Excerpts from

TROPICAL FORESTRY ABSTRACTS III

Frank H. Wadsworth and Isabel M. Fernández

FOREWORD

Frank Wadsworth: During 1942-1949 Frank learned from tropical forestry research based in Puerto Rico. During 1950-2000 Frank traveled much in the tropics, learning from forests and foresters in the Americas, Africa, Asia, and Australia. Based on these experiences, during 1976-2021, Frank selected key abstracts for the *Tropical Forestry Notes* for the International Society of Tropical Foresters and the Society of American Foresters. Through the *Notes*, Frank hopes to help tropical foresters increase their understanding, including of tropical forest ecology and wildlife conservation.

Frank respects the scientists and science behind the selected abstracts. For the busy forester, at times he has strived to express more concisely the information they contain.

Isabel (Beba) M. Fernández: Isabel is an attorney in Puerto Rico, married to Attorney Ivan Fernández, and a resourceful mother of two. She facilitated the production of this volume of *Tropical Forestry Notes* by providing Frank with key information from each selected abstract in large print, assisting with the editing, and arranges and prints the *Tropical Forestry Notes*.

NOTES

This volume is a compendium of excerpts of selected abstracts from recently published tropical forestry research, followed by citations of that research. Many of these abstracts were obtained through the library of the USDA Forest Service International Institute of Tropical Forestry in Puerto Rico.

D = We thought this was of special interest.

Note: It is suggested to use the search function in your PDF reader to find articles on topics of interest.

2021-

TROPICAL FORESTRY NOTES (41)

FORESTRY DEVELOPMENT, POVERTY ALLEVIATION, AND CLIMATE CHANGE MITIGATION

Poverty can be alleviated only if local actions spur economic development in which local communities have a rightful and fair share and earn rewards for their entrepreneurships. Wood is a renewable, recyclable, versatile, and sustainable natural resource. The demands for wood products are rising in the developing countries, as their economies grow. They also face endemic wood deficits. This provides opportunities to pro-actively develop commercial forestry as a path to rural development and poverty alleviation. That would also assist national climate change mitigation measures, because forests sequester carbon, wood products are largely carbon-positive, and timber-based options are on hand to substitute for high-emission materials such as concrete, steel, and aluminum used to build our living environments. To move along this path the businesses of tree growing by small-growers and local value adding should be strengthened, catalyzing the entrepreneurial spirits of local people. Central to this is the need to put in place strategies to improve the productivity of and value from small-scale enterprises, yet there is a serious lack of research and application to serve this key need. Among other constraints faced by small-growers include lack of transparent and legal rights and land ownership in several countries, layers of bureaucratic regulations, and the current international forest certification systems which are cumbersome and unaffordable for small-growers. Actions are possible and needed for simplifying or removing road blocks on all these fronts, along with, importantly, the development of markets for diverse products. Growth of the forest production sector as an engine for rural development warrants far greater recognition and investment than has been the case so far. We need to re-imagine and strengthen the role of forest production, including commercial wood business as an effective path to rural development and poverty alleviation. E. K. S. Nambiar. Forestry business, rural development, and climate change mitigation. [*Forest Ecology and Management* 448 160-173 2019] D

LESSONS FROM LARGEST SCALE AND LONGEST TERM IN THE AMAZON BASIN

The Brazilian Government established the Amazon Turtle Project (Projeto Quelonios da Amazonia – PQA) in 1975 to monitor and protect the main nesting sites of Amazon River turtles. The PQA has become the largest-scale and longest term wildlife conservation initiative in the Brazilian Amazon. We evaluated the outcomes of the PQA across 11 protected localities over 30 years (1977-2008). Inside the protected localities, one population of *Podocnemis expansa* has declined and four have seen an increase in numbers. The PQA conservation efforts for *P. unifilis* were not as successful as those of *P. expansa*, but were sufficient to stabilize or increase populations. These results suggest that there is a minimum effort necessary for positive conservation outcomes, which was not achieved for *P. sextuberculata*. Given the lack of correlation between initial meeting numbers and positive population trends, the current level of success in a given locality cannot be used as a tool to prioritize future protection efforts. We recommend that the PQA should maintain or increase its coverage due to the high levels of local unpredictability. If current harvest trends are maintained, it is likely that the only surviving populations of *P. expansa* will be within protected areas. Considering the scope of the PQA and the period that it has been operational, it is surprising how little recognition it has received; the lack of national and international awareness of its achievements may be one of the main reasons

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behind the lack of support from the Brazilian Government. C. C. Eisemberg and others. Lessons from long term conservation in the Amazon. [*Biological Conservation* 238 108182 2019] D

CONSERVATION AND LIVELIHOOD ON A COFFEE FARM

Ecologically complex agroecosystems often provide multiple conservation benefits; yet understanding the agricultural practices that favor biodiversity is often a theoretical task until we simultaneously demonstrate the economic impact of such practices on farmers. We provide a multifunctional analysis of both biodiversity and ecosystem services that influence coffee farm profit in Puerto Rico. We show that the vegetation heterogeneity of an agroecosystem, more so than any one ecological component (e.g. shade) is associated with higher biodiversity of plants, birds, beetles, bees, lizards, ants, and parasitoid wasps. However, a farm's vegetation heterogeneity does not consistently correlate with profit-related ecosystem services, including coffee yield and biological control of coffee pests and pathogens, due to tradeoffs between services. Therefore, inherent financial incentives that would encourage farmers to manage farms in ways that maintain high associated biodiversity may be lacking. We explored several economic incentives that would allow farms to be simultaneously biodiverse and profitable, which we show is possible through realistic incentive schemes. We found that the combination of a certification premium plus carbon payments (50% premium plus $16t^{-1}$ CO_{2e}) or a restructuring of agricultural subsidies using currently experienced subsidy amounts may be sufficient to make farms that are more heterogeneous, and therefore more biodiverse, the most profitable option for farmers. If these biodiverse farms can also be profitable, it will open critical opportunities for maintaining rural landscapes that support farmers' livelihoods, as well as protect the planet's biodiversity. A. L. Iverson and others. Biodiversity and farm livelihood on a coffee farm. [*Biological Conservation* 238 108179 2019] D

GREEN-TREE RETENTION, LONG-TERM EFFECTIVENESS

Retention forestry is a silvicultural approach that can achieve both ecological and economic objectives in various forest ecosystems. It builds largely on the assumption that the live trees left the unharvested, (the main timber cost) effectively support ecological and economic functioning of post-harvest forest. Such effectiveness can be understood as a combination of the initial ecological value of the tree (that may persist after tree death) and its survival, i.e., the prospect to develop into high-quality veteran trees in the next forest generation. We assessed those aspects among >3,000 live trees actually restrained in 103 Estonian harvested sites and monitored over 16 years. We analyzed how their survival and habitat value (estimated from tree morphology, confirmed by epiphyte surveys) translate to the veteran-tree perspectives. Only 48% of the trees were still alive after 16 years, and this final survival at the stand-scale was poorly predictable from a few years of monitoring. Only 12% retention trees had both high habitat value and high survival. Most trees (75%) were of low initial habitat value, and, combined with low survival, almost 40% of all trees never provided quality habitat for tree-dwelling bird species. Nevertheless, we found considerable potential for post-harvest development of habitat value, notably in European memorial hardwood species (such as *Fraxinus*, *Quercus*, *Ulmus*, *Acer*) which survived well but were usually in subcanopies at the time of the harvest. These findings indicate that retention forestry can improve also highly impoverished (e.g. short rotation) forests, if analytical tools have been developed and applied to predict tree survival and future habitat quality. R. Rosenvald and others. Green tree effectiveness after logging and habitat quality. [*Forest Ecology and Management* 448 543-548 2010] D

TREE IMPROVEMENT EFFECTS ON A SUGI PLANTATION

The main purpose of this study was to investigate how a shift in seed sources owing to the implementation of a tree improvement program affected the genetic diversity of plantain forests. We investigated the genetic diversity and pairwise relatedness between individuals of sugi (*Cryptomeria japonica* D Don) plantations established before (PRE B) and after (POST B) the start of the Japanese tree improvement program. Based on SSR and SNP markers, most genetic diversity indices and the degree of relatedness within plantations were comparable between Pre B and Post B. However, there were large variations in the proportion of closely related pairs within plantations in both groups. Additionally, in Post-B plantations, parental contributions greatly diverged among plus-tree clones. The results of this study indicated that the shift in the seed sources, caused by the implementation of a tree improvement program, did not have a significant effect on the genetic diversity of plantations. However, the results also indicated that the degree of relatedness within plantations varied significantly according to how seeds are collected, regardless of the type of seed sources. Furthermore, it was also revealed that genetic diversity in Post B plantations could have decreased because of a deviation from equal parental contributions in seed orchards. Our results indicated that effective management of seed orchards is important to secure the genetic diversity of plantation forests. H. lwasaki and others. Genetic improvement effects on sugi plantation. [*Forest Ecology and Management* 448 466-473 2019]. D

BUFFER STRIP WIDTH AND LOGGING IN RIPARIAN FOREST

Riparian forests have cool and humid microclimates, and one aim of leaving forested buffer strips between clear-cut areas and streams is to conserve these microclimatic conditions. We used an experimental study setup of 35 streamside sites to study the impacts of buffer strip width (15 or 30 m) and selective logging within the buffer strips on summer-time air temperature, relative air humidity and canopy openness 12 years after logging. The buffer strip treatments were compared to unlogged control sites. We found that 15-meter buffer strips with or without selective logging and 30-meter buffer strips with selective logging were insufficient in maintaining temperature, relative humidity and canopy openness at similar levels compared to in control sites. In contrast, 30-meter buffer strips differed only little from control sites, although they did have significantly lower mean air humidity. Microclimatic changes were increased by southern or southwestern aspect of the clear-cut, and by logging on the opposite side of the stream. We also tested how the cover of three indicator mosses (*Hylocomium splendens*, *Pseudobryum cinclidioides* and *Polytrichum commune*) had changed (from pre-logging to 12 years post-logging) in relation to post-logging air temperature, relative air humidity and canopy openness. We found that each of the species responded to at least one of these physical conditions. Air humidity was the most significant variable for explaining changes in the cover of the indicator moss species, suggesting that the change in this microclimatic component has biological impacts. We conclude that to preserve riparian microclimatic conditions and species dependent on those, buffer strips should exceed 30 m in width, and not be selectively logged. Wider buffer strips are required if the clear-cut is towards south or southwest, or if the two sides of the stream are logged at the same time or during subsequent years. A. Olden and others. Effect of buffer strip width and logging on riparian forest climate. [*Forest Ecology and Management* 453 117623 2019] D

MANGROVE WETLAND PRODUCTIVITY IN BAJA CALIFORNIA

Mangroves provide multiple ecosystem services (ESs), including fish and wildlife habitat, protection from coastal erosion and flooding impacts, food resources, water quality, carbon sequestration and storage. However, most of the mangrove wetlands structural and functional information useful to evaluate the quality, quantity and monetary value of its ESs has been obtained from studies at tropical latitudes usually dominated by large deltas and extensive coastal lagoon and estuaries. Thus, there is a major data gap for mangrove wetlands located in arid and semi-arid regions due to their limited land cover and location at the boundary of transitional climate gradients. Here we analyze the spatial distribution of mangrove wetlands carbon stocks and net primary productivity (i.e., litterfall and root productivity) in La Paz Bay, an arid coastal region in the Gulf of California, Mexico, where mangrove wetlands are spatially distributed in conspicuously extensive patches. We used this information to qualitatively rank ESs. Three peri-urban mangrove wetland sites (Balandra, Enfermeria, and Zacatecas) were characterized by different degrees of anthropogenic impact. Aboveground biomass (interval: 13.6 to 31.6 $Mg\,C\,ha^{-1}$) was in the lower range when compared globally. The average C storage in mangrove soils (at 45 cm depth) in La Paz Bay is 175 $Mg\,C\,ha^{-1}$, which is higher than the values reported for other arid zones ($\geq$1 m soil depth: 43–156 $Mg\,C\,ha^{-1}$). Belowground root biomass and productivity values (roots range: 0.22–0.31 $Mg\,C\,ha^{-1}$; fine roots NPP: 0.06–0.09 $Mg\,C\,ha^{-1}\,yr^{-1}$) were in the lower range. We found distinct differences in aboveground C storage values among sites where mangrove species formed monospecific stands across the landscape within each site. Areas dominated by the species *Rhizophora mangle* reflected the highest soil C density values ($208.9 \pm 144.6\,Mg\,C\,ha^{-1}$), followed by *Laguncularia racemosa* ($181.4 \pm 118.2\,Mg\,C\,ha^{-1}$) and *Avicennia germinans* ($155.5 \pm 72.1\,Mg\,C\,ha^{-1}$). We identified ESs provided by each of the sites, including both cultural (i.e., ecotourism; especially in Balandra), and provisioning (fisheries) services. Our study is a first step in the quantitative assessment of functional and structural properties as ESs of arid mangrove wetlands in La Paz Bay that could be readily translated into robust economic estimates for this arid coastal region. J. G. Ochoa-Gómez and others. Mangrove wetland productivity and carbon stocks in an arid zone of the Gulf of California. [*Forest Ecology and Management* 442 135-147 2019] D

LAND RESTORATION BY TREE PLANTING IN THE TROPICS AND SUBTROPICS IMPROVES SOIL INFILTRATION, BUT SOME CRITICAL GAPS STILL HINDER CONCLUSIVE RESULTS

Infiltration is one of the most important hydrological processes in ecosystems, having important influence on soil erosion control and runoff, soil moisture content and groundwater recharge. This is particularly important considering the recent growing number of restoration initiatives worldwide encouraging forest cover expansion, mainly by tree planting. Here, we conducted a systematic review of scientific literature reporting infiltration measurements in forests restored by tree planting in the tropics and subtropics. We found 11 studies representing 67 data comparisons in 8 countries. Overall results indicate that infiltration increases but is not fully recovered to reference conditions in forests restored by tree planting. Recovery of infiltration varied depending on land-use, soil texture and restoration age. Recovery of infiltration was higher for cultivated than for pastures and bare soils. Clayey soils had higher infiltration recovery than sandy soils. Our findings identified some knowledge gaps that should be addressed to improve understanding of when and why tree planting to restore forests may promote the recovery of infiltration in tropical and subtropical soils. First, information about recovery of

infiltration capacities when using tree planting for forest restoration results are scarce. Second, infiltration in restored forests should be monitored over time, including long-term studies and measurements on water movement through the soil profile and evaluating potential interactions between infiltration and soil attributes. Details on the effects that different forest restoration techniques (e. g. soil preparation, tree species diversity and densities) could have on infiltration is virtually unknown. Information on the influence of disturbance level on infiltration prior to tree planting is also severely lacking. S. E. Lozano-Baez and others. Tropical planting improves soil infiltration, but questioned. [*Forest Ecology and Management* 444 89-95 2019] D

FLOWERING AND FRUIT-SET OF BAOBABS IN SOUTHERN AFRICA

Baobabs (*Adansonia digitata*) are iconic and highly valued trees that characterize many semi-arid environments across Africa. The aim of this study was to describe leaf, flowering, and fruit phenology, flower production, and fruit-set patterns of southern African baobabs. This was done on a sample of 106 trees across five land-use types at monthly intervals over two years. Rainfall in the first year (2006/7, Year 1) was only 275 mm, but doubled in the second year (516mm; 2007/8, Year 2), being below and above the long term mean of 461mm, respectively. Leaf flush preceded the onset of rains (October) in 88% of trees in year 1, but after the onset of rains (August) in all trees in Year 2. Leaves flushed in November and were retained until April and in October and retained into March, respectively. Leaf fall occurred one month later in Year 1(May) than in Year 2 (April). Flowering followed a steady- state pattern, lasting with 1-5 months with peak flowering in November in both years. For adult trees, flower number /tree (Year 1:711 +-72 (S. E.) and Year 2: 2.287 +-33), but not fruit-set (mean of 20% +-4%) varied significantly between years. Flower number showed a logarithmic relationship with tree size (stem diameter) ($R^2 = 0.3830$, P<0.0001),while fruit-set was unrelated to tree size (R^2=0.0045, P=0.5081).Flower number and fruit-set did not vary between five land-use types, but length of flowering did, with village trees flowering for the longest period. Baobabs are hermaphroditic plants with both male and female reproductive structures in the same flower. Yet, across Africa many people refer to individual trees as being "male" (fruiting s absent or minimal) or "female" (substantial fruiting). Producer "female" and poor producer "male" trees did not differ in flowering phenology (number, timing, and length of flowering), but fruit-set over two sequential years differed greatly between producer (33.5 +-5.2%) and poor producer (0.2+-0.1%) trees. Leaf flush was responsive to early rains and hence baobabs appear to be facultative early greeners. However, flowering and fruit-set patterns were not significantly different between these two years, despite the large rainfall difference. Although flower production was not different between producer and poor producer trees in either year, fruit-set was three orders of magnitude higher in producer than poor producer trees. These quantitative results suggest that baobabs may be functionally deciduous and thus a complete characterization of the reproductive biology is required. Mechanisms underlying this pattern are discussed in terms of tree age, environment, pollination, genetics, and evolutionary biology. S. M. Venter and others. Flowering and fruit-set of the baobab. [*Forest Ecology and Management* 453 117593 2018] D

TROPICAL FORESTRY NOTES (42)

EFFECTS ON *PINUS TAEDA* OF CROWN THINNING INTENSITY

Pinus taeda plantations are an important economic activity in southern Brazil, where edaphoclimatic conditions are optimal. Understanding how meteorological conditions influence tree growth is important in such a favorable environment for reaching high growth rates and for predicting tree growth responses to climate change. The study was on 30 years of radial growth of *P. taeda* trees subjected to different crown thinning intensities in southern Brazil. In total, 9,280 measurements of ring width and age were evaluated. Residual chronologies were obtained according to standard dendrochronology techniques. Correlation was calculated between chronologies and meteorological variables, and thus the direction and magnitude of the relationship between meteorology and growth was addressed. Results indicated that, accounting for the whole year, meteorological condition show no particular influence on the radial growth of *P. taeda* trees in the studied region. The exception was the vapor pressure deficit, with a significant and negative correlation with the radial growth of trees at all thinning intensities. When considering seasons, several consistent correlations were detected. Rainfall during winter, previously or at the end of the growing season, was positively correlated with the radial growth of the trees at all thinning intensities. A consistent negative correlation between minimum and maximum temperatures during winter and the radial growth of trees shows that *P. taeda* in southern Brazil, regardless of thinning intensity, benefit from colder winters in general and, particularly, from colder days during winter. Although temperature increases in the highlands of southern Brazil, as a result of global warming, may not render the cultivation of *P. taeda* unfeasible, they may restrict or shift the region of optimum growth as well as require changes in the genetic material. Results also suggest that high-intensity thinning may increase the influence of temperature on growth pattern of the stands. [With the variation in thinning intensities it is regrettable that these were not compared in results. FHW] M. Dobner Jr. and others. Meteorological effects on 30-year growth of *Pinus taeda*. [*Forest Ecology and Management* 453 117624 2019] D

BIODIVERSITY IN PLANTATIONS INFLUENED BY SURROUNDING VEGETATION

Human-modified forests, including plantations and managed forest, will be a major component of tropical landscapes in the near future. To conserve biodiversity across modified tropical landscapes we must first understand what influences diversity in planted areas. We studied dung beetle communities in *Eucalyptus* plantations to assess the influence of local (canopy openness and soil texture) and landscape factors (surrounding native forest cover) on taxonomic and functional diversity, and to determine whether biodiversity in plantations is affected by timber production. Dung beetle community composition in *Eucalyptus* plantations was largely explained by the surrounding native forest cover, as Simpson's diversity and functional diversity (Rao's quadratic entropy) increased with the extent of native forest in buffer areas. However, the abundance of dung beetle species associated with native forest was not explained by any of the explanatory variables. The coarse sand content of the soil explained much of the functional similarity between plantations and native forests, as well as variation in dung beetle community structure. The total abundance of dung beetles in plantations increased with coarse sand content whereas body mass declined, and dung beetle abundance and functional originality decreased with canopy openness. Timber production intensity did not explain the variation in any of the measured diversity parameters. If enhancing biodiversity in plantations is a management goal,

then these results highlight the importance of restoring or retaining native forest areas in modified landscapes. They also suggest that integrated management could improve biodiversity in *Eucalyptus* plantations without reducing timber production. W. Beiroz and others. Biodiversity influenced by surrounding vegetation. [*Forest Ecology and Management* 444 107-114 2019] D

HIGH MANGROVE ROOT PRODUCTION RATES IN MALAYSIA

Mangroves often allocate a relatively large proportion of their total biomass production to their roots, and the belowground biomass of these forests contributes towards globally significant carbon sinks. However, little information is available on root production in mangroves due to difficulties in carrying out measurements of belowground processes, particularly if there is regular flooding. In this study, we examined fine and coarse root production in the east coast of the Malaysian Peninsula. Ingrowth cores were used over the course of 17 months. In September 2014, twenty cores were randomly placed in each of five plots. Three cores were collected from each plot (fifteen cores in total), once every three months. Each core was divided into five 10 cm layers and root dry mass was recorded. After 17 months the final root biomass in the cores was 14% less than the standing root biomass. These data suggest surprisingly rapid growth rates and turnover for mangrove roots. Total root biomass significantly increased with root depth and 78% of the roots, in all soil layers, consisted of fine roots (<3mm diameter). Soil carbon, nitrogen, and phosphorus concentrations were investigated in relation to belowground production, as were soil temperature, salinity, and dissolved oxygen. A data review of global studies reporting similar work was carried out. The results are discussed with consideration to the significance of monsoon rainfall for mangrove ecology. S. M Muhammad-Nor and others. High mangrove root production in Malaysia. [*Forest Ecology and Management* 444 214-224 2019] D

TREE STEM GROWTH AND WOOD PRODUCTION IN MANGROVE

Mangrove forest provides important ecological and economic services including carbon sequestration and storage. The conservation and restoration of mangroves are expected to play an important role in the mitigating climate change, and understanding the factors influencing mangrove stem growth and wood production are important in predicting and improving mangrove carbon sequestration and responses to environmental change. In this study, we collected data of individual diameter at breast height (DBH) growth rate and stand level aboveground wood production in both non-plantation (commonly termed as natural) mangroves and mangrove plantations across the world). Climatic factors, proxies of edaphic factors, as well as biological factors (e.g. mangrove species) were included as explanatory variables in the analyses to determine factors influencing global patterns of tree growth rate and stand wood production of mangroves. Using hierarchical Classification and Regression Tree (CART) analysis we found interactions among environmental and biological factors in controlling mangrove tree growth rate and stand wood production between non-plantation mangroves and plantations. Climatic conditions (precipitation of driest season, precipitation seasonality) were the most important factors influencing the global pattern of tree DBH growth rate in non-plantation mangroves, with edaphic and biological characteristics also playing a role under specific climatic conditions. The global pattern of stand wood production in non-plantation mangroves was primarily determined by stand mean DBH growth rate of individual trees. However, in mangrove plantations management measures, specifically species selection and planting density, were the most important factors influencing the global patterns of tree growth

rate and stand wood production. Our study provides parameters for a global estimation of long-term carbon sequestration in both non-plantation mangroves and mangrove plantations. In addition, our results help us better predict the dynamics of tree growth and carbon sequestration of non-plantation mangroves under changing climate. Y. Xiong and others. Tree growth and stand wood production of mangrove forests. [*Forest Ecology and Management* 444 382-392 2019] D

LIGHT USE EFFICIECY OF *EUCALYPTUS* IN BRAZIL

Stemwood productivity in forest ecosystems depends on the amount of light absorbed by the trees (APAR) and on the Light Use Efficiency (LUE), i. e. the amount of stemwood produced per amount of absorbed light. In fertilized *Eucalyptus* plantations of Brazil, growth is expected to be strongly limited by light absorption in the first years after planting, when trees can benefit from high soil water stocks, recharged after clearcutting the previous stand. Other limiting factors, such as water or nutrient shortage are thought to increase in importance after canopy closure, and changes in allocation patterns are expected, affecting the LUE. Studying changes in APAR and LUE along a complete rotation is paramount for gaining insight into mechanisms that drive the inter- and intra-genotype variabilities of productivity and stemwood biomass the time of harvest. Here, we present a 6 year survey of productivity, APAR and LUE of 16 *Eucalyptus* genotypes of several species used in commercial plantations and planted in 10 randomized replications in the Sao Paulo Region, Brazil. APAR was estimated using the MAESTRA tridimensional model parameterized at tree scale for each plot (a total of 16,000 trees) using local measurements of leaf and canopy properties. Stand growth was estimated based on allometric relationships established through successive destructive biomass measurements at the study site. Allometric relationships predicting biomass of tree components, leaf surface, crown dimension and leaf inclination angle distribution throughout the rotation for the 16 productive genotypes are shown. Results at stand scale showed that (1) LUE increased with stand age for all genotypes from 0.15 at age 1 year to 1.70 MJ^{-1} at age 6 years on average; (2) light absorption was a major limiting factor over the first year of growth (R^2 between APAR and stand biomass ranging from 0.5 to 0.95), explaining most of the inter- and intra- genotype growth variability; (3) at rotation scale, the variability of final stemwood biomass among genotypes was in general attributable to other factors than average APAR; (4) differences in stemwood productions among genotypes remained large throughout the rotation; (5) LUEs over the second half of the rotation, rather than initial growth of APAR, was the major driver of stemwood biomass at the time of harvest. G. Le Maire and others. Light efficiency of *Eucalyptus* in Brazil. [*Forest Ecology and Management* 449 117443 2019] D

TRANSPIRATION OF MOSO BAMBOO INFLUENCED BY AGE, PHENOLOGY, AND DROUGHT

Forest transpiration is coupled with environmental variables and has a profound effect on regional water cycle and water balance. Understanding how the biotic and abiotic environments influence transpiration is vital in understanding forest water use strategies, and for evaluating forest feedback to climate change. Moso bamboo (*Phyllostachys edulis*), a woody bamboo species, is rapidly spreading in the southern parts of China and must have a significant influence in ecosystem processes here. This study examined culm sap flow in *P. edulis* in southern China to identify key factors that determine its transpiration at individual and stand scale. Sap flux density was higher in the 1-2 years old ramets than those >3 years old, during the entire growing

season. Daily accumulated sap flux density and its sensitivity to the physical environment (air vapor pressure deficit -VFD and solar radiation) during the non-shooting period were approximately 2 and 3 times higher than during the shooting-leafing period for 1-2 and >3 years old culms, respectively. During the non-shooting period, daily maximum and accumulated sap flux density of the 1-2 years old ramets had no correlation with soil water content, while that of >3 years old ramets declined linearly with decreasing soil water content (SWC). Stand transpiration remained low and was not affected by changes in SWC during the shooting-leafing period, while that of non-shooting period was linearly correlated with SWC. The results showed that transpiration of Moso bamboo was interactively influenced by culm age, phenological stages and soil drought. We demonstrate the role of ramet age and phenology on bamboo stand transpiration and how it responds to soil drought. Our study reveals the special water use strategies in Moso bamboo forests. D. Gu and others. Transpiration of Moso bamboo of southern China influenced by ramet age, phenology, and drought. [*Forest Ecology and Management* 450 117526 2019] D

