands. A decrease in soil nutrient status hampers the establishment of the fast-growing and acquisitive exotic species relative to slow-growing conservative native species. Furthermore, we indicate that soil chemical conditions have an important effect

on diversity patterns in Cerrado grasslands and that these concepts can be applied in the ecological restoration of these ecosystems to improve the successful accomplishment of desired outcomes. Keywords : Grasslands, soil, nutrients, functional composition, savanna, restoration, traits, acidification, Cerrado

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Ecosystem Function, Ecosystem Services

Root Trait Variation in Tree Species Prioritized in the Restoration of a Tropical Dry Pasture

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Root traits are important for plant and ecosystem function. Root economic spectrum (RES) has not been very well described, especially in a dry environment like a tropical dry forest. RES is described first with traditional acquisitive-conservative trade-off between species prioritizing resource uptake versus resource storage, however, recently it has been described as another functional trade-off between root diameter and exploring and foraging capacity related with endomycorrhizal associations. Here we show these variation gradients in saplings of elven tree species planted in a restoration experiment in Huila, Colombia. We found the root diameter and branching intensity gradient being the most important for root variations among species, this first trait related negatively with all other traits. The other gradient, of acquisition by specific length and tissue density for carbon conservation, is shown as well but did not represent significant variation between species. Some species like *Celtis iguanaea* and *Casearya corymbosa* present the most different functional strategy with high specific length and branching but less root diameter, other species grouped in opposite trait values. Root functional strategies thus bring information for known species performance in soil and can be used to prioritize species for ecological restoration plans. **Keywords:** Specific root length, root dry matter content, restoration, functional ecology

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Xylem Anatomical Traits and Their Relation to Measures of Hydraulic Safety in a Neotropical Rainforest

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Introduction: The anatomical composition of wood underpins hydraulic transport and storage functions of trees. Together, anatomical traits of the vessels, fibers, and parenchyma influence the plants resistance to embolism formation (P50) and availability of internal water storage (sapwood capacitance), both of which can impact hydraulic vulnerability under drought stress. However, the degree to which interspecific variation in anatomical traits correspond with measures of hydraulic vulnerability has not been extensively studied in tropical angiosperms. **Objectives:** We compared a suite of xylem anatomical measurements to measures of embolism resistance and stem sapwood capacitance for branches from five individuals of twelve species representing a range of life history strategies in a tropical rainforest in Puerto Rico. We asked: (1) how do stem anatomical traits correlate with embolism resistance and sapwood capacitance? (2) how do structure-function relationships vary across species with different life-history traits? **Methods:** We used a sledge microtome and high-resolution slide scanner with digital analysis software to quantify a suite of anatomical traits (vessel dimensions, potential hydraulic conductivity, vessel grouping indices) of branch-wood cross sections, and compared these with hydraulic traits (P50 and stem capacitance) previously collected on the same individuals. **Results:** We found correlations at the site level between hydraulic traits (P50 and sapwood capacitance), and anatomical traits (including the size and grouping of vessels). Vessel diameter and vessel density were negatively and positively correlated, respectively, with more embolism resistant P50 values. While vessel diameter and the

vessel grouping index were positively correlated with sapwood capacitance and vessel density was negatively correlated. **Conclusions:** At the site level, vessel characteristics were related to hydraulic traits indicating a link in how branches manage hydraulic stress. These results suggest that the anatomical design of a tree's xylem has implications on its ability to manage different kinds of drought stress, therefore, a better understanding of anatomical traits and their inter- and intraspecific variability will help to improve our understanding of trees' hydraulic vulnerability. **Keywords:** Xylem, hydraulics, anatomy, structure-function, drought

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Geodiversity in Colombian Paramos and Its Relationship to Biodiversity Patterns

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Geodiversity is becoming an important tool to build conservation strategies that transcend the biological components of nature. Greater diversity in the abiotic components of nature translates into more resources and different niches, lowering intraspecific competition, therefore, promoting biodiversity. Geodiversity has rarely been studied in Colombia[pa1], studies regarding this topic have been mostly focused in Europe and Brazil, but it has the potential to become a tool to study natural diversity patterns. Paramos are heterogeneous, high-altitude Andean ecosystems that play a key role in water balance and maintain many endemic species. Paramos exist in the three Colombian cordilleras. Given the differences in their geological and climatic histories, studying their geodiversity can help describe those differences and thus understand the relationship between geodiversity and biodiversity patterns in the area. To test this relationship, we chose three different national parks: Tatamá (Western Cordillera), Los Nevados (Central Cordillera), and Chingaza (Eastern Cordillera). We applied the methodology of Araujo & Pereira (2018) to estimate a geodiversity index, based on the construction of five subindices (geology, geomorphology, pedology, hydrology, and climate) that were normalized and added. We then explored the correlation between those indices and bird richness and a proxy for biodiversity, habitat heterogeneity data based on EVI measurements. Geodiversity maps show significant differences between the studied areas with Chingaza having the highest geodiversity index values (3.11 out of 5), followed by Los Nevados, although both have great variability. Tatamá has the lowest geodiversity values and the lowest variability. The geodiversity index correlates positively with both biodiversity measurements for high geodiversity values (>1). Individual subindexes (i. e. climate) better predict biodiversity than the general index, probably because of the different directions of the predictions. The strongest components explaining biodiversity patterns are soil and climate, followed by geomorphology. Furthermore, the relative importance of components varied among Paramos suggesting that geodiversity indexes are regionally variable. Bird richness and habitat heterogeneity both showed similar results compared to geodiversity subindexes. Nowadays soil diversity in Paramos is threatened by anthropic activities and climate diversity by global warming, these are the abiotic elements that may be shaping the biodiversity patterns in Paramos and therefore must be the priority to define conservation strategies. Conservation of natural landscapes should consider more than the biological component to ensure healthy and functional ecosystems in the future. Geodiversity estimations help to predict biodiversity and add value to heritage sites and protected areas from a more holistic perspective. **Keywords:** Geodiversity, Biodiversity, Paramo, Geographic Information Systems (GIS).

Habitat Dynamics of Plant Communities Typical of the Colombian – South American Eastern Andes.

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Understanding the factors that control the dynamics of plant populations is fundamental for the generation of tools that allow the quantification of the goods and services generated by ecosystems. The Colombian paramos are located mainly in the northern Andes of South America, dominated by species of the genera *Espeletia* and *Espeletiopsis* of the Asteraceae family. Mortality and recruitment in the paramo vegetation was determined as an effect of the changing climate in the rainy and dry seasons during 5 years, in 6 localities and in the altitudinal gradient between 3000 and 3800 meters. A network of 200 permanent monitoring plots (100 m) was established in the Guerrero and Guacheneque paramos of the eastern cordillera. Climatic variability was also monitored, recording information during drought and rainy seasons. A multiple-factor analysis of variance (locality, altitudinal gradient and climatic season) was performed with a confidence level of 95%. Annual mortality (rm%) and recruitment (rr%) rates were used as response variables. Average mortality was 12.5%.

In the dry period this value exceeded 18%, classifying mortality as catastrophic due to the effect of soil water deficit. The middle part of the altitudinal gradient located between 3450 and 3500 meters generates the highest mortality for the vegetation, exceeding 16% on average. In the rainy season, mortality only reaches 8%. When comparing the annual mortality rate between climatic seasons, they differ by more than 70%. The average recruitment value was 19%, decreasing to 7% in the dry season. The highest recruitment value was 29% in the rainy season. The middle part of the altitudinal gradient showed the highest value with 21%. These results contribute to the identification of restoration and conservation tools for these communities. **Keywords:** Climate change, ecology, restoration, paramo

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Functional Traits Predict Leaf-litter Decomposition along a Successional Gradient in High Andean Tropical Forests at Early Stages of Decay

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Background: Highland Andean Tropical Forests (HATFs) represent a global hotspot of biodiversity, characterized by rapid-human transformation, extraordinary local endemism, high rates of beta-diversity, and major global carbon sinks. However, despite being one of the most threatened ecosystems in the Neotropics, our understanding of critical carbon fluxes, such as leaf-litter decomposition, are limited. In particular, the relationships between decomposition, leaf functional traits and forest succession remain poorly known. **Objective and Hypothesis:** Our main goal was to determine how leaf functional traits relate to leaf-litter decomposition in 15 plant species, along a broad successional gradient in HATFs. We hypothesized that 1) leaf traits will show a slow–fast-continuum following the leaf economic spectrum (LES) where species with cheap leaves constructed of low-density tissue will decompose faster than species with well-protected leaves and 2) decomposition will be higher in mature forests than secondary ones because of higher biomass and diversity of decomposer community in the former. **Methods:** 14 permanent plots (20x20 m) encompassing early and late successional forests were established a Bogota, Colombia, between 2600 and 3000 m elevation. We established three litter beds per plot (n=42) with litterbags of 15 individual species and two litter mixtures. Litterbags were collected at 3 and 6 months (n=1428). Fresh green leaves from three individuals per species were collected to measure eight functional traits of the LES. Plots were classified as mature or secondary forests based on previous studies of floristic composition and aboveground biomass measured in the plots. Results: We found strong relationships between decomposition and specific leaf area (R^2=0.6, β=0.32), maximum leaf photosynthetic rate (R^2=0.49, β=0.27), leaf carbon concentration (R^2=0.55, β=-0.23), leaf nitrogen concentration (R^2=0,39, β=1.02), leaf mass per area (R^2 = 0,40, β=-0.15) and leaf thickness (R^2=0,26, β=-0). Although mature forests had higher values of decomposition than secondary ones, the differences were not significant (U=60021, P>0,05). Conclusions: The LES predicts leaf-litter decomposition in HATFs, which shows that traits from living plants are important in the first stages of decay, thus affecting nutrient and carbon cycling. At these initial phases of decay, no difference was found between mature and secondary forests, but this pattern could change at later stages of decomposition, considering that soil carbon cycling in HATFs is generally slow **Keywords:** Trait-based approach, Mountain ecosystems, Litter decomposition, Ecological succession

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Soil Respiration and Litter Decomposition Rates between High Andean Forests at Different Aging Stages

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Conservation of secondary tropical forests represents a great opportunity to capture carbon from the atmosphere as they have been growing in abandoned areas where previous productive activities occurred. Considering that the soil is the greatest long term carbon sink in terrestrial ecosystems and that secondary forests are the most widely distributed ecosystems around the world, it is a priority to understand how soil processes related to carbon cycling and storage, such as litter decomposition and soil respiration, vary with forest age. We hypothesized that, along ecological succession, differences in ecosystem functioning, structure, and microclimate, might result in differences in respiration and decomposition rates. We measured soil respiration (Rs) and litter decomposition (using the Tea Bag Index) rates in 18 plots of secondary high-Andean forests, in 3 different sites near the city of Bogotá, Colombia. The forests in the plots belonged to two different age stages, the younger ones which are 10 to 30 years old, and the more mature ones which are 60 to 100 years old. Additionally, we quantified the relative importance of functional traits of woody species, forest structure, and microclimatic variables such as soil moisture, temperature, and pH, to study their potential links with decomposition and respiration rates. We found differences in decomposition and respiration rates between the sites but no significant differences between the age stages of the forests. This is correlated with the fact that the soil microclimate varied slightly between the stages, but more remarkably between sites. These results highlight the resilience of secondary high Andean forests in maintaining ecosystem processes related with carbon accumulation despite its aging time and it is considerable as another good reason to conserve these naturally regenerated areas, especially when aboveground-only approaches to estimate ecosystem C balances are blind to these similarities between younger and mature secondary forests. **Keywords:** Soil respiration, decomposition, High-Andean forests, carbon cycling, succession

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Seed Germination of a Mirmechocorous Plant Endemic of the Brazilian Semiarid Region: the Wolf Is Not so Bad

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Analyzing the mechanisms and processes that affect seed dispersal and germination is important to understand distribution and abundance of plant species, and help establish strategies for the restoration of ecosystem services. In this study we evaluated the role of two different vectors (ants and maned Wolf) on seed germination of *Copaifera arenicola* (Fabaceae). This plant species is endemic of Brazilian semi-arid region, has typical traits of the myrmechocory syndrome, and great potential to be used in restoration programs of degraded areas. In order to evaluate the role of these two potential dispersing vectors in the germination of *C. arenicola* seeds we compared the speed and germination percentage of seeds submitted to four treatments under controlled conditions: (t1) seeds manipulated by ant *Atta laevigata* (Formicidae), (t2) seeds ingested and defecated by maned wolf (*Chrysocyon brachyurus: Carnivora, Canidae*), (t3) seeds that had the elaiosome removed manually and, (t4) seeds with elaiosomes (unmanipulated seeds). The results of survival analysis showed that seeds manipulated by ants and seeds that had the elaiosome removed manually required less time to germinate than seeds ingested by maned wolf and unmanipulated seeds. In this case it is probably that the presence of elaiosome may act as an inhibitor of seed germination. We also suggest that small remnants of the elaiosome that resisted digestion during its passage through the digestive tract of the maned wolf may have affected the speed of seed germination. Our results also showed that seeds manipulated by ants and those handled for elaiosome removal showed higher germination percentage than the other two treatments (i.e. seeds ingested by maned wolf and unmanipulated seeds). However, the seeds ingested by maned wolf showed a high germination percentage (about 87%) which was statistically higher (about 72%) than seeds belonging to treatment t4 (unmanipulated seeds). Generally, the ant *A. laevigata* collect seeds from the plants and transport them inside the anthills for use the elaiosome. After elaiosome removal, ants discard the seeds near anthill. This procedure usually results in a grouped pattern of seed distribution in the environment. In contrast, the wide area of life of the maned wolf allows the seeds to be dispersed over long distances from the mother plant, decreasing mortality associated with density-dependent factors, promoting the colonization of new habitats and connectivity among populations. Therefore, the presence of these vectors occurring in sympatric condition provides complementary seed dispersal services that are important for the diversity conservation. **Keywords:** *Atta laevigata, Copaifera arenicola*, maned wolf, myrmecochory, seed dispersal.

Functional Responses of Species of the Genus Zamia Due to Anthropic Disturbances in the Biogeographic Chocó, Colombia.

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In plant ecology there is a global pattern known as "Economic spectrum of leaves", on the one hand, there are "purchasing" plants and on the other "conservative" plants. However, the functional adaptations when the light habitat of individuals of the same species are affected by human disturbances are unknown. In situ functional traits and habitat variables were evaluated in three endemic species of the genus *Zamia* (*Z. amplifolia*, *Z. chigua* and *Z. roezlii*) and whether these change intra and interspecifically associated with a pattern of adaptation to the environment in environments of contrast. The research was carried out in two forests in the Bajo Calima region of the Colombian Biogeographical Chocó, considered one of the most humid and diverse places in the world. Two plots of 1 ha were established with registration units in contrasting forest areas, a secondary forest with more than 50 years of recovery and a contemporary secondary forest, but with recurrent logging. For each of the plots, the individuals of the *Zamia* genus were evaluated, and the variables associated with the structure of the forest, the diversity, and the habitat of the growth environment of the individuals were characterized. Two contrasting light habitats were identified, an undisturbed forest with high species richness and an intervened forest with high presence of light, but low species richness. *Z. amplifolia* individuals presented purchasing tendencies with high AFE and low R/S ratio, in contrast to *Z. chigua* and *Z. roezlii*, which showed conservative tendencies with low AFE and high R/S ratio, preferring open and light-rich environments. In intervened forests, the population density decreases and the mortality rate increases, so the permanence of these species in the ecological community are endangered. With the above, adaptation and conservation strategies can be generated in habitats intervened by humans. **Keywords:** Biodiversity conservation, deforestation, investigation, ecology

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Ecosystem Function, Ecosystem Services

Machine Learning as a Tool for the Identification of Palm Phytoliths in the Province of Napo-Ecuador

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Palms are the most abundant plants in the Amazon that play a fundamental role in the carbon cycle and climate. However, how palms have changed their distribution and abundance over time under the impact of pre-Columbian cultures is still under debate. Understanding whether the current distribution of palms is natural or anthropogenic is fundamental to outlining conservation or restoration plans. To reconstruct how palm distribution has changed in the past, indicators such as phytoliths can be used. Amazonian palms produce large quantities of phytoliths, which are silica bodies formed inside the cells. Phytoliths, due to their stable chemical composition, low solubility and resistance to degradation are preserved in soils for thousands or millions of years. This means that soils are capable of recording and storing information about the palm communities that existed in the past. However, one of the challenges in the study of phytoliths centers on the precise description of their morphology that allows their identification. Traditional methods of phytolith identification are carried out by trained personnel, take a long time and are susceptible to biases. The development of new tools such as machine learning, allows to eliminate human bias when performing repetitive tasks, especially in the recognition and classification of images. In this study we propose to develop a tool that allows the identification of phytoliths based on machine learning algorithms oriented to differentiate palms at the taxonomic level of genus or species. For this purpose, 21 palm species were collected in Napo, Ecuador (*Aphandra*, *Astrocaryum, Bactris, Ceroxylon, Dyctocaryum, Euterpe, Geonoma, Iriartea, Mauritia, Oenocarpus, Prestoea, Wittinia)*. The selection was made considering their socioeconomic value (utility) and abundance in the communities. This was done as an indicator of their possible use by pre-Columbian communities. Phytolith samples were prepared by chemical digestion and incineration. 4000 photographs were taken in an inverted microscope with magnification of 100x and evaluated using machine learning techniques to identify phytolith species and facilitate the reconstruction process of the pre-Columbian Amazonian landscape **Keywords:** Machine learning, phytoliths, reconstruction, landscape restoration and vegetation.

Characterization of the Xylophage Fungi Community and Their Functional Traits in a Lower Montane Forest of Colombia

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Introduction/Background/Justification: Xylophage fungi are organisms that use wood's structural components as a source of energy. They play a crucial role in biogeochemical cycles using different metabolic pathways to carry out organic matter degradation processes. Based on their enzymatic capabilities, there are classified in three categories: white, brown, and soft rot. Recently it has been recognized that fungal functional diversity and traits are important to predict ecosystem responses to environmental changes. However, there is little knowledge regarding the traits of tropical xylophage fungi. For example, in Colombia, the rot type of about 40% of saprotroph wood fungi is unknow. **Objective(s)/Hypothesis(es):** The objective is to characterize the xylophage fungal community and associated functional traits to explore potential trade-offs in a lower mountain rainforest in the Andean cordillera of Colombia. **Methods:** Sampling of xylophage fungi took place in the

municipality of La Vega, Cundinamarca, using opportunistic collection. Fungi decay type was documented in the field, and morphological descriptions of the fruiting bodies were done in fresh. Furthermore, the collected species were isolated in petri dishes with Potato Dextrose Agar substrate. Then, growth rate, hyphae diameter and coloration, enzyme production and spore morphology were measured on pure cultures. In addition, DNA extractions from both the fruiting body and cultures were done for molecular identification. **Results:** Polyporales was the most abundant order, with the *Ganoderma* and *Hexagonia* being the most abundant genera. All the species collected showed white rot, and in the case of some genera such as *Xylaria,* this is to our knowledge, the first report of its rot type for this genus. We expect that fungi enzymatic activity will show a relationship with some of the measured morphological traits to stablish potential trade-offs, life history strategies and phylogenetic conservatism or not of the selected fungal traits. **Implications/Conclusions:** Xylophagous fungi are of great importance due to their role as indicators of environmental changes since their diversity is influenced by the availability of resources in the environment. Information about the enzymatic activity of this group is critical given its influence in the carbon cycle. For this reason, it is essential to characterize the community of wood-decomposing fungi and their functional traits to be able to predict their potential responses to global change. **Keywords:** Fungi, Xylophage, functional traits, rot, ITS, phylogenetic

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Examining the Impacts of Edge Effects on Plant Water Use in Amazon-Cerrado Transitional Forest

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Introduction: Agriculture is driving large scale deforestation along the southern edge of the Amazon rainforest creating long edge regions where the forest borders on cropland. Trees in these edge regions are exposed to both higher temperatures and more arid conditions on average as well as experiencing more extreme temperatures and frequent droughts. These conditions can negatively impact the structure and function of these forests, but the extent to which this is the case has yet to be adequately explored. Our study aims to quantify how trees at the edge are forced to change their water use strategies in response to these conditions. Hypotheses: Our first hypothesis was that trees at the edge would be subject to increased evaporative demand during the day and thus we expected that they would have higher (more negative) leaf water potentials (LWP) at midday. Our second hypothesis was that trees at the edge would have their stomata open earlier due to decreased evaporative demand in the morning and as a result we expected that they would also show a higher LWP predawn compared to the forest interior. Our third hypothesis was that due to the increased water stress trees at the edge would have to closely regulate their stomata and therefore the absolute difference between the predawn and midday LWPs would be lower for the trees at the edge. **Methods:** We used a dataset of predawn and midday LWP measurements for 53 tree species from the edge and 57 tree species in the interior. The data was collected in a Amazon-Cerrado transitional forest at the Tanguro Farm which borders on active cropland which is located in the Upper Xingu Basin, MT, Brazil. **Results:** We found that the mean LWP values were significantly higher at the forest edge compared with the forest interior during both the predawn and midday ($p > 0.0001$ & $p > 0.001$ respectively). We did not observe any significant change in the absolute difference between the predawn and midday LWP for species at the edge and the interior. In contrast, we did observe that there was a significant variation in how the absolute difference changed between the edge and interior for individual species. **Implications:** Our findings suggest that trees in the edge regions are having to acclimate to use water differently to those in the forest interior. Understanding how this impacts forest structure and function is crucial as these edge regions expand through continuing deforestation and fragmentation. **Keywords:** Traits, ecophysiology, Amazon, Cerrado, edge, deforestation, fragmentation, water-use, land-use, stress

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Effect of Species Prioritized for Restoration on Soil Properties in an Inter-Andean Tropical Dry Forest (Huila, Colombia)

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Tropical dry forests are the most critically endangered ecosystem in the Neotropic, and active restoration has been a prioritized activity to recover forest cover and soil properties. However, abandoned pastures are a significant challenge to successful restoration because soils have been strongly degraded. We used a restoration experiment involving 11 tree species growing in the same abandoned pasture for eight years to determine if species with different functional strategies have a contrasting impact on soil properties. We expect acquisitive species with high hydraulic efficiency have drier and more compact soils than conservative species and controls dominated by grasses. We did find significant differences in all soil properties (Kolmogorov-Smirnov test) between species and controls. Species such as *Sapindus saponaria, Guazuma ulmifolia, Ochroma pyramidale* showed soils with high humidity for both seasons and higher content of aggregates in the soil, here species such as *Chloroleucom manguense* and *Celtis iguanaea* were also included. On the other hand, it was evidenced that species such as *S. Saponaria, C. manguense, O. pyramidale* and *C. iguanaea* indicated less compact soils and with less salinity than grasses. Contrary to expected, it was found that species such as *G. ulmifolia, J. caucana* and *S. saponaria* with high values of dry matter root content, thick root density and average diameter traits related to resource conservation, showed very wet soils , while *Celtis iguanaea* and *Caseraia corimbosa*, the species with high specific root length , fine root density and branching frequency characteristic of the acquisitive strategies, showed soils with low moisture. Our results show that species have different impacts on soil properties and explore which functional characteristics determine which impacts will be key to species prioritization. Keywords: restoration, soil propierties, species, roots, dry forest, pastures. **Keywords:** Restoration, soil properties, species, roots, dry forest, pastures.

Loss of Diversity Caused by Fire and the Future Trajectories of Transitional Tropical Forests in the Amazon

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Background*:* Episodic droughts play important roles in shaping the structure, diversity, and functioning of tropical forests and their capacity to carbon stock. Droughts contribute to tree mortality, alter ecosystem processes, and interfere with plant competition for resources. Such disturbances increasingly interact with anthropogenic activities, as forests become more fragmented and more flammable. Identifying plant traits that confer increased forest resilience to global changes and disturbances can certainly inform more effective future trajectories of tropical forests in the Amazon. **Objectives**: In this perspective, we quantified the impacts of drought-fire interactions on species, functional, and phylogenetic diversity in transitional tropical forests in the Amazon. We also seek to understand how fast do drought- and fire-disturbed forests recover their structure, diversity, and functioning. We hypothesized that low-intensity, repeated fires select for species that are taxonomically and functionally aggregated, more adapted to fire, and collectively form a less diverse forest. Moreover, severe but less frequent fires drive greater losses in diversity, with more seedlings dominated by fire-resistant species. **Methods**: To test this hypothesis, we used a large-scale, long-term (nine-year) fire experiment in southeast Amazonia in three 50-ha plots, with unburned Control and two different fire regimes (burned annually - B1yr and burned every three years – B3yr), between 2004 and 2010. During the subsequent years (8 years), we are evaluating the forest recovery process. We used biannual inventory data on tree recruitment and tree mortality, and when severe droughts occurred—in 2007, 2010, 2015. We used these inventories to quantify the change over time in patterns of structure, diversity, and functioning of tropical forests. **Results**: We found a marked change in the richness, diversity, and functioning patterns of the communities during the experiment, which were related to the frequency and intensity of disturbances. We registered that species richness sharply declined with fires co-occurring with droughts, and species composition shifted throughout the duration of the experiment. Along the forest edge of the burned plots, the forest community became dominated by species with faster relative growth, thinner leaves, thinner bark, and lower height. **Implications**: Our results point to Amazonian forests being highly resilient to compounding disturbances but also that high-intense repeated fires

along the forest edge can lead to substantial reductions in species richness, shifts in species composition, and changes in functional traits towards fast-growth, smaller-sized species. **Keywords:** Amazon, climate change, drought, ecosystems resilience, functional traits, mortality

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Phenology and Stem Growth in Trees from the Arboretum at National University of Colombia, Medellín.

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The study of cyclic or recurrent biological events in plants often is called phenology. While seasonal growth rhythms in tropical tree species often are inferred from leaf turnover or reproductive structures, stem phenology is little studied. We still lack a broad understanding of rhythmic growth in tropical tree species. Hence, we asked if growth rhythms are evident through phenological observations (leaf turnover and dendrometers)? what determines growth rhythms? When and by how much do trees are growing? To explore these questions, we study 38 tree species from the arboretum at the National University of Colombia, Medellín campus. The arboretum is one of the most diverse green areas in Medellín city ca more than 500 tree species. The study area is characterized by bimodal precipitation, two peaks of high precipitation, and two periods of reduced precipitation, only one is categorized as a dry season (December to February: precipitation < 100mm month^{-1}). We performed phenological observations (i.e., detailed leaf observations and band dendrometers measurements) weekly for 15 months. We found that the stem increment in most species is reduced or stopped between November – February: the second late rainy season, and during the dry season. The leaf shedding occurs during the dry season and new leaves at the end of the same season. The higher stem growth increment occurs during the first rainfall peak but often continues until the second peak (September - November). Our preliminary phenological observations suggest that most tree species studied tend to have an annual growth cycle, probably limited by the dry season. Such evidence also allows us to know when and how long-time tree growth occurs throughout the year. Seasonal stem increment may also imply regular tree-ring formation. However, more observations together with wood anatomy descriptions should complement future phenological monitoring at the campus Arboretum. **Keywords:** Dendrometers, phenology, tree growth, seasonal growth, tropical trees, biodiversity.

Hydraulic Adjustments Linked to Leaf Phenology in Brazil Nut Trees (*Bertholletia excelsa*)

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Introduction: Brazil nut trees (*Bertholletia excelsa)* have economic, social, and ecological importance in the Amazon region. This species is widely distributed along the basin. In the Amazon Forest, tree mortality is linked to reduced forest productivity and has been related mainly to extreme drought events. Mechanisms associated with xylem vulnerability to embolism, leaf osmotic adjustments, and leaf phenology interacting in determining the species' resistance to extreme droughts. Tradeoffs between hydraulic and phenology regulation remain under-studied in Brazil nut trees. **Hypothesis:** Our first hypothesis is that *B. excelsa* have low hydraulic safety than other Amazon species because this species is deciduous losing their leaves during the dry season to reduce water loss and tension over the xylem. We also hypothesize that old leaves have lower water regulation capacity and less drought tolerance. In contrast, young leaves have higher water content and turgor loss point. **Methods:** We sampled nine trees' branches corresponding to different leaf ages (young, mature, and old) that were growing in a commercial plantation in the central Amazon. We built embolism vulnerability and pressure-volume curves, then we determined the leaf osmotic potential at maximum turgor (Po), turgor loss point (TLP), leaf modulus of elasticity (E) and leaf relative water content (RWC), and the points of 12%, 50%, and 88% loss of hydraulic conductivity in the branches (P12, P50, and P88, respectively). **Results:** We found that this species has a narrow hydraulic safety margin – the difference between the point at which 50% loss of conductivity occurs and the minimum water potential measured in the field (0.46 MPa). Young leaves have more elastic walls and high RWC. As the leaves age, they reduce their ability to control their hydration status (showing lower Po, lower TLP, higher E with an inelastic cell wall, and low RWC), experiencing high-stress levels in the field. The species avoids increasing embolism levels in the stem caused by the deregulation of water potential in old leaves, dropping old leaves, and growing new leaves that are more efficient in water regulation through

the dry season. Additionally, shedding old leaves may reduce water loss by transpiration during the dry season, resulting in a complementary mechanism that helps individuals surviving during the seasonal drought period. **Conclusions/Implications:** *Bertholletia excelsa* respond to seasonal droughts connecting the deciduousness with water regulation physiology. Increasing droughts frequency and intensity, this species may face timing-adapting issues coordinating leaf, xylem, and phenology responses. Implying in growth reduction, irregular fruit production under prolonged drought. **Keywords:** Amazon, hydraulic traits, tree mortality, climate change.

How Is Leaf Silicon Concentration Related with Other Leaf Traits in Lowland Tropical Forest Trees in Pasoh, Malaysia?

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For many plants, silicon is a beneficial element that enhances defense against herbivores and alleviate abiotic stresses. Leaf silicon concentration varies widely among plants, however, its ecological significance remains unknown in a species-rich lowland tropical forest. This study asked how leaf silicon concentration is coordinated with other leaf traits. First, we hypothesized that leaf silicon concentration is negatively correlated with other traits linked with defense against herbivores (e.g., leaf mass per area and toughness). Second, the direction in relationships of leaf silicon concentration with other leaf traits may not differ among families. We conducted this study in a lowland tropical forest in Pasoh Forest Reserve in Malaysia. Leaf samples were collected 2-5 leaves from the outer crowns of 77 tree species in the Forest Reserve. The subsample was used to measure leaf silicon concentration. We measured leaf area (LA), leaf mass per area (LMA), thickness, toughness, succulence, and leaf dry matter content (LDMC) for subsample of 1-3 leaves per tree. We examined correlations between silicon concentration and other traits, and then performed the principal component analysis (PCA). We chose top-five dominant families (Annonaceae, Burseraceae, Dipterocarpaceae, Euphorbiaceae and Fabaceae, N 6 spp. per family) for testing the second hypothesis. Leaf silicon concentration ranged from 0.4 to 125.8 mg g^{-1} among 77 study species. Leaf silicon concentration was not significantly correlated with LA, LMA, toughness, succulence and LDMC but weakly with thickness. The first axis of PCA explained 37.0% of the total variation, substantially contributed by LA, LMA and thickness. The second axis explained 27.1% and was largely related with toughness, succulence and LDMC. Leaf silicon concentration showed the largest contribution to the third axis. In a family-level analysis, the directions in the relationships for LA, LMA, and succulence did not significantly differ among the five families, while the directions for leaf dry mass content, thickness and toughness differed. The significant correlations between leaf silicon concentration and some other traits were found in two families of Burseraceae and Dipterocarpaceae. In Burseraceae, leaf silicon concentration was positively correlated with LMA, thickness, toughness and LDMC. In Dipterocarpaceae, leaf silicon concentration was negatively correlated with toughness. Overall, our results suggest that leaf Si concentration is independent from commonly measured leaf traits. The directions in relationships between leaf Si concentration and some leaf traits differ among families possibly because families show different distribution and localization patterns of silica bodies in leaves. **Keywords:** Silicon, traits, trees, Malaysia, lowland forest

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Malagasy Fruit-frugivore Network:Ficus as a Model System

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Seed dispersal play a critical part in forest regeneration dynamics. In tropical systems most woody species rely on dispersal by animals in a mutualistic interaction in which animals receive a nutritional reward in return for seed dispersal services, forming a complex network of entities. Madagascar is a hotspot of endemic biodiversity in both plants and frugivores. One of its unique features is the paucity of Malagasy frugivores: only 10% of birds, 7% of bats include fruits in their diet and few species are known to be effective dispersers for forest regeneration. The main seed disperser on the island are lemurs, 91% of which are classified as at risk of extinction due to habitat loss and climate change effects. Thus, understanding frugivore-plant network is crucial, for both basic knowledge and conservation. Fruit-frugivore interactions are governed by trait matching between fruit characteristic and animal senses. However, few studies have included fruit traits analysis and sensorial capacity of frugivores in their natural habitat. The objectives of this study are to

examine the importance of Malagasy frugivores for seed dispersal using figs (*Ficus spp.*) as a model system. We aim at (a) identifying the network structure, and particularly the degree of specialization among different biomes across the island, (b) assess the relationship between network structure and fruit traits. We will collect data through fruiting tree observation by using camera-trap to establish a quantitative seed-dispersal network, and collect various fruit traits. The results can be extrapolated to other plant taxa and thus be relevant for both fundamental understanding of tropical forest dynamics and conservation efforts. **Keywords:** Seed dispersal, Ficus, frugivore sensorial capacity, Madagascar

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Effect of Leaf Litter Flow and Light Environment on the Dynamics of the Seedling Bank of the Valley of Magdalena.

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The research was carried out in the tropical dry forest of the upper Magdalena (Tolima - Colombia). A network of permanent monitoring plots were established through protocols described in the Dryflor Manual for dry forest, consisting of a main unit of 1 ha and 4 peripheral units of 0.25 ha, located in topographical reliefs of valleys and hills, as well as in undisturbed canopy covers and canopy affected by the action of clearings. Two experiments were proposed, the first, located within the main monitoring unit associated with the sources of variation of the climatic seasons and relief topography, in which litter and debris were measured at the end of each climatic season. The second experiment has been established in the peripheral units related to sources of variation of light environments of clearing and undisturbed canopy, as well as different levels of litter and percentages of population density within the seedling banks, evaluating structural and functional variables having as response mortality rates, recruitment, relative growth. The results showed that litter production is differentiated in each source of variation and in their interactions, presenting its highest value in the dry season in the valley relief with 2590.9Kg.ha-1. The dynamics of the seedling bank presented the greatest differences in their mortality, recruitment and growth rates when they depend directly on the light environment to which they are exposed. The results found contribute significantly to the generation of knowledge about tropical dry forests and the lower categories of natural regeneration, which are the important basis for the generation of ecological management strategies for subsequent conservation and ecological restoration of forests. **Keywords:** Investigation, habit, dry forest, seedling bank

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Environmental Change (Global/Local)

Global Patterns of Net Primary Production Change and Species Richness Change in the Anthropocene

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Humans have altered ecosystem productivity and biodiversity worldwide by changing land cover types and influencing nutrient cycling. It has long been discussed that net primary productivity (NPP) is correlated with species richness. However, the long-term effects of human modification on productivity and biodiversity change, and particularly on the relationship between the two, are poorly understood. This study tested the hypothesis that human modification tends to increase biodiversity in low productivity ecosystems (where human habitat management is likely to increase productivity) and decreases biodiversity in ecosystems that originally had high productivity. We generated a large worldwide dataset of NPP and associated species richness from MODIS land cover and NPP products (from 2001 to 2019) and the PREDICTS biodiversity database, involving 13,275 sites and 9 taxonomic groups. This enabled comparisons of species richness differences between relatively natural (RNV) and human-modified vegetation (MV) in the same local area, considering 102 types of land-use transitions. We found that 1) The more productive an area (i.e., the productivity of RNV) is, the greater the reduction of productivity (i.e., the productivity of MV) in human-transformed areas. On average, NPP was 0.03 gC/m^2/yr higher in RNV than in MV, when comparing sites within a particular area (study). NPP is reduced when humans transform the forests to other vegetation types but often increases when shrublands, savannas and grasslands are converted to other land uses. 2) Species richness is usually reduced when the vegetation changes to a completely different land-use type, but sometimes increases when vegetation modification is relatively minor. Conversion to croplands generates the greatest decrease in species richness. 3) Contrary to the original hypothesis, there is no significant relationship between species richness differences (comparisons between RNV and MV) and the productivity differences, when considering conversions across land cover types. The results reveal that human modification tends to increase NPP in low productive ecosystems, but species richness declines in most major conversions of human-induced land-use changes, even in places where a modification has made the productivity increase. **Keywords:** Biodiversity change, land-use change, PREDICTS project, Anthropogenic drivers

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Comparison between a Native Forest and Vegetation Introduced regarding Plant Diversity and Soil Quality

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Pine and eucalyptus plantations are common in the Ecuadorian highlands duo to their traditional forest use. However, these plantations have displaced the native flora, due to the deforestation of native forest and the introduction of more commercial species. This transformation of the forest is causing the loss of species and also changes in the ecosystem services. In this study, the structure and composition of the plant community of the herbaceous and shrub-arboreal stratum were compared in addition to the quality of the soil between two ecosystems with different land use in an Andean landscape of northern Ecuador, specifically in La Esperanza parish, Pedro Moncayo County, Pichincha Province. It was observed that the plant structure and composition in the three layers was different between the two systems studied, there was greater richness, abundance and diversity in the native forest. The herb layer in the native forest was dominated by *Leptostigma pilosum* and *Peperomia fruticetorum,* while, in the planted forest, dominance of *Calamagrostis cf. effusa* and *Pennisetum*

clandestinum was detected. Likewise, the results suggest better soil quality conditions in the native forest than in the planted forest: where the content of organic material and the values of Cation Exchange Capacity were significantly higher in the native forest, while planted forest presented a more acidic soil pH than in native forest. In this way, the impact of the land cover change can be observed over the characteristics of the soil and over the composition and structure of herbaceous plants, like loss of species and changes in ecosystem services. **Keywords:** Eucalyptus, Herbaceous, Native forest, Soil Organic Material, Pinus, Soil.

Effects of Elevated CO2 and Phosphorus Availability on Productivity of Inga Edulis Seedlings in the Understory of an Amazon Forest

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Theory predicts that plants exposed to increased atmospheric CO_2 concentration increase their photosynthetic rates, which in turn, may increase the carbon stock in plant biomass. However, it is still uncertain if plants in tropical forests, especially in the Amazon rainforest, will respond in this way, as the natural low phosphorus (P) soil availability in the region may change elevated CO_2 effects. To investigate whether soil P availability limits productivity and biomass production in response to elevated CO_2, we conducted an experiment using seedlings of *Inga edulis* Mart., a native nitrogen-fixing tree species, as a model species. Eight open top chambers (OTC) were installed in the understory of a primary forest in Central Amazon (Manaus, Brazil): four with ambient CO_2 (aCO_2) and four with elevated CO_2 (aCO_2 + 200 ppm, eCO_2). Inside each OTC, six *I. edulis* seedlings grew in pots, half with natural P availability (-P) and half with P fertilized soil (+P), resulting in 46 seedlings in total. After almost two experimental years (November 2019 - September 2021), plants were harvested and the light-saturated CO_2 net assimilation (A_{sat}), number of leaves, plant height (cm), plant diameter (mm), total leaf dry mass (g), and total root dry mass (g) were measured. We found that A_{sat} increased under eCO_2, irrespective of P availability. The number of leaves, height, and diameter, all increased in plants exposed to P addition, regardless of CO_2 treatment. Leaf dry mass was greater under eCO_2+P and +P. In both treatments with eCO_2, plants produced more root biomass. Total dry mass (leaves and roots) was higher in plants under eCO_2+P followed by eCO_2, +P, and control. Root:shoot ratio also differed between treatments in the following order $eCO_2 > eCO_2+P > + P >$ control. Our results indicate that aboveground components strongly responded to P addition (except for A_{sat}), while belowground components responded more to eCO_2. Although plants produced more biomass when exposed to both treatments, there were different allocation patterns, where plants under eCO_2 allocated proportionally more biomass into belowground whilst plants under P addition allocated more into aboveground. These findings suggest that when exposed to increased CO_2 concentration, understory plants in the Amazon region may enhance their productivity. However, the extra carbon assimilated would be invested on nutrient uptake strategies (i.e. increasing root biomass) rather than aboveground biomass accumulation, which may bring implications to the carbon sink activity of this system in the future. **Keywords:** Elevated CO2, plant productivity, belowground biomass, Central Amazon forest

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Relationships between Landscape-level Conservation and Vegetation Persistence in East Africa: A Remote-sensing Perspective

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Introduction: Interest in human impact on the natural environment has increased dramatically over the last quarter century. Over the same period, repeat digital, synoptic measures of the Earth 's surface has stimulated many research questions designed to improve understanding of human-environment interactions. Satellite remote sensing is ideal for this task, providing consistent, repeatable measurements across a suite of spatial scales, and is well-suited to capture processes of land surface change. Detection and characterization of such changes is often the first step in understanding the mechanisms and identifying their drivers. **Objectives:** This research attempts to quantify and visualize one of those drivers by examining if there are linkages between vegetation persistence and conservation of landscapes in the study region of East Africa. **Methods:** Directional Persistence (D) is a measure of the cumulative direction of change over the time series relative to the first observation. Cumulative frequency can be used to determine critical values of D, corresponding to the upper and lower desired significance level. The smallest value of D which equals, or is less than the generally used levels of significance can be extracted from the simulated frequencies of directional persistence generated under the conditions of the null hypothesis: values of the indices, such as NDVI, are independently and normally distributed. The greater the absolute value of the preceding NDVI, the less likely the series is to continue in that direction (increasing/decreasing). These approaches for examining vegetation change are conducted in a spatially explicit manner and will further understandings of the impact of climate variability, and policy and institutional change on the landscape by supporting the identification of sites within the study area experiencing critical changes in vegetation now, and back across the preceding 20 years. **Results:** Results indicate a visualized correlation between protected areas within the study area and more positive levels of vegetation persistence. While this correlation is readily observable when mapping results, many protected areas do not display statistically significant vegetation persistence results. **Implications:** This research therefore argues for a deeper need for nuanced understanding of specific conservation strategies employed within protected areas in order to gauge what methods of conservation are successful in maintaining positive vegetation persistence. Future field-based ground truthing will be a next step in this research. **Keywords:** Land cover change, vegetation persistence, protected areas

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Phosphorus Limitation and Fine Root Presence Effects on Wood Debris Decomposition in a Tropical Rainforest in Central Amazon

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Tropical forests are the main terrestrial carbon (C) sink globally, accounting for up to 40% of all atmospheric CO_2 fixed by vegetation in terrestrial ecosystems. Dead logs and branches in tropical areas encompass ˜ 14% of all C storage in terrestrial ecosystems, making it the largest pool of C storage of coarse woody debris (CWD) globally. Approximately 60% of rainforest in the Amazon basin is growing on geologically old and highly weathered soils, depleted in P and cations and woody debris also represents an important sink of scarce nutrients which suggests that root proliferation could be an important factor controlling the rates of woody decay. Therefore, we hypothesize that the alleviation of P limitation and fine root proliferation will increase CWD decomposition, and this effect will be associated with species identity (e.g., species with lower density). To test our hypothesis, we conducted a CWD decomposition experiment in the Central Amazonian rainforest over two years (2016-2018), with a factorial root colonization and P treatment addition experiment established with different species. We found that P addition significantly increased root biomass in wood debris throughout the decomposition process. Furthermore, after two years the fine root presence and P addition treatment reduce wood remaining mass compared to without root presence and without P addition (without root: 50.9 % and with root 44.6%, without P: 50% and with P 45.5%). Moreover, we observed that the significant reduction in wood remaining mass with root presence varied by species with a higher remaining mass reduction with root presence for Dimorphandra sp., and for Croton sp., The presence of fine root influenced significantly the relative content of N, Ca and Mg remaining (%) in contrast to root exclusion, but such effect depended on specific times of sampling. On the other hand, we observed a higher reduction in the wood P, K, Ca, and Mg content remaining (%) with P addition treatment in contrast without P addition. Despite P addition

significantly increasing the fine root colonization we did not observe an interaction between fine root presence and P addition treatment in wood debris decomposition and nutrient dynamics Our results suggest that roots are actively colonizing nutrient-rich woody debris, with an important role in the wood decomposition process, possibly alleviating microbial C limitation by labile C exudates. Furthermore, P additions stimulated mass loss and nutrient release indicating that decomposer microbial communities are likely limited by mineral nutrients of woody materials. **Keywords:** Amazon Forest, nutrient cycling, CWD, fine root biomass, P limitation

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Hotter Summers and Dryer Winters Are Slowing the Growth of the Subtropical Pine, *Pinus elliotti*

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Introduction / Background / Justification: The slash pine, *Pinus elliottii*, is the USA's southernmost pine species and is a foundation species of the endangered subtropical Pine Rocklands. The effects of climate and global change, including altered temperature, precipitation and fire regimes, on *P. elliottii* are poorly known. It is critical to understand the ecology and disturbance responses of *P. elliottii* if we hope to conserve south Florida's natural subtropical ecosystems. **Objective(s)/Hypothesis(es)/Methods:** Using dendrochronology, we measured the annual growth rates of 30 *P. elliottii* trees growing in five Miami-Dade County parks to examine spatial and temporal growth patterns. This research sought to answer three questions. Q1: Have growth rates of *P. elliottii* changed through time? Q2: Do growth rates of *P. elliottii* differ between protected areas? And Q3: What environmental factors are driving changes in tree growth rates? Given that South Florida is in the hotter, southern extent of *P. elliottii's* range we hypothesized that its growth rate should decrease through time due to rising temperatures and decreasing water availability. We also hypothesized that growth rates would differ between parks primarily as a result of different fire regimes and management practices. To test these hypotheses, we calculated the average standardized growth rates for each tree and park through time and performed correlations and linear regressions to assess the relationships between growth rates and climate. **Results:** Growth rates of *P. elliottii* generally decreased through time. The parks differed significantly in mean growth rates and growth patterns, however, we did not find any relationship between tree growth rates and fire frequency. We found a significant negative correlation between tree growth and December precipitation and August temperature (December is usually a dry month and August is a hot month) suggesting that climate change is negatively affecting *P. elliottii* growth rates and that additional warming may cause further growth slowdowns in the future. **Implications/Conclusions:** These results show that as the climate of South Florida changes, the endangered pine rocklands will face more challenges as its foundation species, *P. elliottii,* suffers from declining growth due to hotter summers and dryer winters. We must continue to study the effects of climate change on *P. elliottii* if we hope to conserve Florida's subtropical Pine Rocklands ecosystems and the many endemic species they support. **Keywords:** Dendrochronology, Climate change, Subtropical, Pinus elliottii, Florida, growth patterns

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Tropical Dendrochronology: an Analysis of Achievements and a Path Forward

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Due to the importance of tropical forests and woodlands in the global carbon and water cycles, we need to better understand present and future responses of tropical tree growth to climatic variation. Tree-ring analyses can aid in addressing these questions by providing long-term datasets from which such responses can be derived. In recent years, a substantial number of tropical tree-ring chronologies have been published and papers have reviewed the potential of hundreds of topical tree species for tree-ring analyses. Despite its large potential, a quantitative analysis of the distribution and characteristics of tropical tree-ring chronologies is missing. Here we compiled a network of >480 tropical ring-width chronologies and assess their geographic and climatic distribution, identifying regions and species with high potential, and where gaps are. To evaluate what the potential of tropical chronologies is for climate reconstructions, and where this potential is highest, we

also assessed the timespan covered by these chronologies, the strength of their common growth signal (rbar), where the strongest climate-growth correlations are found, and how these chronology attributes correlate with mean climatic conditions per site. We answer these questions at pantropical and continental levels and address important regional differences. We show that tropical chronologies have been built in all continents and tropical climate types. Pantropically, the geographic distribution of chronologies is biased to colder regions, while showing a good coverage of the precipitation envelope. This representativeness of the climatic envelope changes between the continents, with the poorest coverage found in Africa. Chronology length correlated negatively with mean annual temperature (MAT), while the common growth signal decreases with increasing mean annual precipitation (MAP) and MAT. The longest chronologies are thus in the coldest areas, while the highest growth synchronicity can be found in drier and colder sites. Drier sites have the most responsive chronologies: the strength of the precipitation-growth correlations decreases with increasing MAP, but showed no correlation with MAT. Temperature-growth correlations did not change with either MAP or MAT. Tropical dendrochronological studies already cover a substantial part of the tropics. To improve our understanding of the climatic drivers of tropical forest tree growth, efforts should be made to expand dendrochronological studies in general, but especially to better represent understudied areas. **Keywords:** Dendrochronolgy, tropical forests, climate, tree growth, distribution, precipitation, temperature

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Phenotypic Variation of *Guzmania triangularis* Functional Traits along Precipitation and Elevation Gradients in the Colombian Cloud Forests

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Tropical species occupy narrower climatic niches compared to species in temperate zones, which renders them more vulnerable to climate change. Most research addressing resilience has emphasised their response towards predicted changes in temperature, much less evidence is available on the impacts of covarying hydric parameters, which are arguably crucial for many life forms and entire ecosystems. The tropical montane cloud forests (TMCF) are unique and species-rich ecosystems, with high levels of endemism and a strong dependence on high environmental humidity. The high abundance of epiphytes is one of the TMCF hallmarks and a key factor to sustain its high levels of biodiversity. Therefore, the study of epiphytes phenotypic plasticity should improve our ability to predict the effect of climatic variation on TMCF. We studied the relationship between environmental humidity and morphophysiological functional traits in the epiphyte bromeliad *Guzmania triangularis* along an altitudinal gradient, and across rainward and leeward slopes, in a montane cloud forest of the Colombian northwestern Andes. To characterise climate, we installed field stations recording humidity, rain and run-off precipitation, and temperature. To examine associated variation in bromeliad functional traits, we combined correlative and manipulative approaches, including a translocation experiment among slopes and elevation. As output variables, we examined bromeliad traits associated to water balance and photosynthetic performance, namely the density of trichomes and stomata, and the colouration and morphology of the leaves. As expected, daily and elevational variation in temperature was much larger (between 12–20 C) than concomitant variation in relative humidity, which remained most of the time at the saturation point. The ratio of rain to run-off precipitation was unrelated to elevation, and more variable within the rainward compared to the leeward slope. Among the plant functional traits, the density of trichomes covaried negatively with elevation on the rainward slope, but positively on the leeward slope. An opposite interaction term was found regarding the density of stomata on the leaves underside: the plants exhibited more stomata at higher elevation on the rainward slope, but less at higher elevation on the leeward slope. Whether this variation can be attributed to phenotypic plasticity is yet to be confirmed by the translocation experiment. In any case, the data already show unexpected variation in bromeliad functional traits that is related to both elevation and precipitation, and would thereby affect their ecological performance under scenarios of climate change. **Keywords:** Tropical Cloud, rain forest, resilience phenotypic, plasticity bromeliad, water balance

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Holocene Fire, Vegetation Change, and Ecological Novelty in the High Colombian Cordillera Oriental

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Background: Rapid climate changes and the increasing presence of humans define the Holocene Epoch (11.6 calibrated kiloyears before present - hereafter ka BP), encompassing the most recent and abrupt environmental changes that biological systems have faced. Understanding how biodiversity subsists with extrinsic factors requires determining the effects of varying climatic conditions, disturbance regime shifts, and increasing anthropogenic impacts. Despite being one centre for biodiversity, how tropical ecosystems respond to those environmental stressors remains an open question. **Objective:** Here we present pollen and charcoal records from the Pantano de Moquentiva (herafter Monquentiva) in eastern flank of the Colombian Cordillera Oriental (CCO) at 3000 metres above sea level (masl) to document relationships between climate, vegetation and fire through the Holocene. **Methods:** We carried out palynological analysis to reconstruct vegetation changes. We studied microscopic charcoal particles to track variations in fire history. We performed a regime shift detection analysis and a detrended correspondence analysis (DCA) to summarise long-term ecological changes. **Results:** We found compositional transitions at 8.7, 6.1, and 4.2 ka BP at Monquentiva resulting from the interplay among climate, fire and human occupation. The pollen record provided a proxy for temperature and moisture changes at a temporal resolution of ca. 200 years. Reduced moisture and temperature caused a compositional shift in Páramo vegetation from ca. 8.7 ka BP. Fire activity was recorded throughout the Holocene and is likely a natural component of the CCO. Fire activity increased slightly during the Mid-Holocene when regional and local fire decoupling suggested human activities as the source of ignition. Mid-Holocene fires had a large effect on the vegetation composition at Monquentiva which recorded a rapid shift at ca. 6.8 ka BP. Fire occurrence increased sharply throughout the last four millennia, with associated changes in vegetation at 3.8 ka BP and promoting the reorganisation of plant communities. This shift in fire activity was likely related to more severe ENSO events and subsequently intensified by human activities after 3.8 ka BP. **Conclusions:** Although high climatic sensitivity explains most changes in the eastern flank of the CCO vegetation through the Holocene, our study gives insights into the relevance of fire activity, uneven climatic variables distribution and human intervention to the composition of the vegetation we see today. **Keywords:** Andes, holocene, paleoecology, ecological novelty, fire, charcoal, pollen

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Environmental Change (Global/Local)

Perspectives in the Study of the Effect of Environmental Variability Associated with Climate Change on the Morpho-physiology of Pollen

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The increase in greenhouse gas emissions has favored changes in climate dynamics that cause different types of responses in living organisms, which can be evidenced in aspects such as their biology, physiology, and ecology. Among those, plants represent one of the groups of greatest interest due to its diversity, relevance and level of impact, in which alterations in distribution ranges, life cycles, physiology and even interactions with other species have been observed at multiple scales. Despite the importance of understanding these responses, few data are still available at the micro-level scale, as is the case of the pollen. In this review, we assess the status of knowledge of the relationship between pollen morphology and climate change, aiming to detect gaps and highlight future perspectives of study in this field to impulse the investigation in this theme. We searched databases in order to find studies related to this topic, and analyzed, through bibliometric methods, which studies are linked to pollen studies, which characteristics of pollen and environmental variability were considered, localities, and responses in terms of morphology, phenology and biochemistry, among others. We found that grain size and viability are typical common quantified characteristics of pollen, meanwhile temperature is the most common environmental variable used. Multiple studies recorded that, in the case of pollen, morphological and physiological changes mediated by environmental variability have been evidenced, such as the increase in size and number of pores, loss of viability, and biochemical changes as the increment of allergenicity due to temperature increases. Most of these studies have been carried out in temperate zones, with few information available for the Neotropics, a place of great interest in the study of climate change, given its condition as a reservoir of species of flora and fauna. Based on this analysis, we aim to propose new questions that allow to the investigators generate new knowledge about how climate change may be modifying the morphology of pollen and its interactions with other plants, pollinators and humans. **Keywords:** Pollen, morphology, phenology, physiology, climate change.