CLONAL COMPOSITES FOR PRODUCTION SUSTAINABILITY IN *EUCALYPTUS* FORESTS

The use of eucalypt clonal composites framed by improved, phenotypically similar and unrelated clones may be an important strategy to help breeders prevent commercial eucalypt plantations from unpredictable future adverse events, as well as to promote sustainable productivity gains. The present study was conducted to test this hypothesis by comparing the growth (MAI) at ages three to four years of significant number of clones in clonal composite (CC) and monoclonal (MC) typologies under distinct environmental conditions, both at experimental and commercial scales. The CC presented MAI performance superior to MC in both experimental (9.8%) and commercial (6.3%) conditions. In each region, different clones respond differently to allo- (CC) and auto-competition (MC), but most of them (73%) performed better in CC. Furthermore, CC commercial plantations presented growth uniformity at different ages, similar to MC plantations as well as lower generic vulnerability given by the proportion of replanting before the end of the rotation age due to biotic or abiotic damage agents. G. D. S. P. Rezende and others. Clonal composites for sustainability of eucalypt forests. [*Forest Ecology and Management* 449 117445 2019] D

LONG-TERM (25 YEAR) EFFECTS OF SELECTIVE LOGGING IN THE BRAZILIAN AMAZON

Selective logging is one of the most prominent land uses in tropical forests and although it involves harvesting a limited number of trees, the impact on forest structure, composition, and aboveground biomass can be significant. Although these impacts are well documented, what is little known is the extent to which selective logging affects tree floristic composition and its recovery process. Understanding how floristic composition is affected by logging activities is essential for determining subsequent cutting cycles, for the maintenance of carbon stocks and for biodiversity conservation. This research investigates the effect of logging on long-term trends on the recovery of species composition in tropical forests using a unique logging experiment where measurements have been taken annually over a period of 25 years. Changes in 12 long-term 1-hectare (ha) permanent plots were assessed where different selective logging intensities occurred. In the first years after logging floristic composition differed widely between intact and selectively logged forests, with exploited areas deviating from pre-logged composition. Over

time, exploited areas shifted towards the original composition, with more pronounced changes in this trend after 13 years. Shifts in floristic composition were caused mainly by a significant increase in light-demanding, fast-growing pioneer species and their subsequent continuous high mortality rates after 13 years of the recovery process. In contrast, the control plots showed similar shifts in composition over time, suggesting external factors such as long-term climate changes may be driving these shifts. The results suggest that 25 years after an experimental selective logging has taken place, floristic composition tends to recover closer to the pre-logged status. Thus, in the absence of further human disturbances experimental selectively logged forests in low to moderate intensities are compatible with biodiversity conservation, at least during the first cycle of exploitation. Reconciling conservation strategies with the recovery of stocks of commercial timber species would be greatly improved by using these results and leads towards more sustainable forest management plans. T. D. Gaui and others. Long-term effects of 25 years of selective logging in the Amazon. [*Forest Ecology and Management* 440 258-266 2019]

TREE SPECIES OF HIGH ECONOMIC AND LIVELIHOOD VALUE FOR ZAMBIA

The sustainable management of dry forests and woodlands Sub-Saharan Africa (SSA) is crucial for the SSA economy and people's livelihoods, but it remains a key challenge to address. Maps of tree species distributions of economic value are lacking for the region; yet this information is essential for supporting sustainable use. We capitalized on new nation-wide field survey data for the Republic of Zambia (Southern Africa) to generate the first suite of baseline species distribution models (SDMs) for 20 tree species of economic significance to support for sustainable management and conservation. We employed one regression- and two machine learning- based techniques to model and predict tree distribution. For each species, we compared the three model results for the relative importance of different predictive variables, revealing the most important predictors of each species niche and providing insight into how human activities influence current tree species distribution. Overall, environmental predictors that best explained tree species distribution were related to water availability, including mean potential evapotranspiration (PET), annual rainfall, and the variation in PET, as well as elevation and soil fertility. Human impact on distribution was notable for tree species used for charcoal and timber, including the proximity to roads for charcoal-favored species and the proximity to settlement for timber species. For all tree species, fire did not stand out as a variable of importance, contrary to expectations. The SDMs generated from this study will provide essential baseline information to support national conservation and management efforts, especially for preferred timber and charcoal species for which selective harvesting has had an impact on their distribution. Our results highlight the importance of rainfalls for the distribution of tree species in this seasonally dry region and calls for future research to forecast the impacts of climate change on habitat suitability. J. Pelletier and others. Distribution of tree species with high economic and livelihood value for Zambia. [*Forest Ecology and Management* 441 280-292 2019] D

USING LINEAR MIXED MODELS TO EXAMINE STAND LEVEL GROWTH RATES FOR DIPTEROCARPS AND *MACARANGA* FOLLOWING SELECTIVE LOGGING IN SABAH, BORNEO

To understand and predict the dynamics and productivity of the world's tropical rainforests after logging is a major challenge for ecologists and forest managers. Realistic forest-dynamics models for this biome are largely lacking. Using linear mixed models, we analyze basal area

development for the commercially valuable tree species of dipterocarps and the fast-growing pioneer *Macaranga* spp., following two selective logging methods; supervised logging (SL) and conventional logging (CL) combined with- or without pre-harvest climber cutting (SLC and SL, and CLC and CL, respectively). After logging there was an initial period of about five years before recovery started. During the 18-year study period, the average stand basal area growth rates of the dipterocarp group in the SLC treatment was double that in the CL treatment, revealing a faster recovery. Eighteen years after logging, SL and SLC treatments recovered 93% and 84%, respectively, of the initial standing dipterocarp basal area, compared to 73% and 72% recovery for the CL and CLC treatments. SLC treatments reduced the overall establishment of pioneer species (*Macaranga* spp.) by about 45% in contrast to CL and CLC treatments. Our study provides a framework for evaluating and comparing growth rates in tropical forests for different logging methods. The results suggest that a combination of directional felling, pre-aligned skid trails and pre-harvest climber cutting can improve future yields in tropical rainforests. **Distribution of tree species of high value for Zambia.** D. Lussetti and others. Using mixed models to evaluate stand level growth rates for dipterocarp and *Macaranga*. [*Forest Ecology and Management* 437 372-370 2019] D

TROPICAL FORESTRY NOTES (43)

HISTORICAL DOMESTICATION IN ANCESTRAL FORESTS IN AMAZONIA

Past human modification of forests has been documented in central, southeastern and eastern Amazonia, especially near large rivers. Northwestern Amazonia, and interfluvial forests there in particular, are assumed to exhibit little past human impact. We analyzed soils and floristic structure and composition of interfluvial forests located in the Icana River basin, northwestern Amazonia, to assess their degree of past human modification. Ancient Baniwa village sites, abandoned centuries ago, have given rise to "ancestral forests", with as much as 57% of all trees/palms belonging to a group of species managed currently by the Baniwa, compared to only 10% of such species in old growth forests that are not remembered as having been inhabited or managed in Baniwa oral tradition. Participatory mapping and direct observations revealed ancestral forests to be widely distributed throughout the region, whereas old-growth forests are rare. Managed species in ancestral forests constituted 5-fold more to total tree/palm biomass than in old-growth forests. Human management has produced lasting changes in floristic composition, maintained total tree/palm biomass, and improved soil quality. This is the first study to demonstrate past human modification in Amazonian interfluvial forests, while explicitly isolating historical human management from edaphic effects on floristic structure and composition. Despite environmental limitations on human population size posed by nutrient-poor black-water rivers and acidic, sandy soils, indigenous peoples of northwestern Amazonia left a clear lasting cultural legacy in ancestral forests. Given legal changes that threaten indigenous people land rights currently under debate in Brazil, we call for a reconsideration of biodiversity conservation policies and indigenous rights in areas that show enduring legacies of management by indigenous populations. J. Franco-Moraes and others. Ancestral forests in northwestern Amazonia. [*Forest Ecology and Management* 446 317-330 2019] D

INTEGRATED TREATMENT OPPORTUNITY FOR DWELLERS: SUSTAINABLE MANAGEMENT

Nearly 25% of the world's poor are dependent on forests, with 0.5-1 billion smallholders managing trees. This extensive human use of forests points to the need for sustainable timber management (STM) at smallholder scales. Similar to other tropical regions, households in the Amazon Estuary have harvested timber informally with minimum management for decades. This research provides a comprehensible look at the ecological and economic sustainability of forest use by local smallholders by integrating detailed plant demography, microeconomic, management and land use models at a whole watershed and community scale. In terms of conservation outcomes, resulting models show that forest management results in extensive harvests that allow for faster tree population recovery. In terms of economic outcomes, management also improves the long-term viability of the local timber industry in all scenarios considered. However, with respect to harvest regulations, given the costs of legalizing these small informal operations, legalization may indirectly lead to heavier ecological impacts as households need to harvest more to keep economic returns similar to the predominant alternative land use in the region (acai palm fruit agroforestry). Despite a fast growing and resource rich forest, an increasing extent of degraded forest area reduces the ecological and economic prospects for long term management. Consequently, for this and other similar tropical forests the viability of STM should not be evaluated as a binary and static yes or no response but instead as a moving window of opportunity that occurs when ecological, economic, and policy conditions

are met. Integrated model projections show that regionally- derived and ecologically-based sustainable management guidelines widen this window of opportunity by delivering the best ecological and economic outcomes under a range of scenarios considered. L. B. Fortini and others. Integrated opportunity for forest dwellers. [*Forest Ecology and Management* 438 233-242 2019] D

ABOVE GROUND BIOMASS VIA SPECIES DIVERSITY AND STAND STRUCTURAL COMPLEXITY

Theoretical and empirical studies have suggested that climate and soils are the main drivers of biodiversity, stand structure and aboveground biomass in natural forests. Yet, the direct effects of climate and soils on aboveground biomass versus the indirect effects mediated by species diversity and stand structural complexity remain unclear in forest ecosystems across large-scale ecological gradients. Here, we hypothesized that (1) climate and soils would influence aboveground biomass through strong indirect effects (2) stand structural complexity rather than species diversity would strongly mediate the response of aboveground biomass to climate and soils; and (3)species diversity and stand structural complexity would promote each other under the niche differentiation and facilitation effects, and that stand structural complexity would have positive effects on aboveground biomass across large-scale ecological gradients. To test these hypotheses we quantified climatic water availability, soil total exchangeable bases, species diversity, stand structural complexity, including tree DBH (diameter at breast height) diversity and height diversity, and aboveground biomass across 907 plots in tropical forests of Hainan Island, Southern China. We tested 126 structural equation models to examine the direct and indirect effects of climate and soil on aboveground biomass via species diversity and stand structural complexity. Climatic water availability and soil fertility did not affect aboveground biomass directly but did affect indirectly via increasing stand structural complexity rather than species diversity. Species diversity and stand structural complexity promoted each other and both increased with increasing climatic water availability. Stand structural complexity increased aboveground biomass directly, whereas species diversity increased it indirectly via increasing stand structural complexity. The total effects of climatic water availability, soil fertility, stand structural complexity, and species diversity on aboveground biomass were significantly positive. This study shows that climatic water availability exerts a strong direct effect on stand structural complexity, indicating that any decrease in climatic water availability (i. e. increasing atmospheric drought) may directly diminish stand structural complexity and hence indirectly reduce aboveground biomass and carbon storage. This study suggests that maintaining high stand structural complexity can enhance aboveground biomass under favorable climate and soils while maintaining the benefits of species diversity on stand structural complexity for better ecosystem services such as carbon storage. A. Arshad and others. Climate and soils determine aboveground biomass [*Forest Ecology and Management* 432 823-831 2019] D

ENHANCE GUAVA FOR CARBON STORAGE

Tropical forests account for a substantial percentage of the world's carbon stocks, but the consequences to carbon storage of the rapid invasiveness of the guava tree in these forests is not known. Two different forest management strategies are practiced in a tropical forest in western Kenya: (1) a protection strategy where human entry is prohibited except for minimalistic human presence (e.g., research activities); and (2) a conservation strategy where human access to the forest and its resources are permitted. We assessed the effects of these management strategies

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and different levels of disturbance caused by the legacy effects of legal logging activities and the contemporary effects of unauthorized harvesting of forest products on the abundance of guava and non-guava trees and carbon storage in both plant biomass and soil in this forest. We found that guava trees were less likely to thrive and carbon storage in plants and soils was similar in sites with minimal disturbance under both the protection and conservation strategies. However, as disturbance increased, whether by the historical or contemporary effects of human activities, guava trees were more likely to thrive and carbon storage in plants shifted from non-guava trees to guava trees, but without an effect on more stable soil carbon. We conclude that regulations should be strictly enforced to prevent all logging activity, but the conservation strategy would provide similar effects on both forest plant and soil carbon to the protection strategy, while providing benefits to the surrounding community who rely on the forest for cultural and spiritual nourishment. R. Adhiambo and others. Favoring the invasion of guava trees for carbon storage. [*Forest Ecology and Management* 432 623-630 2019] D

MATERNAL ENVIRONMENT REGULATES MORPHOLOGICAL AND PHYSICOLOGICAL CHARACTERISTICS IN *EUCALYPTUS GRANDIS*

The phenotype of a plant can be shaped by the biotic and abiotic conditions to which their parents are subjected. This phenotypic plasticity known as maternal environmental effect occurs regardless of the changes in the DNA sequences. Whereas the effect of the maternal environment on plant phenotypic has been studied, its specific influence on plant physiology is less clear. This study considered the influence of the maternal environment on the regulation of plant morphology and physiology in progeny of *Eucalyptus grandis*. Plants were grown from seed collected from two *E. grandis* clonal seed orchards that differed in environmental conditions (e. g, precipitation). Plant relative growth rate (RGR), leaf gas exchange and water use efficiency (WUE) were measured in the seedlings. RGR was 10% higher in the offspring from the maternal environment receiving higher precipitation levels. Leaf gas exchange, specifically leaves intercellular CO_2 and intrinsic WUE, were also influenced by maternal environments. Intrinsic WUE was significantly lower in the orchard that received lower precipitation levels. The results demonstrate that the maternal environment can regulate physiology of *E. grandis* in the subsequent generation. These analyses are useful to optimize tree improvement in a changing environment. Moreover, in a scenario of climate change, maternal environmental effects maybe a crucial mechanism for certain species to get acclimated to sudden changes in environmental conditions. M. Vivas and others. Maternal environment regulates *Eucalyptus grandis*. [*Forest Ecology and Management* 432 631-636 2019] D

SLOW RECOVERY FOLLOWING SHIFTING CULTIVATION IN HEATH FORESTS OF SARAWAK, MALAYSIA

Heath forests which are tropical forests on sandy soils are widely distributed in Borneo and provide many ecosystem services, such as carbon storage and non-timber forest products. Over the past several decades, such forests have been disturbed by non-traditional shifting cultivation, which is usually conducted in unsuitable land with short fallow duration. Anthropogenic disturbances in forests growing on sandy soils that have low nutrient retention capacities may promote further reductions in soil fertility. Long-term monitoring of soil nutrients and biomass accumulation is rare in degraded tropical rainforests growing on sandy soils despite the known negative effects of non-traditional shifting cultivation practices on soil fertility, vegetation and biomass recovery, and the growth of trees planted to rehabilitate forests. The objective of the

current study was therefore to elucidate changes in soil fertility and biomass recovery potential in degraded forests on sandy soils in Borneo. We monitored soil nutrients and chemical properties in fifty-four 12×12 m plots located on different topographical positions along upper and lower slopes. Samples were collected in plots aged 7 and 14 years after abandonment of shifting cultivation. The biomass of secondary forest trees in all plots 12 years after the abandonment was also measured to determine the relationship between biomass accumulation and changes in soil nutrients. We found that soil pH and cation exchange capacity, and the concentrations of most nutrients, including nitrogen, magnesium, and phosphorus, had decreased significantly 7–14 years after abandonment; biomass accumulation in the plots was also limited 12 years after abandonment (<0.8 Mg ha^{-1} year^{-1}). These changes in soil traits within the study plots were similar regardless of topographical position, and the changes were not related to the amount of biomass. Soil nutrients in the plots may have leached out as a result of removal of thick root mats in the surface soil, high sand content, and large amounts of rainfall in the area rather than uptake by recovering trees. These results indicate that it may be difficult to recover soil fertility on steep slopes in sandy soil conditions because of high leaching rates and erosion when the soil surface layer is destroyed by shifting cultivation. It is therefore important to carefully manage shifting cultivation practices in tropical forests on sandy soils in Borneo. D. Hattori and others. Degradation of soil nutrients and slow recovery of biomass following shifting cultivation in the heath forests of Sarawak, Malaysia. [*Forest Ecology and Management* 432 467-477 2019] D

REVISED MAXIMUM BIOMASS LAYER IN AUSTRALIA

The carbon accounting model FullCAM is used in Australia's National Greenhous Gas Inventory to provide estimates of carbon stock changes and emissions in response to deforestation and afforestation/reforestation. FullCAM-predicted above-ground woody biomass is heavily influenced by the parameter *M*, which defines the maximum upper limit to biomass accumulation for any location within the Australian continent. In this study we update FullCAM's *M* spatial input layer through combining an extensive database of 5739 site-based records of above-ground biomass (AGB) with the Random Forest ensemble machine learning algorithm, with model predictions of AGB based on 23 environmental predictor covariates. A Monte-Carlo approach was used, allowing estimates of uncertainty to be calculated. Overall, the new biomass predictions for woodlands, with 20–50% canopy cover, were on average 49.5 ± 1.3 (s.d.) t DM ha^{-1}, and very similar to existing model predictions of 48.5 t DM ha^{-1}. This validates the original FullCAM model calibrations, which had a particular focus on accounting for greenhouse gas emissions in Australian woodlands. In contrast, the prediction of biomass of forests with a canopy cover >50% increased significantly, from 172.1 t DM ha^{-1} to 234.4 ± 5.1 t DM ha^{-1}. The change in forest biomass was most pronounced at sub-continental scales, with the largest increases in the states of Tasmania (166 to 351 ± 22 t DM ha^{-1}), Victoria (201 to 333 ± 14 t DM ha^{-1}), New South Wales (210 to 287 ± 9 t DM ha^{-1}), and Western Australia (103 to 264 ± 14 s.d. t DM ha^{-1}). Testing of model predictions against independent data from the savanna woodlands of northern Australia, and from the high biomass *Eucalyptus regnans* forests of Victoria, provided confidence in the predictions across a wide range of forest types and standing biomass. When applied to the Australian Government's National Inventory land clearing accounts there was an overall increase of 6% in continental emissions over the period 1970–2016. Greater changes were seen at sub-continental scales calculated within $6° \times 4°$ analysis tiles, with differences in emissions varying from -21% to $+35\%$. Further testing is required to assess the impacts on other land management activities covered by the National Inventory, such as reforestation; and at more

local scales for sequestration projects that utilise FullCAM for determining abatement credits. S.H. Roxburgh and others. A revised above-ground maximum biomass layer for the Australian continent. [*Forest Ecology and Management* 432 264-275 2019] D

STAND DENSITY AND GENETICS AFFECT *PINUS RADIATA* ECONOMIC RETURN

Intensively managed forests are expected to play an increasingly important role in meeting future global demand for wood products. To meet this challenge, a key focus will be on lifting yields from these forests along with economic returns. In this study, we used data from a long-term series of trials that were established in radiata pine (*Pinus radiata* D. Don) to examine the effect that stand density, deployment of genetically-improved seedlots, and site have on economic returns. This dataset comprised end-of-rotation assessments of eight installations of a trail series in New Zealand that spanned a wide range of site productivity. Each installation typically contained four seedlots with differing levels of genetic improvement growing at three levels of stand density. Mixed effects models were used to examine the effects of stand density, site, seedlot genetic rating, and their interactions Total Value (NZs/ha^{-1}) and Relative Value (NZS m^{-3}). There was a strong positive relationship between stand density and Total Value, but there was generally no significant relationship between stand density and Relative Value. Of the variation in Total Value not explained by the fixed effect of stand density, approximately 60% was due to differences among trial installations (i.e. site) and 5-7% was due to seedlot genetic worth. There were significant first order interactions between seedlot and site, and between site and stand density. Seedlot generic worth was able to explain a higher proportion of the variation in Relative Value (between 10 and 18% depending on the genetic trait under consideration). The genetic worth of a seedlot in terms of stem straightness rating was able to explain the greatest proportion of variation in Relative Value. These results highlight the importance of the choice of location and stand density management have on the economic returns from intensively-managed forests. While seedlot genetic rating has a smaller effect on economic returns, improvements in traits such as stem straightness and branch characteristics also make an important contribution. As silvicultural practices move towards higher stand densities, and the next generation of genetically improved trees are deployed, a more precise understanding of the interactions of site, silviculture, and genetics will be needed. New ways of testing and modelling these interactions will be required but will ensure the delivery of a more informed approach to forest management. J. P. Dash and others. Stand density and genetic improvement affect a *Pinus radiata* plantation. [*Forest Ecology and Management* 446 80-92 2010] D

LINKING *EUCALYPTUS* CLONES, TREE, AND STAND GROWTH IN BRAZIL

Tree and stand level growth is required for estimating future forest stand structure, while maintaining the desired accuracy for forest management decision making. There is a scarcity of studies addressing this issue for clonal *Eucalyptus* stands in Brazil. Thus, this paper aims to develop a compatible individual-tree and stand-level growth and yield for clonal Eucalypt stands in Brazil. The dataset used in this study is derived from remeasurement information of sixteen TECHs sites. At every site eleven Eucalyptus clones were planted in single block plots, while extra plots under a rainfall exclusion regime were installed in fourteen sites. Prediction and projection diameter percentile equations were developed, as well as an individual tree mortality equation and a generalized height-diameter equation. In addition, a detailed explanation of the structural architecture of the developed compatible growth and yield system is provided. Differences when forecasting forest afforestation and updating forest inventories were

highlighted in order to provide the proper use of the developed growth and yield system. Finally, the individual-tree equations were validated through the use of the rainfall exclusion regime plots as was the growth and yield system when applied for prediction and projection purposes. The individual-tree level equations provided accurate estimates. The newly developed compatible growth and yield system also displayed unbiased and accurate estimates. The system achieved full compatibility between individual-tree and stand-level estimates and produced accurate stand-level estimates and produced accurate stand table estimates. The growth and yield system presented is a powerful analytical tool that can serve to update inventory data in tropical Brazil and also provide estimates for expected forest afforestation. The system has the capability of providing detailed outputs, which allows forest managers to consider merchandizing the clonal Eucalypt stands into multiple products. H. Ferrasco Scolforo and others. Linking individual-tree and stand-table yields of timber in Brazil. [*Forest Ecology and Management* 432:1-16 2019]

MANGROVE BIOMASS ACCUMULATION IN VIETNAM

In many tropical nations mangrove forests are essential ecosystems for climate change mitigation and adaptation in coastal regions as they provide important forest resources as well as a suite of other benefits to communities including carbon sequestration. Empirical growth and yield modeling methods derived from terrestrial forestry, which are often robust with respect to forestry forecasting and management, have not so often been assessed in mangrove forest yet they are important for underpinning sustainable forest management. We surveyed 89 *Rhizophora apiculata* mangrove plantations with age range from 4 to 26 year old in Vietnam, destructively harvesting 25 trees for biomass measurements and 70 for stem analyses, to assess increments in biomass and standing timber. Systems of equations were developed to model site index, mean diameter, dominant height, stoking, biomass and timber volume. We found that conventional forest growth modeling methods fitted the observed data well. Similar to terrestrial forests, stand height is a good indicator of site productivity. Mean errors for stand volume and biomass estimated from yield tables were both less than 5.3%. The root mean square error (RMSE) of the biomass model was 12 and RMSE of the volume model was 10.8, suggesting that these methods are applicable to evenly aged monoculture mangrove plantation in Vietnam. Our research also indicated high variation in mean annual increment of biomass (MAI) in the surveyed plantations due to a wide range of age and site conditions. Some *R. apiculata* plantations in Vietnam can reach a peak aboveground biomass MAI of 22.7Mg ha^{-1} year^{-1}, which is among the highest of published values from plantations of the same species worldwide. Further studies addressing the application of terrestrial forest growth methods to mangrove systems are suggested in order to develop reliable and useful tools for sustainable management of this important ecosystem. S. M. Phan and others. Modelling above ground biomass accumulation of mangrove plantations in Vietnam. [*Forest Ecology and Management* 432:376-386 2019]

TROPICAL FORESTRY NOTES (44)

EFFECTIVENESS OF LIDAR FOR MONITORING FOREST COVER

Ambitious pledges to restore over 400 million hectares of degraded lands by 2030 have been made by several countries within the Global Partnership for Forest Landscape Restoration (FLR). Monitoring restoration outcomes at this time requires cost-effective methods to quantify not only forest cover, but also forest structure and diversity of useful species. Here we obtain and analyze structural attributes of forest canopies undergoing restoration in the Atlantic Forest of Brazil using a portable ground lidar remote sensing device as a proxy for airborne laser scanners. We assess the ability of these attributes to distinguish forest cover types, to estimate aboveground dry woody biomass (AGB) and to estimate tree species diversity (Shannon index and richness). A set of six canopy structure attributes were able to classify five cover types with an overall accuracy of 75% increasing to 87% when combining two secondary forest classes. Canopy height and the unprecedented "leaf area height volume" (a cumulative product of canopy height and vegetation density) were good predictors of AGB. An index based on the height and evenness of the leaf area density profile was weakly related to the Shannon index of tree species diversity and showed no relationship to richness or to change in species composition. These findings illustrate the potential and limitations of lidar remote sensing for monitoring compliance FLR goals of landscape multifunctionality, beyond a simple assessment of forest cover gain and loss. D. R. A. Almeida and others. Effectiveness of lidar for monitoring forest cover and landscape restoration. [*Forest Ecology and Management* 438 34-43 2019] D

GROWTH DETERMINENTS FOR *TRIPLOCHITON SCLEROXYLON*

The sustainability of the polycyclic logging system in tropical forests has been increasingly questioned for a variety of reasons, and particularly in central Africa as commercial species, mostly light-demanding long-lived pioneer species, usually fail to recover a stable number of large trees after exploitation. Several factors are known to affect tropical tree demographic processes, like tree growth, survival and recruitment. Tree growth has particularly been showed to depend on ecological conditions, tree genetics, and competition with surrounding vegetation, as well as tree size or ontogeny. Yet, due to the paucity of available data, the importance of such factors is unclear and usually ignored when estimating future timber yields. To fill this gap, we chose to evaluate the variability in growth of one African long-lived pioneer and commercially very important species: *Triplochiton scleroxylon* K. Schum, gathering a broad dataset composed of tree ring data recorded in one site in Cameroon and periodic field inventory data recorded in seven sites across central Africa. In total, we analyzed 13,225 records of annual tree diameter increments recorded over 920 trees from seven sites in Cameroon, Republic of the Congo and Central African Republic. We evaluated (*i*) to what extent the average growth of trees that reach harvestable dimensions differs from population average and (*ii*) to what extent past perturbations influence the growth of remaining trees. We found the diameter growth of *T. scleroxylon* to be remarkably variable and this study provided an unprecedented quantification of the magnitude of some key growth determinants. In unlogged forests, the diameter increment of *T. scleroxylon* ranged between 0.40 cm year^{-1} in Southern Cameroon and 0.83 cm year^{-1} in South-Eastern Cameroon. The diameter increment was weakly related to tree size but increased twofold from unlogged to logged forests. Perturbation caused by logging stimulates growth of *T. scleroxylon* for at least 10–15 years. Finally, harvestable timber stock of large-sized *T. scleroxylon* was found to be constituted by trees that grew in average twice faster than trees of the entire extant

population. As more and more inventory data become available, quantifying these effects could be replicated for other timber species and in other sites, to improve the accuracy of future timber resource estimates and improve forest management guidelines. G. Ligot and others. Growth determinants for *Triplochiton schleroxylon* management in central Africa. [*Forest Ecology and Management* 437 211-221 2019] D

GROWTH OF TWO COMMERCIAL SPECIES IN UPLAND AMAZONIA

Despite all efforts to promote sustainable use of timber resources in tropical forests, the current management criteria still require adjustments at a species level, considering specific growth patterns and ecological features. Forest management in upland forests (*terra firme*) of the Brazilian Amazon region generally applies for all commercial tree species a common minimum logging diameter (MLD) of 50 cm and a felling cycle (FC) varying according to the harvest intensity between 25 and 35 years. In this study, we define species-specific FCs and MLDs for the two commercial tree species *Hymenaea courbaril* L. (Fabaceae) and *Handroanthus serratifolius* (Vahl) S.O. Grose (Bignoniaceae) from the *terra firme* of the Southern Brazilian Amazon, applying growth models based on the relationships between estimated tree age, diameter, height and volume. A total of 37 transversal cross-sections (20 stem discs from *Hymenaea* and 17 from *Handroanthus*) were obtained at a height of 20–60 cm above soil level in a private forest concession close to the municipality of Novo Aripuanã in the southern region of the Amazonas state. The two species are common in *terra firme* forests and have high wood densities of 0.76–0.96 g cm^{-3} (*H. courbaril*) and 0.85–1.08 g cm^{-3} (*H. serratifolius*). The mean age of *H. courbaril* and *H. serratifolius*, estimated by ring counting, varied from 104 to 241 years and both species had similar mean diameter increments of 3.9 ± 0.5 mm year^{-1} and 4.1 ± 0.6 mm year^{-1}, respectively. Both species present similar tree growth in diameter, height and volume resulting in a FC of 24.2 years and a MLD of 64.9 cm for *H. courbaril*, and a FC of 26.0 years and a MLD of 69.5 cm for *H. serratifolius*. These results demonstrate the need to adjust the selective logging systems practiced in the Brazilian Amazon region towards a species-specific management of timber species to increase the sustainability of selective logging. V. H. Ferreira Andrade and others. Growth models for two commercial tree species in upland forests of the Southern Brazilian Amazon. [*Forest Ecology and Management* 438 215-223 2019] D

BRAZIL NUT FRUIT YIELD WITH SPACE IN EASTERN AMAZON

Brazil nut (*Bertholletia excelsa*) is one of the most important non-timber forest products (NTFP) species in the world. Better management and conservation practices will only be possible with an in-depth knowledge of tree species ecology. This study aimed to assess the spatial association of fruit yield of *Bertholletia excelsa* trees in two forest types (old growth terra firme forest and Amazon-cerrado transitional forest) in the Brazilian Amazon. Fruit yield was measured in both forest types in 2010. At each forest type fruit yield was divided into different yield classes (number of fruits) for subsequent spatial modeling. The bivariate Ripley's A function was applied to quantify the spatial association of fruit yield of B. excelsa trees over different fruit yield classes. The results revealed that the forest type influences the spatial association of B. excels fruit yield. The old growth terra firme forest presented random spatial association for fruit yield which implies that fruit yield of *B. excelsa* trees over different fruit yield classes. The results revealed that the forest type influences the spatial association of *B. excelsa* fruit yield. The old growth terra firme forest presented random special association for fruit yield, which implies that fruit yield of *B. excelsa* trees in this forest type is not limited by tree location and the

resources. On the other hand the Amazon-cerrado transitional forest presented significant negative spatial association for fruit yield across different yield classes, which means that under same conditions fruit yield of a given tree influences the fruit yield of the neighboring tree in this forest type. Site resources in the Amazon-cerrado transitional forest is limited and naturally favors inter and intra specific composition. Finally, the results imply the need for adoption of different management and conservation strategies for *B. excelsa* in different forest types in the Brazilian Amazon. A. P. B. Batista and others. Spatial association with Brazil nut yield. [*Forest Ecology and Management* 441 99-105 2019] D

FOREST COVER THRESHOLD EFFECTS ON MANED SLOTHS IN ATLANTIC FOREST

Habitat loss and the isolation of remaining habitats are undoubtedly the two greatest threats to biological conservation, especially for the maned sloth, due to its ecological restrictions. In this study we identified a critical threshold of forest cover for maned sloth occurrence and exploited the effects of other local and landscape variables. We sampled 68 sites where we searched for the maned sloth and collected local habitat variables. We calculated the percentage of forest cover and open areas, addressing the appropriated scale through model selection. We used occupancy models and model selection methods to identify the threshold and assess occupancy and detection probabilities. The occupancy probability of the maned sloth is 0.97% but it decreases abruptly at 35% of forest cover, reaching zero in areas with less than 20% of forest cover. The two landscape variables are the most important predictors of sloth occupancy, based on cumulative weight of evidence were forest cover (78%) and open areas cover (46%) the latter influencing negatively maned sloth occupancy. This is the first attempt to identify the habitat requirements of the threatened maned sloth in a fragmented area using landscape and local variables. Our results imply that conservation of maned sloth will benefit from an increase in the amount of native forest at the landscape scale. Given difficulties in new public protected areas, this improvement could be achieved via the recovery of areas located in private properties that are protected by the Brazilian Forest Code. P. M. Santos and others. Forest cover and the maned sloth. [*Biological Conservation* 240 108-204 2019] D

SISTEMATIC COST ASSESSMENT RESTORATION IN BRAZIL

Limited funding is a major barrier to implementing activities global restoration commitments, so reducing restoration costs is essential to upscale restoration. The lack of rigorous analyses about the major components and drivers of restoration costs limit the development of alternatives to reduce costs and the selection of the most cost effective methods to achieve restoration goals. We conducted data set restoration cost assessments for the three most widespread biomes in Brazil (Amazon, Cerrado, and Atlantic forest) and estimated the restoration costs associated with implementing Brazil's National Plan for Native Vegetation Recovery (12M hectares). Most surveys (60%-90%) reported using the costly methods of planting seedlings or sowing seeds throughout the sites, regardless of the biome. Natural regeneration and assisted approaches were an order of magnitude cheaper but were reported in, <15% of projects. The vast majority of tree planting and direct seeding costs were incurred during the implementation phase and nearly 80% of projects ended maintenance within 30 months. We estimated a price tag of US0.7-1.2 billion per year until 2030 to implement Brazil's restoration plan depending on the area that recovers through natural regeneration. Our survey also provides a starting point for sound assessments of restoration costs and their drivers in other biomes, which are needed to reduce the financial

barriers to scaling up restoration at a global scale. P. H. S. Brancalion and others. A systematic cost assessment of ecosystem restoration in Brazil. [*Biological Conservation* 240 108-274 2019] D

TREE PERFORMANCE: IN GUNUNGKIDUL, INDONESIA

Smallholder farmers' choices of tree species in the Gunungkidul region have been limited by lack of management information. This paper describes activities to help inform farmers' choices of three common timber species: *Tectona grandis*, *Swietenia macrophylla*, and *Acacia auriculiformis*, in agroforestry systems in the region through (1) developing models predicting tree diameter growth based on reference growth function and the growth retardation performance and (2) estimating the contributions of site quality variables to the diameter growth retardation of <5 and >5-year-old stands. A total of 48 farms were selected, representing three slope ranges and two soil types, with a circular sample plot of 10m radius established in each farm. A Quadratic model for each timber species indicated that the age of the tree explains a high percentage of the variance in diameter growth. Diameter growth varies with tree age and responds differently in each soil type and slope position. A set of site quality variables were able to predict retarded diameter performances of each tree species in two group ages and two soil types. These results suggest that the models can inform farmers' choices of tree species and management. G. E. Sabastian and others. Tree performance in Gunungkidul, Indonesia. [*Agroforestry Systems* 92:103 -115 2018] D

***PINUS TAEDA* AT 30 YEARS WITH CROWN THINNING**

Pinus taeda plantations are an important economic activity in southern Brazil, where edaphoclimatic conditions are optimal. Understanding how meteorological conditions influence tree growth is important in such a favorable environment for reaching high growth rates and for predicting tree growth response to climate change. The study was designed to evaluate the influence of meteorological variables on 30 years of radial growth of P. taeda trees subjected to different crown thinning intensities in southern Brazil. In total, 9,280 measurements of ring width and age were evaluated. Residual chronologies were obtained according to standard dendrochronology techniques. Correlation was calculated between chronologies and meteorological variables, and thus the direction and magnitude of the relationship between meteorology and growth was addressed. Results indicated that, accounting for the whole year, meteorological conditions show no particular influence on radial growth of P. taeda trees in the studied region. The exception was the vapor pressure deficit, with significant and negative correlation with radial growth of trees at all thinning intensities. When considering seasons, several consistent correlations were detected. Rainfall during winter, previously or at the end of the growing season, was positively correlated with the radial growth of trees of at all thinning intensities. A consistent negative correlation between minimum and maximum temperature during winter and the radial growth of trees shows that *Pinus taeda* in southern Brazil, regardless of thinning intensity, benefit from colder winters in general and, particularly, from colder days during winter. Although temperature increases in the highlands of southern Brazil, as a result of global warming may not render the cultivation of *Pinus taeda* unfeasible, they may restrict or shift the region of optimum growth as well as require changes in the genetic material. Results also suggest that high-intensity thinning may increase the influence of temperature on the growth pattern of the stands. M. Dobner Jr. and others. Meteorological effects on 30-year growth of *Pinus taeda* in southern Brazil. [*Forest Ecology and Management* 453 117624 2019] D

CONSERVATIONIST OBLIGATION TOWARD WILDLIFE VALUES

Recent debate among scholars reveals potential rifts in the conservation community concerning the moral bases of conservation, and the nature of humanity's obligations to nature. We reasoned that conflict within the conservation community could stem both from divergent values and identification with relevant interest groups. We used secondary data from three recent studies that quantify wildlife value orientations, belief in the intrinsic value of wildlife, and perceived moral obligations to wildlife among US residents and self-identified conservationists. Results indicate the vast majority (>75%) of conservationists both endorse the idea that wildlife possesses intrinsic value, and that humans have an obligation to treat wild animals with concern for their welfare - ideas that are consistent with, though not unique to, compassionate conservation. Further, we found that both mutualism value orientations and identification with other interest groups relevant to conservation (e.g. animal rights, hunting) were moderately correlated with beliefs about an individual' obligations toward wildlife-providing evidence that both values and identity are sources of social conflict within the conservation community. Identity could provide a mechanism linking individual-level, cognitive processes with group-level processes (e. g. immergence) that promote both within-group conformity and between-group conflict, but more research is needed to unravel causality. J. T. Bruskotter and others. Conservationist's moral obligations toward wildlife. [*Biological Conservation* 240 108-296 2019] D

TROPICAL FORESTRY NOTES (45)

LIBERATION OF CROP TREES: COMPLETENESS, COST, YIELD

Lianas (woody climbing plants) often abound in tropical forests after selective logging and other disturbances. Liana cutting is an often-prescribed but seldom applied silvicultural treatment designed to foster the growth of future crop trees (hereafter: FCTs). Small-scale studies indicate that this treatment is effective, but little is known about its efficiency (i.e., proportions of lianas missed) or financial cost effectiveness at operational scales. To fill these gaps, we worked in a commercial forest concession in Belize where FCTs and trees to be felled were liberated from lianas in 500–1000 ha annual timber harvest blocks. We found that field crews assigned this and inventory-related tasks spent 11.8% of their time cutting lianas from FCTs at a cost of $0.11 per tree. Workers failed to cut 31.9% of the lianas that infested the 701 FCTs they were supposed to liberate; most of the missed lianas grew into the FCT crowns from neighbors or hung down far from the bole. [an additional 48 FCTs (6%) were completely missed]. In a logging block treated 9-years prior to this study, 39% of the liberated *Swietenia macrophylla* FCTs 29–56 cm DBH were still liana-free whereas in an untreated stand, 94% of similar-sized conspecific control FCTs were liana-infested. Based on tree ring data for the same 9-year period, the liberated FCTs grew 38–63% faster than control FCTs. If the mean growth benefit is sustained over the entire 40-year cutting cycle, each liberated FCT will yield an average of 1.51 m^3 (639 board feet) more roundwood than comparable FCTs in unliberated forest. Over this 40-year period with an annual discount rate of 4.5%, this added volume gives the $0.11 investment per tree a net present value of US $161.38 and a profitability index of 1467 for export quality timber. These results argue for the application of this inexpensive and effective treatment in managed forests where lianas abound. D. J. Mills and others. Liberation of crop trees from lianas. [*Forest Ecology and Management* 439 97-104 2019] D

FORECASTING CONSERVATION IN PINPOINT SPATIAL PRIORITIES

Proper assessing [sic] the impacts of conservation interventions can create interaction spaces between researcher and implementation. For example, protected areas (PAs) are the main strategy to conserve biodiversity, but there is a widespread bias in their location towards unproductive and inaccessible lands. Thus, investments on PAs are likely to have been allocated to areas that did not need protection, at least in the short term, creating communication noise to the society. Here, we estimate the likely conservation impact of the recently established (2002-2012) PAs and indigenous lands (ILs) in a future scenario of land use projected to 2050. We selected areas that were similar to the PAs/ILs with positive conservation impact to propose spatial priorities aiming to minimize loss of Cerrado vegetation in the future. In our analyses PAs in general and those of strict protection had significantly lower conversion rates than control areas, while suitable use PAs and ILs showed no difference between control and protected areas. We did not find differences in impact values between PAs and ILs, but impact values were higher for strict protection than for sustainable use areas. We found a high density of potential priority areas to maximize impact in northern Cerrado. This region is the next agricultural frontier in the biome, having extensive vegetation cover that can be legally converted according to national legislation. By pinpointing conservation priorities based on impact, we can improve the benefit from land protection and increase the space for interactions between science, policymaking, and society at large. F. T. Brum and others. Forecasting conservation impact on pinpoint spatial priorities in the Cerrado. [*Biological Conservation* 240 108283 2019] D

POLLINATOR ABUNDANCE AND DIVERSITY ON FLOWERS ON CACAO IN BOLIVIA

Despite the economic importance of *Theobroma cacao*, surprisingly little is known about its pollination ecology. Ceratopogonid midges are considered to be the main pollinators, but the limited available evidence on the sexual reproduction is based almost exclusively on cultivated cacao and knowledge is nonexistent for wild populations. We documented flower visitors in wild and cultivated plants by applying glue on 2,237 flowers of wild and cultivated cacao trees in Bolivia to trap floral visitors. We caught 631 insects belonging to seven orders, corresponding to a mean capture rate of 0.3 insect per flower. The most abundant and diverse insect order on both cacao types was Hymenoptera, represented mainly by small parasitoids. Hymenoptera were more abundant on wild cacao, whereas species richness was higher on cultivated cacao. The abundance and species richness of Diptera were not significantly different between wild and cultivated cacao. Ceratopogonidae were represented by only13 individuals belonging to seven species. Cacao pollen was carried by only a single specimen of Encyrtidae. We were thus unable to identify actual pollinators. We found significant differences among the visitor assemblages between wild and cultivated cacao, which suggest that midges alone were probably too rare to act as main or even sole pollinators of cacao in our study region. Potential additional pollinators would be small Diptera (e.g., Chloropidae and Phoridae) and Hymenoptera (e.g. Eulophidae and Platygastridae). C. C. de Schawe and others. Abundance and diversity of cacao flower visitors. [*Agroforestry Systems* 92:117-125 2018] D

ORANGUTAN CONSERVATION ACTIONS IN BORNEO

Each year an estimated US $20-50 million is spent by government and non-government organizations in efforts to conserve the Bornean orangutan. However, recent population analysis reveals that these efforts have been unable to reduce species decline. A major aim of the Indonesian National Action Plan for orangutan conservation is to "improve in-situ conservation as the principal activity ensuring the orangutan's survival in its native habitats". This paper summarizes and examines current investment in conservation activities and provides recommendations on the strategic allocation of funds for future conservation. The cost data of major conservation activities, including orangutan rescue and rehabilitation, habitat protection, habitat restoration, and community education, was collected from non-government agency annual reports and primary literature. A recent population density and distribution model, and reports documenting the effectiveness of conservation strategies for the species were then used to calculate population trends in the presence and absence of interventions. Using an open-access cost-effectiveness resource allocator tool, we investigate expenditure and program performance. We then provide recommendations on how to strategically allocate conservation funding to future programs to ensure maximum effectiveness. C. L. Morgans and others. Orangutan conservation activities in Borneo. [*Biological Conservation* 238 108236 2019] D

TIGER POPULATION DENSITY AND DISTRIBUTION IN BHUTAN

Habitat loss, prey depletion, and direct poaching for the illegal wildlife trade are endangering large carnivores across the globe. Tigers (*Panthera tigris*) have lost 93% of their historical range and are experiencing rapid population declines. A dominant paradigm of current tiger conservation focuses on conservation of 6% of the presently occupied tiger habitat deemed to be tiger source sites. In Bhutan, little was known about tiger distribution or abundance during the

time of each classification, and no part of the country was included in the so-called 6% solution. Here we evaluate whether Bhutan is a potential tiger source site by rigorously estimating tiger density and spatial distribution across the country. We used large-scale remote camera trapping across n=1,129 sites in 2014-2015 to survey all potential tiger range in Bhutan. We estimated 90 individual tigers (60 females) and a mean density of 0.23 adult tiger per 100 Km2. Bhutan has significantly higher numbers of tigers than almost all identified source sites in the 6% solution. With low human density and large swaths of forest cover, the landscape of Bhutan and adjacent northeast India is a promising stronghold for tigers and should be prioritized in large-scale conservation efforts. T. Tempa and others. Distribution and population density of tigers in Bhutan. [*Biological Conservation* 238 108192 2019] D

QUANTIFYING ORNAMENTAL ORCHIDS IN SOUTH CHINA

Despite the grave threat illegal wildlife trade poses to species survival, few studies have attempted to link supply and demand data for the same wildlife product. All ca. 29,000 orchid species are linked by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and many are protected under domestic legislation too, but a growing body of evidence suggests that orchids continue to be subject to unsustainable harvesting and undocumented trade. South China is a known black spot trade in wild-collected ornamental orchids but understanding of the drivers determining the flow of species diversity, volume and value remains wanting. We conducted systematic monthly surveys at five markets along a West-East transect from Yunnan to Hong Kong for one year, recording variables including species, numbers of individuals, weight and price. Although wild orchid diversity is highest in Yunnan, the diversity of orchids in trade increased eastwards and mean price per stem rose more than four-fold albeit always significantly cheaper than for artificially processed hybrids. Part of this trade appears to be in breach of CITES. Few orchids in trade conformed to six criteria highlighted in prior demand-side studies as being of higher utility value, but most conformed to a combination of four or more, suggesting that vendors can readily offer products that meet a majority of consumer preferences. Effective supply-side regulation, through government intervention and social media campaigns, is needed to facilitate behavioural changes and allow artificially propagated plants to compete in the market-place. S.W. Gale and others. Quantifying the trade in wild-collected ornamental orchids in South China: Diversity, volume and gradients underscore the primacy of supply. [*Biological Conservation* 238 108204 2019] D

BIRD VULNERABILITY TO CLIMATE AND LAND USE CHANGES IN THE BRAZILIAN CERRADO

Estimating species vulnerability to global changes and understanding what drives their vulnerability has become an important task in the last decades. Here we evaluated the vulnerability of Cerrado bird species to climate and land-use changes projected to take place up to 2050, compared our vulnerability estimates to the national red list of threatened species, and evaluated the level of protection of vulnerable species. For 103 species we gathered information on biological traits and associated them in three components of vulnerability (sensitivity, adaptive capacity and exposure). For each trait we assigned high or low scores according to their relationship with climate and land-use changes. We considered as exposed, sensitive, and with low adaptive capacity those species that reached high score for any of the traits. Species that reached high score for all the three components were classified as highly vulnerable. We found that 67%, 71% and 39% of species were sensitive had low adaptive capacity or were exposed,

respectively, 25% of them were highly vulnerable. Among these species 10 are currently threatened in Brazil. Overall, the network of protected areas (PAs) harbors a small extent of highly-valuable species' range, with 19 species (73%) having <10% of range coverage within PAs. Understanding which species are the most vulnerable and where they are found is crucial to establish conservation priorities aiming to mitigate the negative impacts of environmental changes on species. J. A. Borges and others. Bird vulnerability to climate and land-use changes. [*Biological Conservation* 236 347-355 2019] D

INITIAL SPACING OF TEAK WITH COMPANION CROPS IN LAOS

Teak (*Tectona grandis*) has been planted extensively by smallholder farmers in Luang Prabang province of northern Laos, primarily in small woodlots established at high initial stocking rates with little/no management until the largest trees are harvested selectively, commencing at 15–20 years after planting. This study used a Nelder wheel experiment planted in 2008, and measured annually after the end of the first 10 growing seasons, to evaluate the effects of the initial planting density on the growth of teak. The potential for intercropping established teak was also evaluated using this Nelder wheel, when the trees were 5–6 years of age, to emulate what might be achievable from companion cropping under an agroforestry system with teak. Individual tree diameter was maximised at the lowest initial stocking, but tree height showed optimum development between 637 and 1020 trees ha^{-1}. While standing volume ($m^3\,ha^{-1}$) was maximised at the highest initial stocking (2424 trees ha^{-1}), merchantable volume maximised at initial stocking rates between 423 and 637 trees ha^{-1}. Companion cropping demonstrated that modest yields of maize, cassava and pigeon pea are possible under established teak, where the spacing between trees exceeds 8 m. Both maize and cassava achieved yields of over 2 $t\,ha^{-1}$ with a spacing of 8 m between trees, while pigeon pea achieved 3 $t\,ha^{-1}$ at 10 m spacing between trees. These results demonstrate that the adoption of reduced initial stocking rates for teak (i.e. below 1000 trees ha^{-1}) can significantly increase the growth rates of teak, improving individual tree volumes, and potentially reducing time to commercial harvest. Further, where row spacing is at least 8–10 m, these results suggest that extended periods of companion cropping (2–6 years after planting) may be possible. Finally, given that Lao farmers are reluctant to adopt pre-commercial thinning, serious consideration should be given to the promotion of simple, regimes for teak woodlots using an initial stocking rate of around 600 trees ha^{-1}. Alleys widths of 10 m are recommended for farmers wishing to establish grow teak in an agroforestry system and extend the period for companion cropping. Nevertheless, revision of Government of Lao policy frameworks are required to support the adoption of more appropriate initial spacing in teak woodlots and agroforestry systems by smallholders. A. Pachas and others. Initial spacing of planted teak in Laos. [*Forest Ecology and Management* 435 77-88 2019] D

RESPONSE OF IGAPO FOREST TO FLOOD PULSE REGULATION IN AMAZONIA

The monomodal flood pulse of major Amazonian rivers is a seasonal phenomenon that determines ecological and biogeochemical processes in adjacent floodplain forests. River damming transforms the pattern of downstream flood pulses and provides a natural disturbance to which the native biota might be poorly adapted. Severe modifications of the flood pulse were recorded in the Uatuma River after the installation of the Balbina dam, Central Amazonia. Flood pulse regulation increased mortality of flood-adapted species in the black water floodplain (igapo) forest. No previous studies have investigated impacts of flood pulse regulation on the species composition and forest structure of igapo forests. Therefore, we examined species

composition and forest structure of igapo forests along a regulated river in comparison to a pristine tributary, the Abacate River, evaluating soil texture characteristics and flood duration. In order to assess potential encroachment of species less sensitive to flood alteration, we also inventoried adjacent non-flooded upland forest in each river section. A quantitative inventory of all trees with diameter at breast height (DBH) ≥5 cm was carried out in low-igapo, high-agapo, and adjacent upland forest, totaling one half hectare in each river. In both rivers investigated, the clay fraction of the soil was significantly related to tree height. Flood duration was correlated to DBH and basal area, with the largest trees found in low-igapo forests which are exposed to long-term flooding. Species composition, richness, and diversity significantly responded to flood duration. Species richness was highest in upland forest and lowest in low-igapo forest. In the pristine river, the species composition exhibited a turnover of species along the flooding gradient. In the regulated river, flood intensification in the low-igapo forest increased dominance of a few flood-adapted species, which produced floristic dissimilarity to all forest types investigated. On the other hand, high-igapo forest showed higher floristic similarity to upland forest due to flood suppression that contributed to encroachment of species commonly described in secondary upland forests. Our results emphasize the urgent need for Brazilian environmental regulatory agencies to incorporate downstream impacts in the environmental assessments of dam projects in the Amazon Basin. G. de Sousa Lobo and others. Response of igapo forest to flood pulse regulation in the Amazon Basin. [*Forest Ecology and Management* 434 110-118 2019] D

ENDANGERED BAT MANAGED BY PROFESSIONAL FORESTERS

Integration of conservation efforts that benefit endangered species in forest lands of the US are highly dependent on decisions made by professional foresters. Federal guidelines generally do not require private landowners to search for endangered species before conducting forest management activities. Because private lands make up 85% of Indiana's forests, recommendations by professional foresters can influence a large proportion of the management decisions made on Indiana bat (*Myotis sodalis*) habitat in the state. Thus, we wanted to determine what factors lead professional foresters in Indiana to adopt management strategies that benefit bat conservation. We conducted an online survey of Indiana consultant and state foresters to address two main objectives: (1) to address forester understanding of guidelines for adequate bat habitat, and (2) to identify the factors that influence professional forester intention to manage forests to improve bat habitat quality. For a subset of survey respondents, we also determined whether forester intent to manage for Indiana bat habitat, translated to on-the-ground behavior via an assessment of their stands marked for single tree selection harvest. We found that most respondents knew some of the forest management guidelines for the Indiana bat, but few were familiar with all guidelines. Through structural equation modeling, we determined that intention to manage forests for the Indiana bat was influenced most by whether foresters believed following the guidelines would strongly influence the conservation of the species. We found a difference in the relative strength (path loading) of this factor between government and consultant foresters. We assessed the management decisions of a subsample of our survey respondents and found that respondent's decisions aligned with their intention to maintain or create Indiana bat habitat. We suggest two strategies can be employed to improve the habitat management occurring on private lands in Indiana: (1) increasing forester knowledge of federal guidelines and (2) providing evidence to foresters that the guidelines directly contribute to Indiana bat conservation. L. E. D'Acunto and others. Conservation management of the

endangered Indiana bat by professional foresters. [*Forest Ecology and Management* 434 172-180 2019] D