Resilience to Drought in a Humid Tropical Dipterocarp Forest, India

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Climate change has led to an increase in drought intensity and frequency and this trend is predicted to accelerate. The response of biodiverse humid tropical forests to such droughts has been of particular concern given their importance to global carbon cycling and biodiversity. Extreme drought events have been linked to reduced forest productivity and elevated tree mortality. However, predicting the response of humid tropical forest communities to droughts remains a challenge, particularly in biodiversity hotspots, such as the Western Ghats in southern India. We use data from a long-term monitored plot in an old growth Dipterocarp forest to test the response of the tree community and species to a drought event. We expected reduced tree growth rates and increased tree mortality rates in response to the drought event. We also expected demographic responses to be linked to species traits like specific leaf area, wood density and mycorrhizal associations. We assessed tree community growth and mortality response prior to and following the drought event using Bayesian hierarchical models. We analyzed the demographic response at the community, guild, and species level where appropriate. We also tested whether the responses were related to species traits such as specific leaf area, leaf area, leaf thickness, leaf dry matter content and wood density. We found that growth rate was reduced in response to the drought event, while mortality rates marginally increased. Species level estimates had high uncertainty

around them due to the limited sample sizes in this diverse community, though the four most dominant species showed a significant negative response. At the guild level, mycorrhizal associations were found to explain tree mortality, with ecto-mycorrhizal trees having lower baseline and drought response. Canopy position did not show clear mortality trends. Overall, the tree community response to the drought event was less extreme than other humid tropical forests, suggesting there is resilience in this community to drought perturbations. A likely reason for this may be the dominance of ecto-mycorrhizal associations in the Dipterocarp community. Continued monitoring is warranted to assess the response of the community to greater intensity or frequency of precipitation anomalies to assess tipping points in this ecosystem. Further, this study highlights the need for large long-term monitoring efforts to more accurately assess demographic rates and resilience to climate change in forests globally **Keywords:** Tropical, forest, drought, mortality, climate change, growth, ectomycorrhizal, traits

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In Situ Photosynthetic Responses of Understory Plants to Elevated CO2 in a Central Amazon Forest

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The current scenario of global climate and environmental changes has raised uncertainties about how tropical forests, and especially the Amazon Forest, will respond to these changes since these forests hold a large carbon stock and play an essential role as a carbon dioxide (CO_2) sink. Although previous studies evaluated the effect of elevated CO_2 (eCO_2) on plant metabolism, no in situ plant has ever been subjected to eCO_2 in the Amazon Forest. Here, we investigated the *short-term* leaf gas exchange response to eCO_2 of an understory plant community in a central Amazon Forest. Eight open-top chambers (OTCs), four control (ambient [CO_2] - aCO_2), and four treatments (aCO_2 + 200 ppmv - eCO_2) were installed in the understory of the AmazonFACE experimental area. After 120 days of CO_2 treatment, the net CO_2 assimilation at saturating light (A_{sat}), stomatal conductance (g_s), leaf transpiration (E), and water use efficiency (WUE) were measured through light-saturated CO_2 assimilation *versus* intercellular CO_2 concentration (A/Ci) curves in up to three leaves of three plants per OTC ($n = 70$). We determined the difference between the parameters measured on the same A/Ci curve (r = response under 600 ppmv - response under 400 ppmv) to calculate the mean percentage change [(r − 1) × 100] for each treatment (aCO_2 and eCO_2) and evaluate the difference in parameter change between the treatments. We observed that the mean percentage change of A_{sat} was significantly higher under eCO_2 (46.81 *versus* 33.19% under aCO_2, $p = 0.0002$), as well as the WUE (49.85% under eCO_2 *versus* 33.02% under aCO_2, $p = 0.0012$). However, no differences were observed in gs and E between treatments. Our results showed that this tropical understory community increased the CO_2 assimilation under eCO_2, but does not show changes in gs and E, thus increasing the WUE. In the current scenario of increased atmospheric CO_2 and ongoing climate change, this study is important to help us to understand how tropical biodiverse forests carbon and water cycle will respond to increases in CO_2. **Keywords:** Climate change, tropical forest, photosynthesis, open top chambers

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Reconstructing past Fossil-fuel CO2 Concentrations Using Tree Rings and Radiocarbon in the Urban Area of City Medellín, Colombia

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To meet international and national commitments to decrease emissions of fossil fuels, cities around the world must obtain information on their historical levels of emissions, identifying hotspots that require special attention. Direct atmospheric measurements of pollution sources are almost impossible to obtain retrospectively. However, tree rings serve as an archive of environmental information for reconstructing the temporal and spatial distribution of fossil fuels emissions in urban areas. Our objectives were to (i) develop a statistical model to reconstruct of fossil fuels´ CO_2 concentration [CO2F] in space and time using dendrochronology and radiocarbon methods, (ii) characterize the changes in [CO2F] that have occurred spatially and temporally in urban area of Medellín with significant population growth, and (iii) discuss possible factors that have induced changes in [CO2F] in space and time. Thirty five Fraxinus uhdei urban trees were sampled using an increment borer taking three cores from each tree. The core samples were dried, sanded and scanned. Tree rings were marked and its widths were measured. One core from each sampled tree was selected for radiocarbon measurements, estimation of concentrations of fossil fuels, statistical and spatial modeling. We obtained annual maps of [CO2F] from 1977 to 2018 that describe changes in its spatial distribution over time. Our method was successful identifying hotspots of emissions around industrial areas and areas with high traffic density such as the downtown, main streets and avenues. It also identified temporal trends that may be related to socioeconomic and technological factors such as the global dynamics of oil price, changes in combustion technologies of vehicles and urban population growth. We observed an important increase in [CO2F] during the last decade, which suggests that efforts of city officials to reduce emissions from traffic did not have a significant impact on the contribution of fossil fuels to local air. The method presented could be of significant value for city planners and environmental officials from other urban areas around the world. It allows to identify fossil fuels emissions hotspots, evaluate the impact of previous environmental policies, and plan new actions to reduce emissions and meet commitments to decrease fossil fuels emissions. **Keywords:** Dendrochronology, radiocarbon, fossil fuel emissions, fossil CO_2

Rising Temperature Could Be Favoring the Arrival of Crop Pests to High Mountain Paramo Vegetation

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Paramos are tropical alpine ecosystems found in Central America and the Andean mountains. They are critical water reservoirs for neighboring cities, crucial carbon reservoirs, and important biodiversity hotspots. Despite their importance, Páramos are threatened by agriculture, mining, deforestation, climate change, and loss of native vegetation to invasive species. Many of these threats may be acting in synergy. For example, the increase in agricultural land and climate change may favor the arrival of invasive species or crop pests to natural ecosystems such as the Páramo. Recent observations on the populations of the native paramo species *Paepalanthus columbiensis* in the Matarredonda páramo in the eastern cordillera of Colombia indicate that an unknown moth is heavily eating plants. In this research, we identified the moth attacking *P. columbiensis* plants using molecular barcodes (COI) amplification from larval and adult insects collected from injured plants. The sequences of these amplicons were subjected to GenBank and iBOLD databases for taxonomic identification. We *identified Mythimna unipuncta* (Lepidoptera: Noctuidae) as the insect that significantly attacks *P. columbiensis* in its larval stage. *Mythimna unipuncta* has been previously reported as a global crop pest with high dispersal capacity that does not survive at temperatures below 20°C. Given its biology, this species is unlikely to be from the Páramo and could be a pest with the potential to colonize high mountain ecosystems in response to rising temperatures due to climate change. To further explore this possibility, we studied the temperature effect on larval development by rearing larvae in climatic chambers at three temperatures: 30°C day/ 20°C night, 25°C day/15°C night and 20°C day/10°C night). We calculated the growth larval index and survival rate. We found lower growth larval index at the lowest temperatures, 20/10°, in agreement with previous studies that suggest this species needs warmer temperatures for successful development. These results could indicate that the arrival and spread of *Mythimna larvae* in the Páramo could result from the temperature increase caused by climate change. Future studies will be needed to elucidate the impact of this pest on Páramo vegetation and the ecosystem services they provide. **Keywords:** Paramo vegetation, climate change, pests, barcoding.

Genetics, Evolution

Niche Lability Correlates with Different Life Forms in a South American Legume Lineage

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Despite the assumption that niche conservatism is a largely widespread pattern in nature, some macroevolutionary studies show lineages with highly labile niches. Moreover, niche evolution can occur in association with morphological trait evolution able to provide adaptive advantages in new environments. Indeed, the ecological relationship between plant life forms and the occupation of specific niches are commonly observed, although we lack evidence about their evolutionary association. Here, we used ecological niche models and comparative phylogenetic methods to investigate environmental niche evolution and its association with different life forms in a lineage of Chamaecrista (Fabaceae), mainly distributed in South America. We used trait-dependent evolution models, including pure Brownian motion (BM) and more complex Ornstein–Uhlenbeck (OU) models, to investigate whether the occupation of different environmental niches occurred conjointly with the evolution of different life forms. We found no evidence of phylogenetic niche conservatism, and our data show that different life forms have distinct evolutionary niche optima. Specifically, our findings indicate that the annual life form has evolutionary optima in niches with low availability of water and nutrients. On the other hand, the geophyte life form has its evolutionary optima in niches with higher fire frequency and higher temperature seasonality. Regardless of the life form, we found no lineages capable of occupying niches with low resource availability and high disturbance frequency, suggesting the existence of a prohibitive condition between these niche axes during this plant lineage diversification. The best fit of OU models with different optimums highlights that eco-evolutionary forces beyond stochastic processes were relevant during niche evolution within the Chamaecrista lineage. In sum, our results illustrate how the traditional ecological description of the association between life forms and environmental axes reflects the joint diversification between environmental niches and complex morphological traits. **Keywords:** Adaptation, niche shift, Neotropic, ecological opportunity, macroevolution, climate.

Tracing 250 Years of Taxonomic Change in the Largest Clade of Neotropical Lianas

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Introduction/Justification: Taxonomic delimitation of species underpins our knowledge about the world´s biodiversity. Yet, reaching an accurate delimitation requires continuous taxonomic exploration. Temporal trends in species descriptions, including the description of accepted species and their synonyms, can reveal fluctuations in the identity and number of species that emerge purely from taxonomic research. Such fluctuations, if not recognized, challenge the establishment of robust species checklists – the baseline information for biodiversity research and conservation. **Objective:** We assessed temporal trends in the taxonomic descriptions of the tribe Bignonieae (Bignoniaceae), the largest clade of Neotropical liana. We focus on Bignonieae because it is one of the best-studied and taxonomically resolved groups of Neotropical plants. **Methods:** We retrieved from iPlants 1,746 unique taxa names of the tribe Bignonieae, including accepted names and their homotypic and heterotypic synonyms. We also retrieved information about ancillary bibliography (i.e., author names, year of publication). **Results:** Since the 1750s, 422 accepted species, 525 homotypic synonyms, and 799 heterotypic

synonyms have been described. On average, 3.7 accepted species and 4.6 homotypic synonyms were described per year. Descriptions of heterotypic synonyms decreased after the 1950s (until 1950: 7.8 names/year, after 1950: 2.2 names/year). Peaks in description in 1845 and 1896 coincide with periods in which taxonomic revisions were carried out for the tribe. Of the 422 currently accepted species, 106 do not have synonyms, 126 have only homotypic synonyms, and 190 have heterotypic synonyms. *Dolichandra unguis-cati* (L.) L.G.Lohmann and *Tanaecium dichotomum* (Jacq.) Kaehler & L.G.Lohmann hold the highest number of heterotypic synonyms, with 32 heterotypic synonyms each. The decrease in the number of heterotypic synonyms after 1950 may be related to (i) the adoption of the International Code of Botanical Nomenclature from 1930, which established consistent rules for plant species description, (ii) greater access to information with the use of the internet from 1990 onwards, and (iii) an integrative taxonomic approach from 2005, in which different evidences are used to delimit the species. **Implications/Conclusions:** The tribe Bignonieae has been subject to intensive taxonomic revisions in recent years, revealing several duplicated descriptions of the same taxa. In addition, recent descriptions seem to pro a robust species delimitation, as only a few recently described taxa later became synonyms. Our results suggest that Bignonieae experiences a period of taxonomic stability. We highlight the crucial work of taxonomists in reducing knowledge gaps and providing species lists of sufficient quality for application in ecology and conservation studies. **Keywords:** Bignoniaceae, macroecology, species description, taxonomic uncertainty, taxonomy

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Adaptive Genomics and Ecological Resilience: Relevance for Tropical Biology and Conservation

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Two decades following the completion of the human genome sequencing in 2001, provided the means and methods for extend the importance of whole genome sequencing projects to a wide range of taxa, with thousands of species being the target of whole genome sequencing, from simple bacteria to more complex organisms, such as mammals. Such voluminous sequencing data generated across multiple phylogenetically diversified organisms provides also the framework to better understand the genetic makeup of such species and related ones, allowing to explore the genetic changes underlining the evolution of diverse phenotypic and adaptive traits and their relevance for conservation. Here, recent results from our group retrieved from comparative evolutionary genomic analyses of varied endangered metazoan species will be considered to exemplify how gene novelty and gene enhancement by positive selection might have been determinant in the success of adaptive radiations into diverse tropical environments and lifestyles. The findings pinpoint unique molecular products of critical relevance in species evolution, diversification, ecological resilience and conservation, but further highlight genomic novelties relevant for environmental and biomedical research. **Keywords:** Adaption, genomics, ecological resilience, tropical biology, conservation

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Crassulacean Acid Metabolism Diversification in the Orchidaceae

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Introduction: The plant family Orchidaceae harbors one of the largest diversities in terms of species numbers and worldwide distribution. Orchids are an important component of plant diversity in tropical regions of the world. It is proposed that the epiphytic habitat, and the presence of Crassulacean acid metabolism (CAM), a water-conserving mode of photosynthesis, allow many tropical orchids to adapt to changing environments. **Objectives and Methods:** To better understand the factors that contribute to orchid species radiations, phylogenetic trait analyses were performed using leaf carbon isotope signatures from over 2,000 neotropical orchid species, leaf anatomical and physiological traits, and character state reconstructions to provide an up-to-date status of the evolution of CAM in the Orchidaceae. **Results and Conclusion:** In orchids, CAM has evolved multiple times independently. C_3 is the ancestral state, however, it is noted that the presence of CAM in multiples nodes of the tree, coupled with physiological and anatomical changes partially explain the photosynthetic shifts associated with species diversification. For example, a large CAM radiation event, prominent within the subfamily Epidendroideae, provided the majority of extant CAM species in the group. Physiological measurements also showed that some orchid species with weakly expressed CAM can significantly increase their CAM activity when water stressed and, in some cases, revert to weak CAM upon re-watering, suggesting that modulation of CAM as a response to environmental stresses may have also contributed to diversification within the subfamily Epidendroideae. **Keywords:** CAM, Orchidaceae, orchids, epiphytes, carbon isotopes

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Ferns of Colombia

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With 1450 species, Colombia has the greatest fern diversity of any country in the Americas, yet most of these species remain poorly understood. Nearly half of these taxa are known from less than 10 herbarium specimens, and the vast majority have little to no DNA sequence data available. This lack of basic taxonomic knowledge impedes much needed conservation efforts in a country with increasing rates of biodiversity loss. The Ferns of Colombia project aims to address this knowledge gap by generating new herbarium collections and genomic resources for all species of ferns in Colombia. The taxonomic and phylogenetic findings gleaned from these new data will be publicly available in both English and Spanish in an online data portal to aid in fern diversity research. Additionally, the data generated through this work will be used for systematic revision of 4 major fern clades: *Elaphoglossum* section *Lepidoglossa* (Dryopteridaceae), *Pityrogramma* (Pteridaceae), *Pleopeltis* (Polypodiaceae) and *Polystichum* (Dryopteridaceae). In February 2022, we completed the 1st of 6 field expeditions to fill major fern and lycophyte sampling gaps in Colombia. Over the next 3 years, we will complete the remaining 5 field expeditions targeting the following regions: the Chocó, Cordillera Occidental, Cordillera Central, Cordillera Oriental and Sierra Nevada de Santa Marta. While our team includes both Colombian- and US-based botanists, we are actively looking for more Colombia-based collaborators interested in documenting fern diversity in Colombia. **Keywords:** Ferns, taxonomy, phylogenetics, collections-based research, Colombia, conservation, lycophytes ________________________________

Genetic Diversity of Central American Red Brocket Deer and Brown Brocket Deer Using Novel Informative Microsatellite Markers

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Mexican brocket deer (*Mazama temama* and *M. pandora*) are species of ecologic and economic importance and over the years they have faced overhunting and habitat loss, thus, many populations are now in danger of extinction. Considering that genetic variation is the raw material for adaptation to environmental changes, we identified, characterized, and tested novel and informative microsatellites for *M. temama* and their transferability to *M. pandora.* We performed a library enrichment using Illumina shotgun paired-end sequencing, followed by bioinformatics analyses to identify microsatellite sequences to design primers. Our study provided a database with more than 6,000 microsatellite primers but we tested genetic diversity on two populations of *M. temama* and one population of M. pandora with 23 polymorphic microsatellites. We observed moderate to high genetic diversity, heterozygote excess, and Hardy-Weinberg disequilibrium on *M. temama*. We also found that *M. pandora* performed low genetic diversity and Hardy-Weinberg disequilibrium. Our findings suggest that both brocket deer are facing conservation issues that are influencing their genetic patterns. **Keywords:** Conservation genetics, genetic markers, mammals, next-generation sequencing, population genetics

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Genetic Patterns of Three Colombian Magnolia Species (MAGNOLIACEAE) Using SSR Markers

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Magnolias are one of the most interesting and threatened taxonomic group of plants in the world. In Colombia, the largest biodiversity hotspot of Magnolias in South America, 39 of the species distributed in the region are endemic. Unfortunately, most Colombian species (95%) are considered endangered due to overexploitation, habitat loss, and forest fragmentation. Consequently, it is necessary to propose solid strategies that allow the conservation of these species and one of these, to preserve species as dynamic entities of the ecosystem capable of coping with environmental change, is the study of genetic analyses of populations. These studies represent fundamental tools when designing effective conservation plans that reduce the probability of extinction, allowing to know the adaptation to environmental changes and determine the biological efficacy to understand the long-term evolutionary success of the species. These genetic analyses applied to the remaining forest fragments are of great relevance for rare, endemic and threatened tree species, such as *Magnolia polyhypsophylla* (CR), *M. guatapensis* (EN), and *M. jardinensis* (CR). These Andean species are highly threatened by the expansion of the agricultural frontier, the increasing rate of deforestation and phytosanitary problems related to the development of flowers and fruits. Therefore, understanding the patterns and extent of genetic divergence among these populations is crucial for protecting these species and developing effective conservation plans. For these reasons, we have been doing a population genetic analysis of these *Magnolia* species, using SSR markers, to determine the genetic patterns and design an effective conservation plan that will reduce their probabilities of extinction. We sampled a total of 125 individuals of the three species in the municipalities of Valdivia, Briceño, Yarumal and Jardín, in Antioquia, Colombia, and consequently dried them in silica gel. DNA was extracted, and SSR markers were tested and genotyped using the methodology of Veltjen et al., (2019). Currently, we are realizing both genetic diversity and population structure analyses, based on the results of which we will present a conservation strategy for these species. Currently, we are making analysis about 18 SSR markers to determine both the structure and diversity of the population species in order to make a conservation analysis of these populations. This study is essential to understand the current genetic diversity and patterns of these species, based on which conservation strategies can be proposed for the recovery of populations. Finally, this research is important for the generation of knowledge about the family Magnoliaceae in Colombia, especially at genetic level. **Keywords:** Magnolia, population genetics, SSR markers, conservancy, conservation genetics, Andes.

Looking for the past to Search for a Future: First Assessment of Demographic Changes in the Hoary Fox

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Introduction: Human development results in habitat fragmentation and biodiversity loss. The shrinking of natural habitats and fragmentation of ecosystems may alter animal movement patterns, resulting in problems associated to drastic demographic variations and fluctuations in the population size of species. **Justification:** Understanding the past demographic panorama of a species and modeling it´s population viability in the next 100 years is helpful to identify the species conservation status and implement efficient conservation and management plans. Background: The hoary fox (*Lycalopex vetulus*) is a Neotropical canid, originally endemic to the Brazilian savanna, and Near Threatened to extinction. It's population apparently have been affected due to anthropogenic effects, however, to our knowledge any demographic, long term studies on population size have been carried. **Objectives:** In order to detect signals of past demographic changes in *L. vetulus*, we assessed genetic populational parameters of a wild population inhabiting the Central-Western Brazilian region. **Methods:** We assessed 44 hoary fox blood samples from captured wild animals between 2011 and 2016 in Cumari, Goiás, Brazil. We amplified by PCR eleven microsatellites previously described for domestic dog (*Canis lupus familiaris*). We tested three different demographic scenarios using DIYABC v 2.1.0: (1) population size did not change during the time (null hypothesis, $N1 = N2$, where N1 is the ancestral effective population size, and N2 the recent effective population size), (2) the population was reduced in the population size at coalescent time t (bottleneck event, $N1 < N2$), and (3) there was a past expansion in the effective population size ($N1 > N2$). **Results:** Our results suggest a bottleneck signature (TPM model, $p = 0.014$), suggesting a

significative population size reduction in the past. The demographic change found in the past could result in a loss in the current population viability, once it is possible that the hoary fox did not retain enough genetic diversity to face the consequences of anthropogenic actions. **Conclusion:** For this, we recommend future research to understand population genetic dynamic in the Brazilian savanna for the species. Also, investing on long term populational studies may help to describe hoary fox population size and its fluctuations among different natural and anthropized landscapes. **Keywords:** Conservation, bottleneck, genetic diversity, canids, *Lycalopex vetulus*

Matrilineal Structure of In-situ and Ex-situ Populations of the Black Lion Tamarin (L*eontopithecus chrysopygus*) and Insights for Its Conservation

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Introduction: The black lion tamarin (BLT), *Leontopithecus chrysopygus*, is endemic to the Atlantic Forest of the São Paulo state (Brazil), one of the most fragmented biomes in the American continent. Currently there are about 1600 BLTs in nature, distributed over small fragments with low demographic densities and under threat of local extinction. In captivity there are over 60 BLTs in Europe and mainly in Brazilian institutions, however, their offspring are highly-related. Thus, efforts have been taken to produce knowledge and support policies for its conservation. **Objectives:** Here we characterized the matrilineal genetic diversity and structure of ex-situ and in-situ populations and analyzed pedigree data from the BLT Studbook aiming to provide useful information for aiding the species' management. **Methods:** We sampled 43 wild BLTs from five fragments (MD, PB, SM, CB and GU), and 71 captive individuals from the main institutions that manage the species (FPZSP, CPRJ and DWCT). We analyzed mitochondrial DNA control region sequences employing different statistical and bioinformatic tools to assess genetic diversity and structure, and construct haplotype networks. **Results:** We identified seven haplotypes, with three of them present in both captive and wild populations. One haplotype was found only in captivity while two others were found exclusively in nature. The haplotype diversity ranged from zero to 0.675. The mean genetic diversity was higher in nature than in captivity. Bayesian analyses identified four genetic clusters (CB-PB, ST-PB, MD-CPRJ-DWCT, and FPZSP), evidencing the common origin of founders from MD to form the captive groups. Interestingly, MD was not grouped with SM and PB, which are located at the same geographic region. In addition, we detected common haplotypes in wild individuals from non-connected distant fragments. **Implications:** Our data revealed the existence of ancestral haplotypes and suggested a historical connectivity among fragmented wild populations, indicating probable gene flow prior to fragmentation. The genetic structuring reinforced the scenario of gene flow decrease and subsequent genetic drift as probable factors responsible for the differentiation, which favor genetic diversity loss and increase the local extinction risk. For the ex-situ groups our findings highlighted the need of special attention for their metapopulation management, since one haplotype was only found in FPZSP and no matrilineal genetic diversity was observed in CPRJ. Overall, this study raised relevant information for ex-situ and in-situ conservation plans that consider genetically-based management decision-making to translocate BLTs, repopulate areas of their historical occurrence and/or supplement populations with drastically reduced population sizes. **Keywords:** Primates, conservation, genetic diversity, ex-situ and in-situ management

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Population, Community, or Landscape Ecology

The Composition of Mixed-species Bird Flocks in Four Habitats in the Southern Ecuadorian Andes

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Mixed species bird flocks are complex interspecies assemblages that provide foraging and predator avoidance benefits to individual participants.Studying species assemblages such as mixed flocks is important for understanding the function and resilience of ecosystems and helps to predict the response of species to environmental change.Our goals were to gain natural history information on mixed-species flocks in this region and to determine whether mixed-species flock structure and composition varied across the four habitat types.We surveyed flocks in four different habitats (native scrub, native forest, non-native forest, and regenerating forest) between 2500 and 3400 m elevation in the southern Ecuadorian Andes between October 2018 and August 2019. In total, we observed 389 mixed-species flocks composed of 47 different species, with an average of 4.61 species per flock. Sites did not differ in mean flock species richness (range: 4.26 to 4.83 species, $p > 0.05$), however, mean flock size was significantly different among habitats (range: 7.20 to 11.0, $p = 0.004$), with larger flocks found in the native scrub habitat. The species with the highest overall abundance in the flocks across all sites were the Yellow-breasted Brush-Finch (*Atlapetes latinuchus*), Scarlet-bellied Mountain-Tanager (*Anisognathus igniventris*), and Spectacled Whitestart (*Myioborus melanocephalus*). In general, flock networks from native scrub showed the highest levels of connectivity and cohesion, while there was little variation among metrics in the native forest, non-native forest, and regenerating forest habitats. We identified two nuclear species, the Scarlet-bellied Mountain-Tanager and the Spectacled Whitestart. The presence of these important nuclear species, as well as the similarity between metrics among habitats, suggests that flocks in this region are resilient to environmental change.
Keywords: Mixed-Species, bird flocks, ecological networks, conservation, environmental change, nuclear species

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Indirect Effects via Ant Sharing Have a Limited Impact on Herbivory Levels in an Ant-plant Mutualistic Network in Central Amazon

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Within a community, plant species bearing extrafloral nectaries (EFNs) share ant bodyguards that can protect them against herbivores. Thus, plant species may indirectly influence each other's ant visitation and, consequently, the protection service provided by ants, especially when plants share aggressive ant species. This study investigated indirect effects via ant sharing across twenty-one EFN-bearing plant species of the tribe Bignonieae distributed on 28 plots in the central Brazilian Amazon. Through an ecological network index that quantifies the potential indirect effects among plant species via ant sharing, we distinguished plant species that could most affect and be most affected by others via shared dominant and subordinate ant species visiting EFNs. We experimentally determined the behavioural dominance hierarchy of ant species based on the monopolization of honey baits. Our Bignonieae species markedly differ in ant attractiveness, and we investigated how such variation influenced the indirect effects between plant species. We also tested if plant species that have the higher

potential to influence ant visitation in other plants were those that have less foliar herbivory, mainly because by concentrating the visit of more aggressive dominant ants. We found that the more attractive plant species had the most potential to indirectly affect the patterns of ant visitation, to other plant species in the community. These potential indirect effects between plants are mainly via the sharing of dominant ants. In contrast, the potential indirect effects among plants were not related to foliar herbivory patterns. At the plot scale, we found that the probability of ant attendance, the number of dominant and subordinate ants, and herbivory levels did not differ among plant species that most affect others, its close neighbours, and distant plants. We conclude that the propagation of indirect effects between plant species is limited in this ant-plant protection mutualism, characterizing a neutral impact on protection benefits among plants. This pattern could be explained by the general low herbivory levels across species and the small foraging areas of ants from the same colony. So, the indirect effects must occur only when herbivory pressure is higher and restricted to a few pairs of nearby plant species. These results highlight the absence of cost and benefit in the indirect interaction between plants that share protective ants, unlike other animal-plant interactions such as pollination mutualisms. **Keywords:** Ant-plant mutualism, herbivory, EFN-traits, indirect interactions, mutualistic networks,

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Demographic Analysis of Two Endangered Populations of *Pristimantis bacchus* (Anura: Craugastoridae) from Cloud Forests Fragments

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Demographic analyses are essential to understand natural population dynamics and carry out effective strategies for monitoring population vital rates such as abundance, survival, and population growth, key parameters to determine the risk of extinction, and population trends. *Pristimantis bacchus* is a direct-developing frog from the Andean cloudy forests of the Eastern Cordillera (department of Santander, Colombia). Currently, the IUCN Red List of Threatened Species considers this species to be endangered due to its small distribution area and habitat loss and degradation. Therefore, we evaluated the population size (N), the apparent survival (φ), recapture (p) and population growth rate (λ), and their relationship with the rainy and dry seasons, of two populations of *P. bacchus* from the foothills of National Natural Park Serranía de Los Yariguíes, to understand their population dynamics. The first population was located in the municipality of San Vicente de Chucurí where there is a 15-ha remnant forest fragment surrounded by two active pasturelands that create a sharp edge, and the second population in the municipality of Zapatoca, with 22,6-ha forest fragments surrounded by active pastures, and blackberry and lulo crops. A capture-marked-recaptured sampling of these populations was carried out for 14 months at the first site and 15 months at the second. We marked 356 and 101 individuals from the San Vicente´s and Zapatoca´s populations, respectively. The φ and p rates values were fairly similar for both populations (φ=0.73-0.75, and p=0.07-0.03). The N was higher for the population of San Vicente than of the Zapatoca (5085 and 2657 individuals, respectively), this first population showed significant differences in N between sexes (38,4% more males than females), and in females between seasons (more females during dry seasons). There was no relation between N and seasons for the Zapatoca population. We found a λ rate that decreases over time in both populations, with the Zapatoca population showing the highest decrease (11.4%). Our results show that, despite good vital rates relative to other frogs, both populations will likely not be able to survive in future years in their forest fragments. Variations in N and λ have been common in direct-developing frogs, revealing that they must face higher extinction risks because they are subject to demographic and environmental stochasticity. This and future studies of other populations of the species may provide some insight into the conservation status of the species and future conservation strategies. **Keywords:** Demography, endemic species, population decline, population dynamics, *Pristimantis bacchus*

Tropical Tree Species Differ in Damage and Mortality from Lightning

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Background: Lightning is an important agent of mortality for large tropical trees with implications for tree demography and forest carbon budgets. The structure of future forests depends on how agents of mortality affect individual species. Anecdotal accounts suggest that some tree species are more resistant to lightning damage, but empirical support for such patterns is lacking, especially in the tropics. **Objectives/Hypotheses:** Our principal goal was to determine whether tree species in a lowland tropical forest exhibit evidence of lightning tolerance and resilience. We hypothesized that the probability of exposure to and damage from lightning differs among species. We predicted that some species consistently exhibit lower overall mortality and less physical damage when exposed to lightning (i.e., tolerance), and that some species consistently recover from a lightning strike, even when the damage is severe (i.e., resilience). **Methods:** We used data from 95 lightning strikes documented in the Barro Colorado Nature Monument, Panama, during 2015-2020. We recorded lightning strikes using video cameras mounted on canopy towers running continuously during the wet season. We triangulated flashes recorded on two or more cameras to pinpoint an approximate strike site, which was then verified using drone and ground-based observer surveys. We recorded all trees damaged by lightning in each site and measured their diameter at breast height and distance from the directly struck tree. We also estimated percent crown dieback. We subsequently revisited most strike sites to track decline or recovery over time. **Results:** Eighteen of 30 focal species had lightning mortality rates that deviated from expectations. Several species showed little damage and 3 species had no mortality from lightning, whereas palms were especially likely to die from strikes. Directly-struck trees were two orders of magnitude more likely to die than secondarily damaged trees. The likelihood of surviving increased with the likelihood of being struck. Only one species showed a propensity to recover following lightning damage, while most others declined over time. Preliminary analysis suggests that lightning tolerance is correlated with wood functional traits. **Conclusions/Implications:** Interspecific differences in tree tolerance to lightning suggest that lightning-caused mortality shapes compositional dynamics over time and space. Shifts in lightning frequency due to climatic change are likely to alter species composition and carbon cycling in tropical forests. These results have important implications for predicting future forest dynamics and species turnover in tropical forests, especially where lightning strikes are frequent. **Keywords:** Disturbance, species composition, global change, large tree mortality, functional traits

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Computer Simulation of the Demographic Effects of Sexual Dispersal

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Dispersal plays a crucial role in the population structuring of a species, avoiding, for example, local competition and inbreeding, in addition to allowing the increase of genetic variability with the arrival of new individuals. For mammals it is commonly sex-directed (sex-biased dispersal). In this perspective, the objective of this study was to evaluate, through computer simulation, the demographic effects of sexual dispersal in populations of *Sapajus* sp.. For this purpose, an individual-based model (IBM) called Penna Model (4) in its modified version (5) was used. The alterations proposed by (5) proved to be adequate to evaluate the behavior of populations subjected to the effects of fragmented environments and consequent deleterious effects due to the low genetic variability of small populations. In the model, each entity is represented by a double string indicative of its chronological (life expectancy) and hereditary life history. Each position in a string represents an entity's life cycle filled with 0 or 1, where 1 indicates a mutation (M) or hereditary disease in its life cycle. The maximum number of mutations (bits = 1) previously defined (threshold T) that an individual can have throughout his life will determine how many years he will survive. Ecological and social characteristics of *Sapajus* sp. were added to the algorithm, as well as the age of dispersion (from 6 years old for males). Four scenarios were considered in the simulation: populations without dispersal, with dispersal for both sexes, with male dispersal, and with female dispersal. The results found indicate that dispersal increases the survival of populations regardless of population size (N= 80, 160 and 500) and sex. Despite the results indicating a greater population survival for the dispersal of females, in nature, this phenomenon rarely occurs due to the philopatric behavior of capuchins. Thus, the results corroborate the dispersal behavior of capuchins males and indicate that the dispersal of males between groups works similarly to a dynamic in metapopulation, increasing genetic variability (represented in the model by a shift in the T threshold towards more advanced ages). with significant effects, especially in small populations (n=80). The study highlights the importance of movement dynamics and connectivity between populations for population survival. **Keywords:** Dynamics population, sex-biased dispersal, penna model, IBM, movement dynamics, connectivity.

Biological Aspects and Movements of Neotropical Fruit-feeding Butterflies

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The patterns of insect movement are the cumulate product of many individual decisions and can be shaped by the way morphology and behaviour interacts with landscape structure and composition. Hence, the ongoing process of habitat fragmentation increases the distance among suitable habitats and changes those in such a way that it may favour some movement behaviour. Our study described some biological traits throughout the year (sex ratio, age structure and individual permanence in a population) for six more abundant species of fruit-feeding butterflies, as well as the movements carried out by all captured butterflies among three habitats in a conservation unit (forest interior, natural transition forest-lake – ecotone, and anthropogenic forest transition – edge) and between strata (canopy and understory) in a conservation unity of Atlantic Forest in southeastern Brazil. We sampled butterflies monthly over one year, following a standardized design using banana-bait traps, settled up in alternating strata. After capture, we recorded the individual characteristics of each individual (age, sex, point of capture), and each butterfly received a sequential number on the right posterior wing made with a permanent marker, and were released at the capture site. We captured 11,594 individuals from 98 butterfly species, 411 of which were recaptured at least once (3.5% of all records). Six butterfly species had more than 3% recapture success (the minimum sample size), totalling 335 individuals (*Hamadryas feronia*, *H. amphinome*, *Paulogramma pygas*, *H. laodamia*, *Fountainea ryphea*, *Taygetis rufomarginata*). Sex ratio was male biased for five out of the six species and the age structure showed an increase in recruitment of new individuals in the dry season, followed by a noticeable aging of the populations along the wet season. Our results revealed an aggregated spatial distribution, in which few individuals travelled long distances while most individuals were recaptured close to the place of first capture or a few metres away, suggesting that all studied habitats currently provide the necessary conditions and resources for the maintenance of butterfly populations, favouring fewer movements and narrow home ranges. Our data suggest that the conservation of a set of heterogeneous habitats is especially important for the maintenance of tropical butterfly populations, including more sedentary and also the vagile species. The study was supported by CNPq, CAPES and FAPEMIG. AVLF thanks CNPq, SISBIOTA Brasil/CNPq, NSF and BIOTA-FAPESP. **Keywords:** Atlantic rainforest, canopy, edges, ecotone, Lepidoptera, mark-release-recapture

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Trees Size Influences on Anatomical and Functional Traits in Two Populations of Tropical Tree Species

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How plants respond to their environment is determined, among other things, by a plant's structure, architecture and physiology. Plant's response also varies between species, and location. These parameters also change throughout the lifespan of the trees as they grow and encounter different environmental stressors while passing through ontogenetic change. Tree's responses to environmental change are often measured using plant functional traits and these traits can be used to examine the influence of the environment or ontogeny on an individual's performance or susceptibility to drought-induced death. Hence we examined the effect of the tree size on leaf traits, hydraulic traits, and wood (anatomical) traits of two tropical tree species (*Cordia bicolor* and *Hymenaea courbaril*) from a rainforest in Northeast Brazil. We collected 10 individuals of different size (three to four branches per individual) for species and measured different functional traits: Leaf Mass per Area (LMA), branch embolism resistance (P50, P88), wood density and relative content, xylem vessel area, and xylem tissue ratios (parenchyma vs fiber vs vessel lumen areas). We correlated traits with individual tree size and also explored the main axes of variation in their traits space. Tree size affected leaf and wood anatomical traits in both species: large trees have large LMA, smaller embolism resistance, and large lumen vessels. Tree size affects embolism resistance for one of the two species examined (*H. courbaril*). Two main axes of traits

variations (vessel area and anatomies traits), with xylem vessel area showed a positive correlation with the embolism resistance and parenchyma. These results show that the tree size influences differentially plant functional traits and is related to the individual's response to the environment mainly to embolism resistance, presenting different modulations during growth. Moreover, highlighting the importance of evaluating tree vulnerability in different ontogenetic states, to better understand how climate change differentially affect ecological aspects between species and populations **Keywords:** Tree size, functional traits, wood anatomy, embolism resistance

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What Is the Influence of Seed-size Based Competitive Hierarchy on the Seedling Community Structure in a Tropical Forest?

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Seed size has been regarded as a key factor for seedling establishment. Seedlings from species having larger seeds are associated with a best competitive ability, since their seedlings have higher survival rates during recruitment when compared to seedlings from smaller seeds. Such higher survivorship has been related to larger energetic reserves and less influence on external environmental conditions. Therefore, it would be expected that seedlings from smaller seeds only establish themselves where there are no larger seeds in the competitive neighborhood. Here we aimed to estimate how much a competitive hierarchy model based on seed size and seedling neighborhood explains the seedling community structure observed in the field. Our study was conducted in a forest fragment located at the Atlantic coastal plain in Brazil. We used seed traps data to create a prediction about the seedling community that would be formed from these seeds. For this, we considered both seed size and the neighborhood scale (i.e seeds that occur together at the sampling units). For each trap we consider that only the largest seed would establish itself as a seedling. As the competitive neighborhood is defined by the set of seeds within each trap, seeds of all sizes could establish themselves as seedlings, depending on the sizes of the neighbor seeds. We call this prediction as expected ranking of seedlings frequency. We compared it with the observed ranking of seedlings frequency, obtained from the seedling inventory carried out in plots adjacent to seed traps for different time periods. These rankings were compared using Kendall correlation test, by means of the tau index, that ranges from -1 (entirely discordant rankings) to +1 (entirely concordant rankings). Among different time periods, we found some high positive correlation values (> 0.300), however all values were non-significant. We also found negative and non-significant values ($-0.8 < \text{tau} < -0.02$). These results indicate that seed size and competitive neighborhood did not explain the frequency of established seedling species in this community. Consequently, the competitive hierarchy model evaluated in this study was not the predominant process in seedling community structuring. However, these results should be interpreted with caution. Since there are several difficulties in the identification of species in tropical forests, we found a low number of species in common between seeds and seedlings. Thus, the effect of the competitive hierarchy based on seed size and seedling neighborhood on the seedling community structure still deserves further attention. **Keywords:** Seed, seedling, competition, dispersal limitation

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Different Axes of Biodiversity Reveal High Heterogeneity in the Rainforest of Amazonia at a Local Spatial Scale

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Environmental climatic gradients are important drivers of tree communities across the Amazon basin. Regions with strong rainfall seasonality select tree species with different drought tolerance strategies determined by xylem hydraulic traits. However, we still lack a more comprehensive understanding on how different dimensions of biodiversity, such as functional, phylogenetic, and floristic (taxonomic) diversity are driven by local scale environmental conditions such as nutrient availability. We aimed to compare hydraulic traits, floristic composition and vegetation structure in two close Eastern Amazonian tropical forests, under the same seasonal rainfall conditions and contrasting soil phosphorus (P) availability. We sampled hydraulic traits related to xylem vulnerability to embolism formation (namely P50) and hydraulic safety margin (HSM), floristic composition, and stand structural parameters in two 1-ha forest sites (Forest-117: lower soil P content, Forest-67: higher soil P content), located within the Tapajós National Forest (TFN, Pará) in Brazil and 40 km apart. Despite their close geographical proximity, our results reveal functional, structural, and floristic heterogeneity. Specifically, we found greater investment in xylem hydraulic safety (more negative P50) and lower risk of hydraulic failure (high HSM) in Forest-117, where soil P is lower. Moreover, we observed a high species turnover between the two sites, as well as a high turnover in the abundance of co-occurring species, such as the upper canopy species *Minquartia guianensis* (higher abundance at Forest-117 site than in Forest-67), and the middle canopy species *Coussarea paniculata* and *Aparisthmium cordatum* (higher abundance at Forest-67 site than in Forest-117). Our results suggest that, at the local scale, the distribution of species and hydraulic functional diversity can be modulated by the variation in soil P and highlight the need to consider different both functional and structural diversity for a better representation of the spatial heterogeneity of Amazonian tree communities. **Keywords:** Diversity, drought tolerance strategies, structural parameters, species turnover, phosphorus availability

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Canopy Tree Mortality Depends on the Proportion of Crown Exposed to Direct Sunlight, Tree Growth, and Species Wood Density

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Tree mortality rates have been increasing over the last decades in the Amazon basin, impacting carbon dynamics and species composition, therefore, understanding tropical tree mortality drivers is nowadays an important issue in forest ecology. Recent studies have shown that tree mortality depends on tree- and species-level factors. Since light is an important resource for trees, its availability is expected to be positively associated with survival. However, bigger and presumably older trees exposed to sunlight are more prone to die not necessarily because of light excess, but because of other mortality risks correlated with large trees (*e.g.,* damage accumulation, senescence). Other important, non-exclusive factors related to tree death are crown damage, prior growth rate and species wood density. However, tree mortality drivers have not been exclusively assessed on tropical canopy trees (*i.e.,* those directly exposed to sunlight), which contribute disproportionately to carbon dynamics. Here, we assessed the influence of relative crown exposure to light (*i.e.,* relative to total crown), individual-level growth rates, tree size, and species wood density on canopy tree mortality for the 25ha Amacayacu Forest Dynamics Plot (AFDP), northwestern Amazon. We used a drone-derived orthomosaic and full censuses of the AFDP to model with GLMMs the influence of these factors on canopy tree mortality between 2013 and 2019 for 884 trees (241 species). We found that relative crown exposure to light, wood density and individual-level growth rates explained canopy tree mortality. Light-wooded trees were more likely to die in more shaded conditions, while hard-wooded trees were more likely to die when they were more exposed to direct sunlight. Also, the probability of death was always higher for trees that grew less than the species average. Our results indicate that species light-use strategies influence canopy tree mortality, light-demanding species (as proxied by light wood density) died less when they were more sun-exposed, while shade-tolerant species died more under the same conditions. A post-hoc analysis showed that shrubs (*i.e.,* species with their life cycle on the understory) were more likely to die when exposed to direct sunlight, indicating key light dependencies based on species growth forms. Our results suggest that the inclusion of plant functional types based on life-history strategies as well as the level of individual tree light exposure in vegetation models is crucial to improve demographic estimates on Earth System Models and therefore, predictions about their responses under the ongoing global changes. **Keywords:** Canopy, mortality drivers, tree crowns, light-use strategies, drone, growth rates

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Development of Methods for Quantifying Tropical Moist Forest Structure with the GeoSLAM Zeb Horizon Mobile Laser Scanner in Panama

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Motivation: Tropical forests vary widely in their structure and thus in their biomass carbon stocks, and this variation is of great basic and applied interest. However, we lack widespread high-quality data on tropical forest structure and biomass: estimates based on traditional tree censuses are labor-intensive, have large errors (in part due to variability in tree allometry), and are absolutely scarce, while estimates using terrestrial laser scanning are even more expensive and scarce. Relatively new mobile laser scanners combined with SLAM algorithms offer the potential for rapid collection of high-quality three-dimensional data on forest structure and biomass. Objectives: To evaluate alternative methods for collecting and processing mobile laser scanning data with the GeoSLAM ZEB Horizon scanner, and to develop optimal protocols for use of this scanner to census trees, lianas, and woody debris in tropical forest plots. **Methods:** We tested the performance of the GeoSLAM ZEB Horizon mobile laser scanner in capturing the 3D structure of moist tropical forests in Central Panama. We evaluated alternative walking paths for collecting data with the scanner, different settings for processing the scanner data into 3D point clouds, and different tools for using the point cloud data. We compared methods in terms of systematic and random errors in measuring diameters, cross-sectional area, and volume of stems and woody debris, as well as the costs in personnel, time and computing resources. **Results:** Mobile laser scanner data are considerably noisier than terrestrial laser scanning data. Alignment errors that accumulate over the course of a given 10–20-minute scan result in spatial location errors of 0-10 cm between points at the start and end of a given scan. Despite these errors, the abundance of points and the ability to systematically filter points enables highly precise and accurate measurement of diameters, cross-sectional areas, and volumes within the forest understory. The time to collect scan data is fairly short (20 minutes for 0.25 ha approximately), but additional field time is needed to map out the walking route in advance to ensure that no part of the plot is missed, and subsequent data processing remains time-consuming. **Conclusions:** Mobile laser scanners show promise as a tool for rapid collection of understory forest structure data in tropical forests. The magnitude of errors varies considerably depending on the details of data collection, processing, and site complexity. Thus, care needs to be taken to utilize procedures that minimize these errors. **Keywords:** Tropical forest, lidar mobile, laser forest, structure rainforest, pointcloud, biomass

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"Paradox" of Diversity in Asian Dipterocarp Forests: Preliminary Results from a Pairwise Plant-soil Feedback Experiment in Sri Lanka

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In tropical Africa and Americas, trees that host ectomycorrhizal (EcM) fungi primarily occur in monodominant forests, where overall tree diversity is low. Thus, it is often assumed that EcM fungi provides a benefit to their host trees, especially on nutrient-poor soils, that compensates for the costs of host-specific soil pathogens, which would otherwise prevent tree species from becoming monodominant. But Asian rainforests, despite their dominance by EcM-host trees in the family Dipterocarpaceae (dipterocarps), maintain high tree species diversity. This "paradox" of diversity in Asian dipterocarp forests remains poorly understood. To better understand how the soil microbial communities affects coexistence of tropical tree species in Asian dipterocarp forests, we conducted a pairwise plant-soil feedback experiment in dipterocarp forests of Sinharaja, Sri Lanka. We selected two EcM-host dipterocarp species (*Shorea trapezifolia* and *Dipterocarpus zeylanicus*) and two non-EcM-host tree species (*Horsfieldia irya* – Myristicaceae and *Bhesa ceylanica* – Centroplacaceae) and transplanted seedlings of each of these species into plots beneath adult trees in a pairwise, full-factorial manner ($N_{\text{plots}} = 80$). We predicted that non-EcM-host seedlings would survive better beneath heterospecific adults than beneath conspecific adults due to pathogen escape, while EcM-host dipterocarps would survive better beneath conspecific than beneath heterospecific adults due to colonization by host- or habitat-specific EcM fungi. Four months after the experiment began, we observed a survival advantage beneath conspecifics compared to heterospecifics for both EcM-host species: *Dipterocarpus* (Home>Away by 8%) and *Shorea* (Home>Away by 19%). However, we also discovered an unexpected home-site advantage among the two non-EcM host species, *Horsfieldia* (Home>Away by 3%) and *Bhesa* (Home>Away by 5%). While our results reveal the importance of EcM-fungi as a putative driver of home-site advantage, a similar (but weaker) home-site advantage in non-EcM-host species indicate that benefit from pathogen escape may be weaker than costs of growing in sub-optimal away habitat. These preliminary results neither validate nor refute the "paradox" of diversity in

dipterocarp forests. Instead, they indicate that the "paradox" of diversity is borne off of a simplification of ectomycorrhizal advantage – in reality, the EcM-advantage trades off against other drivers of plant performance such as pathogen escape and occurrence within or away from the abiotic optima. **Keywords:** Diversity, tropics, trees, soils, Asia, mycorrhizae, pathogens, coexistence

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Local-scale Changes in Topography Influence Tree Growth and Mortality in a Terra Firme Forest in the Northwestern Amazon

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Background: Spatial variation in tree species diversity and distribution is thought to be mediated by environmental variation, including topography, but the underlying processes are not well understood. Wetter habitats like valleys should support higher growth and survival than drier habitats like ridges because most trees perform better with more resources. However, deviations from this may occur due to the species' habitat associations, which should be aligned with species' ecological strategy along the interspecific acquisitive-conservative spectrum: fast growth at the cost of lower survival, and higher survival at the cost of slower growth. Moreover, for habitat associations to rise, species should perform better (higher survival and growth) on their home versus non-home habitats (*best-at-home* hypothesis) and, in a particular habitat, species associated with this habitat (residents) should perform better than species present, but not strongly associated with that habitat (foreigners) (*resident-advantage* hypothesis). **Objective:** We tested the *best-at-home* and *resident-advantage* hypotheses using demographic data of tree species across topographic habitats (valley, slope, ridges) at the 25 ha Amacayacu Forest Dynamics Plot (AFDP), Northwestern Amazon. Specifically, we ask: (1) Do tree growth and mortality rates vary across topographic habitats? and, (2) Do these patterns vary depending on the species' habitat associations, and are they consistent with expectations based on the acquisitive-conservative spectrum? **Methods:** We used two full censuses (in 2007 and 2013) of 123,977 trees (1,266 species) with dbh 1 cm in the AFDP, an aseasonal forest with only 22 m of elevational change across 25 ha. Mixed-effects models were used to examine the demographic variation in growth and mortality rates across topographic habitats and species' habitat associations controlling for tree size (dbh). **Results:** Trees growing on valleys had significantly higher mortality and growth rates compared to trees growing on slopes and ridges. This pattern held true regardless of the species' habitat associations. As a result, only species associated with the valley supported the *best-at-home* and *resident-advantage* hypotheses, in that only valley specialists performed better on their home habitat than elsewhere and outperformed non-specialist species in the valleys. **Conclusions:** Despite little elevational change, our results showed marked variation in tree growth and mortality across topographic habitats that were in line with expectations based on the acquisitive-conservative strategies. Our findings suggest that even small differences in topography can translate into differences in access to soil water affecting tree performance, which has implications for understanding species' ecological strategies and forest responses to climate change. **Keywords:** Amazon basin, habitat association, demographic variation, tree species, acquisitive-conservative

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Diversity of Potential Mycorrhizal Fungi Associated with the Endangered Orchid *Cattleya Quadricolor Lindl* Endemic to Tropical Dry Forest in Colombia.