TROPICAL FORESTRY NOTES (46)

FOREST RESTORATION IN BRAZIL: SOIL PREPARATION ATTRACTS NATURAL REGENERATION

Forest regeneration in abandoned pastures in Amazonia has been well studied, but active restoration of non-resilient pastures has not. In this work, we evaluated large-scale active restoration of intensively used pastures in southern Amazonia, where the highest deforestation rates are observed. With the construction of the Jirau Dam in the Madeira River (state of Rondônia, Brazil), a 3000-ha forest buffer zone has been established. This area was previously covered by African pasture grasses for cattle ranching. Eight mixed-species planting sites with variable grass management and ranging from 6 to 60 months post-planting were measured three times over 2.5 years. We also tested a gradient of restoration intensity in an experimental planting: (i) no intervention (control), (ii) harrowing and herbicides to control grasses, and (iii) harrowing and herbicides plus tree planting. Our goals were to understand the initial trajectory of actively restored sites, the role of harrowing and herbicide application in triggering natural regeneration, and the role of seedling planting on the initial vegetation structure. All tree species ≥30 cm in height were sampled in five circular 10-m-radius plots per site. Plant cover was also monitored using the step-point method. At 18 months, stem density ranged from 2500 to 14,490 ind·ha^{-1}, demonstrating that density increased suddenly in most sites through colonization, although this was highly variable. Tree cover reached 81% in five years, virtually eliminating grass cover after 36 months. Recruits contributed more to basal area than planted seedlings. Although 17 species, on average, were planted in restoration sites, the number of species at the sites steadily increased over time, at a rate of 7 species·yr^{-1} per 1570 m^2. *Cecropia* spp. and *Trema micrantha* recruits had the highest stem densities and basal areas. Harrowing and grass control were enough to trigger succession in sites where natural regeneration was not taking place, shifting these sites to the highly resilient route of early secondary forest succession in the Amazon. Future restoration efforts should use a combination of methods, first evaluating the potential for natural regeneration and then gradually eliminating barriers. G. M. Rezende and D. L. Mascia Vieria. Forest soil preparation in the Amazon attracts nature generation. [*Forest Ecology and Management* 433 93-104 2019] D

FOREST OUTGROWER SCHEMES FOR SMALL AND MEDIUM-SIZED FARMERS IN BRAZIL

Outgrower schemes are an alternative for supplying companies and can generate benefits for both the farmers and for the community. The main reasons that lead companies to adapt /this type of strategy are the reduction of investment in land purchases, lower cost of wood at the factory, to increase the diversification of sources of raw materials, as well as greater integration with landowners close of companies. Of the total of 7.84 million hectares of trees planted in Brazil in 2016, 34% belonged to companies in the pulp and paper industry, 29% were independent operators and participants in outgrower schemes, and the charcoal-fired steel industry represented 14% of the planted area. In 2016, 19,900 people benefitted from the outgrower programs adapted by Brazilian Tree Industry (IBA) member companies, planting 545,000 ha. For rural producers, the forest development consists of an alternative to traditional income generation to their properties, which may use idle or underused areas with low technical risk due to production inputs and technical assistance provided by the companies. The most frequent outgrower modalities include providing forest species seedlings, revenue anticipation

programs and wood purchase guarantee at harvest time. For the community, these include the possibility of creating new wood-based forest business and generating jobs in the region. This program prevents land concentration, makes local activities feasible, creates opportunities of additional income and assists in setting people in the countryside. Also, greatly improves the acceptability of eucalypt plantations in the region and is positive for this certification of forest products. From the environmental standpoint, outgrower scheme mitigates the pressure on native forests, recovers degraded soils and promotes soil conservation. J. L. de Moraes Gonsalves and others. Forest out grower schemes in Brazil for small and medium-sized farmers. [*Forest Ecology and Management* 456 117654 2020] D

WOODY ACCUMULATION 27 YEARS AFTER SILVICULTURE IN BRAZILIAN CERRADO

The Brazilian Cerrado is the second largest biome in Brazil, and its natural landscapes have undergone transformations, due in large part to anthropic activities. However, little is known about the effects of these activities on the natural regeneration of Cerrado vegetation. Thus, the objective of this study was to evaluate the accumulation of woody biomass in an area of Cerrado sensu stricto that was monitored for 27 years after the implementation of six silvicultural systems. A period of 17 years was sufficient for the woody community of the Cerrado sensu strict to naturally recover its original stock of aerial biomass after the application of silvicultural systems. A few woody species contribute to the total aerial biomass accumulated over time, and such contribution is variable with time and with the type of silvicultural system. At 27 years after cutting, the largest fraction of biomass accumulated in the area were represented by the species *Miconia leucocarpa*, *Blepharocalyx salicifolius*, *Schefflera macrocarpa*, *Qualea grandiflora*, *Dalbergia miscolobium*, *Eriotheca pubescens*, *Qualea parviflora*, and *Caryocar brasiliense*, which also demonstrated higher fire resistance. A period of 17 years after the implementation of silvicultural systems is considered sufficient for an area to recover naturally to the original stock of woody biomass at the community level. This result causes a greater reduction in the biomass of fire-sensitive species and transforms a cerrado from carbon sink into a source of C02 emissions to the atmosphere. G. B. de Acevedo and others. Woody biomass accumulation 27 years after silvicultural systems implemented. [*Forest Ecology and Management* 455 117718 2020] D

EFFECT OF *EUCALYPTUS* ROTATION LENGTH ON SOIL ENZYMES AND SOIL QUALITY

Eucalyptus is widely cultivated in southern China as a short-rotation fast-growing species for timber production. However, this kind of business model has aroused widespread concern on soil quality. This study aimed to determine the cutting period of *Eucalyptus* plantation by comparing the effects of different cultivation years on soil quality. Four *Eucalyptus* stands, including 2-, 6-, 10-, and 15-year-old (abbreviated as 2 yr, 6 yr, 10 yr, and 15 yr, respectively) were used, and 25 soil physicochemical and biological indicators were determined. Results showed that the soil texture of the 10 yr and 15 yr plantations significantly improved. Soil organic matter, macronutrients, enzyme activity, and microbial biomass decreased significantly at 6 yr and then increased at 10 yr. However, the contents of available nutrients and the activities of urease and catalase decreased again at 15 yr. Redundancy analysis showed that the contents of total phosphorus, available phosphorus, available potassium, available zinc, and available calcium considerably influenced the soil bacterial community, whereas the contents of total nitrogen and

available nitrogen greatly affected the fungal community. Meanwhile, pH and soil texture exerted a significant impact on microbial community structure. Bacterial diversity showed an increasing trend with the rotation period, whereas the fungal diversity ranked by 2 yr > 6 yr < 10 yr > 15 yr. The relative abundances of soil major microbial taxa were closely related to the soil physicochemical properties and were roughly similar to ecological strategy. These results suggest that cultivation period significantly affected the soil quality. Thus, we propose to extend the rotation period of *Eucalyptus* plantation to 10 yr. Extending the cultivation period to 10 yr significantly improved soil quality, but the available nutrients and enzyme activity of the 15 yr plantation showed a decreasing trend. Microbial community structure may be a sensitive indicator of soil quality in *Eucalyptus* plantations. Y. Xu and others. Effects of different rotation periods of Eucalyptus plantations on soil physiochemical properties, enzyme activities, microbial biomass and microbial community structure and diversity. [*Forest Ecology and Management* 456 117683 2020] D

GENERAL ESTIMATION MODELS FOR ABOVE- AND BELOW-GROUND BIOMASS OF TEAK PLANTATIONS IN THAILAND

To estimate above- and below-ground biomass in teak (*Tectona grandis*) plantations throughout Thailand, we developed general allometric relationships between tree size parameters (stem diameter and height) and tree biomass (of leaves, stems, and roots). Trees were harvested from 18 plantations within the native range of teak in Thailand and across the area covered by these plantations. Allometric equations for total above- and below-ground biomass showed no significant inter-site differences and high correlation coefficients (0.90-0.99). This similarity across sites may be due to similarities in wood density among different age and size of teak trees. The majority of previous biomass estimation models for teak trees gave higher estimated values for both above- and below-ground biomass, suggesting that they should not be applied within Thailand. To estimate belowground biomass using root: shoot ratio (RSR) we evaluated RSR among stands of various ages and sizes. We further identified differences in RSR between Thailand and other regions. Estimated RSR varied among stands and decreased significantly with stand age and average tree size. This relationship suggests that below-ground biomass can be estimated from aboveground biomass using RSR. However, RSR values differed among countries and regions. In summary, general allometric equations and RSR value can be used to accurately estimate above- and below- ground biomass in teak plantations across Thailand. T. Kenzo and others. General estimation models for above- and below-ground biomass of teak (*Tectona grandis*) plantations in Thailand. [*Forest Ecology and Management* 457 117701 2020] D

EFFECTS OF SILVICULTURAL TREATMENTS AND TOPOGRAPHY ON INDIVIDUAL TREE GROWTH IN A TROPICAL MOUNTAIN FOREST IN ECUADOR

Few studies have analysed the effect of silvicultural treatments on tree growth in tropical montane forests (TMF). These forests have strong topographic gradients, which influence growth rates and can potentially interact with silvicultural treatments. The present study investigated the relative effects of silvicultural treatments and topography on growth rates at the tree level in a TMF. For this, we combined two distinct data sources: (1) field data from a silvicultural experiment in the Andes of southern Ecuador where liberation thinnings, i.e. the removal of the strongest crown competitors, were applied to potential crop trees (PCT) in 2004; and (2) topographic variables obtained from a high-resolution digital terrain model created from an

airborne LIDAR survey. We fitted all data in a single linear mixed-effect model. Based on monitoring data from 174 released and 200 reference PCTs of 8 timber species, we calculated periodic annual increment (PAI) in DBH 6 years after the silvicultural treatment as our outcome variable. As topographic predictors, we used elevation and a topographic position index. To control for the by-species growth variability we included random intercepts for species and random slopes for the effect of treatment on species in our model. PAI was significantly influenced by the topographic predictors. Over the elevational gradient, growth rates declined on average by 0.73 mm a^{-1} per 100 m increase in elevation. For the topographic position, PCTs in valleys had an average PAI of 2.02 mm a^{-1} compared to 1.04 mm a^{-1} on ridges. The effect of the silvicultural treatment across all species was only marginally significant, but its effect size was nevertheless within the range, but at the lower end of values reported for other tropical forest ecosystems (reference trees: 1.35 mm a^{-1}; released trees: 1.60 mm a^{-1}). Between species, baseline growth rates as well as the treatment effect varied considerably. Best linear unbiased predictions of species effects suggested that 5 species responded positively to the silvicultural treatment, whereas 3 species showed no treatment effect. Overall, tree growth varied substantially as indicated by the large residual variance that remained unaccounted for in the model. Our findings indicate that positive effects of silvicultural treatments in TMF are likely to exist, but that they are possibly obfuscated by strong topographical gradients and large between-tree growth variability. Overall, our results suggest that "broad-brush" management prescriptions are not suited for sustainable forest management of TMF. Instead, granular and spatially explicit prescriptions that take the strong impact of topography on diameter growth as well as species-specific responses to silvicultural treatments into account should be favoured. D. Kübler and others. Effects of silvicultural treatments and topography on individual tree growth in a tropical mountain forest in Ecuador. [*Forest Ecology and Management* 457 117726 2020] D

LINKING VEGETATION AND SOIL FUNCTIONS DURING SECONDARY FOREST SUCCESSION IN THE ATLANTIC FOREST

Secondary forest succession can be an effective and low- cost strategy to increase forest cover and the associated biodiversity and soil functions. However, little is known about how soil functions develop during succession, and how vegetation attributes influence soil functions, especially in highly biodiverse and fragmented landscapes in the tropics. Here we assessed a wide range of indicators of taxonomic (e.g. number of tree species), structural (e.g. basal area, canopy openness) and functional diversity (e.g. community weighted means of fundamental traits) of tree species, as well as indicators for soil functions related to soil organic matter accumulation, nutrient cycling and soil cover in secondary forest patches ranging from 5 to 80 years. Two recently abandoned agricultural fields were included as the starting point of forest succession and two primary forest patches served as references for the end point of forest succession. Four ecological hypotheses, centred around the role of functional diversity, structural diversity and biomass, were tested to explore mechanisms in which forest vegetation may influence soil functions. Most measures of structural, taxonomic and functional diversity converged to values found in primary forests after 25-50 years of succession, whereas functional composition changed from acquisitive to conservative species. Soil carbon and nutrient cycling showed a quick recovery to the levels of primary forests after 15 years of succession. Although soil cover also increased during succession, levels of primary forest were not reached within 80 years. Variation in tree height and trait dominance were identified as aboveground drivers of carbon and nutrient cycling, while aboveground biomass was the main driver of litter

accumulation, and the associated soil cover and water retention. Our results indicate that secondary forest succession can lead to a relative fast recovery of nutrient and carbon cycling functions, but not of soil cover. Our findings highlight the essential role of secondary forests in providing multiple ecosystem services. These results can be used to inform management and reforestation programmes targeted at strengthening soil functions, such as soil cover, nutrient and carbon cycling. H. M. Teixeira and others. Linking vegetation and soil functions during secondary forest succession in the Atlantic forest. [*Forest Ecology and Management* 457 117696 2020] D

SILVICULTURAL TREATMENT EFFECTS ON COMMERCIAL TIMBER VOLUME AND FUNCTIONAL COMPOSITION OF A SELECTIVELY LOGGED AUSTRALIAN TROPICAL FOREST OVER 48 YEARS

Post-logging silvicultural treatments involving thinning are commonly recommended to increase the commercial timber production under polycyclic harvesting regimes in tropical forests. However, thinning practices intentionally designed to improve commercial timber production may alter species composition and functional composition. Low, medium, and high intensity thinning following logging plus a logged only control was applied in an Australian tropical forest in 1969 to assess the long-term liberation thinning impacts on the commercial timber volume and the functional composition of the regenerating forest. Over 46 years following thinning, only medium- and high-intensity thinning promoted recruitment of commercial trees into the >10 cm diameter class. All three thinning treatments enhanced the standing volume of most desirable commercial species, mainly driven by the growth of remaining non-harvested trees in the 10–20 cm diameter class. The merchantable timber volume of other less desirable species was also promoted in the four treatments. Over the first 28 years after treatment (1969–1997), the average annual timber volume accumulation rate was highest in the medium-intensity thinning $(1.97 \text{ m}^3 \text{ ha}^{-1} \text{ year}^{-1})$. The positive impacts of medium- and high-intensity thinning on commercial timber volume growth lasted longer than the low-intensity thinning. From 1997 to 2015, average annual volume increments increased in the medium- and high-intensity thinning, changed little in the low-intensity thinning, and decreased in the untreated control. Moreover, the medium- and high-intensity thinning led the community functional composition to shift towards early-successional species, which reduced community-weighted mean wood densities. The changes induced by intensive thinning treatments may affect the recovery of forest biomass and biodiversity. Hence, the trade-off between enhancing timber stocks and maintaining functional composition should be considered during planning and implementation of tropical forest management. J. Hu and others. Silvicultural treatment effects on commercial timber volume and functional composition of a selectively logged Australian tropical forest over 48 years. [*Forest Ecology and Management* 457 117690 2020] D

WILDFIRE EFFECTS ON FOREST STRUCTURE OF *PINUS MERKUSII* IN SUMATRA, INDONESIA

Pinus merkusii (Jungh & de Vriese), the only pine species native to Indonesia, is threatened by land-use change, resource extraction, and fire. *P. merkusii* forests in Sumatra are subject to mixed-severity wildfires that can change forest structure over time. This project is only the second study to quantify differences between burned and unburned *P. merkusii* forests in Sumatra. We measured six burned-unburned paired sites for forest characteristics, regeneration, forest floor, and woody debris, and effects of resin tapping. Fires killed more than 60% of *P.*

merkusii trees and reduced tree biomass and carbon by about 40%. Fire killed trees of all sizes up to 60 cm in diameter at breast height (DBH), but preferentially killed small trees with DBH less than 10 cm. Seedling regeneration of *P. merkusii* in the burned forest was higher on average than in the unburned forest. But the difference was not statistically significantly different and *P. merkusi*i regeneration was low overall. Unlike continental Asian *P. merkusii* forests, the insular populations did not have a seedling grass stage of evidence of fire stimulated germination. Forest floor and woody debris values were relatively low by the standards of global pine forests, but comparable data do not exist for Indonesia. Recent tapping of trees for *P. merkusii* resin affected most trees over 20 cm DBH and was associated with high mortality in fires, suggesting that the interaction between resin tapping and fire could be lethal. Further research is needed to evaluate longer-term forest dynamics, especially for regeneration and the effects of resin tapping. D. Hartiningtias and others. Wildfire effects on forest structure of *Pinus merkusii* in Sumatra, Indonesia. [*Forest Ecology and Management* 457 117660 2020] D

TROPICAL FORESTRY NOTES (47)

AGROFORESTRY EDUCATION FOR HIGH SCHOOL AGRICULTURAL SCIENCE: AN EVALUATION OF NOVEL CONTENT ADOPTION FOLLOWING EDUCATOR PROFESSIONAL DEVELOPMENT PROGRAMS

High school agricultural science programs are recognized as meaningful areas to reach young agriculture professionals as they gain a foundational understanding of their field. Agroforestry content is largely lacking in High School agriculture science classrooms, despite its relevance to modern advancements in management in agricultural sustainability for economic, environmental, and social resilience. Due to the contextual nature of content adoption by agricultural educators, the curriculum This implementation process for novel content is dependent on an understanding of teacher learning, teacher self-efficacy, professional development, and curriculum modification. This professional development for and content adoption among participating Missouri high school agricultural educators provides insight into the potential for the integration of agroforestry content in high school agriculture programs using a mixed method approach. While substantial growth in expected classroom hours dedicated to agroforestry resulted from these professional development events. Identified complexities of the teacher and student learning context necessitate alternative approaches to engage teachers and students in previously unfamiliar agroforestry content. The importance of teacher- learning, support networks, and experimental learning in curriculum and professional development emerged as major themes for effective agroforestry content implementation. H. Hennelgam and others. Agroforestry education for high school agriculture science: an evaluation of novel content adoption following educator professional development programs. [*Agroforestry Systems* 93 1659-1671 2019] D

BIRD SPECIES RICHNESS IN PLANTATIONS AND NATURAL FORESTS IN A NORTH AFRICAN AGROFORESTRY SYSTEM

Watershed tree plantations in Morocco are expanding under the National Watershed Management Plan and thus their value for native fauna and agroforestry system dynamics requires investigation. Using generalized linear mixed models, we assessed the relative value of artificial habitats- olive and eucalypt plantations-over four seasonal periods, by comparing their avifauna richness to those of natural habitats- Thuya forests. Bird species richness depended on both habitat type and season. Our results showed that natural Thuya forests supported higher bird diversity than both olive and eucalypt plantations. Moreover bird diversity was higher in eucalyptus plantations compared to olive plantations during the winter period, while the opposite trend was observed in autumn. A principal component analysis also revealed a significant positive effect of shrub layer complexity (PC1) in all seasons, habitat artificiality (PC3) in spring, breeding season, and autumn, and tree size (PC2) during winter and autumn. Overall, our findings stress that, in our study area, artificial plantations do not have the same ecological value as the original habitat. We therefore advise restoring native forest rather than reforesting eucalypt species. Research programs should continue in order to assess the impact of conservation actions on biodiversity and determine how this agroforestry system would change under the increasingly detrimental effects of drought. S. Hanane and others. Bird species richness in artificial plantations and natural forests in a North African agroforestry system: assessment and implications. [*Agroforestry System* 93 1755-1764 2019] D

REDUCING SOIL COMPACTION AFTER THINNING WORK IN AGROFORESTRY PLANTATIONS

Afforestation of marginal farmland with fast-growing tree species is a cost-effective way to produce wood fiber for industrial and energy use. The final harvest is often performed with terrain chipping, in order to achieve high productivity and minimum cost supply. Several machine manufactures have developed new chipper models, specifically designed for this practice in agroforestry plantations. Soil impacts, particularly soil compaction, represent a concern in such practice. This study evaluated impact of terrain chipping work on soil compaction in agroforestry plantations. This study tested two different options for the chipper and namely: a new all-road chipper specifically designed for agroforestry plantations (evaluated under two tire-pressure configurations) and capable of both cross-country and road traffic, and a high-mobility chipper truck. In contrast, one option was tested for the chip shuttle, which consisted in a farm tractor equipped with a two-axle trailer. The four treatments were tested on three different sites, representing the most common soil conditions encountered in the new agroforestry plantations. Soil texture ranged from loam to sandy loam. The occurrence of soil compaction in the upper 30 cm. of the soil was evaluated with two different methods: bulk density determination and penetration resistance sampling. Measurements were conducted in the machine tracks after a single pass. The two methods seemed to give contradictory results, especially in two of the three test sites. In general bulk density seemed more sensitive to changes than penetration resistance after a single passage. Bulk density measurements showed that the all-road chipper at low tire pressure and the chipper truck caused soil compaction at almost all sites. In contrast, the all-road chipper at standard tire pressure and the chip shuttle were much gentler in the soil. The limited increments found in this study are likely dependent on a relatively high soil density before traffic. The higher impact of the all-road chipper after reducing tire pressure is contrary to expectations, probably due to the use of relatively stiff tires that may deny the benefits of deflation. This study indicates that well organized terrain chipping may not cause such high soil compaction levels as to jeopardize tree root development and growth, despite the heavy weight of the equipment used for this task. In that regard, the especially designed all-road chipper performs better than the chipper truck. R. Spinelli and others. Reducing soil compaction after thinning work in agroforestry plantations. [*Agroforestry Systems* 93:1765-1779 2019] D

VERY FREQUENT BURNING ENCOURAGES TREE GROWTH IN SUB-TROPICAL AUSTRALIAN EUCALYPT FOREST

Frequent fire often has a negative impact of tree recruitment and growth. Tree growth rates, density and recruitment were compared among treatments of annual burning since 1952, triennial burning since 1973 and no burning (1946-1996) or single wildfire (1996-2018), in a dry sclerophyll eucalyptus forest, southeastern Queensland, Australia. Tree diameter (at breast height, DBH) growth rates were greater in the annually burnt treatment than in the triennially burn and single wildfire treatments over the period from 1974 to 2018, and these differences were also apparent pre-wildfire (period from 1974 to 1996). In the period from 1996 to 2018, the annually burnt treatment had greater DBH growth relative to the single wildfire treatment, but the triennial treatment had intermediate growth rates. Competitive interactions between trees (assessed using plot basal area) also had a negative impact on individual tree growth rates. The impacts of different fire regimes at this site on tree crown health were not apparent (P>0.05) and there was only limited evidence that differences in growth rates were due to differences in soil nutrients (marginally higher topsoil phosphorus in the frequently burnt treatments, (p=0.075).