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Orchids have an obligatory symbiosis with orchid mycorrhizal fungi (OMF) for seed germination in the wild, and nutrition in adult plants. These symbionts are essential for natural demographic recruitment, as well as population restoration and conservation initiatives. The diversity and specificity of OMF varies between orchid species, and it is not yet clear whether those fungi present in adult orchid roots are the same symbionts as those involved in seed germination. Thus, it is necessary to study OMF diversity across developmental life-stages in each orchid species. We studied the diversity of pontential OMF associated with *Cattleya quadricolor* Lindl., a highly endemic, epiphytic orchid, with a distribution restricted to the middle basin of the Cauca River in Colombia. The species is categorized as 'Endangered' at the national level, a consequence of extensive degradation of its native tropical dry forest habitat, as well as severe historical, and still ongoing illegal extraction of plants for trade. Endophytic fungi were isolated from three root sections from six plants of *C.quadricolor* occurring

on different phorophytes of the same species (*Erythroxylum hondense* Kunth) in a single remnant population of *C. quadricolor* in the municipality of Bolivar, Valle del Cauca Department. Seed baits for mycorrhizal fungi capture were also placed in the same orchid population over two periods: 63 and 181 days. Associated fungi were isolated to pure culture, and subject to molecular identification using DNA sequences from the rRNA-ITS barcode region. Pure fungal isolates were conserved *ex situ*. To date, 24 fungi have been isolated from the sampled roots and seed baits, including isolates of the genus *Tulasnella*, with known orchid mycorrhizal function. This is the first study of potential orchid mycorrhizal fungi in *Cattleya quadricolor*. The fungi isolated and conserved represent an important resource for future actions in *ex situ* symbiotic germination for population restoration strategies in this the highly endemic, and endangered orchid. **Keywords:** *Cattleya quadricolor*, obligatory symbiosis, mycorrhizal fungi, endophytic fungi, rRNA-ITS, conservation

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How Ectomycorrhizal Communities Vary from Natural to Urban Ecosystems: *Quercus humboldtii* as a Study Case in the Tropical Andes

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Introduction / Background / Justification: Urban landscapes are becoming more important due to the accelerated population growth and increasing urbanization. Urban ecosystems serve as home to diverse plant and fungal communities. However, studies focusing on the diversity and structure of biological communities are uncommon in this habitat. In Colombia, *Quercus humboldtii* Bonpl. is a conspicuous ectomycorrhizal species present in tropical montane forests that hosts a high diversity of ectomycorrhizal fungi in its roots. *Quercus humboldtii* is commonly used as an urban tree in Bogotá, but the ectomycorrhizal communities of this species have not yet been studied in urban ecosystems. **Objective(s)/Hypothesis(es):** We studied how the composition of ectomycorrhizal fungal communities associated with *Q. humboldtii* change between natural and urban ecosystems, and determine which environmental variables influence the species composition. **Methods:** Roots of 24 trees were sampled in two sites, Chicaque Natural Reserve (natural) and three neighborhoods of Bogotá city (urban). Soil samples were collected under each sampled tree and analyzed for various soil nutrients and characteristics. Using Illumina sequencing, the ITS1 region of all root associated fungi was amplified and analyzed using both OTUs and ASVs bioinformatics pipelines. **Results:** We found 949 OTUs in Bogotá and 514 OTUs in Chicaque. We didn't find significant differences in the species richness between Bogotá and Chicaque sites based on Fisher's alpha or species-accumulation curves. In Chicaque communities, the most abundant genera were *Russula* and *Lactarius*, while *Scleroderma*, *Laccaria*, and *Trechispora* were highly abundant in Bogotá. The high abundance of *Scleroderma* in urban trees could have been caused by inoculation with an exotic species. Additionally, the high abundance of the genus *Laccaria* could imply a high presence of nitrophilic species, frequently found in disturbed sites. An NMDS analysis showed that samples from the natural site had a significantly different community composition compared with urban trees. We found that tree DAP was significantly correlated with the ECM community composition suggesting that tree age could significantly alter the symbionts species present in *Q. humboldtii* roots. The use of OTUs or ASVs did not influence species composition when studying communities of root-associated ectomycorrhizal fungi. **Implications/Conclusions:** Our results highlight the importance of *Quercus* trees as reservoirs of ectomycorrhizal fungal diversity in Bogotá. We must continue studying urban mycorrhizal communities to promote the inclusion of this biotic interaction when implementing environmental management plans and ecological restoration programs in tropical areas.
Keywords: Ectomycorrhizal fungi, *Quercus humboldtii*, community structure, rural vs urban communities

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Population, Community, or Landscape Ecology

A Generalized Plant-frugivore Network Involving Cactaceae and Functionally Diverse Vertebrates in Brazilian Caatinga

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Introduction / Background / Justification: Cacti species play a major role in resource availability in arid and semiarid ecosystems. Several studies reinforced the role of birds, bats, and lizards as effective cacti seed dispersers. However, the structure of a cacti-frugivore interaction network, such as the nestedness and modularity, with all its potential frugivores is not yet known. Plant resources, such as fruits, may impose limitations to frugivores in accessibility, such as height, which affect the feeding behavior of frugivores that have a preference or are limited to certain forest strata. **Objective(s)/Hypothesis(es):** We aimed to describe the network structure of a cacti-frugivore interaction network. We hypothesized that if cacti height is a constrain to animals given its mobile capacities, the network should be more modular than nested and that less mobile animals should form modules with the shortest cacti species and more mobile animals with the tallest cacti species. Also, we described the cacti frugivory patterns and tested for differences in the mean height of fruits consumed by vertebrates, and for the similarity degree between cacti species. We expected that cacti species from similar heights should share a similar set of frugivores. Methods: We monitored frugivory in *Melocactus zehntneri, Tacinga inamoena, Xiquexique gounellei, P. pachycladus,* and *Cereus jamacaru* species in a Brazilian semiarid region, known as Caatinga, at Rio Grande do Norte state. We used camera traps for over a year, contemplating both daytime and nighttime. We built an interaction matrix with the records to perform network analysis with the Bipartite Package in software R and to perform the Bray-Curtis index in software Past. We explored differences in the mean height of fruits consumed by birds, mammals, and reptiles in R. **Results:** In 2,929 camera-days, we found 23 vertebrate species consuming cacti fruits, except *T. inamoena*, all recorded as primary dispersers, seven of which were new records. The network was not nested or modular and cacti presented a generalist strategy attracting different animals that potentially play complementary roles in seed dispersal. Interactions within the network were vertically stratified and proximity to the ground seemed to increase the diversity of animals who consumed cacti fruits. **Implications/Conclusions:** In addition to new information, we reinforce the importance of cacti on a community scale, where cacti offer fleshy fruits with small seeds year-round. Future research should evaluate the role of cacti as keystone species at Caatinga and the effective role of frugivores in cacti seed dispersal. **Keywords:** Camera traps, frugivory, fruiting phenology, modularity, mutualism, nestedness, plant-animal interactions

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Neotropical Butterflies: an Integrative Approach to Investigate Diversity Patterns

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Introduction: This study investigated how historical and contemporary climatic conditions and biogeographical processes shape patterns of diversity in montane areas in the Neotropical region. The availability of robust and dated phylogenies, climate models that recreate conditions in past geological periods, and the evolution of geoprocessing technology have opened a window for the understanding of biodiversity distribution. Butterflies of the genus *Actinote* (Nymphalidae: Heliconiinae: Acraeini) was used as a study model. The group is distributed mostly in the Atlantic Forest and the northern Andean region. **Objectives**: 1) It was explored whether the expansion of the species richness areas was related to climatic events that allowed the creation of corridors between the disjoint areas found nowadays, 2) It was analyzed how these past conditions could shape the current patterns of diversity. Specifically, it was compared the species richness distribution with the distribution of the phylogenetic diversity (PD). **Hypotheses**: 1) In periods with higher temperatures, there was a retraction of the richest areas, which remained only in mountainous regions, while in colder periods, these areas expanded, with a connection between the different mountainous massifs and also between the Atlantic Forest and the Andean region, 2) In species-rich areas, it is expected that if the region has a high speciation rate and rare immigration events, the PD will be lower when compared with regions with slower diversification rates and more frequent immigration events. **Methods**: Potential distributions were predicted for the current, Mid-Holocene (6ka), and Last Glacial Maximum (21ka) climatic scenarios using an ensemble approach. Event-based models (DEC) were used to infer the ancestral distribution of the group. PD was measured by 3 approaches: Faith's PD, Faith's PD residuals and Mean Pairwise distance (MPD). **Results**: The results suggest that the ancestral distribution of Actinote comprises an area now dominated by the Atlantic Forest. Thus, the posterior colonization of the Andean possibly occurred through events of dispersion. Based on the niche modeling, it was suggested that the dispersion events may be related to climatic events, since an expansion of the rich areas was found during the LGM. The results for Faith's PD residuals and MPD reflected the possible group dispersal events from Atlantic Forest to Andes. Meanwhile, Faith's PD was highly correlated with species richness. **Conclusions**: This study demonstrated how past climate change can structure diversity and show the different biases of different measures of phylogenetic diversity, which, so, must be used carefully in conservation studies. **Keywords:** Neotropical butterflies, distribution, climate change, richness, phylogenetic diversity

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Hydrologic Controls on Vegetation Function and Structure across Nested Scales in a Neotropical Savanna

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While precipitation patterns correlate well with the large-scale distribution of vegetation, local scale vegetation mosaics cannot be explained by climate alone. In the Cerrado savannas of Brazil, hydrology has been shown to determine the existence of forest formations in otherwise savanna-dominated landscapes. In this study, we test the influence of hydrology on plant distribution and function across spatial scales. First, at the hillslope scale, we test whether the gradient from deep to shallow water table is reflected in the hydraulic function of the vegetation. We monitored water table depth at three wells at the slope base and valley and measured hydraulic traits – resistance to embolism (P_{50}) and hydraulic safety margin (HSM) – for dominant woody species in two communities in contrasting topographic positions: upland woody savanna and valley gallery forest. We then turn to finer topographic variability (0-2 m of elevation difference), looking at the *campos de murundu* formation, where islands of waterlogging-intolerant woody savannas form on earth mound tops, surrounded by grass cover. We monitored water table depth at the top and base of different size mounds, and measured woody vegetation structure (e.g., height, diameter), if present. Our results show that the hydrologic gradient drives changes in community hydraulic function, with significant differences in resistance to embolism and hydraulic safety margin between communities at different topographic positions. At the microtopographic level, we show that the base of murundus suffer more waterlogging than murundu tops. This is reflected in the vegetation, with maximum woody vegetation height following a threshold-like relationship with murundu height and thus sheltering from waterlogging. Taken together, our findings highlight that the hydrologic gradient is a key vegetation driver across spatial scales, controlling vegetation either through enhanced water supply (as in gallery forests) or waterlogging stress (as in the murundu fields), even in the strongly seasonal Cerrado savannas. **Keywords:** Crosscale ecology, Cerrado, ecohydrology, hydrologic niche, vegetation distribution

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The Birds of the Moorland Campanario, in Calarca, Quindío Colombia

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The moorland, a portion of biogeophysical and sociocultural land whose uniqueness and fragility is evidenced by those who have had the opportunity to observe it from up close and from afar, and where a considerable diversity of flora and fauna species live, which in most cases are presenting in a unique way for this ecosystem, being water regulation one of the most important ecosystem services as well as carbon sequestration. It is in this, that the interactions that occur between the populations of birds and the present flora, through processes of pollination and seed dispersal, allow the maintenance and sustainability of what is considered an ecosystem highly vulnerable to the transformations that natural or anthropocentric is presented, changing in the same way in the composition and structure of the populations that live there. Due to the above, the objective of this study was to determine the structure and composition of the birdlife in the "El Campanario" moorland, municipality of Calarcá, Quindío. To meet this objective, for four months six two-kilometre tours were carried out along trails in the area, where the birds were recorded by direct observation with 10X42 binoculars and vocal and mechanical sounds, the identification was corroborated with the Illustrated Guide to birdlife Colombian (2018) and the digital platform Xenocanto. They belong to 89 species, grouped into 24 families, being Thraupidae and Trochilidae the families with the highest number of species, 22% and 16% respectively. The species with the highest number of records during the sampling correspond to taxa typical of moorland ecosystems, among these are the Herrán's Hummingbird (*Chalcostigma herrani*), the Mosquera Calzadito (*Eriocnemis mosquera*) and Red-tailed Metalura (*Metallura tyrianthina*). The representation of the families with the highest number of records is a very important fact, taking into account that the representatives of these two families correspond to species whose diet is rich in fruit and flower nectar, this means that they play a fundamental role in the regeneration of moorland ecosystems and disturbed areas through seed dispersal and pollination processes.
Keywords: Birds, Paramo bell tower, composition and structure

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Gain of Habitat-generalist Birds Does Not Compensate for Loss of Forest-dependent Birds across a Gradient of Forest Cover

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The amount of native habitat cover in anthropized landscapes plays a major role in driving species richness and composition. The decrease in tropical forest cover causes different effects on species with different habitat requirements. While forest-specialist species are highly sensitive to deforestation due to their dependency on closed habitats, habitat-generalists are less affected by changes in habitat structure. Nevertheless, the diversity components of species compositional shifts and the species distribution thresholds according to the amount of habitat cover remain poorly understood. Here, we evaluated how the amount of forest cover determines the richness and composition patterns of forest-dependent and habitat-generalist bird species in the Atlantic Forest from Brazil. We additionally established a threshold for the change in species distribution along a forest cover gradient. We sampled the bird communities from 40 landscapes with independent gradients of forest cover ranging from ~1.3% to ~90% (within a 1000 m radius). Decreasing forest cover reduced the richness of forest-dependent species and increased the richness of habitat-generalist birds. However, the gain of habitat generalists did not compensate for the loss of forest-dependents birds. For example, a 10% decrease in forest cover led to the loss of ~4 forest-dependents and the gain of only ~2 habitat generalists. As a result, we demonstrated that the loss of forest-dependent bird species and the gain of habitat-generalist were the primary causes of increased differences in bird community composition. Furthermore, the main threshold for the change in species composition was determined to be 32% of forest cover. In landscapes with less than 32% of forest cover, the exclusion of forest-dependent species may reach up to 23%. Thus, the amount of forest cover in tropical landscapes is a deterministic factor for the structure and dynamics of communities. Evaluating

the thresholds at the species level proved to be a more effective tool for conservation of species, mainly for forest-dependent species, and are essential for devising more effective environmental policies in tropical forests to maintain ecosystem integrity. **Keywords:** Forest Amount, thresholds, Atlantic Rainforest

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The Cerrado Flowering Duration Are Being Affected by the Climate?

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The cerrado is a mega-diverse seasonal tropical vegetation, considered a biodiversity conservation hotspot. Plant communities are structured according to their reproductive strategies, by interacting with local floral visitors and depending on climatic conditions. Climate change is altering flowering patterns in temperate vegetations, such as, the decrease in flowering duration affect interactions and causing ripple effects on pollinators, frugivores, and seedling establishment. These effects also affect the quality of life and human well-being, which are vulnerable due to the decrease in ecosystem services. In the cerrado and tropics in general, the effects of climate change on plant phenology and their consequences are still poorly understood. Therefore, to evaluate the flowering phenology duration over time in the tropics, and establish relationships with climate change (ODS 13 and 15), we seek to answer: (i) There are differences in the flowering duration of species over time? (ii) These differences are related with climate change? We used a unique tropical cerrado *sensu stricto* long-term phenological monitoring, with 37 plant species and 15 years of monthly observation, from 2005 to 2019. The data was compiled and a generalized linear model was calculated. We found significant differences in flowering duration over time in the community, which mostly species decreased their duration. Only four species did not change significantly the duration time. In addition, we found a positive relationship between flowering duration and temperature, which the increase of temperature, decrease the duration of flowers in the community. The results showed that the resource availability is decreasing for pollinators. A cascade effect is expected with mismatch between interactions, and consequently, less fruit production and seedling establishment. The biodiversity in the cerrado becomes highly threatened by climate change and human actions. **Keywords:** Cerrado, brazilian savanna, phenology, flowering, climate change

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Assessing Linear Vs. Non-linear Effects of Landscape Forest Loss across Tree Ontogenetic Stages and Regions with Different Deforestation Level

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Forest loss threatens biodiversity worldwide, especially in the tropics. However, the impact of forest loss is not always linear, as there can be threshold values of forest loss beyond which species can become locally extinct. Evaluating potential extinction thresholds is needed to identify the amount of habitat needed to achieve conservation goals. We evaluated linear and non-linear effects of landscape-scale forest loss on species diversity of forest-specialist (shade-tolerant) trees in 40 landscapes across two Mexican rainforests (Lacandona, Los Tuxtlas) with contrasting degrees of deforestation. We expected that tree responses are positively related to forest cover, especially in the region that has experienced higher deforestation and during a longer time period. Also, we expected that the extinction threshold is likely higher (trees need more forest to prevent extinction) in the more deforested region. Using a multi-scale approach, we compared the linear (GLM) and non-linear (four parameter logistic regression model) effects of forest cover on species richness (q0), exponential Shannon entropy (number of common species, q1) and inverse Simpson concentration (number of dominant species, q2), separately assessing the response of seeds, saplings, juveniles and adult trees. Overall, linear models better-predicted tree responses to forest loss across regions, but responses were generally weak (<34% of explained deviance in all cases). Forest cover was positively related to diversity of seeds (q0, q1 and q2) in the more conserved (Lacandona) region, and to q0 in the more deforested (Los Tuxtlas) region. Nevertheless, q1 and q2 of seeds decreased non-linearly with forest loss in Los Tuxtlas, with extinction thresholds located at 39% and 38% forest cover, respectively. Forest cover related negatively to q1 and q2 of saplings in Lacandona, but positively to q0, q1 and q2 of saplings in Los Tuxtlas. q0 and q2 of juvenile trees responded linearly and positively to forest cover in both regions, whereas forest cover had negative effects on q0, q1and q2 of adult trees in Lacandona. These findings indicate that seeds are more sensitive to forest loss than the rest of ontogenetic stages, especially in more deforested regions like Los Tuxtlas. Therefore, preserving 40% forest cover and preventing forest loss is needed to promote the persistence of trees in human-modified rainforests. **Keywords:** Extinction thresholds, rainforest, trees, forest loss

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Pollinator Network on the Highlands of the Colombian Andean Region: A Case Study in the Páramo of Matarredonda.

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Páramos are tropical alpine ecosystems found above 3000 m in Central America and the Andean region. They are essential water reservoirs for neighboring populations and important biodiversity hotspots with around 80% endemic species. Their unique species and the stability of their interactions are threatened by climate change, mining, and habitat fragmentation. To understand how sensitive the páramo may be to climatic and anthropogenic changes, we need to evaluate whether their plant-pollinator networks are specific or generalist. The more specialized the networks are, the more vulnerable the ecosystem will be because if one member of the interaction disappears, the other will also be affected. The only pollination networks that have been published to date for the páramo were constructed for the páramos of Venezuela and show a specialist pollination system where most species interact with few species. However, that networks were based on visitation data and did not evaluate pollinators' effectiveness. Given the limited number of studies, the question remains whether the páramos have a generalist or a specialist network. Here we studied the plant-pollinator network of a Colombian Páramo using pollinator´s visit data and incorporating data on pollinator´s effectiveness obtained from the count of pollen tubes germinating in the stigma of flowers after a single visit by each pollinator species. Additionally, we carried out hand pollinations using self and cross pollen to identify the breeding system of the species. After seven months of observation, we have recorded 67 morphospecies visiting the flowers, including hummingbirds, hymenopteran, dipteran, lepidopteran, coleopteran, and hemipteran. The richest group of pollinators are dipterans of the Syrphidae family, with 18 morphospecies registered. The most generalist pollinator is *Bombus rubicundus*, recorded visiting more than 20 plant species. In a preliminary analysis, we found a specialized index of 0.49, significantly different from indexes obtained by calculating 10000 random bootstrapped networks ($P < 0.001$) suggesting that this Colombian páramo also has a specialist network. Our data shows that this páramo in Colombia has a higher pollinator richness than the Venezuelan páramo, where 13 morphospecies were recorded visiting flowers. We expect to give a definitive conclusion on the specialized index of the pollinator network at the meeting after finishing collecting observation data and incorporating the effectiveness data. Our work establishing a robust pollination network for this páramo will contribute to the ecological knowledge of Colombian Páramos and support conservation decisions in this extraordinary yet threatened ecosystem. **Keywords:** Pollination network, pollinator effectiveness, community interactions, specialized index, syrphidae family.

Phylogenetic Structure of Coastal Plain Forest and Lower Montane Forest Tree Communities in Brazilian Atlantic Forest

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Along the latitudinal axis of the southern portion of the Brazilian Atlantic Forest two environments that are geographically contiguous and share a regional species pool can be found: the coastal plain forest (CPF) and lower montane forest (LMF). The edaphic conditions in the CPF are more restrictive to plant development because the soil is sandy and nutrient poor. Therefore, it was expected that environmental filtering would be stronger in CPF tree communities. Assuming that environmental filtering selects taxons with similar traits and that there is niche conservatism in Angiosperms, we expected that the phylogenetic structure of tree communities in the CPF would be more clustered than in the LMF. We analyzed 363 genus that occur in at least one of the 60 sites studied, being 16 sites in the CPF and 44 in the LMF. To access the phylogenetic structure we measured the alpha-phylogenetic diversity of each site with the standardized effect size of the Mean Phylogenetic Distance (sesMPD) and Mean Nearest Taxon Distance (sesMNTD). For both sesMPD and sesMNTD the phylogenetic structure did not differ between the CPF and LMF (t-test = 0.975, P-value = 0.338, t-test = -0.205, P-value = 0.839, respectively) and the community phylogenetic structure in each environment was not, on average, different than expected by chance (mean sesMPD = 0.28 and 0.66, mean sesMNTD = -1.35 and -1.28 for CPF and LMF, respectively). These results suggest that environmental filtering would not be the main process structuring CPF tree communities at these systematic precision, or at least that this is not the only process structuring these communities. Due to the great variation in sesMPD and sesMNTD values observed between communities of the same environment, we conducted an additional analysis to assess if this variation was associated with the latitudinal gradient. This analysis was performed using linear models. For the LMF communities sesMPD ($R^2 = 0.3165$ P-value = 4.211e-05) and sesMNTD

($R^2 = 0.197$ P-value = 0.001496) values indicated more clustered patterns towards lower latitudes. For the CPF communities, neither sesMPD ($R^2 = 0.005449$ P-valor = 0.3158) or sesMNTD ($R^2 = 0.1038$ P-valor = 0.1203) had a significant relation with the latitude. Indicating that factors that vary along this gradient, such as climate and biogeographical history, could be relevant to determine the phylogenetic structure of LMF communities. However, despite the geographical proximity between the environments, these factors do not have the same importance for CPF. **Keywords:** Plant ecology, phylogenetic analysis, environmental filtering, coastal plain

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Natural Regeneration Patterns of the Tropical Dry Forest in Successional Forests of the Magdalena River Valley.

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Forest regeneration potential has a substantial impact on successional pathways, since the species composition observed in seedling assemblages is expected to determine the floristic trajectory of secondary forests. Addressing this issue is particularly important in tropical dry forests (TDF) since it is an vulnerable ecosystem that may be at the verge of extinction. Indeed, more than 50% of dry forest current coverage is secondary forests in different stages of succession and this can have critical implications for its future state as TDF exhibit multiple successional barriers as a result of its climate seasonality. Here we evaluate the regeneration potential of secondary forests in the Magdalena valley (Tolima, Colombia), were less that 36% of TDF remain and most of them are regrowth forests. We established four 0.1-ha plots differing in successional status (initial, early, intermediate, and late succession) in three sites for a total of 12 plots. Within each plot, we measured trees with DBH$>$ 2.5, as well as seedlings with height $<$1 m in 24 subplots of 1 m^2. By comparing floristic composition across sites and ontogenetic stages, we found that the regeneration process is influenced mostly by site variability. Although there were significant floristic differences between some of the successional states, floristic turnover along succession did not show a directional trend. Seedling assemblages in initial and early stages were dominated by a few species. In contrast, mature forests showed a higher diversity of abundant species, typical of intermediate and advanced successional stages. Understanding forests regeneration potential is critical for identifying those successional stages that present the strongest environmental barriers and to evaluate where assisted regeneration is needed. Overall, integrating this knowledge woth restoration practices will strengthen TDF management. **Keywords:** Floristic similarity, pioneers, replacement, secondary forests, seedlings, successional trajectory.

Habitat Edges Affect Tree Diversity More than Biomass Regeneration in a Wet Tropical Forest

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Introduction: About half of all forests are tropical and secondary, making tropical forest regeneration processes integral to the future of forests globally. However, syntheses find forest regeneration to be quick yet inconsistent–stand biomass and taxonomic richness recovers almost completely in about half a century, but relative abundances may take centuries to recover or instead may diverge entirely. Given that three quarters of all forests are within a km of a habitat edge, nearby habitat edges also likely affect biomass and taxonomic regeneration trends, as well as management history legacies. In wet tropical forests specifically, succession tends to depend on light availability, compared to water availability and hydraulic traits like more open or dry forests, which may also extend to mediate edge effects. **Objective(s)/Hypothesis(es):** This study addresses how wet tropical secondary forest regeneration is affected by distance to habitat edge in a former timber plantation context, and addresses the hypothesis that old plantations facilitate regeneration by favoring shade tolorant or late successional taxa, and that habitat edges affect regenerating community composition. **Methods:** A 20 ha timber plantation abandoned ca 20 years ago surrounded by primary forest on two sides and a main service road on a third was censused for over a thousand trees using random stratified sampling plots representing 5% of total parcel area along a 300 m edge distance gradient in the Osa Peninsula, SW Costa Rica, and analysis

used relevant databases from the literature. **Results:** As distance from primary forest edge increased, biomass and stem and wood density tended to increase, with ca 10% variation explained, while canopy light and stand height tended to stay the same. Stand tree richness also tended to increase, but diversity decreased steeply and non-linearly, and composition varied notably. Tree taxa associated with both early and late successional stages increased, but biomass by dispersal mode did not tend to change. **Implications/Conclusions:** Overall this study supports main ideas about forest regeneration that stand composition is less resilient and more subject to edge effects than biomass and richness, suggesting that global forests will likely be distinctly new assemblages in the future with timber and diversity trade-offs based on local and regional management activity. **Keywords:** Forest secondary regeneration edge biomass diversity community composition function trait

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Chlorophyll and Stomatal Traits of Tropical Dry Forest Species: Are They Coupled to the Leaf Economic Spectrum and Hydraulic Trade-offs?