Greater tree growth rates in the annually burnt treatment may be related to the lower density of understory woody plants in this treatment and potentially reduced competition for soil moisture. The density of trees (DBH>10 cm) in 2018 was surprisingly higher in the triennially burnt treatment (381 stems/ ha) relative to both the annually burnt (192 stems/ha) and single wildfire (234 stems/ha) treatments. This was largely due a higher level of recruitment over time and a higher density of stems 10-20 cm DBH in triennially burned plots. Concerns regarding the impacts of frequent prescribed fire on tree recruitment and growth may be unwarranted in these remarkably resilient dry eucalypt forests. T. Lewis. Very frequent burning encourages tree growth in sub-tropical Australian eucalypt forest. [*Forest Ecology and Management* 459 117842 2020] D

FIRE SEVERITY IMPACTS ON TREE MORTALITY AND POST-FIRE RECRUITMENT IN TALL EUCALYPT FORESTS OF SOUTHWEST AUSTRALIA

Wildfires are predicted to increase in both frequency and severity across Mediterranean climate regions worldwide. While many Mediterranean-type ecosystems are considered broadly as fire-tolerant, there is little understanding of how differences in fire severity affect plant community dynamics, tree mortality and recruitment. In the tall karri (*Eucalyptus diversicolor* F. Muell) forests of southwest Australia, low to moderate severity wild and prescribed fires are relatively common. Mature karri trees survive these events and recover rapidly due to their thick bark and ability to prolifically resprout from epicormic buds. However, despite a projected increase in the frequency of high severity wildfires, the impact of such extreme fires on tree mortality, and understory community composition is not well understood. We used a large and severe wildfire event in southwest Australia to assess how fire severity impacted recruitment and survival of karri seedlings, the mortality of mature karri trees, and the composition of the understory plant community. Mature karri mortality was 87% greater at sites burnt at high severity compared to unburnt sites and sites burned at low severity. Understory plant community composition of burnt sites was different to unburnt sites, driven largely by significant shifts in dominance. Notably, the usually dominant understory shrub *Trymalium odoratissimum* was entirely absent from forests burnt at extreme high severity. These results indicate that karri forests burnt at very high severity undergo changes in stand structure that will persist for many decades, and that the structure and species composition of the understory may also be altered significantly. This indication of a possible fire severity threshold is consistent with findings of recent studies in other Mediterranean climates following catastrophic wildfires. This study highlights the need for further research into the effects of severe wildfire on forest ecosystems that are otherwise considered fire tolerant. H. Etchells and others. Fire severity impacts on tree mortality and post-fire recruitment in tall eucalypt forests of southwest Australia. [*Forest Ecology and Management* 459 117850 2020] D

RESPONSES OF TERRESTRIAL ANIMALS TO FOREST CHARACTERISTICS AND CLIMATE REVEAL ECOLOGICAL IINDICATORS FOR SUSTAINING WILDLIFE IN MANAGED FOREST

Assessing the impacts of forest harvest on biodiversity is a key mandate for demonstrating sustainable forest management in many jurisdictions, yet the identification of an appropriate suite of wildlife and habitat indicators remains a challenge. We used individual species-based modelling and a spatially extensive dataset of forest-dependent bird, amphibian, and mammal species to measure the strength of response and prominent patterns among taxa to variation in

forest habitat conditions, ranging from understory site characteristics to landscape level patterns. Our findings revealed that understory habitat was a significant contributor to species relative abundance. Stand level features and climate were generally more important than disturbance or landscape patterns in affecting wildlife response. There was much variability among species in the specific habitat conditions and scales of importance, consistent with the inherent complexity and diversity of forest ecosystems. Our work highlights at setting targets and monitoring for a diverse range of wildlife and habitat indicators at multiple scales, including understory features, may be needed to adequately assess biodiversity response to sustainable forest management activities. G. S. Brown and others. Responses of terrestrial animals to forest characteristics and climate reveals ecological indicators for sustaining wildlife in managed forests. [*Forest Ecology and Managemen*t 459 117854 2020] D

BLOCKED-OFF: TERMINARIA CAUSE THE OVERESTIMATION OF TREE HOLLOW AVAILABILITY BY GROUND-BASED SURVEYS IN NORTHERN AUSTRALIA

Hollows in standing trees are an important ecological resource for many Australian vertebrates, including a range of threatened mammals, reptiles and birds. However, the ecology of tree hollows, and the extent to which they support hollow-dependent fauna, has been severely under-studied in northern Australia. This study evaluated the reliability of ground-based surveys of tree hollows in northern Australian eucalypt savanna. We counted hollows in trees using two approaches: (1) ground-based surveys and (2) climbing surveys, i. e. double sampling. Assuming the climbing surveys are accurate, ground-based surveys tended to overestimate hollow density (per tree) by around 15%. However, of the hollows counted in the climbing surveys (n = 202), 44.5% were blocked by hard termitaria. Once unavailable (blocked) hollows were accounted for, ground-based surveys tended to overestimate available hollow density (per tree) by 59%. According to generalized linear mixed models (GLMMs), a hollow was more likely to be blocked if it had a smaller entrance diameter, occurred on a tree with a termite mound at its base and smaller DBH. We calibrated site-level ground-based counts using GLMMs of climbing counts and available climbing counts as a function of ground-based counts for double-sampled trees. Overall, our uncalibrated counts resulted in over-reporting of mean site-based density of available hollows by 38%. The discrepancy between densities of total hollows and available hollows has important implications for the conservation of many threatened and declining species known to rely on tree hollows in northern Australia. We suggest that when conducting ground-based hollow surveys to assess tree hollow availability in northern Australia, a subsample of trees should be double-sampled, i.e. both ground-based and climbing counts, to account for survey error due to the blocking of hollows by termitaria. C. E. Penton and others. Blocked-off: Termitaria cause the overestimation of tree hollow availability by ground-based surveys in northern Australia. [*Forest Ecology and Management* 458 117707 2020] D

STRUCTURE, COMPOSITION, AND REGENERATION OF MIOMBO WOODLANDS WITHIN HARVESTED AND UNHARVESTED FORESTS

Production of tobacco by small holder farmers in Zimbabwe after the year 2000 land reform programme impacted woodlands due to the widespread use of fuel wood instead of coal for tobacco curing, but impacts have been rarely quantified. We assessed the effect of fuel wood harvesting for tobacco curing on structure, composition, and diversity in harvested and unharvested miombo woodlands in the central watershed of Zimbabwe. Tree size class

distributions provide demographic information on regeneration and recovery from disturbances. Vegetation structure and plant species composition were assessed in thirty 20x20 m plots in each site. Tree basal area, canopy cover and height were significantly higher in the less disturbed unharvested compared with the harvested site. Species composition differed between harvested and unharvested sites, with higher diversity in the harvested compared with unharvested site. Trees had reverse-J-shaped size class distribution curves for both stem diameter and height at the harvested site and bimodal distributions with fairly large densities in larger size classes at the unharvested site. Recruitment and regeneration were higher in the harvested than unharvested site. Our finding show that harvesting fuel wood for tobacco curing has negative effects on tree structure, but not yet the diversity of the miombo woodland, however the latter will likely negatively impact tree species favored for harvesting over the medium-long term. When species composition was compared using NMDS ordination, the harvested and unharvested plots were distinctly separated. Because of the rotational time for miombo woodlands of >25 years, continuous harvesting of the woodland may permanently keep the trees small, failing to provide sufficient wood for tobacco curing. Therefore, there is need for the consideration of alternative or supplementary sources of energy such as solar, with zero deforestation in the production chain of tobacco in the whole miombo eco-region. J. Muvengwi and others. Structure, composition and regeneration of miombo woodlands within harvested and unharvested areas. [*Forest Ecology and Management* 458 117792 2020] D

DYNAMIC STRUCTURAL STAND DENSITY MANAGEMENT DIAGRAMS FOR EVEN-AGED NATURAL STANDS AND PLANTATIONS

A forest stand model that is able to account for individual stand characteristics and uses this information for state prediction, growth and yield projection and for management decisions at individual-stand level can be expected to possess the best properties and be of the highest utility. The aim of our study was to combine the advantages of graphically presented whole-stand models called Stand Density Management Diagrams (SDMDs) with those of the state-space models to developed, stand-specific density management model and to examine its performance with data from even-aged natural stands and plantations. A dynamic, structural Stand Density Management Diagram (DSSDMD) consisting of a whole-stand model and distribution sub-models was developed. The whole-stand model is composed of a state vector and transition functions and is presented diagrammatically by four sets of isolines on a density-total volume/biomass chart. The state alternatives, according to specified objective, can be optimized for any particular stand, using its DSSDMD, and the model can be incorporated into a simulator to ensure its most efficient usage. T. V. Stankova and others. Dynamic Structural Stand Density Management Diagrams for even-aged natural stands and plantations. [*Forest Ecology and Management* 458 117733 2020] D

BUTTERFLY DIVERSITY IN AGROFORESTRY PLANTATIONS OF EASTERN GHATS OF SOUTHERN ODISHA, INDIA

Agroforestry plays an important role in food security, sustainable development, and biodiversity conservation. For understanding the role of agroforestry on biodiversity, a study was undertaken to assess butterfly diversity in coffee, cashew, and guava plantations in Eastern Ghats of southern Odisha, during February-April, 2916. A total of 1075 individuals of butterflies belonging to 60 species and 46 genera under five families were recorded during the study. Species richness (S) as well as Shannon diversity (H) were found to be higher in coffee (S= 45, H=3.051) plantation,

followed by cashew (S=31, H=2.8) and guava (S=20, H=2.519). However, though butterfly abundance was found to be maximum in coffee (43%), it was higher in guava (33%) followed by cashew (24). Also, a significant difference was observed between butterfly abundance among three plantations. This shows coffee plantation was the best habitat for butterflies among the three agroforestry habitats studied. The reason for this was habitat heterogeneity in coffee plantation supporting maximum exclusive butterfly species and was least-human influenced with close canopy forest. Over all, family Nymphalidae was found to be the most abundant and Lycaenidae was the least abundant. The findings of the present study are promising and may set new directions for management of agroforestry plantations in the region to support a rich biodiversity. A. Mahata and others. Butterfly diversity in agroforestry plantations of Eastern Ghats of southern Odisha, India. [*Agroforestry Systems* 93:1423 -1438 2020] D

TROPICAL FORESTRY NOTES (48)

CALL FOR A COLLABORATIVE MANAGEMENT AT MATANG MANGROVE FOREST RESERVE, MALAYSIA: AN ASSESSMENT FROM LOCAL STAKEHOLDERS VIEWPOINT

Effective management of a socio-ecological system (SES) requires a good understanding of (ecosystem functionality (2) interactions between social and ecological units, and (3) stakeholder perceptions and activities. Matang Mangrove Forest Reserve (MMFR) covering 40,200 ha in Peninsular Malaysia is under silvicultural management (with a 30-year forest rotation cycle) for charcoal and timber production since 1902. The aim of this study is to assess the perceptions of (select) local stakeholders on the ongoing mangrove management of MMFR. Earlier, Huge et al. (2016), using Q methodology, identified three main shared perceptions, called discourses: (1) Optimization- 'keep up the good work, but keep improving', (2) Change for the better- 'ecotourism & participatory management for sustainability', and (3) Continuity – 'business as usual is the way to go'. The current study is a follow-up on Huge et al (2016) and reports on a survey which assessed the degree of support of the local stakeholders towards those three management discourses. The core statements of each discourse were presented as questions and then ranked by the participants. Based on the findings of the survey, the local stakeholders were clustered into three main working categories: (1) charcoal and timber workers, (2) fishermen and (3) service providers. The interviews held with 114 stakeholders indicated that discourse (2) 'change for the better' is the most popular (supported by 72% of the participants) regardless of the stakeholders' working category. This discourse voices the involvement of local people in decision making, adopts participatory management, and encourages diverse mangrove-based economic activities beyond mere charcoal and timber production. Single-use management (focusing only on maximizing charcoal and timber yields) was perceived as not equitable benefiting all local stakeholders. The insight of this study can guide the managers of Matang Mangrove Forest Reserve to improve the sustainability and the local support base for the existing mangrove management regime, e.g. by promoting diverse livelihood options for the local stakeholders. C. Martínez-Espinosa and others. Call for a collaborative management at Matang Mangrove Forest Reserve, Malaysia: An assessment from local stakeholders' view point. [*Forest Ecology and Management* 458 117741 2020] D

LAND USE AND COVER EFFECTS ON AN ECOSYSTEM ENGINEER

Human induced land-use change in the form of urbanization and agriculture are rapidly transforming our planet's terrestrial landscapes and causing the loss of species at unprecedented rates. Studies documenting the impacts of development are extensive; however, less is known about the scale at which species respond to development and specific features of altered landscapes that make them vulnerable. This shortcoming may be due to the difficulty of collecting data across large spatial extents, but filling these information gaps are critical, particularly for species that have a disproportionate influence on ecosystems, such as ecosystem engineers. One such species, the southeastern pocket gopher (*Geomys pinentis*) has been declining throughout its range (southeastern United States) and continued loss will likely have strong effects on the imperiled longleaf pine ecosystem in which it is closely associated. Using range-wide data from presence-absence surveys and publicly available presence-only data, we used recent advances in species distribution modeling to understand this ecosystem engineer's association with extensive land use and cover changes. Our study showed that pocket gophers

inhabit a variety of land-use types, including regions with low levels of anthropogenic development, but are largely absent from intensely urbanized areas and closed-canopy forests. Conservation planning to reduce the spread of extensive development and forest management strategies to reduce closed-canopy systems will be instrumental in reducing the decline of the species and ultimately protection of the longleaf pine ecosystem. The approach used in this study will be increasingly beneficial for understanding species response to land-use change. S. I. Duncan and others. Land use and cover effects on an ecosystem engineer. [*Forest Ecology and Management* 456 117642 2020] D

TERRESTRAIL LASER SCANNING FOR NON-DESTRUCTIVE ESTIMATES OF LIANA STEM BIOMASS

Lianas are important and yet understudied components of tropical forests. Recent studies have shown that lianas are increasing in abundance and biomass in neotropical forests. However, aboveground biomass estimates of lianas are highly uncertain when calculated from allometric relations. This is mainly because of the limited sample size, especially for large lianas, used to construct the allometric models. Furthermore, the allometry of lianas can be weakly constrained mechanically throughout its development from sapling to mature form. In this study, we propose to extract liana stem biomass from terrestrial laser scanning (TLS) data of tropical forests. We show good agreement with a concordance correlation coefficient (CCC) of 0.94 between the TLS-derived volume to reference volume from eleven synthetic lianas. We also compare the TLS-derived biomass for ten real lianas in Nouragues, French Guiana, with the biomass derived from all existing allometric equations for lianas. Our results show relatively low CCC values for all the allometric models with the most commonly used pantropical model overestimating the total biomass by up to 133% compared to the TLS-derived biomass. Our study not only facilitates the testing of allometric equations but also enables non-destructive estimation of liana stem biomass. Since lianas are disturbance-adapted plants, liana abundance is likely to increase with increased forest disturbance. Our method will facilitate the long-term monitoring of liana biomass change in regenerating forests after disturbance, which is critical for developing effective forest management strategies. S. M. K. Moorthy and others. Terrestrial laser scanning for non-destructive estimates of liana stem biomass. [*Forest Ecology and Management* 456 117751 2020] D

GROWTH, MORTALITY AND RECRUITMENT OF TREE IN AN AMAZONIAN RAINFOREST OVER 13 YEARS OF REDUCED IMPACT LOGGING.

Forest harvesting causes disturbances in the forest, affecting the dynamics of tree species. In this study, growth, mortality, and recruitment of trees ≥45 cm DBH were assessed in different forests logged along 13 years (2002–2015) in the Eastern Amazon. The data were collected in a control unlogged forest and in four 100-ha working units divided into 20 plots of 5 ha (total of 100 plots in 500 ha sampled) and inventoried at 100% one year before harvesting and again in 2015. A total of 49 species were analyzed in the study. The highest mortality rate occurred in the first five years after harvesting (5.6%), with a reduction from the seventh year (3.2% year^{-1}), a period in which recruitment rate significantly increased for species from all ecological groups. Harvesting reduced both the number of individuals and species in the first five years after logging. Logged areas presented the highest growth rates five and seven years and only stabilized eleven years after logging. Within the range of 3–40 $\text{m}^3\,\text{ha}^{-1}$ of logging intensity no differences were observed

in growth rates of remaining trees ≥45 cm DBH. Pioneer, light-demanding, and shade-tolerant species presented higher growth rates in the first five years after logging. From seven years after harvesting, light-demanding presented a higher growth when compared to the shade-tolerant species. Larger diameter classes presented the highest relative growth rates (RGR). All diameter classes increased RGR up to 11 years after logging. L. F. S. Dionisio and others. Growth, mortality, and recruitment of tree species in an Amazonian rainforest over 13 years of reduced impact logging. [*Forest Ecology and Management* 430 150-156 2018] D

TO PRUNE OR NOT TO PRUNE: PRUNING INDUCED DECAY IN TROPICAL SANDALWOOD

Heartwood rot (a fungal disease) has the potential to significantly reduce the Sandalwood oil production of *Santalum album*. With new plantations being established with sandalwood oil as the major product, it is imperative to know the consequences of routine form-pruning in tropical areas. Examining pruning wound responses in 1 and 5-year-old trees at the end of the dry and wet seasons, it was possible to ascertain the best pruning age and season in relation to occlusion. Pathogenic wood fungi were isolated from wounds and fungal spores monitoring was undertaken at the two trail sites at time of pruning. Younger trees had smaller wounds which were quicker to occlude and produced a lower decay rating which decreased over time. Wood inhabiting fungi were isolated from all pruning wounds and identified using the ITS gene region. There was a total of 531 fungal isolates, identified in 75 fungal taxa. Older trees had significantly more fungal species compared to younger trees. Pruning season did not significantly affect occlusion, the amount of resultant decay, nor the total number of fungal species isolated. Endophytes were isolated from every tree, comprising 52% of isolations. Younger trees had more endophytes but less rot fungi than older trees. Canker fungi were isolated from almost all the older trees. In the older trees, rot fungi were predominant in trees pruned at end of the dry season. Metabar coding of spores collected in spore traps resulted in 565 operational taxonomic units (OTUs) which were placed in 211 genera and 114 families, with about 55% classified as unknown fungi. About 23% of all reads corresponded to potential pathogens; however, the proportion of spore groups present at time of pruning at each plantation was not indicative of the fungal niches isolated from wounds. This study has shown that it is better to prune *S. album* when they are young to decrease the amount of potential decay. To reduce the risk of heartwood rot fungal diseases entering via the pruning wound, it would be preferable to prune at the beginning of the dry season. This will be applicable to other tropical tree species. T. I. Burgess and others. To prune or not to prune, pruning induced decay in tropical sandalwood. [*Forest Ecology and Management* 430:204-218 2018] D

A REGIONAL ALLOMETRY FOR THE CONGO BASIN FORESTS BASED ON THE LARGEST EVER DESTRUCTIVE SAMPLING

The estimation and monitoring of the huge amount of carbon contained in tropical forests, and specifically in the above-ground biomass (AGB) of trees is needed for the successful implementation of climate change mitigation strategies. Its accuracy depends on the availability of reliable allometric equations to convert forest inventory data into AGB estimates. In this study, we tested whether central African forests are really different from other tropical forests with respect to biomass allometry, and further examined the regional variation in tropical tree allometry across the Congo basin forests. Following the same standardized protocol, trees were destructively sampled for AGB in six sites representative of terra firme forests. We fitted

regional and local allometric models, including tree diameter, wood specific gravity, tree height, and crown radius in the AGB praetors. We also evaluated AGB predictions at the tree level across the six sites of our new models and of existing allometric models including the pantropical equations developed by Chave et al. (2014, 2005) and the local equations developed by Ngomanda et al. (2014) in Gabon. With a total of 845 tropical trees belonging to 55 African species and covering a large range of diameters (up to 200 cm), the original data presented here can be considered as the largest ever destructive sampling for a tropical region. Regional allometric models were established and including tree height and crown radius had a small but significant effect on AGB predictions. In contrast to our expectations, tree height and crown radius did not explain much between-site variation. Examining the performance of general models (pantropical or regional) versus local models (site-specific), we found little advantage of using local equations. Earlier pantropical equations developed for moist forests were found to provide reasonable predictions of tree AGB in moist sites, though the wettest sites, i.e., evergreen forests in Equatorial Guinea and, to a lesser extent in Gabon tended to show a wet forest allometry. For the Congo basin forests, except in Equatorial Guinea where local models might be preferred, we recommend using our regional models, and otherwise the most recent pantropical models, that were validated here. The results constitute a critical step for the estimation and monitoring of biomass/carbon stocks contained in the second largest continuous block of tropical forests worldwide, and the successful implementation of climate change mitigation strategies, such as REDD+. A. Fayolle and others. A regional allometry for the Congo basin forests based on the largest ever destructive sampling. [*Forest Ecology and Management* 430 228-240 2018] D

THE ROAD TO OBLIVION: QUANTIFYING PATHWAYS IN THE DECLINE OF LARGE OLD TREES

Large old hollow-bearing trees have wide range of key ecological roles in forest and other ecosystems globally. Patterns and rates of mortality and decay of these trees had profound effects on the size and composition of their populations. Using an 18-year empirical study of large old trees in the Mountain Ash (*Eucalyptus regnans*) forests of the Central Highlands of Victoria, we sought to determine if there are particular patterns of decline that are shared by a proportion of the trees in a tree population. We also sought to identify drivers of decline of these trees by quantifying relationships between the condition state of trees (*viz*: tree form) and a range of covariates. We found that time, stand age, and fire can individually and in combination, strongly affect the decay (and eventual collapse) of large old trees. In particular, we found compelling evidence that patterns of tree decline were markedly different in old-growth forests (stands dating from ~1850) relative to three other younger age classes examined. Trees in older forest decayed less rapidly than trees of equivalent tree form in a younger forest. Old growth stands also were characterized by trees in an overall much lower (more intact) form category than the other age classes of forest. A key pattern in our study was he rapid deterioration of large old trees in the youngest aged stands (*viz*: those regenerating after fires in 1939 and following disturbances between 1960 and 1990). In these forests a very high proportion of large old trees were either in the most advanced state of tree decay (form 8) or had collapsed (form 9). This is a major concern given that 98.8% of the Mountain Ash forest ecosystem supports forest belonging to these) or even younger) age cohorts. Our investigation highlights the need for forest management to: (1) increase levels of protection for all existing large old hollow-bearing trees, (2) expand the protection of existing regrowth forest so there is the potential to significantly

expand the currently very limited areas of remaining old growth forest. D. B. Lindenmayer and others. The road to oblivion – Quantifying pathways in the decline of large old trees. [*Forest Ecology and Management* 430 259-264 2018] D

LEAF TRAITS EXPLAINING GROWTH OF TREES PLANTED IN AN AMAZONIAN DISTURBED AREA

Tree species selected for planting should exhibit both high survival and fast growth. The growth of a tree or forest plantation is affected by the resource supply (light, water and nutrients), the fraction of resources acquired and resource use efficiency. Leaf traits related to the last two processes have the potential to explain the growth rates. In this study, we evaluated 24 leaf traits (morphological and physiological) at the individual level to investigate whether simple leaf traits can be used to predict the variation in relative growth rates of eight native tree species in a mixed plantation in disturbed areas in Central Amazonia 15 months after planting. *Tachigali vulgaris* and *Trattinnickia rhoifolia* exhibited the highest growth rates in both height and diameter, which were approximately three and two times higher than those of *Bombacopsis macrocalyx*, respectively. Species exhibited different establishment strategies as indicated by the functional leaf trait performance. *Tachigali vulgaris*, *Ochroma pyramidale*, *Trattinnickia rhoifolia* and *Ceiba pentandra* are efficient resource use species, have high light-saturated photosynthetic rates and are tolerant to high irradiance stress. *Endlicheria anomala* exhibited the worst performance based on functional traits, with the lowest light-saturated photosynthetic rate (A_{max}) and maximum quantum yield of photosystem II (F_V/F_M). Of all traits analyzed, 12 leaf traits were correlated with the relative growth rate (RGR). Leaf traits related to resource acquisition, such as individual leaf area, chlorophyll content, leaf water potential and leaf nutrient concentration, were not good predictors of growth. Only stomatal conductance (g_s) was related to the RGR. Leaf traits related to photosynthetic use efficiency (carbon use efficiency and photosynthetic nitrogen and phosphorus use efficiency) explained, on average, 20% and 30% of tree growth in height and diameter, respectively. Resource use efficiency traits were better predictors of growth than the individual physiological traits g_s and A_{max}, which explained, on average, 12% and 19% of the growth in height and diameter, respectively. Photosynthetic efficiency-related traits are good predictors of tree growth, and species with high efficiency – such as *T. vulgaris*, *O. pyramidale*, *T. rhoifolia* and *C. pentandra* – can achieve high growth in Amazonian disturbed areas. The identification of species with better performance during initial establishment can improve the design of mixture plantations in disturbed areas. Additionally, the selection of traits most correlated with growth performance can be more informative for reforestation monitoring; consequently, previous silvicultural interventions can be adopted prior to the reduction in both growth and survival rates. Z. T. M. Guimarães and others. Leaf traits explaining the growth of tree species planted in a Central Amazonian disturbed area. [*Forest Ecology and Management* 430 618-628 2018] D

NO DIFFERENCE IN PLANT SPECIES DIVERSITY BETWEEN PROTECTED AND MANAGED RAVINE FORESTS

The influence of management practices on forest ecosystems is usually analyzed by a comparison of species composition and richness. Different types of management practices increase plant species richness, mainly due to an increase in the number of ruderal and open habitat species. So far, most of the studies have been performed in the forest types that were most common in the studied regions. In this study we focused on broadleaved ravine forests that

are spatially limited to specific habitat conditions, including steep rocky slopes with skeletal soil and unstable ground. These forests are local biodiversity hotspots, and due to limited accessibility, have been subject to only limited management practices, mainly of single trees. We collected a dataset of 215 plots sampled between 1991 and 2015 in both managed forests and protected areas. We used multivariate techniques to compare the differences in the overall species composition. In addition, we compared differences in diversity, structural and habitat indices to find any possible differences. There were no differences in both the plot level and accumulative species richness and diversity indices between protected and managed forests. In addition, a comparison of habitat conditions and different ecological groups, including ruderal and open habitat species, alien species and ancient forest indicator species also revealed no differences. The only significant differences between the protected and managed forests related to the evenness and shrub cover. We concluded that low intensity forest management in ravine forests resembles natural disturbances, which are characteristic of natural ravine forests. The species composing these communities are adapted to frequent natural disturbances and thus forest management did not influence significant habitat conditions. However, to fully understand the effect of these practices on biodiversity, a comparison of structural characteristics is needed. J. Baran and others. No difference in plant species diversity between protected and managed ravine forests. [*Forest Ecology and Management* 430 587-593 2018] D

TROPICAL FORESTRY NOTES (49)

BARRIERS AND CORRIDORS FOR SUITABLE HABITAT USE AND PREY AVAILABILITY FOR JAGUARS AND PUMAS IN ATLANTIC FOREST

Large carnivores are key elements of natural ecosystems and most of them are declining due to the impacts of human activities. Jaguars and pumas are the largest felids of the American continent, and particularly jaguars are critically endangered in the Atlantic Forest of South America. As with other tropical forests, the Atlantic Forest has been converted to human land uses, including forest tree plantations with exotic species. We assessed jaguar and pumas habitat in a productive landscape of exotic pine plantations and forest areas in the Atlantic Forest of Argentina. We estimated the availability of their main preys in this landscape and evaluated the variables that affect their occupancy pattern. We developed large scale camera traps surveys between 2013 and 2014 in an area that includes pine plantations, protected areas, and unprotected areas covered by native forest and small rural properties. In total, we sampled 274 sampling stations with an effort of 13,347 camera-trap days. We used single-species single-season occupancy models to evaluate the effect of the proportion of the pine plantations around the sampling stations, the cost of human access, and the distance to the edge of the continuous forest block on the occupancy of the felids and its main prey species. For felids, we also evaluated the effect of the availability of their prey species. With a few exceptions, the occupancy probabilities of most prey were affected by one or two of the landscape variables tested. Habitat use by jaguars and pumas was affected by this anthropogenic landscape change. Even though the relative proportion of plantations to forest around camera stations did not affect the habitat use of either of the two feline species, other factors associated with this anthropic land use, as human accessibility and distance to the continuous forest, did show an effect on these big cat species. According to our results, relatively small and well-managed areas of exotic tree plantations interspersed with forest areas do not constitute barriers for jaguars and pumas in the Atlantic Forest and can function as potential corridors. Forest plantations as such, do not appear to constitute optimal habitats for these felids. The role of tree plantations as potential corridors or supplementary habitat for pumas, jaguars, and their prey relies, to different degrees, on the maintenance of a high proportion of native forest among the plantation, on a good connectivity with the large patches of protected forest, and on the control of poaching. A. Paviolo and others. Barriers, corridors or suitable habitat? Effect of monoculture tree plantations on the habitat use and prey availability for jaguars and pumas in the Atlantic Forest. [*Forest Ecology and Management* 430:576-586 2018] D

PRODUCTIVITY GAINS FROM WEED CONTROL AND FERTILIZATION OF SHORT-ROTATION *EUCALYPTUS* PLANTATIONS IN LLANOS OF VENEZUELA

Increasing forest site productivity is a need. Land use conflicts, high land prices, or owners' objectives, have motivated forest managers to apply more intensive silvicultural treatments to increase forest site productivity. Understanding how intensive silvicultural practices such as weed control and fertilization + weed control affect productivity will permit managers to select the best treatment to increase it. Our objectives were: (1) to estimate the gap between current and attainable productivity of *Eucalyptus* plantations and (2) to determine the effect of treatment on light use and light use efficiency. To estimate the gap between current and attainable productivity, we established 53 pairs of plots, which were measured for two years. Each pair consisted of a control plot, which received the management regime that is regularly applied to

the stands, and a treated plot, which received intensive silvicultural treatment (fertilization + weed control) in addition to the operational management applied to the control plots. At 25% of the sites, a third plot (weed control only) was established. Stem biomass growth in the control and treated plots was 12.4 and 14.8 $\text{Mg ha}^{-1} \text{ yr}^{-1}$, respectively. We found significant differences in light use between the control and treated plots, i.e., averages of 1344 $\text{MJ m}^{-2} \text{ yr}^{-1}$ and 1406 $\text{MJ m}^{-2} \text{ yr}^{-1}$, respectively, representing a 4.6% increase. The increase in light use efficiency (LUE) was higher and reached 20%. On average, the control plots had a LUE of 0.9 g of dry mass (DM)/MJ compared with 1.10 g DM/MJ for the treated plots. There is a considerable opportunity to increase forest productivity through fertilization, and it may be possible to obtain greater gains than those observed in this study. This information is important to estimate the expected responses to intensive silviculture and will help to decide where silvicultural treatments should be applied to maximize the gains obtained from the investment. O. Carrero and others. Productivity gains from weed control and fertilization of short-rotation *Eucalyptus* plantations in the Venezuelan Western Llanos. [*Forest Ecology and Management* 430 566-575 2018] D