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Leaf traits like chlorophyll content and stomatal characteristics are related to photosynthetic rates and water transport. Despite their importance for plant performance, their relationships with two well-known functional continuums as conservative-acquisitive and hydraulic safety-efficiency trade-offs have been less explored. We measured chlorophyll a and b content, stomatal size, density, and index in deciduous and evergreen tree species in a tropical dry forest in Colombia and explored their relationship with seven leaf and nine wood anatomy traits. Our results suggested a decoupling between photosynthetic pigment concentration and stomatal traits with the leaf economic spectrum. Additionally, we found that the hydraulic safety-efficiency trade-off was not correlated with the chlorophyll content and the stomatal size, still, it was positively correlated with the stomatal density and index. Deciduous species with wide vessels and light woods had higher stomatal density and index than to evergreen species. Our results highlight the importance of exploring new biochemical and anatomical traits to improve our understanding of traits coupling and plant performance in tropical dry forest species. **Keywords:** Biochemical and anatomical functional traits, acquisitive, conservative

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A Dispersal Trait-Based Approach for Understanding Limitations In Secondary Succession

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Regeneration in tropical dry forests, where abiotic stress due to water availability prevails, has been studied almost exclusively from the perspective of the habitat filtration mechanism. Ecological theory predicts that mechanisms such as source limitation (insufficient surrounding forest or not viable seeds) and dispersal limitation (propagules do not reach the successional sites or absence of dispersers) can simultaneously shape communities and limit regeneration. Therefore, it is imperative to know the specific contexts that promote and enable species recovery and the conditions that reduce dissimilarity in the species composition of conserved forests. For this reason, the aim was to assess the effect of source and dispersal limitations on community structure during secondary succession in the tropical dry forest. This project sought to elucidate what mechanisms are mediating the structuring of the community by focusing on constraints generated at landscape scales and determined by landscape attributes using a dispersal trait-based approach. We employed a chronosequence approach, with a permanent plot system established in a gradient of surrounding conserved forest (0-99%) that considers the effect of landscape on the secondary succession. In addition, we employed a functional trait approach on seeds and fruits, where we considered seed mass, dispersal syndrome, seed size and dispersal unit. We conducted null models to assess the action of more than one community structuring mechanism, besides an RDA to assess landscape plus regeneration age on attribute composition. We found that animal dispersed species were relatively less frequent in early successional stages, except for particular species dispersed by cattle. Besides, our evidence suggests that landscapes with more forest promote a higher number of species dispersed by animals. This study contributes to an integrated understanding of how seed availability and seed dispersal drive tropical forest succession and, more importantly, how different aspects of seed dispersal initiate forest regeneration and modify successional trajectories over time. **Keywords:** Forest regeneration, dispersal limitation, functional traits, landscapes, secondary succession

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Dynamics of the Early-stage Plant Community in a Secondary Tropical Dry Forest of the Colombian Caribbean

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In tropical dry forests (TDF), seasonality is one of the main factors determining the recruitment, mortality, and growth of individuals in the plant community. This is because most species produce seeds during the dry season, which germinate and grow when water is available in the rainy season. Since the TDF is one of the most threatened ecosystems in the tropics, developing studies on understanding these early stages dynamics is crucial for its restoration and conservation. In this study, we aimed to assess the effect of seasonality on the early stages of the tree community dynamics and composition while comparing with the dynamics of mature standing vegetation. The study was developed in the 1 ha permanent plot of the Botanical Garden of Cartagena, Colombia. For the data of the mature trees, we used the information of previous plot censuses and performed an additional census during the study. For the early stages, we established 25 subplots of 4 m^2 inside the 1 ha plot. We registered the species identification, height, and the number of leaves of seedlings and saplings whose diameter at base ranged between 0.1 and 2.5 cm. Those subplots were censed every 3 months during one year to obtain data for the dry and the rainy seasons. Hemispherical photographs were taken during the censuses in each subplot to calculate the leaf area index (LAI). Environmental variables, such as temperature, soil moisture, and precipitation, were measured across the plot to characterize the seasonal change. We have found that the recruitment was higher during the rainy season, and mortality was higher in the dry season. Community diversity decreased between the rainy and dry seasons, and the similarity in composition between the early stages of the plant community and adult vegetation increased during the dry season. Soil moisture and precipitation correlated more with mortality, recruitment, and growth, while the temperature remained constant during the study. LAI decreased in the dry season. In conclusion, the transition from rainy to dry season implied a demographic reduction in the young plant community, mediated by precipitation and soil moisture reduction. Additionally, the increase in similarity between early and late stages in plant community suggests that seasonality act as a filter of species as they reach a higher stage of development due to differences in species survival ability. We will continue doing more censuses to get more details about the dynamics of these early stages. **Keywords:** Tropical dry forest,seasonality,community dynamics,seedlings,young plants, plant dynamics

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Hornbill Population Status outside Protected Areas in the Northern Western Ghats, India

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Habitats outside protected areas are increasingly gaining traction in the conservation discourse, but quantitative information on threatened species is still limited from such habitats. We assessed hornbill population status in the Tillari region, located at the tri-junction of three states (Maharashtra, Goa and Karnataka) in India. The region, part of the Western Ghats, is outside any protected area and serves as a critical corridor for mammalian wildlife. Though it is an agriculture-dominated landscape, it supports a diversity of flora and fauna. Line transect surveys were conducted from January to March 2019. The total survey effort was 68.31 km across 35 line transects, laid randomly using GIS maps across the study region. Four hornbill species were detected during the survey. Malabar Grey Hornbill (Ocyceros griseus) density (SE) was the highest at 7 ($\pm$ 1.6) birds/sq km while Malabar Pied Hornbill (Anthracoceros coronatus) density was 4 ($\pm$ 1.6) birds/sq km. This is perhaps the first assessment that provides reliable baseline information on Malabar Pied Hornbill and Malabar Grey Hornbill populations in an agriculture dominated land-use matrix of the northern Western Ghats. Areas like Tillari face threats from rapid intensification and commercialization of agriculture. Thus, it is crucial to recognize ecological potential of such areas outside protected areas. **Keywords:** Agriculture, wildlife, northern Western Ghats, non-protected areas

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Signs of Urban Evolution in a Chagas Disease Vector: Morpho-functional Traits Co-variation along a Nature-urban Gradient

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Environmental change (i.e. urbanization, etc.) impacts species in contrasting ways, with some species experiencing benefits due to their way of life (i.e. blood-sucking insects). How these species respond to such change is not well understood and for species involved in human diseases, this "how" question is particularly important. Most Triatominae bug species, inhabit tropical and subtropical forests where their vertebrate hosts' temporal abundance depends on climate seasonality. However, in human encroached landscapes, triatomines can benefit of resource stability leading to adaptive phenotypic change to track novel hosts. We tested for an association between different landscapes and morpho-functional traits linked to sensory, motion, and feeding functions in Triatoma dimidiata and compare fertility (i. e. number of eggs) in each landscape as a measure of fitness. Using geometric and traditional morphometric tools, we predicted that traits will show a morphological simplification in bugs present in urbanized areas. While wing morphology or proboscis were not influenced by landscape class, the opposite occurred for thorax morphology and number of sensilla. As such, wing and thorax morphology did not covariate under modified landscape scenarios, but we detected a morpho-functional convergence for thorax size and antennal phenotype, in both sexes, with a simplification trend, from nature to urban settings. We detected a negligible fitness cost in the urban landscape. The convergence of the thorax size and antennal phenotype suggests differences in flight/locomotion performance and host/environment perception, as a possible adaptive response to a release of the selective pressures of its native habitat. These results imply that this vector species has adapted to urbanized areas. **Keywords:** Triatoma dimidiata, adaptation, Urbanization, Domiciliation, Phenotypic variation, Traditional morphometric, Geometric

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Diet and Seed Dispersal by Oilbirds (*Steatornis caripensis*) in the Southern Andes of Colombia

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The diet and the behavior of frugivorous animals (e.g. feeding choice, handling technics, and movement patterns) usually influence plant populations through processes of seed dispersal. This study analyzed information on the diet, and seed dispersal patterns of a population of oilbirds (*Stearornis caripensis*) in the southern Andes of Colombia. To describe the diet we used fruit traps in the main cave in Cueva de Los Guácharos National Park (Huila, Colombia). We also estimated seed dispersal kernels by capturing five individuals, instlling GPS devices, and modelling dispersal distance based on travel paths, the location of potential feeding trees from forest plots in areas of intense use, and published information on gut retention times. We also measured seed dimensions to test the hypothesis that oilbirds may disperse large seeds to longer distances than the estimated for extinct megafauna. We found a diverse frugivorous diet (ca. 60 plant species), with a marked preference for species with high lipid content in the fleshy fruits, mainly from the families Lauraceae, Arecaceae, Burseraceae and Chloranthaceae, and seasonal changes associated with regional phenological patterns. We found that oilbirds disperse large and small seeds (although not from pioneer plants such as *Cecropia* or *Ficus*), including seeds up to 5.4 cm long and 2.9 cm in width. Finally, comparing to other animals, oilbirds disperse larger seeds than expected according to their weight, and the estimated mean dispersal distances surpass those of any other animal studied so far. Therefore, our results support the hypothesis that extant frugivores may disperse large seeds at long distance, an ecosystem service which recently was said to be lost with the extinction of Neotropical megafauna. **Keywords:** Feeding choice, long distance dispersal, moving patterns, PNN Cueva Guácharos

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Population, Community, or Landscape Ecology

Soil Microbial Community, Tree Community and Soil Environment Shape Seedling Recruitment in Southeast Asia

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Aboveground and belowground communities are linked by complex feedbacks where plants, soil microbes, and the soil environment interact through multiple possible mechanisms. Mutualistic or pathogenic microbial communities can associate with specific tree species, and together respond to resource availability in the soil. With land-use change, disruption to community assembly processes can change the patterns of microbial and tree distributions. We hypothesised that tree communities can predict soil microbial community, particularly that tree mycorrhizal association will determine fungal diversity. However, we expect soil bacterial diversity to be more dependent on soil fertility. We hypothesise that difference in tree communities between primary and secondary forests are also reflected in the nutrient content of the lead litter layer, which in turn shapes the saprotrophic microbial community responsible for decomposition. To test the association between tree and soil microbial communities, we sampled an old-growth mixed Dipterocarp forest and secondary forest in Bukit Timah, Singapore in a grid-based design. We measured the depth of litter accumulation and collected surface litter and soils for chemical analysis and ITS and 16s molecular sequencing for soil bacterial and fungal communities. In addition to census of tree communities, we measured seedling densities. We show that plant diversity and microbial community differ between primary and secondary forests, which is associated with the loss of ectomycorrhizal Dipterocarpaceae trees in the latter. We find that highly recalcitrant litter in the arbuscular mycorrhizae-dominated secondary forest is associated with low seedling density, where the thick litter accumulation due altered microbial communities may be impeding the recruitment of seedlings. Meanwhile, leaf litter in the primary forest is highly diverse and in more varied states of decomposition associated with more fertile soils. Our results suggest that tree community divergence with land-use change drives a difference in microbial composition, which in turn alters ecosystem functions such as decomposition, accounting for the difference in soil chemistry between the primary and secondary forests. This feeds back to the differential seedling establishment, an important implication in forest succession dynamics and recovery from human-mediated disturbance. **Keywords:** mycorrhizae tree community diversity litter soil

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Gather round the Tree: Woody Aboveground Biomass Increases Animal Presence and Species Richness in a Tropical Forest-savanna Ecotone.

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Introduction: Boundaries between ecosystems are often biodiversity hotspots with relatively high vulnerability to global change. The boundary between tropical rainforest and savanna ecosystems in the Amazon presents an ecotone that is undergoing a shift in ecosystem structure, as a warming climate promotes the expansion of grassland. How animal communities in the Amazon will respond to changes in ecosystem structure is a crucial unanswered question with implications for the many ecosystem services that animals provide, from a food source for Indigenous people to seed dispersal for vulnerable tree populations. **Methods:** Recent modeling work has forecasted that faunal savannization will occur in the Amazon, as savanna-dwelling animals replace forest specialists. However, empirical data to test these forecasts has remained scarce, due to the need for large-scale data across local and regional forest-savanna gradients. To overcome this difficulty, we quantified associations between terrestrial vertebrates and ecosystem structure using replicated camera traps across a forest-savanna ecotone in central Guyana. To capture continuous gradients in woody biomass across the ecotone, we paired radar-derived measurements of aboveground biomass from Phased Array-type L-band Synthetic Aperture Radar (PALSAR) with animal species presence at camera trap sites, including >54,000 individual photos. **Hypothesis:** We hypothesized that different animal species communities would emerge in sites with different levels of aboveground biomass, representing forest and savanna specialists. We tested this hypothesis with hierarchical Bayesian models for animal species detection and species richness across our study landscapes. Results: Our results did not support the hypothesis that there is a guild of savanna specialists with increased presence in sites with low aboveground biomass. Instead, nearly all (54 out of 56) species showed increased probability of detection in sites with higher aboveground biomass. Consequently, overall species richness was significantly related to aboveground biomass, including a median proportional increase in species richness of 90.0% (CI: 21.57 to 200.0%) for every kiloton of biomass at a site. **Conclusions:** These results suggest that woody structure plays a critical role in supporting animal species richness at the Amazonian forest-savanna ecotone, including non-forest tree cover such as bush islands, gallery forest, and isolated trees. Ongoing declines in tree cover will likely have detrimental impacts across most groups of animal species. Without landscape conservation strategies to maintain tree cover at the forest-savanna boundary, climate change could have severe consequences for Amazonian animal populations. **Keywords:** Animal community, boundary composition and gradient, camera trap, animal faunal

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Fear or Food? Prey Biomass Is More Important than Predation Risk for Insectivorous Bats across an Amazon Disturbed Forest Landscape

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Habitat disturbance affects, directly and indirectly, the predation risk and food availability of animals. For aerial insectivorous bats, important components of Neotropical bat assemblages, the mechanisms underlying the negative effect of habitat disturbance on forest-dependent species remain little understood, and evaluating how habitat disturbance influences prey-predator interactions can provide useful information for the management of protected reserves. We evaluated how predation risk, insect biomass, and moonlight intensity affect bat activity levels in continuous and disturbed forests (fragments and secondary forest). We hypothesized that, in continuous forest, bat activity will respond to insect biomass rather than predation risk and moonlight. By contrast, in disturbed habitats (fragments and secondary forest), bat activity was predicted to respond to predation risk and moonlight more than to insect biomass. The study was conducted at the Biological Dynamics of Forest Fragments Project, near Manaus, Brazil. To record bat activity, we installed passive ultrasound recorders at three sites in continuous forest, three 10 ha fragments, and three sites in the secondary forest adjacent to the fragments between 2018 and 2019, totaling 138 recording nights. During each recording night per site, we performed one of the predation risk treatments (playback of owl calls, noise treatment, control treatment) and we used four malaise traps distanced by 10 m of the recorder to capture aerial insects. Overall, we found that total bat activity was higher in continuous forest compared to disturbed habitats (almost 2 times higher), and insect biomass was higher in continuous forest than secondary forest, but was similar in fragments and continuous forest. Indeed, in secondary forest, total bat activity was negatively related to insect biomass. Our results suggest that undisturbed forest has greater bat activity which may reflect great insect biomass. Insect biomass was a better predictor of activity levels in disturbed habitats than acoustic predation risk and moonlight. Predation risk does not modulate bat activity in any habitat type, and this was probably because bats perceived the owl calls as non-threatening noise in the forest sites. The effect of moonlight on bat activity was weak and only evident in three species in different habitats. Our findings emphasize that food is more important than predation risk in determining bat activity in disturbed habitats. Consequently, undisturbed continuous forests as hotspots of insect biomass should be prioritized not only for bat conservation but also for other animals that are insect consumers. **Keywords:** acoustic sampling, animal activity, fragmentation, prey-predator interactions, secondary forest

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A Potentially Carnivorous Species? Establishing Nitrogen Acquisition Strategies of *Bejaria resinosa* (Ericaceae) in Colombia.

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Introduction: One of the strategies that plants have evolve to survive in harsh environments is carnivory, a method for obtaining nutrients directly from organic sources. In the Ericales, two families have carnivorous strategies: Sarraceniaceae with pitfall traps (32 spp.) and Roridulaceae with sticky traps (2 spp.). In sticky traps, specialized organs secrete substances for catching preys and sometimes digest and absorb their nutrients. *Bejaria resinosa* (Ericaceae) is found in the paramo/subparamo ecosystems of Colombia. Ericaceae are well known for their adaptations to live in poor nutrient soils, including their associations with ericoid mychorrizae. *B. resinosa* has sticky leaf and flowers that secrete a resin rich in triterpenoids were usually arthropods are trapped. **Objective:** We aim to elucidate if *B. resinosa* have an input of nitrogen (N) from arthropods that are caught in their sticky organs consistent with true carnivory, while considering potential N inputs via ericoid mycorrhizae. **Methods:** We are using leaf, flower and root stable N isotopes to compare the *B. resinosa* signature with true carnivores and non-carnivorous Ericaceae and to estimate the amount of N acquired via leaves (carnivory) and roots (mycorrhizae). We are also using microscopic techniques, to compare the micromorphology of the flowers and leaves surfaces of *B. resinosa* with the one of confirmed carnivorous linages. In addition, we will quantify the percentage of ericoid mycorrhizal colonization in the roots. **Results:** Leaf N isotopic signature of *B. resinosa* is consistent with carnivorous plants showing an enrichment of δ15N compared with non-carnivorous Ericaceae. Morphological evidence suggests that *B. resinosa* have glandules in their trichomes that can help trap and digest preys. Nevertheless, their enzymatic activity remains to be tested. In addition, we found significant differences in the δ15N between *B. resinosa* roots and leaves/flowers, being enriched of δ15N in fine roots. These differences could suggest a high fungal colonization in the roots, showing an enrichment of δ15N in heavily colonized roots with higher presence of fungal biomass. Quantifying the percentage of colonization will help to understand the role of fungi in the isotopic composition of *B. resinosa.* Conclusions: Our preliminary results suggest that *B. resinosa* has an isotopic N signature consistent with carnivorous plants but is necessary more analysis to understand the dynamic of N in the plant considering mycorrhizal symbiosis and other interactions. Given the rarity of the carnivorous lifestyle, if confirmed, this will be the first record of this nutritional strategy in Ericaceae. **Keywords:** Carnivorous plants, Ericoid mycorrhizae, stable isotopes, interactions, sticky plant

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From Microbes to New Tropical Forests: Experiment of Fungal Specialization on Host Tree Genotypes in Context of Reforestation Experiment

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While much attention has been given to understanding the mechanisms that drive patterns of tropical tree diversity and conspecific negative density-dependence, important gaps remain in our knowledge of the underlying interactions among tree seedlings and microbial communities that putatively drive these patterns in many systems. For example, soil fungi can have both positive and negative impacts on seedling development, but the factors influencing the net balance of these counteracting forces are not well understood. Here, we report on an ongoing experiment that explores how within-species specialization by soil fungi (i.e., on different host genotypes of the same tree species) may impact seedling performance and emergent patterns of plant community composition. We have implemented a shadehouse experiment in which we propagate seeds collected from fruiting individuals from 16 shade-tolerant species of tree in maternal and non-maternal conspecific soils. This design allows 36 within-species pairwise comparisons with 8 replicates each, of the growth and performance of seedlings exposed to distinct soil microbial communities, for each of 16 different species. We provide details on the methodology, predictions, and preliminary results. This work is expected to provide novel data on the extent to which within-species specialization by soil fungi occurs, the degree to which genetic similarity between conspecific maternal trees predicts magnitude and direction of soil fungal impacts on seedling performance, and how specific combinations of soil and root fungal communities impact seedling performance. **Keywords:** Ecuadorian Chocó, host genotypes, microbial communities, seedling, FCAT.

Riparian Forest Health in the Amazon: Impacts of Deforestation on Temporal Dynamics of Vegetation

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Background: Riparian forests are critical in protecting biodiversity and water resources, and thus are a priority for conservation in anthropized landscapes. However, fragmentation associated with the expansion of agriculture in the tropics threatens the ecological integrity of these forests. This leads to increased mortality of tree species in this region, especially large trees. **Objectives**: In this context, we compared the percent mortality of individuals by tree plant species in tropical riparian forests within intact watersheds (n=4) and in agricultural landscapes (n= in a region of intense soybean production in the southern Brazilian Amazon. **Methods:** The studied forests were between 120 and 210 m wide, and the forests in agricultural landscapes were maintained to comply with Federal Law 12,651, which deals with the protection of native vegetation. We conducted inventories of the ten riparian forests in the years 2015, 2017, and 2019. We used these inventories to calculate mortality by tree plant species. **Results:** We recorded, in the first inventory, a total of 2834 individuals (DBH 1.30 m 5 cm) belonging to 152 tree plant species, with 52% (79 species) common to both forest types. The remainder occurred exclusively in agricultural landscapes (26%) or forest (22%) watersheds. Overall, mortality in the two forest types was similar in the two periods evaluated - in forests in agricultural landscapes 5.4% (2015 to 2017) and 10.6% (2015 to 2019) and, in forests watersheds 5.1% (2015 to 2017) and 12.2% (2015 to 2019). Considering the total number of species in the two forest types 45% (69 species) had no record of mortality of individuals in their populations. In forests in agricultural landscapes and forests watersheds 11 species that had mortality of 50% or more individuals in their populations. **Implications/Conclusions**: Considering that this region is under great pressure from deforestation for cattle ranching and large-scale agriculture in recent decades, and the importance of riparian forests in protecting small streams and biodiversity, these long-term inventories are essential to monitor changes in the forests of these landscapes. Even with the similarity in the percentages of mortality of tree species in the two periods between the two types of forests, long-term monitoring is essential, mainly because we have shown that these forests have differences in the composition of tree species. With this we will be able to know which are the main species that lose individuals, since each species can play specific roles in the functioning of the ecosystem. **Keywords:** Agriculture, carbon, fragmentation, land use, mortality, trees

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Diversity and Species Composition in Soil Seed Banks of Secondary and Old-growth Tropical Mountain Forests in Colombia

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Background: Soil seed banks (SSBs) are an important determinant of plant community structure and dynamics. SSBs are also central in forest restoration because they can help reestablish key species in areas that have been disturbed. Early successional forests are generally dominated by pioneers species with seed that can persist for extended periods of time in soil. In contrast, old forest woody species tend to have more short-lived transient seeds, that do not contribute to the formation of SSB. Andean Tropical Mountain Forests (ATMFs) are hotspots of biodiversity that have been heavily transformed after decades of human intervention, which has favored the establishment of secondary forests. However, little is known about community dynamics in these forests and what role SSBs play in process of succession. Thus, understanding SSBs in ATMFs will help us understand the ecology of these forests and develop better management programs. **Objective and Hypothesis:** The aim of our study was to understand how SSBs differed between young and old ATMFs. We hypothesized that SSBs species composition would not change between the two successional stages, because SSBs in both type of forests will be dominated by pioneer species with persistent seeds. **Materials and Methods:** This study was carried out in forests around Bogotá, Colombia, in 10 permanent plots belonging to the "Rastrojo" Project. We obtained 100 soil core samples in five young and five old forest plots and studied the SSB using the seedling emergence method. **Results and Conclusions:** We found that a total of 43 seedling morphotypes emerged from the SSBs. Old-growth forest had 33 morphotypes, while young forest had 27 morphotypes. In addition, similarity between young and old-growth forests was low and they only shared 17 morphotypes. These preliminary results suggest that our hypothesis is not supported. This could mean that species of old grown forest have persistent seed and hence, SSBs of old-growth forests are influenced by the species composition of

adult (reproducing) individuals. Ongoing work on seedling identification will help us determine to what extent SSBs species composition differ from species composition of adult individuals in the plots. This study sets a baseline for future research and conservation projects in these ecosystems. **Keywords:** Soil Seed Banks, tropical mountain forests, ecological succession

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Temporal Species Turnover in Amphibian and Reptile Species Assemblages: A Comparison between Forest and Oilpalm Plantation Sites.