CHANGES IN THE LANDSCAPE PATTERN OF THE LA MESA WATERSHED: THE LAST ECOLOGICAL FRONTIER OF METRO MANILA, PHILIPPINES

The La Mesa Watershed (LMW) is considered as the 'lungs' and the last ecological frontier of the Philippines' National Capital Region, Metro Manila. It is among the many watersheds in the country that suffered from severe deforestation in the past. Nevertheless, over the past few decades, reforestation programs for the LMW have also been initiated. The spatiotemporal monitoring of landscape pattern (composition and configuration) is needed to inform policy and support forward-looking management planning toward landscape sustainability. However, the changes in the landscape pattern of the LMW, including the extent of forest cover loss and gain over the past decades, have not been quantified; hence, this study. We used remote sensing data (Landsat) to classify the land use/land cover of the LMW in 1988, 2002 and 2016. We subsequently used spatial metrics to quantify the changes in the landscape pattern of the watershed. We found that between 1988 and 2002, a period that largely preceded the start of the LMW's major rehabilitation (c. 1999), the watershed had a net forest cover loss of 259 ha. From 2002 to 2016, it had a net forest cover gain of 557 ha. The detected increase in forest cover was supported by the percent tree cover change analysis results based on MODIS data. The deforestation of the LMW resulted in landscape fragmentation as indicated by the decrease in the area of forest and mean forest patch size, and the increase in forest patch density, etc. Forest restoration activities have helped improve the watershed's landscape connectivity as signified by the increase in the area of forest and mean forest patch size, and the decrease in forest patch density, etc. The results also revealed that rapid urbanization has been a major factor driving landscape changes around the LMW, and this requires proactive, forward-looking management planning. Overall, the LMW's case presents some valuable learning experience and insights regarding public-private partnerships toward watershed and forest-related rehabilitation initiatives. On a national scale, the Philippine government has embarked on a massive national greening program. The findings of this study suggest that such efforts could lead to the enhancement of denuded forest areas, if done properly. R. C. Estoque and others. Changes in the landscape pattern of the La Mesa Watershed – The last ecological frontier of Metro Manila, Philippines. [*Forest Ecology and Management* 430:280-290 2018] D

USABILITY OF CITIZEN SCIENCE OBSERVATIONS TOGETHER WITH AERBORNE LASER SCANNING

Citizens' field observations are increasingly stored in accessible databases, which makes it possible to use them in research. Citizen science (CS) complements the field work that must necessarily be carried out to gain an understanding of any of bird species' ecology. However, CS data holds multiple biases (e.g. presence only data, location error of bird observations, spatial data coverage) that should be paid attention before using the data in scientific research. The use of Airborne Laser Scanning (ALS) enables investigating forest bird species' habitat preferences in detail and over large areas. In this study the breeding time habitat preferences of 25 forest bird species were investigated by coupling CS observations together with nine forest structure parameters that were computed using ALS data and field plot measurements. Habitat preferences were derived by comparing surroundings of presence-only observations against the full landscape. Also, in order to account for bird observation location errors, we analysed several buffering alternatives. The results correspond well with the known ecology of the selected forest bird species. The size of a bird species' territory as well as some behavioral traits affecting detectability (song volume, mobility etc.) seemed to determine which bird species' CS data could be analyzed with this approach. Especially the habitats of specialized species with small or medium sized territories differed from the whole forest landscape in the light of several forest structure parameters. Further research is needed to tackle issues related to the behavior of the observers (e.g. birdwatchers' preference for roads) and characteristics of the observed species (e.g. preference for edge habitats), which may be the reasons for few unexpected results. Our study shows that coupling CS data with ALS yield meaningful results that can be presented with distribution figures easy to understand and, more importantly, that can cover areas larger than what is normally possible by means of purpose-designed research projects. However, the use of CS data requires an understanding of the process of data collection by volunteers. Some of the biases in the data call for further thinking in terms of how the data is collected and analyzed. L. Mononen and others. Usability of citizen science observations together with airborne laser scanning data in determining the habitat preferences of forest birds. [*Forest Ecology and Management* 430:498-508 2018] D

MULTIPLE-SCALE APPROACH FOR EVALUAT ING THE OCCUPATION OF STINGLESS BEES IN ATLANTIC FOREST PATCHES

Studies at multiple scales are essential to obtaining a holistic view of bee conservation. We aimed to detect the main factors that should be considered in a multiple-scale approach for small forest patches in order to contribute to the conservation plans for stingless bees. The study was conducted in small forest patches of the Atlantic Forest, in the municipality of Salto de Pirapora (SP, Brazil). The spatial analysis was developed based on forest patch size, forest patch core size, distance from the nearest forest patch, and distance from the nearest body of water. Based on these criteria, we selected three hotspot forest patches (including all criteria that favor the presence of stingless bees with arboreal nesting habits) and three control forest patches (which does not fulfill all these criteria), and we evaluated the presence of stingless bees based on the occupation of artificial shelters installed in the patches. From the 72 installed artificial shelters, we observed 27 shelters (37.5%) carrying some association with stingless bees presence. Bees showed a preference for occupying artificial shelters that were located in the patches' cores (66.7%). The structure and composition of the vegetation showed great importance to the occupation of the artificial shelters, as there was a strong correlation between the occupied

shelters and the diameter and the height of the trees. There was also a correlation between the presence of grasses and shrubs ($p < 0.05$), which were the main providers of floral resources. The data of the land cover was an essential factor for the development of spatial analysis, and we found a strong negative correlation with pastures and a positive correlation with forestry ($p < 0.05$). To elaborate multiscale approaches, it is essential to evaluate the quality of foraging (amount of flowers) and nesting (diameter and height of trees) resources, as well as the surroundings of the patches. The study provided data so that the information can be extrapolated to other scenarios and encourage the conservation of small forest patches as a strategy for the conservation of stingless bees. M. V. N. Arena and others. Multiple-scale approach for evaluating the occupation of stingless bees in Atlantic forest patches. [*Forest Ecology and Management* 430:509-516] D

INTENSIFICATION OF SHIFTING CULTIVATION REDUCES FOREST RESILIANCE IN THE NORTERN AMAZON

Shifting cultivation is a traditional land-use system to ensure livelihood in the Northern Amazon. Here, we evaluated how intensification of shifting cultivation (SC) affects secondary forest recovery in the northern Amazon forest. To measure intensity of shifting cultivation, we used the number of previous SC cycles. We selected three study sites containing second-growth forest (SG) with different stand ages (5 and 10 years) after one, three or six SC cycles. Furthermore, we selected old-growth forest (OG) in each study site. In each selected SG and OG, three plots of 20 × 50 m were established, totalizing 63 plots in the study area. In each plot, all trees, palms and lianas with diameter at breast height ≥ 5 cm were tagged and identified to species level. We analyzed the effects of SC intensification and soil fertility on woody species richness, species composition and basal area using mixed effect models. Species richness and basal area, lower in SG than in OG, increased with regeneration time after abandonment, but reduced with intensification of SC. Community dissimilarities (Bray-Curtis distances) between OG and SG increased with the number of shifting cultivation cycles. Soil fertility differed between SG with different regeneration stages and reduced with number of SC cycles. We found that soil fertility and management intensity, i.e., number of previous SC cycles, explained pattern observed in richness, species composition and basal area equally good. Due to nutrient exports with crops and increasing nutrient leaching, soil fertility is expected to reduce with SC intensity. Therefore, our data indicate that intensification of SC reduces recovery of species richness, composition and basal area of SGs following productive periods. Thus, the intensification of SC reduces the resilience of SGs, turning this ancient form of land-use unsustainable. Environmental sustainability of SC may be achieved by extending fallow periods, limiting the maximum yield. To attend growing demands of indigenous and non-indigenous communities, we propose other alternatives of land-use such as permanent agroforestry systems. P. M. Villa and others. Intensification of shifting cultivation reduces forest resilience in the northern Amazon. [*Forest Ecology and Management* 430:312-320 2018] D

YIELD PATTERN OF *EUCALYPTUS* CLONES ACROSS TROPICAL BRAZIL: AN APPROACH TO CLONAL GROUPING

The research objective of this paper was to group eleven widely planted eucalypt clones based on their volume yield pattern by assessing how climatic variation impacts their productivity in tropical Brazil. A total of 187 plots evenly distributed across eleven clones and 17 sites (from Paraná to Pará State) were used. Plot measurements were carried out every six months (from

2013 to 2017) to evaluate eucalyptus growth. Since the year of plot establishment differs across the sites, volumes of all the plots and sites were standardized at a common age of 5 years. Clonal grouping analysis was performed based on the common age for volume yields using a new approach, which consisted of three steps: (1) create general groups based on testing of the slope coefficient, which was applied to every clonal-specific regression with volume yield as a function of annual water deficit index (WDI); (2) split each general group using volume yield deviation computations into subgroups of high and low productivity; (3) apply linear mixed effects models for every subgroup in order to confirm the non-existence of statistical difference among the volume yield of the clones. Statistical tests showed satisfactory yield estimates at the common age of 5 years. Clonal grouping revealed the identification of four groups (A: high productivity and non-sensitive to climate variation, B: high productivity and sensitive to climate variation, C: low productivity and sensitive to climate variation, D: low productivity and non-sensitive to climate variation). The volume yield of the Clonal group B was detected to be the most impacted by annual water deficit index variation, followed by clonal groups C, A and D. The findings of the study highlighted the utility of the proposed approach for grouping clones. Group identification and detection of the climatic impact on yield patterns was evaluated as a measure to increase site-specific productivity. H. F. Scolforo and others. Yield pattern of eucalypt clones across tropical Brazil: An approach to clonal grouping. [*Forest Ecology and Management* 432:30-39 2019] D.

ABOVEGROUND WOODY BIOMASS IN AMAZONIAN FLOODPLAIN FORESTS
The importance of tropical forests in regulating global carbon stocks is well known. However, the role of abiotic variables related to climate conditions and edaphic parameters for patterns of above-ground woody biomass (AGWB) are still under debate. For Amazonian forests subjected to periodic floods, these patterns are even more uncertain. This study aimed to evaluate AGWB stocks in Amazonian floodplain forest, and investigate the importance of forest structure, hydroperiod and edaphic parameters for AGWB. Results are based on floristic inventories conducted in twelve hectares of forest distributed across four floodplains. All trees ≥10 cm DBH were tagged, identified, and had their DBH and height measured. Allometric equations were applied for calculating AGWB. Hydroperiod was estimated for each sample plot, and soil samples were collected, and chemical and physical components analyzed. Hierarchical partitioning was applied to determine importance of forest structure variables for AGWB, and GLMMs to evaluate the individual role of several edaphic parameters and hydroperiod for AGWB stocks. AGWB estimates varied substantially both between and within sites, as did the proportional contribution of forest structure variables to AGWB. Fabaceae contributed most to AGWB overall, and hydroperiod was more important than soil fertility in explaining variation in AGWB values. Amongst the edaphic variables, Iron (Fe) was the component that influenced AGWB the most, followed by Aluminum (Al) and Phosphorus (P). Overall, our results indicate that, on the investigated Amazonian floodplains, AGWB is mainly driven by hydroperiod rather than edaphic properties. This occurs despite a constant input of nutrients caused by flooding events. In addition, this is the first study to suggest that P appears to be of some importance in Amazonian várzea and paleo-várzea floodplains, where soil fertility is generally higher than in non-flooded terra firme forests. R. L. Assis and others. Above-ground woody biomass distribution in Amazonian floodplain forests: Effects of hydroperiod and substrate properties. [*Forest Ecology and Management* 432:365-375 2019] D

MAXIMIZING THE MONITORING OF DIVERSITY FOR MANAGEMENT ACTIVITIES: ADDITIVE PARTITIONING OF PLANT SPECIES DIVERSITY ACROSS FREQUENTLY BURNED ECOSYSTEM

Monitoring understory plant diversity is important, allowing managers to track current diversity status and trends both spatially and temporally at a landscape-scale. Improving precision in quantifying patterns in understory plant diversity improves efficiency in monitoring design and more accurate measures of success of management intervention over time. Patterns of species diversity are dependent upon the scale in which they are examined – an increase in small-scale diversity across a gradient can convert to a decrease in large-scale diversity across that same gradient. Using two extensive datasets including both mined historical data and supplemental experimental data, we performed an additive partitioning of plant diversity to elucidate the hierarchical spatial patterns of understory plant species richness, and independent measures of alpha and beta diversity in the species-rich longleaf pine ecosystem at Eglin Air Force Base in northwestern FL, USA. This analysis allowed us to identify the spatial scale that most effectively captures plant diversity to inform monitoring efforts by using measures of species turnover, specifically beta diversity. We found that while species richness and alpha diversity increased with spatial scale, beta diversity began to reach an asymptote at smaller (1 m2) scales. Furthermore, we found the sampling effort at this 1 m2 scale required as few as 60 plots to effectively estimate plant diversity within management blocks. While our results are attributable to Eglin AFB specifically, these scaling analyses can help to streamline monitoring efforts in other ecosystems that seek to elucidate the individual contributions of diversity components. J. E. Dell and others. Maximizing the monitoring of diversity for management activities: Additive partitioning of plant species diversity across a frequently burned ecosystem. [*Forest Ecology and Management* 432:409-414 2019] D

A MULTIFUNTIONAL APPROACH FOR ACHIEVING SIMULTANEOUS BIODIVERSITY CONSERVATION AND FARMER LIVELIHOOD IN COFFEE AGROECOSYSTEMS

Ecologically complex agroecosystems often provide multiple conservation benefits, yet understanding the agricultural practices that favor biodiversity is often a theoretical task until we simultaneously demonstrate the economic impact of such practices on farmers. We provide a multifunctional analysis of both biodiversity and ecosystem services that influence coffee farm profit in Puerto Rico. We show that the vegetation heterogeneity of an agroecosystem, more so than any one ecological component (e.g. shade), is associated with a higher biodiversity of plants, birds, lizards, bees, ants, and parasitoid wasps. However, a farm's vegetation heterogeneity does not consistently correlate with profit-related ecosystem services, including coffee yield and biological control of coffee pests and pathogens, due to tradeoffs between services. Therefore, inherent financial incentives that would encourage farmers to manage farms in ways that maintain high associated biodiversity may be lacking. We explored several economic incentives that would allow farms to be simultaneously biodiverse and profitable, which we show is possible through realistic incentive schemes. We found that the combination of a certification premium plus carbon payments (50% premium plus \$16 t−1 CO2e) or a restructuring of agricultural subsidies using currently experienced subsidy amounts may be sufficient to make farms that are more heterogeneous, and therefore more biodiverse, the most profitable option for farmers. If these biodiverse farms can also be profitable, it will open critical opportunities for maintaining rural landscapes that support farmers' livelihoods, as well as

protect the planet's biodiversity. A. L. Iverson and others. A multifunctional approach for achieving simultaneous biodiversity conservation and farmer livelihood in coffee agroecosystems. [*Biological Conservation* 238:108179 2019] D

TROPICAL FORESTRY NOTES (50)

PROTECTED AREAS ARE NOT ASSOCIATED WITH HIGHER POVERTY RATES

Countries across the globe are expanding their networks of protected areas in an effort to address the increasing rates of biodiversity loss. Protected areas, though, have been criticized extensively for their negative impact on the local communities. Case studies have shown that protected areas can exacerbate poverty. However, these case studies represent only a small proportion of the over two-hundred thousand protected areas available worldwide today. Hence, it is possible that most protected areas do not impoverish the local communities. In fact, a few recent studies have suggested that protected areas do not impact negatively the local people. The findings of those studies, however, are based predominately on data from small geographical regions. Consequently, it is unclear whether their results are widely applicable. In this study, I have used a large dataset from 5800 administrative regions in eleven countries and four continents to explore in more detail the link between protected areas and local poverty rates. Particularly, I have used the quasi-experimental matching method to test whether administrative regions with protected areas have higher proportions of people living below the poverty line. I found no evidence to support this pattern. Protected areas do not appear to be associated with higher poverty rates. Considering that, firstly, biodiversity conservation and poverty alleviation represent two of the most urgent challenges of our time, and, secondly, that most efforts to conserve biodiversity are channeled through protected areas, it is crucial to know that protected areas do not interfere with our efforts to alleviate poverty. C. Mammides and others. Evidence from eleven countries in four continents suggests that protected areas are not associated with higher poverty rates. [*Biological Conservation* 241 108353 2020] D

HABITAT LOSS VIA FRAGMENTATION: FOREST DEPENDENT SPECIES

Recent studies suggest that habitat amount is the main determinant of species richness, whereas habitat fragmentation has weak and mostly positive effects. Here, we challenge these ideas using a multi-taxa database including 2230 estimates of forest-dependent species richness from 1097 sampling sites across the Brazilian Atlantic Forest biodiversity hotspot. We used a structural equation modeling approach, accounting not only for direct effects of habitat loss, but also for its indirect effects (via habitat fragmentation), on the richness of forest-dependent species. We reveal that in addition to the effects of habitat loss, habitat fragmentation has negative impacts on animal species richness at intermediate (30–60%) levels of habitat amount, and on richness of plants at high (>60%) levels of habitat amount, both of which are mediated by edge effects. Based on these results, we argue that dismissing habitat fragmentation as a powerful force driving species extinction in tropical forest landscapes is premature and unsafe. T Püttker and others. Indirect effects of habitat loss via habitat fragmentation: a cross-taxa analysis of forest-dependent species. [*Biological Conservation* 241 108368 2020] D

ESTIMATING GLOBALLY IMPORTANT TIGER DENSITY IN EASTERN THAILAND

Spatially explicit capture-recapture analysis is widely utilized for estimating densities of tigers (*Panthera tigris*). However, developing a robust study design capable of meeting assumptions and achieving study objectives may be difficult, particularly for low-density populations. Study design decisions for such fieldwork can be aided by simulations. Our goal was to (1) use

simulations to investigate and evaluate study design and (2) generate a reliable estimate of density for a population of tigers in Thailand's Dong Phayayen-Khao Yai forest complex. Scenarios were parameterized with a range of potential density estimates (D) and detection function parameters (g0 and σ). We designed a field-based trap configuration identified and compared it with simulated performance of a regular trapping array, over 45-day and 60-day sampling occasions. We compared simulation results (i.e. number of individuals [n], detections [ndet], relative standard error [RSE] and relative bias [RB]) and identified that the non-regular trapping array deployed for 60 sampling days would generate reliable density estimates. Our survey produced a density estimate of $0.63 \pm SE0.22$; (0.32–1.21) tigers per 100 km^2, from a model incorporating variation in sex for g0 and σ, and a population estimate of 20 (14–33). Simulations closely reflected actual results under the null model. Our survey design performed reasonably well, generating a sufficient number of detections and individuals to estimate density of a globally important tiger population. Our results suggest simulations and use of non-regular trap arrays may be beneficial for areas with low species density in which generating sufficient detections is particularly challenging. E. Ash and others. Estimating the density of a globally important tiger (*Panthera tigris*) population: Using simulations to evaluate survey design in Eastern Thailand. [*Biological Conservation* 241 108349 2020] D

INFORMAL FOREST HARVESTING IN THE EASTERN CAPE, SOUTH AFRICA

Forest management in many developing nations aims to balance the needs of resource users and the ecological integrity of indigenous forests, in terms of both biodiversity conservation and ecosystem services, particularly carbon sequestration. While South Africa has legislated management policies to achieve this, implementation has been lacking, resulting in concern that unregulated resource use is compromising forest biodiversity. However, there is little information regarding resource use since these regulations were promulgated a decade ago. This study reports on the current nature and extent of forest product harvesting in the Eastern Cape, South Africa, which contains just under half of the country's indigenous forests. Extraction rates and target species of key products, namely poles, timber and bark, were assessed across six forests, representing five forest types. Harvest intensities indicated low to moderate levels of use, but there was considerable variation in levels of resource use at the forest-scale, illustrating the importance of site-specific assessments. Furthermore, resource use was species-specific, indicating that sustainability is dependent on the ecology of preferred species. Of concern was widespread commercial-scale bark harvesting; and relatively high timber extraction from a Pondoland scarp forest, a threatened forest type. We urge implementation of existing regulations, which distinguish between subsistence and commercial use, and commensurate capacitation of the new Department of Environment, Forestry and Fisheries. In the case of timber and bark, we recommend licencing of the de facto commercial harvesting taking place in order to promote regulation. J. Leaver and M. I. Cherry. Informal forest product harvesting in the Eastern Cape, South Africa: A recent assessment. [*Biological Conservation* 241 108394 2020] D

LANDSCAPE-SCALE ESTIMATION OF FOREST UNGULATE DIVERSITY AND BIOMASS USING CAMERA TRAPS

Landscape-scale information on animal density is being increasingly recognized as a fundamental parameter for enhancing wildlife conservation practices and management. It is important to obtain such information on forest ungulates because they have profound impacts on vegetation and also often constitute important prey for human hunters and large predators. In this

study, we incorporated habitat covariates into a recently-developed likelihood-based approach (random encounter and staying time [REST] model) and test the potential of estimating the density and biomass of forest ungulates at landscape scales exclusively from camera traps. We targeted four duiker species (subfamily: Cephalophinae) in Central Africa and determined the effects of habitat covariates using Bayesian model averaging. The density of sympatric duikers largely varied across species, with each species exhibiting different spatial patterns; thus, sympatric duikers might exhibit space partitioning at the landscape scale. Topography might be a key factor determining spatial variation in duiker density, within and among species. Yet, total duiker biomass (kg) did not vary largely, and even remained high in naturally- and anthropogenically-disturbed forests; thus, disturbed forests may still be of value to human hunters and large predators. Through determining the habitat-density relationships, this study provides a novel approach for predicting animal density at landscape scales. Given the difficulty in implementing classic line-transect surveys in sloped areas, our approach might provide a viable way of estimating the density of ungulates occupying a wide variety of habitats. Y. Nakashima and others. Landscape-scale estimation of forest ungulate density and biomass using camera traps: Applying the REST model. [*Biodiversity Conservation* 231 108381 2020] D

FACILITATING ADAPTATON OF HAWAII'S BIRDS FROM MALARIA

Avian malaria has played a significant role in causing extinctions, population declines, and limiting the elevational distribution of Hawaiian honeycreepers. Most threatened and endangered honeycreepers only exist in high-elevation forests where the risk of malaria infection is limited. Because *Culex* mosquito vectors and avian malaria dynamics are strongly influenced by temperature and rainfall, future climate change is predicted to expand malaria infection to high-elevation forests and intensify malaria infection at lower elevations, likely resulting in future extinctions and loss of avian biodiversity in Hawaii. Novel, landscape-level mosquito control strategies are promising, but are logistically challenging and require costly long-term efforts. As an alternative or supplemental strategy, we evaluated the potential of releasing a gene-edited malaria-resistant honeycreeper (Iiwi, *Drepanis coccinea*) in Hawaiian rainforests; a strategy known as facilitated adaptation. While this approach also has significant technical challenges and costs, it may offer a more permanent solution to increasing malaria threats. If malaria-resistant honeycreepers can be developed, facilitated adaptation may provide a practical strategy for the reestablishment of abundant avian populations in Hawaiian forests. A successful strategy could be the release of malaria-resistant Iiwi in mid-elevation forests where development of a resistant population has the best chance of success. Establishment of a resistant Iiwi population could provide a source for dispersal and development of resistant populations in high-elevation forests and a permanent source of resistant individuals for translocation to other vulnerable areas. M. D. Samuel and others. Facilitated adaptation for conservation–Can gene editing save Hawaii's endangered birds from climate driven avian malaria? [*Biological Conservation* 241 108390 2020]. D

PATTERNS OF SPECIES RICHNESS AND ENDEMISM OF BUTTERFLIES AND DAY-FLYING MOTHS IN THE MONSOON TROPICS OF NORTHERN AUSTRALIA

Patterns of species richness and endemism were analyzed for 154 resident/breeding diurnal Lepidoptera in 153 grid cells (100 km × 100 km) based on a recently published set of spatial distribution maps (range-map and atlas data) in the western and central Australian Monsoon Tropics biome of northern Australia (~1.2 million km2). Biodiversity hotspots were then

identified on the basis of coincidence of high values of species richness, endemic richness and weighted endemism. Spatial and environmental variables accounting for significant variation in species and endemic richness were determined using multivariate generalized linear models. Broad patterns of species and endemic richness showed a pronounced north-south latitudinal gradient that was significantly correlated with mean annual rainfall, from the wetter northern coastal areas to the drier southern inland areas of the semi-arid zone. Analysis of weighted endemism identified three putative centers of endemism: the Top End (north-western corner), the Kimberley (northern) and Arnhem Land (Gove Peninsula). Overall, the north-western corner of the Top End (86,860 km2) – including the Arnhem Land Plateau (Kakadu NP-Nitmiluk NP and Warddeken IPA), reserves in the Darwin region, Litchfield NP, the Tiwi Islands, Fish River-Daly River, and Cobourg Peninsula (Garig Gunak Barlu NP) – is a major biodiversity hotspot for the conservation of diurnal Lepidoptera based on congruent patterns of species richness, endemic richness and weighted endemism. Large discrepancies between actual survey lists (atlas data) and inferred lists (range-map data) indicate the need for further inventory of the National Reserve System, particularly for several reserves identified as significant for diurnal Lepidoptera diversity. M. F. Braby and others. Patterns of species richness and endemism of butterflies and day-flying moths in the monsoon tropics of northern Australia. [*Biological Conservation* 241 108357 2020] D

IDENTIFYING AT-SEA AREAS FOR SEA BIRDS USING SPECIES DITRIBUTION MODELS

Marine protected areas (MPAs) underpin the sustainable management of marine ecosystems but require accurate knowledge of species distributions. Recently, advances in tracking technology and habitat modelling have enabled the production of large-scale species distribution models (SDM), which provide the basis for hotspot mapping. In the UK, hotspot mapping to inform seabird MPA identification has involved converting observed or predicted distributions to polygons using either Maximum Curvature or Getis-Ord (Gi*) analysis. Here, we apply both mapping techniques to UK-wide, breeding season SDM predictions for four seabird species (Black-legged Kittiwakes *Rissa tridactyla*, Common Guillemots *Uria aalge*, Razorbills *Alca torda* and European Shags *Phalacrocorax aristotelis*) in order to compare their performance and inform seabird MPA. When using Maximum Curvature, grid cells within the identified maximum curvature boundaries were defined as hotspots. For Getis-Ord analysis, we defined hotspots as either (1) grid cells containing the top 1% or (2) the top 5% Gi* scores or (3) cells in which Gi* scores were statistically significant. Hotspots based upon Maximum Curvature or statistically significant Gi* scores covered the greatest area and were generally larger than current marine Special Protection Areas. Hotspots based on the top 1% or top 5% of Gi* scores were smaller and were concentrated around the largest breeding colonies. All hotspot methods consistently identified several high-density areas that should be prioritized for seabird conservation. Ultimately, the choice of hotspot identification method should be informed by considering species ecology alongside conservation goals to ensure hotspots are of sufficient size to protect target populations. R. Cleasby and others. Identifying important at-sea areas for seabirds using species distribution models and hotspot mapping. [*Biological Conservation* 241 108375 2020]

FOREST RESIDUE REMOVAL DECREASES SOIL QUALITY AND AFFECTS WOOD PRODUCTIVITY EVEN WITH HIGH RATES OF FERTILIZER APPLICATION

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Forest residues are frequently used as energy sources by Brazilian forest companies. The removal of such residues is known to reduce wood productivity, especially when fertilizer application rate is low. This study aimed to evaluate after two forest rotations the effects of forest residue management on wood productivity when fertilizer is applied at a high rate, and the effect of timber harvest intensity on soil organic matter and microbial activity. We assessed tree growth, soil microbial biomass and activity, and we fractionated soil organic matter (SOM) via its oxidation resistance. These assessments were performed after conducting a field trial comparing harvest residue management over two successive rotations in the same plots. We found no significant effect of treatments on wood productivity when the residues were removed for the first time; however, wood productivity reduced by 15% during the second rotation with residue removal even with high rates of fertilizer application. Further, 40% reduction in microbial biomass and soil respiration was noted with forest residue removal. At the reestablishment time, the SOM in the top soil (0–0.05 m layer) was 25% lower at the site where the forest residues were removed, and this difference increased to 50% at 300 days after the reestablishment. This reduction was found mainly in the SOM labile fraction. J. H. T. Rocha and others. Forest residue removal decreases soil quality and affects wood productivity even with high rates of fertilizer application. [*Forest Ecology and Management* 430:188-195 2018] D

TROPICAL FORESTRY NOTES (51)

STOICHIOMETRY OF DECOMPOSING *SPATHODEA CAMPANULATA* LEAVES IN NOVEL PUERTO RICAN FORESTS

One of the challenges in the restoration of degraded lands is the re-establishment of soil structure and fertility. Novel forests that regenerate on recently abandoned and degraded agricultural lands are among the first biotic systems that begin the process of soil rehabilitation. The rate of litter decomposition and associated element mobility is one of many processes that contribute to the understanding of how ecosystem-level processes restore eroded soils. We studied the stoichiometry of *Spathodea campanulata* leaves decomposing in novel subtropical moist forests. We found that the speed of leaf decomposition was high (annual decomposition constant of 5.0 to 2.6 or half-life of 51 to 98 days). *Spathodea* leaf mass loss was particularly fast during the first 16 days of decomposition (half-life of 33 days). Leaf litter was characterized by high chemical quality with low C/N, C/P, and N/P. During the leaf decomposition process, macroelements (N, P, K, Ca, and Mg) were more mobile than microelements (Al, Mn, Fe, and Na). As leaf litter decomposed, nitrogen increased in concentration, the quantity of all macroelements decreased, and microelements tended to increase in both concentration and quantity. Because of the rapid rate of decomposition and high chemical quality of *Spathodea* leaf litter, it appears that the potential for yielding residual soil organic matter from its leaves is reduced, but this is a tradeoff with the rapid release of elements, which contributes to the high juvenile tree density and primary productivity observed in novel *Spathodea* forests. A. E. Lugo and others. Stoichiometry of decomposing *Spathodea campanulata* leaves in novel Puerto Rican forests. [*Forest Ecology and Management* 430:176-187 2018] D

GROWTH, MORTALITY, AND RECRUITMENT OF THE SPECIES IN AN AMAZONIAN RAINFOREST OVER 13 YEARS OF REDUCED IMPACT LOGGING

Forest harvesting causes disturbances in the forest, affecting the dynamics of tree species. In this study, growth, mortality, and recruitment of trees ≥45 cm DBH were assessed in different forests logged along 13 years (2002–2015) in the Eastern Amazon. The data were collected in a control unlogged forest and in four 100-ha working units divided into 20 plots of 5 ha (total of 100 plots in 500 ha sampled) and inventoried at 100% one year before harvesting and again in 2015. A total of 49 species were analyzed in the study. The highest mortality rate occurred in the first five years after harvesting (5.6%), with a reduction from the seventh year (3.2% year−1), a period in which recruitment rate significantly increased for species from all ecological groups. Harvesting reduced both the number of individuals and species in the first five years after logging. Logged areas presented the highest growth rates five and seven years and only stabilized eleven years after logging. Within the range of 3–40 m3 ha−1 of logging intensity no differences were observed in growth rates of remaining trees ≥45 cm DBH. Pioneer, light-demanding, and shade-tolerant species presented higher growth rates in the first five years after logging. From seven years after harvesting, light-demanding presented a higher growth when compared to the shade-tolerant species. Larger diameter classes presented the highest relative growth rates (RGR). All diameter classes increased RGR up to 11 years after logging. L. Fernandez Silva Dionisio and others. Growth, mortality, and recruitment of tree species in an Amazonian rainforest over 13 years of reduced impact logging. [*Forest Ecology and Management* 430:150-156 2018] D

ENVIRONMENT AMD ANTHROPOGENIC IMPACTS AS MAIN DRIVERS OF PLANT ASSEMBLAGES IN FOREST MOUNTAIN LANDSCAPES IN SOUTHERN PATAGONIA

Management of natural areas generated multiple trade-offs, and changes in the plant assemblages was identified as one of the most critical ones. In this context, understanding the drivers of change of exotic plant diversity is critically important for biodiversity conservation and land planning. The aim of this work was to evaluate the relationships between environmental gradients in mountain landscapes and anthropogenic impacts related to human uses as drivers for plant assemblages (native and exotic species) in Southern Patagonian forests. The study was located in the Andorra Valley basin (12,934 ha) in the southern Tierra del Fuego Island (Argentina), where mountain landscape units (land-cover and land-use) were identified according to their vegetation types (forests and open-lands), elevational effects (<400 and >400 m.a.s.l.) and anthropogenic impacts derived from economic activities (harvesting and cattle grazing). Classification was based on Landsat 8 OLI images with fieldwork samplings, relevating a total of 101 landscape units. In each unit, forest structure and floristic surveys (dicots, monocots, pteridophytes and bryophytes) were conducted. Data were evaluated using ANOVAs and multivariate analyses (cluster, detrended and canonical correspondence analysis). A total of 104 plant species were surveyed (88% natives and 12% exotics), where managed deciduous forests (*Nothofagus pumilio*) had the highest values of exotic species occurrence frequency (20%). Multivariate analyses showed that environmental gradients and anthropogenic impacts highly affected the distribution of exotic species. Native species had higher cover values at upper elevations, while exotic plants had a higher cover at lower elevations, where the N-S aspects were strongly correlated with plant preferences for shaded/lighted aspects. The occurrence of exotic species can be specifically related to human activities (e.g., *Agrostis stolonifera* and *Rumex acetosella* with cattle grazing; and *Poa nemoralis*, *Ranunculus repens* and *Stellaria media* with harvesting), however one of them (*P. trivialis*) was related with unharvested forests. We conclude that environmental gradients and anthropogenic impacts define the plant assemblages at landscape level, and they also influence the occurrence of the exotic species, where the main driver was the harvesting. We propose that land-sharing conservation strategy in these mountain landscapes could be the better approach towards sustainability ensuring the preservation of the land-cover and the land-use at the low and upper elevations. A. Huertas Herrera and others. Environment and anthropogenic impacts as main drivers of plant assemblages in forest mountain landscapes of Southern Patagonia. [*Forest Ecology and Management* 430:380-393 2018] D

PLOT-LEVEL VARIABILITY IN BIOMASS FOR TROPICAL FOREST INVENTORY DESIGNS

The spatial distribution of biomass is key to optimize forest inventory designs to estimate forest aboveground biomass. Point process theory sets an appropriate mathematical framework to model the spatial distribution of trees, then to derive analytical expressions for the relationship between the variance of biomass in plots and the characteristics (size and shape) of plots, possibly accounting also for plot autocorrelation in biomass. Models derived from point process theory provided a better fit to data from twenty spatially homogeneous sites in tropical rain forests than the commonly used Taylor power model for biomass variance. The model $CV = \sqrt{(\omega + \kappa + |A|)}$ with CV the coefficient of variation of biomass, $|A|$ the plot area, and ω and κ parameters to estimate, provided in particular a better fit than the power model when the range of

autocorrelation in biomass was greater than the plot width. The twenty tropical forest sites greatly differed in the observed relationship between biomass variance and plot size, reflecting differences in the spatial pattern of biomass according to the fitted point process. Accordingly, optimized forest inventory designs also greatly differed between forest sites, with positive biomass autocorrelation favoring cluster sampling design with a distance between subplots in the order of the range of the biomass autocorrelation. In a spatially heterogeneous context consisting of different homogeneous forest strata, large-scale heterogeneity prevailed upon local biomass autocorrelation in determining the optimized plot size and shape. If uncontrolled through stratification, large-scale heterogeneity resulted in much smaller (approximately 0.1–0.2 ha) optimized plot sizes than the homogeneous case (approximately 1–2 ha). N. Picard and others. Plot-level variability in biomass for tropical forest inventory designs. [*Forest Ecology and Management* 430:10-20 2018] D

SIMULATION OF SUCCESSION: IN A NEOTROPICAL FOREST HIGH SELECTIVE LOGGING INTENSETIES PROLONG THE RECOVERY TIMES OF ECOSYSTEM FUNCTIONS

There is increasing concern, to what extent production forests in the Neotropics are sustainably managed. The implementation of effective forest management strategies that are ecologically beneficial plays thus a central role to prevent forest degradation. However, to identify effective forest management strategies, there is a need for methods supporting the decision-making process. The main objective of our study is to analyze the mid- and long-term impacts of different management intensities, such as varying the minimum stem diameter of harvestable commercial trees, on the dynamic and structure of a species-rich tropical lowland forest of French Guiana. Therefore, we have applied the management module of a dynamic forest model and analyzed simulation experiments for undisturbed forest growth and selective logging. For the first time we were able to quantify the mean recovery times of multiple ecosystem functions and properties (biomass, gross primary production, leaf area index, Shannon diversity, timber volume) after selective logging. Accordingly, we validated simulation results (biomass, number of trees harvested) of selective logging with forest inventory data from the last 32 years. The forest model reliably reproduces the observed pre-logging biomass, tree-size distribution, and logging intensity (10 trees/ha, 39 m^3/ha). In addition, it became clear how strongly management with higher logging intensities influences the forest in the long term: (1) the mean recovery times of the investigated ecosystem functions were significantly extended. With very intensive logging (116 m^3/ha), the average recovery time of forest biomass was almost twice as long as in a moderate simulation scenario (t_{int} 138 a, t_{mod} 77 a). Similar patterns were observed for other ecosystem functions, e.g. timber volume (t_{int} 158 a, t_{mod} 62 a). (2) Additionally, the functional composition shifted, as up to 30% pioneer tree species in particular invaded the forest. This innovative use of forest growth models may help in the development of ecologically reasonable forest management strategies. U. Hiltner and others. Simulation of succession in a neotropical forest: High selective logging intensities prolong the recovery times of ecosystem functions. [*Forest Ecology and Management* 430:517-525 2018] D

PRODUCTIVITY GAINS FROM WEED CONTROL AND FERTILIZATION OF SHORT-ROTATION *EUCALYPTUS* PLANTATION IN THE VENEZUELAN LLANOS

Increasing forest site productivity is a need. Land use conflicts, high land prices, or owners' objectives, have motivated forest managers to apply more intensive silvicultural treatments to

increase forest site productivity. Understanding how intensive silvicultural practices such as weed control and fertilization + weed control affect productivity will permit managers to select the best treatment to increase it. Our objectives were: (1) to estimate the gap between current and attainable productivity of *Eucalyptus* plantations and (2) to determine the effect of treatment on light use and light use efficiency. To estimate the gap between current and attainable productivity, we established 53 pairs of plots, which were measured for two years. Each pair consisted of a control plot, which received the management regime that is regularly applied to the stands, and a treated plot, which received intensive silvicultural treatment (fertilization + weed control) in addition to the operational management applied to the control plots. At 25% of the sites, a third plot (weed control only) was established. Stem biomass growth in the control and treated plots was 12.4 and 14.8 $Mg\,ha^{-1}\,yr^{-1}$, respectively. We found significant differences in light use between the control and treated plots, i.e., averages of 1344 $MJ\,m^{-2}\,yr^{-1}$ and 1406 $MJ\,m^{-2}\,yr^{-1}$, respectively, representing a 4.6% increase. The increase in light use efficiency (LUE) was higher and reached 20%. On average, the control plots had a LUE of 0.9 g of dry mass (DM)/MJ compared with 1.10 g DM/MJ for the treated plots. There is a considerable opportunity to increase forest productivity through fertilization, and it may be possible to obtain greater gains than those observed in this study. This information is important to estimate the expected responses to intensive silviculture and will help to decide where silvicultural treatments should be applied to maximize the gains obtained from the investment. O. Carrero and others. Productivity gains from weed control and fertilization of short-rotation *Eucalyptus* plantations in the Venezuelan Western Llanos. [*Forest Ecology and Management* 430:566-575 2018] D

LEAF TRAITS EXPLAIN THE GROWTH OF TREE SPECIES PLANTED IN A CENTRAL AMAZONIAN AREA

Tree species selected for planting should exhibit both high survival and fast growth. The growth of a tree or forest plantation is affected by the resource supply (light, water and nutrients), the fraction of resources acquired and resource use efficiency. Leaf traits related to the last two processes have the potential to explain the growth rates. In this study, we evaluated 24 leaf traits (morphological and physiological) at the individual level to investigate whether simple leaf traits can be used to predict the variation in relative growth rates of eight native tree species in a mixed plantation in disturbed areas in Central Amazonia 15 months after planting. *Tachigali vulgaris* and *Trattinnickia rhoifolia* exhibited the highest growth rates in both height and diameter, which were approximately three and two times higher than those of *Bombacopsis macrocalyx*, respectively. Species exhibited different establishment strategies as indicated by the functional leaf trait performance. *Tachigali vulgaris*, *Ochroma pyramidale*, *Trattinnickia rhoifolia* and *Ceiba pentandra* are efficient resource use species, have high light-saturated photosynthetic rates and are tolerant to high irradiance stress. *Endlicheria anomala* exhibited the worst performance based on functional traits, with the lowest light-saturated photosynthetic rate (A_{max}) and maximum quantum yield of photosystem II (F_V/F_M). Of all traits analyzed, 12 leaf traits were correlated with the relative growth rate (RGR). Leaf traits related to resource acquisition, such as individual leaf area, chlorophyll content, leaf water potential and leaf nutrient concentration, were not good predictors of growth. Only stomatal conductance (g_s) was related to the RGR. Leaf traits related to photosynthetic use efficiency (carbon use efficiency and photosynthetic nitrogen and phosphorus use efficiency) explained, on average, 20% and 30% of tree growth in height and diameter, respectively. Resource use efficiency traits were better predictors of growth

than the individual physiological traits g_s and A_{max}, which explained, on average, 12% and 19% of the growth in height and diameter, respectively. Photosynthetic efficiency-related traits are good predictors of tree growth, and species with high efficiency – such as *T. vulgaris*, *O. pyramidale*, *T. rhoifolia* and *C. pentandra* – can achieve high growth in Amazonian disturbed areas. The identification of species with better performance during initial establishment can improve the design of mixture plantations in disturbed areas. Additionally, the selection of traits most correlated with growth performance can be more informative for reforestation monitoring; consequently, previous silvicultural interventions can be adopted prior to the reduction in both growth and survival rates. Z. T. M. Guimarães and others. Leaf traits explaining the growth of tree species planted in a Central Amazonian disturbed area. [*Forest Ecology and Management* 430:618-628 2018] D

ALLOMERIC RELATIONSHIPS OF STEM VOLUME AND STAND LEVEL CARBON STOCKS AT VARYING STAND DENSITY IN *SWIETENIA MACROPHYLLA* PLANTATIONS, BANGLADESH

Estimation of biomass carbon per unit area of forests or woodlands is of great concern to ecologists and forest managers considering global climate change scenarios. In the framework of this study, we intend to develop allometric models to predict stem volume and stand level carbon stocks in monoculture mahogany (*Swietenia macrophylla* King) plantations. It was also investigated that how stand density would influence stem volume allometric equations as well as carbon stocks per unit area. Results show that the two-variable model having less than 3% mean prediction errors (MPEs) is suitable for stem volume allometric equation, and two-variable or combined-variable models having less than 2% MPEs are equally suitable for allometric equations of stand level carbon stocks. It was also found that in *S. macrophylla*, stem volume allometric equations are not significantly influenced by stand density. We found that mean tree carbon (kg tree^{-1}) in *S. macrophylla* decreases at a rate of -1.58 with increasing stand density and stand level carbon stocks (Mg ha^{-1}) decreases at a rate of -0.58 with increasing stand density (trees ha^{-1}). The biomass carbon stocks (aboveground + belowground) in *S. macrophylla* varied between 34.4 and 351.9 Mg ha^{-1} having a mean of 120.2 Mg ha^{-1}. The allometric equations of stand level carbon stocks show influence of density, which is particularly prominent in the one-variable models, in contrast to the two- or combined-variable models. High precision estimate of stand level carbon stocks can be obtained using stand basal area multiplied by mean or maximum tree height. Our work also has implications on stand density management and the use of allometric equations in estimation of stem volume and carbon stocks. M. N. I. Khan and others. Allometric relationships of stem volume and stand level carbon stocks at varying stand density in *Swietenia macrophylla* King plantations, Bangladesh. [*Forest Ecology and Management* 430:639-648 2018]

TROPICAL FORESTRY NOTES (52)

MONITORING CANOPY BIRD ACTIVITY IN DISTURBED LANDSCAPE WITH AUTOMATIC RECORDERS: A CASE STUDY IN THE TROPICS

Tropical forests are facing threats that may affect the dynamics of seed dispersers which participate in the forest regeneration. To implement appropriate conservation programs, it appears necessary to monitor seed dispersers and to estimate their response to local changes. Here, we used non-invasive ecoacoustic methods to monitor the activity of a canopy bird, the White-throated toucan, *Ramphastos tucanus*, a major seed disperser and flagship species of the Amazonian forest. We deployed nine acoustic recorders over 29 days along a road that connects French Guiana to Brazil. We used template matching to automatically detect the vocalizations of *R. tucanus*. This method, which can easily be repeated with limited human expertise, detected 1748 recordings with *R. tucanus* vocalizations. A GLMM analysis was applied to test for a possible effect of habitat type and human activity, while accounting for time of the day and rainfall. The number of vocalizations varied according to time of the day with peaks at dawn and dusk. The number of vocalizations did not differ significantly among sites, they were not affected by habitat type, and they were only marginally influenced by human activity. These results indicate that the vocal activity of a key conservation species can be monitored automatically in a non-invasive way. The species targeted, *R. tucanus*, does not seem to be significantly impacted by the road and local human activity. This might be related to the mobility of the species, which can easily cross the road, as well as low local forestry pressure. M. Ducrettet and others. Monitoring canopy bird activity in disturbed landscapes with automatic recorders: A case study in the tropics. [*Biological Conservation* 245 108574 2020] D

JOBS, GAME MEAT AND PROFITS: THE BENEFITS OF WILDLIFE RANCHING ON MARGINAL LANDS IN SOUTH AFRICA

The private wildlife sector in South Africa must demonstrate value in the face of political pressures for economic growth, job creation and food security. Through structured survey questionnaires of landowners and managers from 276 private wildlife ranches, we describe patterns of wildlife based land uses (WBLUs), estimate their financial and social contributions and compare these with livestock farming. We show that 46% of surveyed properties combined wildlife with livestock, 86% combined two or more WBLUS and 80% conducted consumptive use activities. Intensive breeding was conducted on 46%of properties and covered 5.1% of their total land area. Revenues were higher on wildlife only properties than livestock farms, but we were unable to compare the compare the profitability of wildlife and livestock due to data gaps for livestock. Profits from WBLUs were highly variable, while mean return on investment (ROI) was 0.068. Wildlife properties employed more people per unit than livestock farms, properties conducting ecotourism employed more than twice as many people as non-ecotourism properties, and biltong hunting properties employed 50% fewer than non-biltong hunting properties. Mean game meat production on wild life only properties was 4.07 kg/ha, while the top producer's harvested game meat at a level comparable with some extensive livestock farms. We suggest that the financial and social benefits of wildlife ranching on marginal land make this viable land use, but that the contributions towards biodiversity conservation need to be towards quantified. The South African model could be suitable option for other African countries seeking sustainable land use alternatives. W. A. Taylor and others. Jobs, game meat and profits: the benefits of

wildlife ranching on marginal lands in South Africa. [*Biological Conservation* 245 108561 2020] D

THE RELATIVE CONTRIBUTION OF CAMERA TRAP TECHNOLOGY AND CITIZEN SCIENCE FOR ESTIMATING SURVIVAL OF AN ENDANGERED AFRICAN VULTURE

Technological advances such as camera traps, and citizen science, coupled with advanced and quantitative approaches, can help fill existing knowledge gaps and aid effective conservation. We combined citizen and camera trap observations to estimate survival of the endangered lappet-faced vulture, assess relative contribution of data from camera traps and citizens, as well as impact of loss of individual marks (wing tags), on survival estimates. We used data from 762 lapped-faced vultures wing tagged as nestlings during 2006-2017 in western Namibia. Observations of wing tagged individuals were provided by citizens or via camera traps. We formulated a multievent capture-mark-recapture model to estimate survival while accounting for probabilities of resighting by citizens and/or camera traps, recovery of dead individuals, and loss of the wing-tag. Survival was relatively high for juveniles (0.79) and increased with age to 0.95. Citizen observations of live and dead birds were low in number. However, when combined with camera trap, resightings of live individuals, citizen observation increased the precision of survival estimates of birds older than one year compared to using data from either source separately. Wing tag loss was high after 5-6 years of tag age. If neglected, tag loss can result in severe underestimation of survival of older age classes. Overall, we show that filling ecological knowledge gaps is possible through the efficient use of data provided by different sources, and by applying state-of the art approaches that minimize potential biases, such as those due to tag loss. A. Santangeli and others. The relative contribution of camera trap technology and citizen science for estimating survival of an endangered African vulture. [*Biological Conservation* 246 108593 2020] D

WHAT MOTIVATES THE MASSES: UNDERSTANDING WHY PEOPLE CONTRIBUTE TO COSERVATION CITIZEN SCIENCE PROJECTS

Participation in conservation citizen science projects is growing rapidly and approaches to project design are diversifying. There has been a recent shift towards projects characterized by contributors collecting data in isolation and submitting findings online, with little training or opportunities for direct social interaction with other citizen scientists. While research is emerging on developing citizen science projects by optimizing technological modalities, little consideration has been given to understanding what motivates individuals to voluntarily contribute data. Here, we use the Volunteer Functions Inventory, combined with open-ended questions, to demonstrate that the two strongest motivations underpinning participation, for both individuals who contribute data systematically (regularly; n=177) and opportunistically (ad hoc basis; n=218), are 'Values' and 'Understanding'. People take part in such projects because they have an intrinsic value for the environment and want to support research efforts (representing, 'Values'), as well as wanting to learn and gain knowledge (signifying 'Understanding'). Unlike more traditional citizen science projects that involve specific training and, considerable time investments, contributors to these newer types of projects are not motivated by the potential to develop their careers or opportunities for social interaction. The person-level characteristics of contributors considered in this study did not reliably forecast levels of motivation, suggesting that predicting high levels of motivation is inherently more complex than is often speculated. We

recommend avenues for future research that may enhance our understanding of contributor motivations and the characteristics that may underpin levels of motivation. R. Maund and others. What motivates the masses: Understanding why people contribute to conservation citizen science projects. [*Biological Conservation* 246 108587 2020] D

ARTIFICIAL HOLLOWS PROVIDE AN EFFECTIVE SHORT-TERM SOLUCTION TO THE LOSS OF NATURAL NESTING HOLLOWS FOR CARNABY'S COCKATOO

The ecology of one breeding population of Carnaby's Cockatoo *Calyptorhynchus latirostris* has been studied at Coomallo Creek, Western Australia, since 1969. A wildfire destroyed breeding habitat in part of the study area and adjoining areas late December 2009. An increase in the number of breeding attempts the following year suggested that hollows were probably limiting. From 2011, the number of hollows available to the cockatoos was increased by repairing derelict natural hollows and providing artificial hollows. By 2017, cockatoo had access to 87 natural and 68 artificial hollows the approximate dimensions of natural hollows. Artificial hollows were readily accepted, however there were significant differences in the probability of hollows being used to location use by type. Despite floor temperatures of black and white artificial hollows being warmer than those of natural hollows, there were no significant differences in the probability of hollow use, the probability of breeding failures, and nestling condition in either white or black and artificial hollows or natural hollow. The number of breeding attempts rose from 52 in 2011 to 127 in 2016 indicating that management intervention was effective. Between 2011 and 2018, artificial hollows provided 45% of available hollows and 54% of breeding attempts were made in them. By 2018, the number of breeding attempts in the area was 112% higher than in 2011. Artificial hollows provide an excellent sort-term solution to the continuing loss of natural hollows. However, without extensive re-establishment of breeding and foraging habitat, the future for Carnaby's Cockatoo is uncertain. D. A. Saunders and others. Artificial hollows provide an effective short-term solution to the loss of natural nesting hollows for Carnaby's Cockatoo *Calyptorhynchus latirostris*. [*Biological Conservation* 245 108556 2020] D

NATURE BASED MEASURES INCREASE FRESHWATER BIODIVERSITY IN AGRICULTURAL CATCHMENTS

This is the first study that describes the effect of adding mitigation measures on the freshwater biodiversity of all waterbody types in agricultural catchments. We measured alpha (site) and gamma (catchment) richness annually over a nine-year period in all the streams, pond and ditches in three upper-catchments in the English lowlands, and investigated whether freshwater plant biodiversity could be increased by adding: (i) multi-functional ecosystem services measures to intercept pollutants, store water and promote biodiversity, and (ii) biodiversity-only protection measures. In the absence of measures, all catchments saw a decline in macrophyte richness during the survey (mean species loss 1%pa, rare species loss for 2% pa). Ponds were a key habitat with a disproportionate influence on catchment trends. Five years after introducing measures, natural colonization of ecosystem services water bodies (dammed streams and ditches, runoff ponds, flood storage ponds) largely cancelled-out the background loss of plant species but, importantly, did not restore the loss of rare plants. Adding clean water ponds as a biodiversity- only enhancement measure brought substantial benefits: increasing total-catchment by 26%, and the number of rare plant species by 181%. Populations of spatially restricted species also increased. Adding stream debris-dams as a biodiversity measure did not affect plant richness or rarity. The findings suggest that ecosystem services measures could bring some biodiversity

benefits to agricultural catchments. However, creating clean-water ponds specifically targeted for biodiversity could hold considerable potential as a tool to help stem, and even reserve, ongoing declines of freshwater plant biodiversity across farming landscapes. P. Williams and others. Nature based measures increase freshwater biodiversity in agricultural catchments. [*Biological Conservation* 244 108515 2020] D