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Amphibians and reptiles are among the most threatened animal groups with significant declines on a global scale and habitat loss and degradation still represent one of the major threats for amphibians and reptiles. While many studies already documented that oil palm cultivations are characterized by depauperate species communities and dominated by widespread generalists, our knowledge on temporal species turnover in this land use system is very limited. Hence, in this study we re-sampled forest and oil palm plantation sites already surveyed five years before to quantify habitat-specific differences in species turnover as well as temporal changes in assemblage structure and functional diversity. Hypothesis 1: On the level of study sites, we expect a more stable species composition in oil palm plantations as the majority of species consist of widespread and abundant generalists, often rather tolerant against disturbance. Hypothesis 2: On the habitat level, we expect fewer temporal changes in forest habitats than in the human modified land-use system, which may suffer an ongoing loss of rarer species, hence resulting in an ongoing biotic homogenization of species assemblages. Hypothesis 3: We assumed that an ongoing loss of habitat specialists in oil palm plantations may result in a further decline of functional diversity of species assemblages. In contrast, functional diversity at rainforest sites may have remained similar over the period of five years. Hypothesis 4: Amphibians and reptiles may respond differentially to ongoing disturbance with amphibian populations suffering more substantially than reptiles. Fieldwork was conducted between 12 November 2018 and 22 January 2019 at the Tropical Research Station La Gamba, Costa Rica. We used distance- and time-constrained visual encounter surveys to assess the herpetofauna of our study sites. Unless we stated otherwise, all statistics were calculated with R 3.6.1 and R Studio Version 1.2.5001. We assessed habitat-specific changes in species richness, species composition, species turnover and functional diversity, separately for amphibians and reptiles. Results and conclusions are still in progress, but analysis shows significant difference in species composition among forest interior and forest margin versus oil palm plantations in the compared years. Finished results and implications will be presented at the conference. **Keywords:** Oil palm, amphibians, reptiles, species turnover, functional diversity, Costa Rica

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Mycorrhizal Fungi Associated with Coccoloba Uvifera in the Colombian Tropical Dry Forest: an Approach for Ecological Restoration

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Introduction/Background/Justification: Little is known about mycorrhizal associations of the tropical dry forest (TDF) plants of the Colombian Caribe. The TDF is an ecosystem that has been reduced in 92% of its original extension and yet still houses a considerable percentage of the Colombian biodiversity. One restoration strategy in TDF is the ex-situ propagation of native plant species in nurseries for ecosystem restauration/reforestation purposes. Mycorrhizal fungi (MF) improve plant's nutrient uptake efficiency, establishment, growth, and resistance to adverse conditions but despite their importance they are often overlooked in restoration efforts. **Objective(s)/Hypothesis(es):** *Coccoloba uvifera* is relevant in coastal restauration and propagated in nurseries for reforestation. This species forms associations with Ectomycorrhizal fungi (EcM), an uncommon type of symbiosis in lowland neotropical forest. We aim to characterize the fungal symbionts present in the roots of seedlings of the species growing with and without natural soil inoculum and in the understory of natural forests. In addition, we aim to generate a reference collection of fruiting bodies of EcM to be used as a reference for studies based on environmental sequencing. **Methods:** The study site was the nursery of the Botanical Garden of Cartagena (JBGP) and a natural *C. uvifera* population found in the Barú island of Cartagena. We compared the structure of the root-associated fungal communities of seedlings experimentally grown in the nursery with and without native soil inoculation and seedlings growing in native populations. For this we collected the entire root systems of 36 seedlings and samples of the substrates used for propagation and amplified the fungal ITS2 region using the Illumina platform. Additionally, measurements of height and stem diameter, wet and dry mass and root colonization were taken to compare seedling growth between essays. **Results:** Preliminary results of seedling's growth rate show no significant difference between treatments during the first two months. However, we found no mycorrhizal colonization in seedlings growing on the traditional nursery treatment (without native soil inoculation) while seedlings grown with native soil inoculation or collected from natural populations were colonized. Morphologic identification of fruiting bodies collected in field show *Scleroderma sp*. and *Russula spp as the main EcM fungal species associated with C. uvifera*. **Implications/Conclusions:** As a preliminary conclusion the characterization of EcM fungal communities associated with TDF allows the improvement of restauration and conservation efforts. The differences found suggest inoculating seedling could be an effective way of restoring soil microbial communities with plants produced ex-situ for reforestation. **Keywords:** Environmental sequencing, Mycorrhizal fungi, Coccoloba uvifera, tropical dry forest.

Predation, but Not Herbivory, Declines with Elevation in a Tropical Rainforest

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Temperature, humidity and UV-B radiation change in a predictable way across elevation. These abiotic stressors can impact ecological functioning. These changes to environmental conditions, in a relatively small geographic area, make elevational gradients ideal study systems to understand how climate shapes species interactions, and to make predictions on how climate change will alter these relationships. For example, a tri-trophic food web of plant, herbivore, and predator. Herbivores are influenced by both leaf nutrition and predation. Predation pressure is generally higher at lower elevations, herbivores are released from predation at higher elevations. However, at higher elevations herbivores may be limited by leaf nutrition, as leaf composition changes with elevation. This study seeks to understand how elevation shapes leaf nutrition, folivory and predation. We used permanent study plots in tropical rainforest in Mengla, Xishuangbanna, China to assess how insect herbivory and predation respond to elevation. We quantified these ecosystem processes along an elevational gradient to test the following hypotheses: 1). The ratio of carbon to nitrogen will increase with elevation, and 2). Herbivory and predation rates will decrease with elevation. Firstly, we analysed the carbon to nitrogen ratio (C:N) of twenty native plant species at elevations of 800, 1000, 1200 and 1400m.a.s.l.. Secondly, we determined folivory rates for 750 plants at each elevation. Finally, 500 plasticine caterpillars were deployed at each elevation and analysed for attack marks. Any marks observed were documented broadly as invertebrate, lizard or rodent. Predation was negatively correlated to elevation, with attack rates at 1400m being almost 10% lower than that at 800m. The C:N in leaves however, had no correlation to elevation. We found that each elevation had significantly different rates of folivory but despite differences among elevations there was no overall trend across the whole gradient. These results contribute to growing data on the effects of environmental conditions on plant-insect and predator-prey interactions. As temperature increases higher and lower trophic level insects will be differentially affected which could limit top-down control of herbivores, leading to increased folivory. Climate change has also been shown to increase the C:N ratio of mature leaves, which could result in an increase in leaf area loss as herbivores need to consume more to gain sufficient nutrients but may also lead to an overall decline in insect herbivores in the tropics. These results advance our understanding of the complexity of the driving forces behind changes in insect food web interactions along elevational gradients. **Keywords:** Plant nutrition, folivory, predation, elevational gradient, interactions, tropical forest

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Data Digging from Photographs of Paraguayan Moths (Lepidoptera) Using Deep-learning-based Object Detection

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Introduction: The recent automatic image analysing methods allow for fast and low-cost solutions in monitoring biodiversity. Biodiversity decline disproportionally affects hyperdiverse, yet low and middle-income, tropical regions, and whereas monitoring in these countries is essential, only implementing low-cost solutions can guarantee success. Lepidoptera are among the most impacted taxa. Their monitoring is relatively simple and can potentially be fully automatised soon. Low-quality photo recordings may hamper the efforts though. **Objective(s):** We aimed to examine whether modern object detection methods allow efficient processing, and data extraction, of photos taken previously not for automated analysis. **Methods:** A year-long, photo-based moths survey was conducted in an under-studied region in Paraguay. Light trapping occurred between September 2015 and September 2016. Close-up photos of each morphospecies within a given timeframe in a day were taken every day, along with four overview images of the four corners of the sheet. We used automatic contour detection, created bounding boxes around the insects on the overview images and labelled if they belonged to Lepidoptera or not, with the help of a YOLOv3 object detection algorithm. The algorithm was taught to recognise Lepidoptera from a training set of 6220 labelled and 160 unlabelled images from the downsized close-ups. We tested the customized trained algorithm on 682 overview images (an average of four images per day). **Results:** Our algorithm found 3347 moths in 682 images. The most insects were found September to November. There were more insects in 2015 than 2016. Moths were recognised in the greatest number in spring and autumn. Mean confidences in the recognition of Lepidoptera was higher in 2016 but values above 0.9% were rare. The algorithm recognized moths with approximately 65% accuracy compared to humans. **Conclusions:** Our result highlights that computer vision-based tracking and deep learning methods, within a limited framework, can allow the evaluation of photo-based light trapping data, even if it was not collected as those aimed at automatic species detection. Yet, the quality of the photos still can be a limiting factor. Although recognition accuracy in our study was relatively low, data evaluation and fine-tuning the algorithms are still ongoing. In the future, we aim to extend the procedure with image classification and unsupervised machine learning for species recognition. Special emphasis should be given to the development of automated monitoring systems because they allow large amounts of data to be obtained quickly in a non-destructive way in poorly explored tropical regions. **Keywords:** Moth detection, light trap, deep learning, automated monitoring

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Ecological Factors That Structure Plant-hummingbird Interactions in Urban Areas. A Case Study of an Interaction Network in a Colombian City

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The interaction between plants and their pollinators is one of the most relevant biological relationships of plant-animal mutualisms. Hummingbirds are the most specialized and diversified group of nectarivorous birds and constitute the main group of importance in plant-bird interactions in the Neotropics. Habitat simplification and land use change have led to decreased richness and changes in the frequency and specificity of interactions. Despite this, urban ecosystems host an important pollinating fauna that finds refuge in the green areas of cities, however, we do not know the drivers that are influencing the structure of plant-hummingbird interactions and their persistence in urban areas. Here we evaluate the ecological factors that structure a plant-hummingbird interaction network in a Colombian city. This study describes the structure of the plant-hummingbird interaction network and determines the importance of abundance, phenology and morphology in the interactions. Knowing the influence of these factors on interactions will be key to planning and managing green areas that contribute to the conservation of pollinators in cities. **Keywords:** Green areas, Neotropics, plant-bird interactions, pollinators, urban ecosystems.

Land Cover Effects on Vascular Epiphytes Diversity in Northwestern Andes, Colombia

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Epiphytes are a remarkable group of plants that contribute to composition, diversity, structure, and, function in tropical forests. They can represent 50% of local richness and around 30% of foliar biomass in the canopy. Global distribution patterns and composition of vascular epiphytes have been related mainly to elevation, humidity, phorophyte size, and dispersion capacity. Lately with factors like precipitation, phorophytes composition, and vertical gradients of abiotic factors. However, today is not totally clear how these assemblages vary at regional spatial scales and land-cover types in the same region. The effect of anthropogenic disturbance on epiphyte diversity has been poorly studied. Although it is known that it may modify climatic conditions at local and regional scales and may affect the response of species coexistence and assemblages' composition. In Colombia, Land-cover classification is a tool used to evaluate perturbation and succession states, and it can be related to drivers for the establishment and survival of vascular epiphytes at the regional level. In this study we are exploring what is the effect of Corine Land cover type on richness, abundance, and assemblage composition of vascular epiphytes, specifically, we want to address: How vascular epiphytes assemblages respond to low, intermediate, and high levels of disturbance? and if the vascular epiphyte diversity changes according to the land-cover classification system. To answer these questions, we surveyed vascular epiphytes assemblages in Northwestern Andes, Colombia (457-1403 masl) according to RRED methodology. Sampling was conducted climbing on single trees located in 57 plots of $400m^2$. Our approach included two scales: along an elevation gradient spanning humid tropical to premontane cloud forests, and within a perturbation gradient using the land-cover classification system used by stakeholders. We are comparing five land-cover types: Dense Forest (DF), High Secondary Vegetation (HSV), Low Secondary Vegetation (LSV), Mix of Native Forest Species, and Pastures (P) (Corine Land Cover). Based on 191 species of vascular epiphytes sampled, we found DF land-cover with the highest number of species. Species richness decreased as land-cover type had higher disturbance or lower succession state (KW-Chi-Sq=38.445, p-value=9.07e-08). There were differences in community composition along with land-cover types, and a high turnover between land-cover types and elevational distant sites (ANOSIM, R=0.8058, p=0.001). In the end, we expect to detect how the variability in epiphyte assemblages between the land-cover types is related to their responses to land-cover changes in tropical forests. **Keywords:** Anthropogenic effects, epiphyte assemblages, disturbance effect.

Intraspecific Variability of Wood Anatomy Traits in Three Widely Distributed Tropical Dry Forest Species in Colombia

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The tropical dry forests (TDF) vary in intensity and frequency of the precipitation, temperature, and length of dry periods. Although there are many studies exploring drought resistance/tolerance strategies of TDF´s species, it is not clear how wood anatomy traits which are essential for water transport and storage, vary along precipitation and temperature gradients. We measure intraspecific variability of eight wood anatomy traits related to water transport and mechanical support in three widely distributed TDF species: *Astronium graveolens, Enterolobium cyclocarpum*, and *Platymiscium pinnatum*. We expected that along gradients the traits associated with water transport contribute to hydraulic safety. For the traits associated with mechanical support, we expected an increase in tissue investment. We found a weak response of anatomical traits to the environmental gradients. Vessels and ray length, fiber wall thickness, vessels and pit diameter aperture for *Astronium graveolens* showed variation in the increase temperature gradient, while in *Platymiscium pinnatum* the increase in vessel diameter was determined by the increase in the precipitation gradient. *Enterolobium cyclocarpum* did not show variation for any trait. Our results suggest that there is no generalized response pattern of species against environmental gradients, however we found that some traits of the species there are modify to increase the safety margins under drought conditions *(A. graveolens)*, as well as to prevent hydraulic cavitation *(P. pinnatum).* Our results are an important contribution to understanding the vulnerability of TDF tree species to climate change and provide tools through species priorization for biodiversity conservation based on ecological trait approaches. **Keywords:** TDF, precipitation, temperature, gradients, wood anatomy traits, funcional ecology

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Intraspecific Variation in Leaf Traits on Fire-prone Landscapes: The Case of "Saladillo Rojo" (*Caraipa llanorum Cuatrec*)

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Caraipa Llanorum Cuatrec. (CARYOPHYLLACEAE), is a native tree species that are of high cultural and conservation importance in the Orinoquia Guayanaesa. However, the high extraction of this species and the change of fire regimen, have compromised the resilience of the ecosystems where this species is found, threatened its conservation. These conditions have led to the ecosystems dominated by this species being classified as endangered (EN). Therefore, it is essential to analyze the strategies that give this species the ability to respond to fire disturbance and post-fire stress conditions. To explore the response of the "saladillo rojo" to fire, populations of this species were selected in mixed communities of burned and unburned flood seasonal forests, flooded savannas, and monospecific associations "Saladillales". In each population, the variability in foliar traits was analyzed: leaf area, specific leaf area, leaf dry matter content, leaf water content, and leaf thickness. The results show significant differences in the foliar functional traits of the individuals according to the environment in which they are found, clearly distinguishing two types of strategies in the foliar economy. "Saladillos" in unburned forests has an acquisitive strategy that is reflected in high values of leaf area and specific leaf area. On the other hand, the "saladillos" present in high-intensity burned forests, "saladillales", and fire-prone savannas have a conservative strategy, with low values of specific leaf area, but with a high investment in leaf structures that confer physical resistance, such as a greater leaf thickness. It was also found that in burned forests the moisture content of the leaves decreases considerably, but the foliar content of dry matter increases. Our results show that the "saladillo rojo" has high phenotypic plasticity of foliar traits, which could give it an advantage so that its adult individuals and populations are resilient to the changes generated in the environment by fire. This enhances the role of the species for the management and conservation of fire-prone landscapes in the Orinoquia´s lowlands under climate change scenarios. **Keywords:** Fire ecology, functional ecology, neotropical ecosystems, flood forest, savanna, Orinoquia

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Local Valuation and Ecological Effects on the Habitat of Baobab (*Adansonia digitata L.*) in Benin

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Adansonia digitata L. is a multipurpose species in Africa and is used therapeutically, food, economically and socioculturally. This study aims to determine the different uses and their implication in the destruction of natural habitats of Baobab in Benin. The data were on the uses of fruits, peels and seeds carried out in the Guinean zone located between 6 ° 25 "N and 7 ° 30" N and in the Sudanese zone located between 9 ° 45 "N and 12 ° 25" N. The results show that the fruits are rich in calcium (12.5-15%) and the populations consume the fruits directly or transformed into juice. The seeds are used in the preparation of broths and the bark is used in the production of strings. Crop losses ranging from 10-25%, 15-36% and 8-45% respectively for fruits, seeds and bark according to the climatic zones of the study. Ecologically, the species is found in dry forests, savannas and on agricultural land with a high capacity for resistance and adaptation to climatic variability. However, human threats reduce the range of the species and cause habitat loss. The uses of the different parts of the species must be regulated and rational. **Keywords:** Habitat loss, multiple uses, NWFP, sustainable management

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Does Biogeography Can Determine Assembly Mechanisms? An Analysis with Mexican Bat Communities

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Understanding what are the mechanisms and processes that shape ecological communities has been a fundamental interest in ecology and biogeography. Since bats have a high ecological relevance, are taxonomically diverse, and exhibiting different distribution patterns, they are an ideal model for understanding the structure of ecological communities, integrating different dimensions of biodiversity, including the phylogenetic component. Our objective is to evaluate if the Mexican biogeographic regions influence the assembly mechanisms of the bat communities. The species composition for 24 Mexican bat communities was obtained from information available in the literature and online databases. For perform the phylogenetic diversity analysis, we used the time-calibrated phylogeny of Mammalia class. For source of trees, we choose the option "Mammals birth-death node-dated completed trees". We trimmed this mammal tree to obtained a subset for 134 bat species. We selected 10,000 trees to download and we generate a consensus tree based on majority-rule. Phylogenetic diversity (PD) index was estimated as sum of total lengths connecting species together to the root of the tree for the ecological communities of each assembly. We performed a Pearson' correlation test to assess the relationship between patterns of species richness and phylogenetic diversity. Since the results indicated a high correlation ($r = 0.96$), a randomization test was carried out to identify ecological communities with values significantly different from those expected from a random assemblage of the same number of taxa. Then, we used a null model to calculate the standardized effect size of PD (SES.PD). SES values were calculated as follows: SES = (mean observed – null) / SD (null). The average richness for the 24 bat communities was 35.92, ranging between 16 and 74 species. Species richness was highly correlated with evolutionary diversity, for which an average value of 518.12 was estimated. In general, the values of phylogenetic diversity obtained with the SES of PD, MPD, and MNTD indices showed that Mexican biogeographic regions show two general patterns: (1) positive values for bat communities occurring in the Neotropics, which indicate a phylogenetic overdispersion, and (2) negative values in bat communities of Nearctic affinity, which show a phylogenetic clustering. Our results have important implications for understanding the organization patterns of Mexican bat communities by disentangling the relative importance of both contemporary and historical factors, and also emphasizes the importance of phylogenetic information to unravel spatial patterns of biodiversity. **Keywords:** Deterministic processes, habitat filtering, phylogenetic clustering, phylogenetic overdispersion

Socio-ecological Dimensions, Resilience, Sustainable Development

Traditional and Potential Uses of Biodiversity in Northwest Antioquia (Colombia): Bioactive Substances and Their Therapeutic Application

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It is often stated that it is challenging to conserve what we do not know. Despite its recognized biodiversity, the internal armed conflicts that devastated Colombia for almost six decades have prevented scientific exploration in many regions of the country, precluding biological and environmental studies at various locations. This situation has affected our understanding of critical components of flora and fauna and their interaction with local communities. Envenomation has been a rather serious issue resulting in significant death and injury. For example, there are over 5,000 cases of snake envenomation annually, resulting in about 530 deaths per year. In addition, scorpion sting poses significant health issues and ranges between 5 and 20 cases per 100,000 inhabitants, suggesting that envenomation due to venomous fauna is a significant health issue in Colombian rural communities. However, it is still not entirely known which species are involved in these incidents, nor the extent of these incidents. Not much is known about the use of medicinal plants and other components of biodiversity in the traditional treatment of envenomation by local communities. Following the peace agreement, forests and ecosystems have been destroyed to establish African Palm crops and grazing areas for cattle, accelerating deforestation throughout the country. The project "Traditional and potential uses of Biodiversity in Northwest Antioquia: bioactive substances and their therapeutic application" seeks to conserve the traditional knowledge of local communities in two locations in the northwest Antioquia: 1) Pavarandocito, a lowland jungle ecosystem inhabited by Afro-Americans, and 2) Llanogrande, a cloud forest inhabited not only by farmers who traditionally inhabited the region but also by individuals who signed the peace agreement and have rejoined civilian life. We are conducting field inventories of flora and toxic fauna (venomous snakes, scorpions, and Theraphosidae and Ctenidae spiders) to increase knowledge of these groups in these locations. We are also bioprospecting for plant and/or animal compounds that might prove medicinally useful and propose alternative uses of plants in their territories. The project also brings valuable information for recognizing venomous animals and increasing public awareness of local communities to conserve animals and avoid the health issues that arise via envenomation. **Keywords:** Ethnobotany, venomous fauna, plant uses, bioprospecting

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Socio-ecological Dimensions, Resilience, Sustainable Development

Can Familiarity with the Campus Flora Enhance Student Awareness of Biodiversity Value? A Case from Universidad EAFIT, Medellín, Colombia

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Introduction: Urban expansion in recent decades has caused major biodiversity loss and brought thousands of species to the verge of extinction. Societal awareness of biodiversity value is a fundamental step towards achieving massive behavioral change and policy reforms that bring forth sustainable cities and societies. Universities play a key role in leading this change towards a green future, and while sustainability is an important topic in most programs, it is almost entirely focused on climate change and carbon emission reduction, while biodiversity takes a secondary role, even in Colombia, the most biodiverse country in the world by area. A key asset may lay in university campuses, which have been recognized as valuable resources for urban biodiversity with the potential to engage directly with students through meaningful and impactful experiences, with plants being a representative and widespread group. EAFIT University Campus (Medellín, Colombia), has been recognized for its green spaces and has adopted a "University-park" concept that aligns with this approach, however, a complete flora of its campus remains to be done and most students walk around oblivious to the botanical abundance that surrounds them. Objectives: This study aims to enhance student awareness of biodiversity value through completing Universidad EAFIT's campus flora and based upon it, designing, and implementing a science dissemination strategy pilot. **Methods**: Eafit's campus flora was completed through botanical identification and mapping of all campus tree, shrub and herb species using family keys and herbarium specimens. Key information for each species was then compiled, with focus on native, endemic, or endangered species. Later, a dissemination strategy derived from this information was designed and executed with the use of visual and interactive pieces and campus tours. Finally, the strategy's impact was measured using surveys and traffic metrics. **Results:** Eafit University has a 131.000 m^2 campus, 39% of which is comprised of green spaces holding 1545 individual trees and palms in 131 species distributed in 38 families and 22 orders. Fifty-four percent of its species are native and of these, five are endangered and one is endemic to Colombia. **Implications:** Creating strategies to bring plant diversity closer to people in one of the world's most biodiverse countries, provides meaningful experiences surrounding biodiversity for students. These experiences could have lasting effects in their conception of biodiversity value and in turn adopt a more biodiversity-conscious outlook.

Keywords: Plant biodiversity, campus flora, biodiversity value, science communication.

MaderApp: A Mobile Application for the Automatic Recognition of Commercial Wood Species in Selva Central, Peru.

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Peru is a megadiverse country with a large number of tropical timber species distributed over a vast territory. Among these species, 200 are used commercially for different uses such as furniture, parquet, fuel, among others. However, these species have very similar characteristics to each other, often in color, odor and macroscopic anatomy, generating difficulties for forest control posts. There is a need to correctly identify the commercialized species so that the control posts carry out an efficient job and in a short time, thus contributing to combating the illegal logging of tropical species. The objective of the study was to identify through the macroscopic anatomical structure 25 species commercialized in the Central Jungle, Peru and with the images of these species to develop a mobile application based on convolutional neural networks (CNN) that identified these species. The wood samples were collected in 13 sawmills located in the Central Selva, located in the provinces of Chanchamayo and Satipo (Junín) and Oxapampa (Pasco). Anatomical analysis, identification, and image capture for model training were performed in the Wood Anatomy Laboratory at Universidad Continental in Huancayo, Peru. Anatomy and identification analyzes of the species were carried out based on the usual norms for the identification of tropical woods and the available bibliography. Once identified, 1000 images of the transverse plane were obtained and captured with the help of a portable microscope, with a resolution of 640 x 480 pixels, these were used for training the CNN model. The identified species belong to 14 botanical families, the most representative were: Moraceae (5), Fabaceae (4), Lauraceae (3) and Meliaceae (2), the other families have an identified species: Bignoneaceae, Burceaceae, Calophyllaceae, Caryocaraceae , Chrysobalanaceae, Combretaceae, Euphorbiaceae, Lecythidaceae, Malvaceae, Myristicaceae and Rhizophoraceae. The CNN model presented an excellent prediction for the recognition and identification of the 25 species, with an accuracy of 99%. This mobile application is an important digital tool that could be used to combat illegal logging of tropical timber at forestry control posts. **Keywords:** Identification of wood species, neural networks, Selva Central, Peru, Maderapp.

Novel Substrates for Cultivation of *Rhynchophorus palmarum*: An Alternative for Conservation of a Complex Human-plant-insect Interaction Network

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The use of insects as a food source is a frequent activity in many indigenous and traditional communities in the Amazon and other tropical areas, with over 135 species consumed by at least 39 indigenous and urban communities only in Brazil. In particular, the larvae of beetles (Order Coleoptera) commonly called *mojojoy* in the Colombian Amazon, shows an ancestral use in this region, mainly as a source of protein and medicine. Many of these bettles are closely related to some palms, such as in the case of the South American palm weevil *Rhynchophorus palmarum* L., which uses the moriche palm (*Mauritia flexuosa*) to lay its eggs and develop larvae, which typically deteriorates and kills the palm. In addition, during traditional cultivation, the palm can be cut down as a strategy to facilitate the arrival of the beetle to lay its eggs and harvest the larvae. This palm also have different ecological functions: they are an important source of food and shelter for various animal species during the fruiting season. They also guarantee the availability of water for the fauna and for the inhabitants who are located in its vicinity. In indigenous communities with small territories the management of the palm for weevil cultivation has generated a negative impact on this species, potentially affecting the life cycle of the mojojoy and, therefore, limiting the access to this resource. In this context, we evaluated alternative and sustainable production methods of *R. palmarum* to reduce the impact on the populations of *M. flexuosa*, and thus contribute to the food security of peri-urban indigenous communities in the municipality of Leticia. Adults palm weevils were fed with three substrates (*Saccharum officinarum*, *Carica papaya*, and *Musa paradisiaca*) that are common in indigenous crops. All the females (n= 36) successfully oviposition (X= 13 eggs/day). The *C. papaya* substrate was the most successful, showing lower mortality in males and a higher number of eggs laid (X= 21 eggs/day). Subsequently, larvae were exposed to two substrates, petiole of *M. flexuosa* and *S. officinarum*, that allowed their successful development up to pupae. These results demonstrated the possibility of using alternative diets for the production of edible larvae of *R. palmarum* and

guaranteeing, on one hand, an important source of animal protein for the indigenous communities and, on the other, reducing the pressure on the moriche palm and thus maintain their important ecological functions.
Keywords: Entomophagy, Amazonian protein, Mauritia flexuosa, food security, sustainable production.

Non Timber Products in Colombia Amazon Region. Research and Development with Local Communities

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The Colombia Amazon region is an important source of non-timber products (NTP) that are proposed as alternative to reduce deforestation and promote value chains. The aim of this study is showing the results of research and development in NTP chain with local communities. The NTP are an opportunity to improve livelihoods, supported by the science, knowledge and technology transfer. Three areas were chosen for this research, Caguan River in Caquetá at Northwest, Guaviare in the northeast and Putumayo River in Tarapaca-Amazonas and the South. The NTP chosen was Canangucha (*Mauritia Flexuosa*), Asai (*Euterpe precatoria*) and Camu camu (*Myrciaria dubia*) respectively. The investigations carried out were in the ecology, harvest, post-harvest and local transformation. The Caguan River area is dominated by forest of firm land and floodplain forest, where Mauritia is dominating because it is recognized as an oligarchic forest. In Guaviare, dominated by firm land forest, Euterpe is abundant as a pioneer specie after the intervention for wood extraction. Tarapaca area correspond to flooded areas at the Putumayo River where Myrciaria occupied the lakes that the river forms when it floods. In Caguan, Mauritia reported 262 individuals per ha, females in reproductive stage were 33, with 3 clusters by plant. With these data, the estimated sustainable production was 1559 kg per ha and the total area was 4239 ha. Euterpe reported in Guaviare 202 individuals per ha, 135 females with 1 cluster by plant. The production estimated was 331.6 kg per ha, in 3287 ha. Myrciaria reported in Amazonas 29267 ramets, 20 Ton per ha and 418 Ton in 21 ha. Mauritia has hight content of carotenoid with 956.83 mg*100g^{-1}, Euterpe report 7.56 mg*100g g^{-1} of β carotene and 1136.3 mg*kg^{-1} of cyanidin 3-glucoside, Myrciaria is important in Vitamin C contend reporting 2374.1 mg*100g^{-1}. The phenology of the Mauritia shows that flowering occurs at the interface, dry humid season, and fruit ripening occurs during the humid season. In Euterpe the development of the fruits is presented from the month of August to April. In Myrciaria the complete cycle from flower bud to ripe fruit takes 85 days in Tarapacá, starting in late December and lasting until mid-March. The transformation process was to obtain pulps and with Mauritia the final products are flours and oils. Pulps and oils are the products that the local communities are processing in each zone and commercialize in Bogota. Today 96 families in Caguan, 170 families in Guaviare and 46 families in Tarapaca benefit from these NTP. **Keywords:**

Wildlife Consumption in the Northeastern Colombian Amazon: Strengthening Community Knowledge and Governance through Local Research

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Wildlife is widely used for food in the Amazon, with a greater richness of species used by indigenous peoples who also have very close cultural ties with animals. This biodiversity exceeds 124 species in the Colombian Amazon, including mammals, reptiles, birds, amphibians and insects. In the northeastern Amazon, in the Ramsar Site Estrella Fluvial Inírida, department of Guainía, 40 local researchers from 24 indigenous communities and of 6 different ethnic groups, are currently monitoring their use of wild species, for direct consumption or for meat commercialization. This research is technically supported by the SINCHI Institute and is carried out to determine the magnitude of use in each watershed and each community, the population availability of species, the levels of sustainability and to propose measures to ensure the conservation of wild populations and, in turn, the food security of the inhabitants of EFI. This process involves direct participation and agreements with the authorities of the communities and resguardos through the Mesa Ramsar EFI, a body representing the indigenous and peasant communities of the EFI site, the project is part of the ASL GEF Heart of the Amazon Program, is funded by the World Bank and is still ongoing. The community researchers are keeping a daily record of the hunting and commercialization of fauna. A total of 66 species are currently used, 890 prey/year, 7106 kl/year, 48% are reptiles and 29% mammals, the 77% is for direct consumption and 14% for in situ economic transactions, the involved species are especially *Dasyprocta fuliginosa*, *Podocnemis erythrocephala*, *Peltocephalus dumerilianus* and *Cuiculus paca*. The wildlife meat sales at the market place in Inírida is around

1861 kl/year and proceeds from 38 different localities, some of them inside the EFI but the most outside the Ramsar site. Species like *Caiman crocodilus* and *Paleosuchus* spp., *Cuniculus paca*, *Tapirus terrestris*, *Podocnemis erythrocephala*, *Chelus orinocensis*, *Peltocephalus dumerilianus* and *Hydrochoerus hydrochaeris* predominate in order of magnitude in this trade. We evaluate now the most pressured species abundance using different methods (camera traps, transects, and capture-recapture methods) in order to known those species that should be considered for management actions. Some decisions towards conservation have been already proposed based on the huge cultural knowledge of hunting.

Virtual Posters

Mismatch between Functional and Interaction Spaces in Response to Extinctions in Predator-prey Networks

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Anthropogenic climate changes and land use are projected to have widespread effects on biodiversity and ecosystem functioning. To better understand the ecological consequences of such changes, however, we need to assess how interactions networks respond to such drivers. In this study, we investigated the effects of climate and land use changes on anuran-prey networks in four different Neotropical biomes and on the multidimensional space of interactions and species traits. We analyzed different scenarios of diversity loss by simulating the extinction of anurans according to their vulnerability to changes in climate and habitat availability. We first used distribution models to forecast the future redistribution of the anurans and ranked them according to their vulnerability, i.e., the proportion of their range lost under future scenarios. Next, we removed species from the most to the least vulnerable in each network and assessed the changes in overall network structure as well as the changes in the multidimensional space (estimated using multivariate methods) formed by anuran functional traits (i.e., size, mass, reproductive mode, habitat, and breeding strategy) and by their interaction patterns. Our analyses show network structure is robust to species loss until a sharp transition towards highly connected impoverished networks after more than half of the species are extinct. We also found a mismatch between functional and interaction spaces in response to extinctions. Whereas the interaction space was more sensitive to extinction, declining almost linearly in volume with species loss, the functional space was robust to low levels of extinction and then declined sharply after a certain proportion of anurans had been removed. These differences seem to be mainly driven by high levels of redundancy in functional traits of vulnerable species but a greater level of complementarity in interaction patterns among them. We caution that by looking only at the functional space we may be over-optimistic about the consequences of the loss of anurans due to climate and land use changes, ignoring relevant losses in the diversity of ecological interactions. Therefore, given that many key functional aspects of ecosystems emerge as the result of biotic interactions, the sensitivity of the interaction space to species loss may have pervasive effects, accelerating the decay of ecosystem functions, even before the collapse of functional entities of the community. **Keywords:** Anura, Brazil, climate change, ecological networks, food webs, invertebrates

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Revaluating Species Topological Importance in the Largest Neotropical Seed Dispersal Network

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Introduction/Background/Justification: Understanding how ecological systems function requires reliable information about species interactions. Yet, sampling ecological interactions in the field is challenging, and many interactions can pass unnoticed, due to sampling constraints and the inherent differences in species detectability. Models that estimate interaction probabilities based on species traits are a useful tool that may allow minimizing this problem. By estimating missing interactions, we should be able to generate more realistic networks and better understand the role of each species within ecological communities. **Objective(s)/Hypothesis(es):** We propose two methods to infer interactions between birds and plants from traits and phylogenetic information and evaluate how they alter the structure of resulting seed-dispersal networks. Our hypothesis is that imputing missing interactions not only increases network connectedness, but may reveal the topological importance of rare species. **Methods:** We used the most comprehensive dataset of plant-frugivore interactions in the Neotropics to build a metanetwork describing all potential interactions. The first model estimates interaction probability based on the mean gape size of birds and the mean length of the seeds, simulating a preference for seeds within a certain size range but limiting interactions based on gape width. The second model uses Singular Value Decomposition to compute latent traits based on the interaction patterns of a group of well-sampled species and then uses phylogenetic imputation to estimate trait values for undersampled species. Latent traits are then used to generate an approximation of the interaction matrix. Using network-level and node level metrics we evaluate how the networks obtained with these models and the original differ. Results: Compared to the original data, our methods predicted on average more than 70% of the observed species interactions and about three times more interactions. For both models, the resulting network had half the number of modules, while their nestedness degree value almost doubled. The first model was better at predicting novel interactions for well-sampled species, while the second model predicted much more interactions for rare species. Besides increasing overall connectedness these methods markedly changed the rank order of topological relevance of species. **Implications/Conclusions:** Despite their differences both models show that inferring missing interactions can drastically change network structure. More importantly, the models reveal we might often underestimate the topological relevance of rare species to network structure, biasing our understanding of species functional roles. We hope these methods will help towards a more comprehensive understanding of the properties of seed-dispersal networks. **Keywords:** Seed dispersal, Atlantic Forest, interaction models, rare species

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Floral Size Drives Patterns of Bee Visitation to Poricidal Anthered Flowers across Case Studies

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Flower size is a key trait determining pollinators' attraction. Large flowers are more visually appealing and are positively associated with higher amounts of rewards when compared to small flowers. Some plant species hide floral resources inside complex floral structures, restricting these resources only to a few visitors with suitable traits. This strategy occurs in plant species with pollen flowers bearing poricidal anthers that depend on bee vibrations to release pollen grains, their only floral resource. Here, we performed a quantitative systematic review, seeking to answer three main questions: (i) How does flower size influence the diversity of floral visitors, including the antagonistic ones? (ii) How does floral size modify the assembly of bee pollinators vibrating poricidal anthers? And (iii) how is flower size related to the size and behavior of the most frequent bee species? We hypothesize that the higher the floral size, (i) the greater the taxonomic and functional diversity of floral visitors, (ii) the larger assembly of bee pollinators visiting the flowers and (iii) the most frequent the floral visiting by large-bodied bee species. We recovered from the literature studies investigating the patterns of floral visitors on plant species with pollen flowers. We gathered the floral size of the plant species used as model in each study case from photographs of herborized plant collections. Then, we tested the relationship between floral visitor metrics and floral size across study cases. On average, larger flowers received almost three times more species of floral visitors than small flowers. In general, only two functional groups (vibrational and non-vibrational bee species) were observed on pollen flowers across studies. The number of vibrational bee species was higher in larger flowered species, while the number of non-vibrational bee species did not differ among plant species with different flower size. Also, we found that the most frequent bee visitor in large flowers was twice bigger than the most common one in small flowers, while the most frequent bee species vibration behavior was similar regardless the flower sizes. We concluded that floral size influences the diversity of floral visitors in pollen-rewarded flowers but not the bee vibrating behavior of the most frequent bee species on flowers, since bees need to vibrate to extract the pollen grain from poricidal anthers and potentially transfer them for other flowers, regardless of the floral size. **Keywords:** Buzz-pollination, floral size, Bee diversity, attraction, poricidal anthers, pollen flower

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Using Genomic Tools to Guide Conservation of an Overexploited Neotropical Tree Species

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Introduction: Although the emergent tree species *Dipteryx ferrea* (Ducke) Ducke has a great ecological and economical importance in the Amazon Rainforest, their populations are facing a drastic reduction due to logging. Considering its slow rate of recruitment and growth, conservation and management strategies are urgent to avoid local extinctions. **Objective:** To support further ecological and evolutionary studies aiming the conservation and management of *Dipteryx ferrea*, we performed the chloroplast genome assembly and annotation, and the identification of a set of chloroplast microsatellite markers. **Methods**: The sample of *D. ferrea* was obtained in the district of Contamana (7°16'18.3"S, 74°58'55.0"W), located in the Departament of Loreto, Peru. Genomic DNA was isolated according to Dumolin et al (1995) at the Peruvian Amazon Research Institute (LBGM-IIAP). Genome skimming with Illumina MiSeq was used for genome sequencing. The quality of raw sequencing reads was checked with FastQC, and we filtered out adapters and reads with Phred Score $<$ 20 with Trimmomatic. For the plastome assembly of *D. ferrea* with NOVOPlasty, we used the gene rbcl of *D. alata* as a seed. We annotated the chloroplast genome for gene prediction with the CHLOROBOX plataform. To idenfity microsatellite regions, we submitted the plastome sequence to the MISA website, considering minimum thresholds of 10 repetitions for mononucleotides, six for dinucleotides, five for trinucleotides, four for tetranucleotides, and three for penta- and hexanucleotides. **Results:** The plastome of *D. ferrea* (165,104 base pairs - bp) presented a quadripartite structure with two inverted repeated regions (IR_A and IR_B) of 25,512 bp each, separated by a large single copy region (LSC) of 94,062 bp and a small single copy region (SSC) of 20,054 bp. We observed a total of 150 genes, of which 115 were protein-coding genes, 37 tRNA genes, and eight rRNA genes. From 83 identified microsatellites, 68 were mononucleotides, 14 dinucleotides, and one trinucleotide. **Conclusions:** The set of microsatellite markers identified here will further be used to access the levels of genetic diversity and population structure of *D. ferrea*. Futhermore, characterization of the plastome of *D. ferrea*, including gene content and genome structure, will improve delineation of the phylogenomic affinities in *Dipteryx*. **Keywords:** Amazon Rainforest, cumaru, Dipteryx ferrea, microsatellite, plastome, chloroplast genome

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The Contradictory Role of Education for Landowner Forest Preferences' near Two Protected Areas in Southern India

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Introduction/Background/Justification: Humans have an innate desire to connect with nature, and many interact with forests and the biodiversity they represent. People often benefit from services provided from this interaction. The benefits perceived from this interaction are influenced by socioeconomic conditions. To engender broader support for future conservation policies, a better understanding of what influences this perception is important. Objective(s)/Hypothesis(es): What is the impact of education, income, and human-wildlife conflict on the desire to live near a forest, and the perceived benefits of doing so? **Methods:** Our survey sample of 699 landowners live in a human-dominated landscape bordering Bandipur and Nagarahole national parks in South India. From their responses, we estimate the influence of education, income, and the recent experience of conflict with wildlife on whether landowners "like to live near to a forest," and if they perceive two specific benefits from the forest: 1) "the forest offers a good atmosphere" and 2) "the forest regulates climate and rainfall." Our estimates control for: the age of the landowner, the distance of the farmland to the nearest protected forest, and other unobserved confounders unique to the surrounding forest range. **Results:** A majority (86%) of the landowners prefer to live near a forest. Among various reasons provided, regulatory services are deemed to be more important than other ecosystem services. Most interestingly, landowners with higher education levels are more likely to perceive that "the forest provides a good atmosphere," but also less likely to say they "like to live near a forest." An experience of material loss from wildlife implies that the landowner is less likely to agree that they "like to live near a forest," and that

"the forest provides a good atmosphere." Poorer landowners are less likely to perceive that "forests regulate climate and rainfall". **Implications/Conclusions:** Our study uniquely compiles landowner preferences for and the intangible benefits from living near two protected forests in India. The protection status of these forests prohibits direct economic benefit extraction. We find higher education to be associated with an increased awareness of ecosystem services, but also in an apparent contradiction, a lower preference of wanting to live near the forest. The contradiction likely reflects a paucity of economic opportunities for the educated in remote forest adjacent communities. We also find that a reduction in wildlife-related losses can raise the perception of non-material ecosystem services provided by the forest. In summary, conflict, and some socioeconomic factors may influence forest and land management strategies in the future. **Keywords:** Ecosystem services, forest, human-wildlife conflict, landowner, nature, perception

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Historical Effective Population Size of the Endangered Malayan Tapir: Implications for Conservation

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The Malayan tapir (*Tapirus indicus* Desmarest) is an endangered species in Southeast Asia. The species can be found in Peninsular Malaysia, southern Myanmar and southern Thailand, and on the Sumatran Island of Indonesia. It is listed in both the International Union for Conservation of Nature (IUCN) and in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). According to the IUCN assessment, its population size is estimated to be less than 2500 mature individuals worldwide. However, the wild tapirs are constantly faced with threats from deforestation, habitat loss, and increased risk of roadkill, and further population decline over time is expected. Captive breeding is an important conservation effort to ensure the continued existence of endangered species and can benefit from the information on historical changes in the effective population size of the species, which can be obtained via a whole-genome approach. Six Malayan tapir samples, putatively from Peninsular Malaysia, Thailand, and Sumatra, were selected amongst the captive tapirs in the Japanese zoos. The selection was made by applying genetic information acquired using 38 microsatellite markers and mitochondrial DNA control region. To infer the population's past demographic history, we used pairwise sequentially Markovian coalescent (PSMC) analysis. We also ran PSMC analysis on pseudo-diploid X chromosomes created for each population pair to investigate the divergence time between the populations. From the PSMC trajectories, we inferred population expansion or migration events during the Early and Late Pleistocene periods. We observed an overall decrease in its effective population sizes over time, which went down to $<$ 10,000 since Middle Pleistocene and $<$ 5000-6000 before entering Holocene. PSMC on pseudo-diploid X chromosomes indicated a divergence time of around 5-9 kya between the Sumatran population and the rest, which corresponded to the rise of seawater level post last glacial maxima that lead to the submergence of the landmass of Sundaland, as well as land-bridges between the Malay Peninsula and the Sumatran Island. We found the PSMC trajectories to be similar to that of the Sumatran rhinoceros from another study, showing that both species share a similar evolutionary history in Southeast Asia. We recommend future investigation into mutational load and functional genes associated with environmental adaptations in these diverging populations to better inform future captive breeding programs. **Keywords:** Asiatic tapir, historical demographic history, genomics, population divergence

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Timber Harvesting Adds Economic and Ecological Value to Secondary Forests of the Brazilian Atlantic Coast

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Wise management of tropical secondary forests can conciliate timber production and biodiversity conservation. The Brazilian Atlantic Forest is largely covered by secondary forests, featuring, at the age of 30-50 years, a significant volume of wood from fast-growing species, whose exploitation can benefit especially small landowners. These forests are frequently dominated by a few timber-producing species, allowing the application of a range of silvicultural systems. While clearcut would restore the ideal ecological conditions for the re-establishment of dominating fast growing pioneer species, the single tree selection method would favour species typical of mature forests, likely increasing biodiversity. However, decision making is still limited by scarce knowledge on how timber harvesting impacts the regeneration of stocks and tree diversity. In this study we asked how the forest responds to different harvesting intensities, up to 60% of its basal area. In a 45-year-old tropical secondary forest in southern Brazil, we measured adult trees in 15 permanent 400 x 400 meters plots, and the regenerants in 60 subplots of 2 x 40 metres, totalling 4,800 m^2 of sampling area. Species richness, density and relative growth rate (RGR) were analysed. We also compared species composition of canopy and understory before and after harvesting. Our results show that the regenerants density increased significantly after tree harvesting, from 5,909 $\pm$ 428 ind/ha before harvesting to 6,908 $\pm$ 641 ind/ha after harvesting. Species richness of regenerants also increased: from 188 before harvesting to 213 species after harvesting. Before harvesting, the number of species of regenerants was smaller than the number of species of adult trees, but after harvesting the number of species of regenerants increased and became higher than the number of species of adult trees. Height RGR of regenerants was high in the first months after tree harvesting (1.5y = 8.32 m.m.year-^{1}) but decreased significantly with time (2.3y = 3.55 m.m.year-^{1}). Regarding the diameter, RGR remained constant (1.5y = 7.70 cm.cm.year-^{1}, 2.3y = 7.17 cm.cm.year-^{1}). These results suggest that regional secondary forests have the potential to replenish the timber stock harvested while maintaining or even increasing tree diversity. The increased diversity following harvesting suggests also that opening the forest canopy accelerates the succession process, and can become an efficient tool for forest conservation purposes. Then, varied intensities of harvesting over the landscape may combine a variety of management purposes. **Keywords:** Regenerants forest, management, fast-growing species, species richness, relative growth rate

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Short-term Responses of the Understory Plant Community to Elevated CO2 in the Central Amazon Forest

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Amazon forests store around 150 to 200 billion tons of carbon and play a key ecosystem service as a carbon sink, compensating a significant fraction of global anthropogenic CO_2 emissions. Ecosystem models predictions for the region range from a large-scale climate-driven Amazon forest dieback to increased resilience of the forest carbon sink due to positive effects of elevated CO_2 on net primary productivity (NPP) and water-use efficiency. However, due to the lack of experiments in the region, there are uncertainties about how the Amazon will respond to the exponential increase in CO_2 in the atmosphere. Here, we present direct field measurements of plant growth, including stem height, base diameter, leaf production, and leaf area under elevated concentration of CO_2 (eCO_2) in an experiment performed in Open Top Chambers (OTC) in an old-growth understory tropical forest in Central Amazon, near to Manaus, Brazil. The experiment was carried out in eight OTCs, four control (with ambient CO_2 - aCO_2), and four treatment (aCO_2+200ppm - eCO_2) to assess the understory plant community responses to increased atmospheric CO_2 concentration. After 266 days of experiment, we observed an increase in base diameter increment in the understory community under eCO_2 that was, on average, almost double that of the community under aCO_2 (0.0041 mm day^{-1} *versus* 0.0023 mm day^{-1}, respectively). Relative growth rate (RGR) was calculated as the ratio between the increment in base diameter and stem height, and under eCO_2 plants showed a higher RGR (0.99 mm^{3}cm^{3}day^{-1} *versus* 0.77 mm^{3}cm^{3}day^{-1}, respectively). The leaf area increased 51% under eCO_2, while no significant effect was observed on total leaf production and plant height increment between treatments. These results suggest that, under eCO_2, understory plants can allocate more carbon to aboveground biomass, increasing their support through growth in diameter and their capacity to capture light through increasing leaf area. These results were observed nine months after the beginning of the experiment, and long-term monitoring is necessary to determine if these responses are sustained. Given the importance of the Amazon Forest in the global scenario, changes in this ecosystem will have relevant impacts on the global hydrological and carbon cycles, and we need to continue to investigate the consequences of the increase in atmospheric CO_2 on the capture and stock of carbon in this forest. **Keywords:** Global changes, Amazon forest, elevated CO2.

Logging and Drought in Bornean Rainforest

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In tropics, selective logging modifies forest structure and composition but the impacts of these changes on the post-logging dynamics and functioning of forests are little understood. The recovery of forests from logging is of importance especially in Southeast Asia, where the relative deforestation rates are the highest among any major tropical regions and selective logging is a widespread harvest technique. In the island of Borneo, despite the key role of logged forests in the human-altered landscape, information on the speed and extent of secondary forest recovery remains scarce. Over the period 2010–2020, we recorded annual tree growth, mortality, and recruitment in 193 permanent plots (25 x 25 m each) within the SAFE Project in selectively logged tropical rainforest in Malaysian Borneo. Along the logging gradient ranging from heavily, moderately, and lightly logged stands to old-growth forests, we studied the dynamics of tree diversity and composition recovery as well as the impacts of El Niño drought (2015–2016) on tree growth and mortality. The results show that increasing the intensity of logging increased the magnitude of the compositional changes, raised the proportion of pioneer species, and decreased the percentage of late-successional species (dipterocarps). In heavily logged forests, there were no signs of recovery in terms of species composition and diversity despite the high species turnover. During 2010–2020, the pioneers grew initially faster than dipterocarps, thus causing faster regrowth of heavily logged plots, however, their growth rate dropped significantly during the El Niño drought (2015–2016) and was similar to or lower than that of dipterocarps since then (i.e., did not recover). The findings indicate that the logging-induced compositional changes may make the forest more vulnerable to future drought events under climate change. **Keywords:** Selective logging, species composition, tree growth, mortality, El Niño

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Variation in Effects of Host Tree Size on the Species Richness and Abundance of Vascular Epiphyte Assemblages among Tropical Forests

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Vascular epiphytes contribute to local plant diversity in tropical rainforests, and they play important roles in ecosystem functions. Tree size variation in a forest is one of the factors that affect the distribution of epiphyte assemblages, for instance, the number of epiphyte species on a tree and the number of epiphyte individuals on a tree generally increase as host tree size increases. These effects of tree size on the epiphyte assemblages likely differ among forests at different sites. However, a few studies have focused on the relationships in the Southeast Asian tropics, and the variation of these effects has been unclear on the global scale. We aimed to clarify the variation of tree-size effects on species richness and abundance of vascular epiphyte assemblages among tropical forests. Firstly, based on a census on epiphyte assemblages in a Bornean lowland tropical rainforest, we analyzed the relationships between epiphyte species richness and diameter at breast height of tree (DBH), and between epiphyte abundance and DBH. Then we compared the results with those of previous studies. The effects of tree size on the species richness and abundance considerably differed among study sites. In Bornean lowland, trees with DBH < 40 cm rarely hosted > 3 species, whereas among trees with DBH > 40 cm, due to a rapid non-linear increase, 40% of tree individuals hosted > 3 species. Contrastingly, in montane China, montane Mexico, and lowland Panama, trees with DBH < 20 cm frequently hosted > 5 species, and the species richness of epiphytes showed a linear increase. In addition, the results from the Bornean lowland suggest that the epiphyte abundance increases exponentially as DBH, whereas two preceding studies done in lowland Panama suggested that this attribute did not necessarily increase in a non-linear fashion. One study suggested that epiphyte abundance showed a non-linear exponential increase and was consistent with our results, but another found a linear increase in the relationship. In Bornean lowland, trees with DBH < 40 cm rarely hosted > 10 epiphyte individuals. This variation in findings implies that, in the lowland forests of the Southeast Asian tropics, large-sized trees, more importantly, contribute to maintaining of species diversity of epiphyte assemblages than those in the other forests. Therefore, it can be considered that preserving forests with large-sized trees is essential for the conservation of the epiphyte assemblages in lowland forests in the Southeast Asian tropics. **Keywords:** Arboreal ecosystem, cross-site analysis, forest canopy, spatial distribution, species diversity

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The Role of Protected Areas in Reducing Fire Degradation Threats in the Triple Border between Brazil, Bolivia and Peru

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The Amazon transboundary region comprising Madre de Dios (Peru), Acre (Brazil) and Pando (Bolivia), known as MAP region, has approximately 31 million hectares of forests. However, fire is anthropically introduced in this environment and it results in significant forest degradation. Protected areas are considered essential for the conservation of tropical forests and their ecosystem services, conferring a barrier against the advance of threats on the forest. Therefore, this study aimed to qualify the role of protected areas on mitigating fire degradation threats between 2000 and 2020. We used the MapBiomas PanAmazônia c3 product to characterize land use and land cover and the GABAM product to quantify the burned area inside and outside protected areas. Spatial data on the delimitation of protected areas, burned area and land use and cover were matched into a regular grid of approximately 500 m to carry out the analyzes. A total of 128 protected areas were identified, totaling 135,766 km^2, classified as Indigenous Territory (IT – 31%), Indirect Use Protected Area (IU – 31%) and Direct Use Protected Area (DU – 38%). Throughout the years of 2000 to 2020, MAP region lost 14,120 km^2 of forests, of which 12% were inside protected areas. In addition, the farming area within protected areas increased 1.478 km^2. Although it corresponds to only 1,1% of the total protected area in 2020, its growth reinforces the advance of the fire threat in these areas. Over the same period, 22.040 km^2 burned in the MAP region, 90,7% outside and 9,3% inside protected areas. The region burned 1.979 km^2 in protected areas, with 793 km^2 burned inside IT, 159 km^2 burned inside IU and 1.028 km^2 burned inside DU. The burned area has varied throughout our time series, being the highest peaks always registered outside protected areas. The most significant increase occurred in 2005, with a total of 4,510 km^2 of burned area, which can be explained by the extreme drought that occurred in the region. During the years 2000 to 2020, the total burned area in regions outside protected areas was equivalent to 6.2% of the MAP region, while the area affected by fire within protected areas was only 0.6% of the tri-national region. Thus, we could confirm that protected areas, in a certain instance, avoided fire threat in the last 20 years, still being areas that harbor healthy ecosystems, fundamental for the mitigation of climate change. **Keywords:** Fire, forest degration, human activities, protected areas, Amazon, MAP region.