UNDERSTANDING HOPE AND WHAT IT MEANS FOR THE FUTURE OF CONSERVATION

Academic papers and media commentaries frequently appeal to hope as a necessary bulwark against despair for the conservation community. Such claims are often made in the absence of rigorous discussion of the nature of hope. In this review, we investigate the importance of hope as it applies to conservation workers, educators, and other involved in environmental protection. We define hope in its many dimensions, ask whether having hope is necessary to motivate people to engage in environmental action, and inquire whether hope can be revived or reframed when conservation action fail. Hope is a multi-faceted emotional state or motivational attitude with many subtypes, including authentic (or active), and passive, false, and radical hopes. The conservation literature generally refers to active hope, although the type of hope considered is often left unstated. Whether hope leads to environmental engagement or actions depends on many factors, including goal and orientation and feasibility, societal y personal norms, personality traits, and group identity. Organizational attributes like leadership, consistent vision, and interpersonal communication affect the experience of hope among conservationist practitioners, environmental educators, and the public. Grief and hopelessness are frequently part of the "emotional labour" of conservation and environmental work, but these may be buffered by a sense of agency and feasible objectives, which encourage authentic hope. Although there has been progress in understanding the role of hope in conservation, conservation communities can continue learn from the rich body of psychological theory and practice that has been used to study hope in other fields. A. Park and others. Understanding hope and what it means for the future of conservation. [*Biological Conservation* 244 108507 2020] D

DIFFERENTIAL EFFECTS OF DROUGHT ON NONSTRUCTURAL CARBOHYDRATE STORAGE IN SEEDLINGS AND MATURE TREES OF FOUR SPECIES IN A SUBTROPICAL FOREST

Nonstructural carbohydrates (NSC) play important roles in forest vulnerability to climate change, especially under increasing drought intensity and frequency. Understanding NSC dynamics is essential for accurately predicting the resistance and resilience of forests in response to drought. However, our knowledge of NSC responses to drought is still limited due to the lack of research in trees of different life stages. In this study, we conducted a thorough fall exclusion experiment (TFE) with four subtropical evergreen tree species to examine drought effects on NSC in mature trees and understory seedlings. Our result showed the differential effects of drought on NSC dynamics of understory seedlings and mature trees. In the TFE experiment, mature trees of all four species were relatively homeostatic with the insignificantly changed NSC pools, photosynthesis, and growth under the drought treatment compared to the control. In contrast, understory seedlings displayed significantly decreased in total NSC and soluble sugars ($-14.70 \pm 3.66\%$ and $-16.93 \pm 3.85\%$, respectively) with the exception of *Linthocarpus glabler* (*L. glaber*). The seedlings of *L. glaber* with the highest hydraulic resistance maintained or slightly increased NSC and its components in response to drought. Our study highlights the importance

of life stage in assessing drought effects of trees on NSC storage and then forest C cycling, which could be incorporated into the dynamic global vegetation models (DGVMs) to better understand drought effects on forest C balance in the future. P. Zhang and others. Differential effects of drought on nonstructural carbohydrate storage in seedlings and mature trees of four species in a subtropical forest. [*Forest Ecology and Management* 469 118159 2020] D

HOW FOREST STRUCTURE VARIES WITH ELEVATION WITH OLD GROWTH AND SECONDARY FOREST IN COSTA RICA

Clarifying how forests vary with elevation can inform our understanding of forests and their responses to climate. Despite the prevalence of secondary forests (defined as regrowth after disturbance), few studies have examined how their structure and recovery vary with elevation. Here, in apparently the first study of its kind, we explored how basal area, stem density and community wood specific gravity of stems >_ 10 cm diameter along an old growth and a 25-30 year old secondary forest transect, each spanning over 2000 m of elevation in Costa Rica. The old growth transect comprises 29 plots of 0.25 ha from 440 to 2900 m asl and the secondary 28 plots of 0.1 ha and 10 plots of 0.25 ha from 600 t0 2750 m asl. We characterized how stand characteristics vary with elevation using linear and generaled additive models. To our surprise, basal area increased with elevation not only in the old growth (from 24 to 56 m2/ha) but also in the secondary forest (11 to 59 m2/ha). This increase reflected the greater density of larger trees (>40cm diameter) at higher elevations. Basal area decreased with inferred water availability (global aridity index) in the secondary, but not the old growth forest. Surprisingly, wood specific gravity revealed no clear pattern with elevation in either transect though within stand variation decreased with elevation in both. In both forests, basal area is positively correlated with mean wood specific gravity, being significantly greater in stands with less variation in wood specific gravity. We interpret these patterns as resulting from reduced mortality of larger trees at higher versus lower elevations in both old-growth and secondary forest. Our results imply that planting trees to enhance recovery would be more beneficial in lowland than in high elevations. M. Muñoz Mazon and other. How forest structure varies with elevation in old growth and secondary forest in Costa Rica. [*Forest Ecology and Management* 469 118191 2020] D

TROPICAL FORESTRY NOTES (53)

GENERALIZED MODEL FOR PLANTATION PRODUCTON OF *EUCALYPTUS GRANDIS* AND HYBRIDS FOR GENOTYPE-SITE-MANAGEMENT APPLICATIONS

The use of process-based modelling of wood production in forest plantation has increased in recent decades amongst researchers and forest companies. Although, such models are used by several plantations researchers and managers, improved options and sensitivity to soil characteristics, genotype, and management options are desirable. A new generation of forest productivity modeling needs to extend previous capabilities and incorporate modern software engineering technologies. Our objective was to develop and evaluate an Agricultural Production Systems sIMulator (APAIM) Next Generation model for simulating the growth *Eucalyptus grandis* and hybrids with or of *E. globus* and *E. urophylla*. The model simulates stem, canopy and root development, resource capture and use (light, water, N) and C and N allocation as mediated by climate, soil, genotype physiological characteristics and management. Tree dimensions (stem diameter, height, and volume) are calculated as empirical functions of above-ground biomass. Datasets used for model calibration or independent evaluation were from diverse conditions in Australia (5 sites) and Brazil (13 sites), and at several of these sites there were treatments for fertilizer, irrigation or genotype. For the calibration and evaluation datasets, model performance was very good for above-ground biomass (Nash Sutcliffe Efficiency, NSE=0.96 and 0.84 respectively). Notwithstanding this general performance, and as an example, local calibration improved performance in one of the independent test datasets, suggesting that applications of the model for specific sites or clones may benefit from parameterization to local conditions. Simulation of management for weed cover, N fertilizer and genotype are also demonstrated. As the model performed well and has high flexibility, it warrants consideration by forest plantation managers and researchers for knowledge synthesis and operational productivity predictions of Eucalyptus and other plantation genotypes. P. J. Smethurst and others. Generalized model for plantation production of *Eucalyptus grandis* and hybrids for genotype-site-management applications. [*Forest Ecology and Management* 469 118164 2020] D

THE INFLUENCE OF FOREST SURROUNDINGS ON THE SOIL FUNGAL COMMUNITY OF BLACK TRUFFLE (*TUBER MELANOSPORUM*) PLANTATIONS

Black truffles are a highly value non-wood forest product. The success of truffle plantations is arousing the interest to establish orchards within forest settings. One main concern is that the forest may act as a source of ectomycorrhizal fungi that could displace *Tuber melanosporum* in plantations and impair truffle production. We studied the effects of host tree distance to the surrounding forest on *T. melanosporum* development and on the root-associated fungal community. Our research was carried out in a 5-year old holm oak (*Quercus ilex*) plantation established in an abandoned pasture surrounded by a *Q. ilex* forest in the Pyrenees. The spatial distribution of different fungal guilds as well as of *T. melanosporum* mycelium quantity and mating type's frequency was correlated with the distance to the forest and the diameter of the trees. We found a higher relative abundance of non-*T. melanosporum* EcM fungi associated with the trees closer to the forest. Larger root collar diameter had greater biomass of *T. melanosporum* mycelium and displayed fungal community compositions lees affected by the distance to the forest. No associations between the biomass of T. *melanosporum* mycelium in the soil and the distance to the forest or the abundance of non-T. *melanosporum* EcM fungi were observed. Our results indicated that T. melanosporum inoculated oaks planted in oaks in areas surrounded by

forests may be colonized by other ecto-mycorrhizal species, and develop a distinct microbial community from those usually established in agricultural lands. Further investigations should be carried out to determine whether a different fungal community may affect truffle production in the future, but to date, truffle mycelium does not seem to be impaired. D. Oliach and others. The influence of forest surroundings on the soil fungal community of black truffle (*Tuber melanosporum*) plantations. [*Forest Ecology and Management* 469 118199 2020] D.

SATELLITE OBSERVATIONS OF FOREST RESILIENCE TO HURRICANES ALONG THE NORTHERN GULF OF MEXICO

As one of the most destructive natural disasters, hurricanes pose a great threat to forest ecosystems, particularly, in the coastal regions. A better understanding of forest resilience to hurricane disturbances is essential for reducing hazard risks as well as sustaining forests in a time of increasing climate disasters. Although hurricane-induced forest damage has been extensively studied at both local and regional levels, the lack of large-scale assessments of post-hurricane recovery still limits our understanding of forest resilience to hurricanes disturbances. In this study, we utilized four remotely sensed vegetation indices (VIs), including the normalized difference infrared index (NGII), enhanced vegetation index (EVI), leaf area index (LAI), and solar-induced chlorophyll fluorescence (SIF), to examine the forest resilience to hurricanes of different strengths by quantifying the resistance, net change, and recovery of the forest after hurricanes that made landfall along the northern Gulf of Mexico from 2001 to 2015. The results revealed that the NDII was superior in monitoring the large-scale forest resilience. SIF exhibited a performance similar to that of the EVI. Wind speed was found to be the leading factor affecting forest damage and post-hurricane recovery. The impacted forest canopy began to recover approximately one month after the landfall. Woody wetlands exhibited less VI reduction and shorter recovery time than evergreen forest for the same category of hurricanes. For regions dominated by evergreen forest, NDII values lower than the multiyear average were observed across all seasons during the year after being impacted by a major hurricane. The widespread drought of 2006/2007 has aggravated the VI decrease and substantially extended the recovery period after hurricanes Ivan and Katrina. Overall, our findings derived from satellite observations provide essential information for understanding forest resilience to hurricanes as well as implementing efficient post-hurricane forest restoration. C. Gang and others. Satellite observations of forest resilience to hurricanes along the northern Gulf of Mexico. [*Forest Ecology and Management* 472 118243 2020] D

OPTIMIZED FOREST PLANNING: ALLOCATION OF LOG STORAGE YARDS IN THE AMAZONIIAN SUSTAINABLE FOREST MANAGEMENT AREA

In Amazonian native forest management, forest road infrastructures such as log storage yards and skid trails, are the most expensive attributes and are responsible for the significant environmental impacts with selective tree felling. Road optimization is crucial for reducing environmental impacts and production costs and is strongly linked to the optimal location of storage yards, which are essential to forest road planning. Considering the present problem and the current solutions available, this case study aimed to evaluate the efficiency and eventual gains of optimized forest planning (OFP), as compared to traditional forest planning (TFP). The TPF method is currently used most frequently by forest companies in the Amazon region. The study area of 126.41 ha belongs to the National Forest (NAFO) Saraca-Taquera, Forest Management Unit II (FMU-II), Annual Production Unit (APU) 04/2018, and Work Unit (WU) 2.

For the analysis, two areas were defined for exploration: the first was explored using the OFP mathematical model (57.75 ha) and the second followed the TFP plan of the company (68.66 ha). Plans and executions for both areas were compared. The OFP model significantly reduced the Euclidean distances between tree and yards, with only 0.23 km difference in the amount of planned forest roads, when compared to TFP. Additionally, OFP demonstrated a higher productivity (trees h^{-1} and m^3 h^{-1}), a reduction of skid distance (by an average of 17.16%), and reduce the cost of logging skidding (m^3 by 25.76%). Thus, this study proved that OFP is a viable solution that can be adopted by companies to increase productivity. E. Ferreira da Silva and others. Optimized forest planning: allocation of log storage yards in the Amazonian sustainable forest management area. [*Forest Ecology and Management* 472 118231 2020] D.

GROWTH, PHYSIOLOGICAL RESPONSES AND WOOD PRODUCTION OF AN *ACACIA AURICULIFORMIS* PLANTATION IN SOUTHERN VIETNAM FOLLOWING MID-ROTATION THINNING, APPLICATION OF PHOSPHORUS FERTILIZER AND ORGANIC MATTER RETENTION

Acacia auriculiformis plantations are widely planted in Vietnam. Initially they were grown for wood chip production, but these plantations have potential to be managed for higher value sawing and/or peeling grade logs, through enhanced silvicultural management. This study sought to understand the impact of resource constraints on responses of *A. auriculiformis* plantations to thinning, phosphorus fertiliser application and slash retention at age four years on growth and physiology of *A. auriculiformis* trees to rotation end at age nine years. A trial in South Vietnam had a factorial combination of thinning (unthinned (planted at 1666 trees ha^{-1}), or thinned to 833 trees ha^{-1}), P fertilizer (Nil, or 50 kg P ha^{-1}), and organic matter manipulation (slash and litter retained or removed). Thinning significantly increased photosynthetic rate (A_{max}) compared to control (unthinned) for at least 12 months after treatment application. Combined thinning and phosphorus fertiliser (P) application increased A_{max}, but A_{max} in the unthinned treatment did not significantly increase when supplied with additional P. Foliar nitrogen and phosphorus concentrations were greater in thinned than in unthinned treatments. Thinning commensurately reduced the leaf area, but subsequently, leaf area increased again in the thinned treatments compared to the unthinned treatments, such that twenty months after thinning there were no significant differences in leaf area index between thinned plus P fertiliser and unthinned treatments. There were significant differences in the mean diameter under different thinning regimes at one and five years after thinning. At nine years, average diameter of unthinned treatments (16.2 cm) was significantly less than the average diameter of the thinned treatments (19.0 cm). The application of P fertiliser or differences in management of slash and litter had no significant effect on mean tree diameter. The recovery of larger sawlogs was significantly higher in thinned (68%) than in unthinned treatments (25%). At nine years, the total stand volume of wood products from the thinned treatments (including the thinnings harvested in year four) was 340 m^3 ha^{-1}, which was 11 m^3 ha^{-1} higher than for the unthinned treatments (329 m^3 ha^{-1}). The results suggest that a commercial mid-rotation thinning of *A. auriculiformis* in these environments can increase the value of these plantations to acacia growers. V. D. Houng and others. Growth, physiological responses and wood production of an *Acacia auriculiformis* plantation in southern Vietnam following mid-rotation thinning, application of phosphorus fertiliser and organic matter retention. [*Forest Ecology and Management* 472 118211 2020] D

CLIMATE ADAPTIVE SILVICUTURE STRATEGIES: HOW DO THEY IMPACT GROWTH, YIELD, DIVERSITY AND VALUE IN FORESTED LANDSCAPES?

Forest managers have been wrestling with questions of how best to prepare today's forests for a future climate that may be quite different from the climate under which they were established. We used the LANDIS forest landscape model to conduct a factorial simulation experiment to assess the landscape-wide effects of alternative cutting and planting practices in northern Wisconsin (USA) under three climate change scenarios simulated for 300 years to allow demographic legacies to be overcome by the experimental treatments. Our objective was to assess the relative ability of actionable components of silvicultural strategies to maintain productivity and economical and ecological values of forests under future climates compared to a "business as usual" (BAU) silviculture scenario representing current sustained yield practices. We found that the general effect of climate change was to increase the biomass of all species (CO_2 fertilization and increased growing season), although the most cold-adapted species eventually declined under warming climate scenarios. Two alternative silvicultural strategies produced clearly different outcomes compared to the BAU scenario. Total landscape tree biomass was least under BAU, reflecting its high biomass removal rates, and greatest under the most aggressive climate-adapted silviculture strategy coupled with a high CO_2 climate scenario due to increased growth and relatively high removal rates. Harvested outputs responded to both climate and silvicultural strategy, with the high CO_2 scenario reducing biomass available for harvesting compared to a moderate CO_2 scenario, except under the aggressive climate-adapted strategy. Our study suggests that creative silvicultural practices can be developed (and tested) to maintain productive and ecologically healthy forests under future climate conditions. E. J. Gustafson and others. Climate adaptive silviculture strategies: How do they impact growth, yield, diversity and value in forested landscapes? [*Forest Ecology and Management* 470-471 118208 2020] D

HABITAT RESILIENCE FOR SONGBIRDS: THE ROLE OF TOPOGRAPHIC POSITION IN A MIXED DECIDUOUS FOREST

Climate change is altering patterns of resource availability and this may have negative effects on insectivorous forest birds in the US upper Midwest. As invertebrate life circle phenology shifts due to earlier spring leaf-out, nesting birds are vulnerable to phenological mismatches between food supply and demand. Areas with complex topography, and thus a variety of thermal and humidity conditions, may support a greater variety of plant and invertebrate phenological rates and stages within close proximity than are found in areas with simple topography. However, the extent and magnitude of this phenomenon is unclear, as is the degree to which topographic position may influence the ability of species to persist during extreme conditions. We examined the effects of topographic position on the phenology of a tri-trophic forest system over two years from spring through mid-summer. We hypothesized that in cool microsites the likelihood of trophic mismatches and late season food shortages is lower than in warm microsites. At 70 sites in the Baraboo Hills, part of the Driftless Area of the US Midwest, we recorded leaf-out timing of over 700 deciduous trees, measured weekly changes in invertebrate biomass on understory foliage, and conducted bird point counts to assess avian species richness and density. In stream gorges, cooler temperatures were associated with slight but significant delays in leaf-out timing of canopy and understory deciduous trees relative to upland sites. At all sites, invertebrate biomass was distributed relatively evenly across the study period, in contrast to other temperate zone sites where phenological mismatches have been reported between birds and their

invertebrate prey. Invertebrate biomass was similar in stream and gorges and uplands in both study years. Insectivorous bird species richness was greater in stream gorges than in the surrounding upland forest during both seasons and was positively related to Lepidoptera larvae biomass in the understory. Among eight abundant insectivorous bird species, density was similar in the uplands and stream gorges, among four species density was higher in uplands, and density of two species was higher in stream gorges. These results suggest that insectivorous birds within this study area are unlikely to experience trophic mismatches and that despite having cooler microclimates and higher avian species richness; stream gorges did not provide more invertebrate food resources than uplands under the climate conditions of the years in which we sampled this tri-trophic system. M. E. Persche and others. Habitat resilience for songbirds: The role of topographic position in a mixed deciduous forest. [*Forest Ecology and Management* 472 118238 2020] D.

SUPERVISED LOGGING AND CLIMBER CUTTING IMPROVES STAND DEVELOPMENT: 18 YEARS OF POST-LOGGING DATA IN A TROPICAL RAIN FOREST IN BORNEO

We analyzed 18 years of post-logging data from Sabah, Borneo to evaluate the impact of two selective logging methods – Supervised logging (SL) including pre-aligned skid trails and directional felling, and conventional logging (CL), where trees were felled before the crawler tractor was called in for skidding and the fellers had no formal training in felling techniques – on net standing volume recovery, survivor growth, ingrowth and mortality of trees ($\geqslant$10 cm DBH). The logging treatments were either combined with- (CC) or without (NCC) pre-harvest climber cutting in a randomized 2×2 factorial design consisting of 16 one-hectare treatment plots. We investigated the effect on the complete stand including all trees ($\geqslant$10 cm DBH) regardless of species, but also distinguished between the effects on the commercially interesting species of dipterocarps (Dipterocarpaceae family) and pioneer species (mainly *Macaranga* species). Supervised logging in combination with climber cutting was in many ways beneficial to stand development and these effects were mainly expressed at higher harvest intensities. For example, supervised logging reduced the ingrowth and survivor growth of pioneer *Macaranga* spp.; at high harvest intensities approximately 50% fewer pioneers grew in when SL was used in comparison to CL. In addition, climber cutting increased the ingrowth as well as decreased the mortality of highly valuable dipterocarp species with increasing harvest intensity. These effects appeared also to have stand level consequences as forests treated with the combination of supervised logging and climber cutting also exhibited faster recovery in standing volume of high value dipterocarps compared to any other combination of treatments. We conclude that, with improved ingrowth of dipterocarps, reduced overall mortality and generally better stand volume recovery; supervised logging (SL) in combination with climber cutting (CC) could be an attractive forest management system in mixed dipterocarp forests. D. Lussetti and others. Supervised logging and climber cutting improves stand development: 18 years of post-logging data in a tropical rain forest in Borneo. [*Forest Ecology and Management* 381 335-346 2016] D

ACCELERATING TROPICAL FOREST RESTORATION THROUGH THE SELECTIVE REMOVAL OF PIONEER SPECIES

Demand for tropical forest restoration has grown rapidly as the potential role of recovering secondary forests in sequestering carbon and enhancing biodiversity has been recognized. Active forest management is often prescribed to accelerate natural regeneration, but evidence for the

efficacy of interventions is scarce for tropical forests. In this study we examine the hypothesis that the selective removal of abundant pioneers in the understory of recovering selectively logged forests can improve the composition of forest stands and accelerate succession. Four selective treatments of increasing intensity were implemented in 8.75 ha compartments, and replicated six times. Within each compartment, three monitoring plots were established and measured immediately after thinning and one year later to assess implementation of thinning treatments, growth and survival of stems, and changes in stand composition. Canopy openness was measured using a hemispherical photography. Thinning treatments substantially reduced the abundance of pioneers, but there was only a slight increase in canopy openness (3.7-4.3%) relative to the control (1.8%) 8 months after implementation. Canopy openness increased dramatically across all treatments in the follow year due to the 2015-16 El Nino event and increased more in thinning treatments. Large ($\geq$10 cm dbh) and small (2-10 cm dbh) late-successional stems showed enhanced growth only in the low intensity thinning treatment, whereas the growth of small pioneer stems increased across the thinning intensity gradient. The cost of implementing thinning treatments was $US80 per ha or approximately 10% of the cost of planting treatments in the same forest. Our findings suggest that selective thinning of understory pioneer stems is a practical option for manipulating stand composition and potentially accelerating natural regeneration. Continued monitoring of the experiment should reveal the long-term impact and cost-effectiveness of treatments. T. Swinfield and others. Accelerating tropical forest restoration through the selective removal of pioneer species. [*Forest Ecology and Management* 381:209-216 2016] D

PROGNOSIS ON THE DIAMETER OF INDIVIDUAL TREES IN THE EASTERN REGION OF THE AMAZON USING ARTIFICIAL NETWORKS

The prognosis of forest structure along the cutting cycle, using models of individual trees, is one of the alternatives to manage tropical forests aiming at sustainability. Currently, in forest management practiced in the Amazon Region, growth and production models are not used to predict the future stock of the forest. Thus, the sustainable economic and environmental aspects of this activity remain uncertain. The aim of this present work was to model the growth of individual trees in a forest managed in the Amazon Region, by using artificial neural networks (ANN) to serve as subsidy to the wielder in obtaining future stock after logging, thus reducing uncertainty on forest management sustainability. Selective harvest was carried out in 1979 with an intensity of 72.5 m^3 ha^{-1} in a 64 ha area in the Tapajós National Forest - PA. In 1981, 36 permanent plots (50 m $\times$ 50 m) were installed at random and inventoried. There were nine successive measurements in 1982, 1983, 1985, 1987, 1992, 1997, 2007, 2010, and 2012. In the modeling of the future diameter, training and testing of ANN were carried out, including different semi-independent competition indexes (*DSICI*). All ANN, with and without *DSICI*, presented correlation above 99%, RMSE below 11%, and EF above 0.98. Based on the prognosis of tree growth, we were able to conclude that ANN can be effectively used to assist in the management of tropical forests and, thus, allow for the most suitable cutting intensity and cutting cycle per species, ensuring environmental and economic sustainability of forest management. L. Pequeno Reis and others. [*Forest Ecology and Management* 382 161-167 2016] D

ALLOMETRIC EQUATIONS FOR ESTIMATING TREE ABOVEGROUND BIOMASS IN EVERGREEN BROADLEAF FORESTS OF VIET NAM

For mitigating climate change through carbon sequestration and for reporting, Viet Nam needs to develop biomass equations at a national scale. These equations need to be accurate and provide quantifiable uncertainty. Using data from 968 trees across five ecoregions of Viet Nam, we developed a set of models to estimate tree aboveground biomass (*AGB*) in evergreen broadleaf forests (EBLF) at the national level. Diameter at breast height (*DBH*), tree height (*H*), wood density (*WD*), and combination of these three tree characteristics were used as covariates of the biomass models. Effect of ecoregion, wood density, plant family on *AGB* were examined. Best models were selected based on AIC, Adjusted R^2, and visual interpretation of model diagnostics. Cross-validation statistics of percent bias, root mean square percentage error (RMSPE), and mean absolute percent error (MAPE) were computed by randomly splitting data 200 times into model development (80%) and validation (20%) datasets and averaging over the 200 realizations. Effects models were used, the best results were obtained by using a combined variable (DBH^2HWD (kg) = (DBH (cm)/100)^2 × H (m) × WD (g/cm^3) × 1000) model $AGB = a \times (DBH^2HWD)^b$. Including a categorical *WD* variable as a random effect reduced AIC, percent bias, RMSPE, MAPE of models $AGB = a \times DBH^b$ and $AGB = a \times (DBH^2H)^b$; ecoregion as a random effect reduced the AIC of models $AGB = DBH^b \times WD$, $AGB = a \times (DBH^2H)^b$, and $AGB = a \times (DBH^2HWD)^b$. For models that did not include *WD* variable, including plant family as a random effect reduced AIC, RMSE, and MAPE; recommendations are provided for models with specific parameters for main families and without *WD* if this variable is not available. The overall best model for estimating *AGB* was the equation form $AGB = a \times (DBH^2HWD)^b$ with ecoregion as a random effect. B. Huy and others. Allometric equations for estimating tree aboveground biomass in evergreen broadleaf forests of Viet Nam. [*Forest Ecology and Management* 382:193-205 2016] D

TROPICAL FORESTRY NOTES (54)

ARE ODONATA COMMUNITIES IMPACTED BY CONVENTIAL OR REDUCED IMPACT LOGGING?

Timber harvest is a prevailing economic activity in Amazonia, which contributes to forest degradation and biodiversity loss. However, Reduced Impact Logging has been used to mitigate the loss of environmental integrity and biodiversity, since it has been assumed to be less detrimental than conventional logging practices. The objective of this study was to evaluate if environmental conditions, streams and Odonata communities in reduced- impact logging areas (RIL) are similar to those of unlogged areas (Control), whilst all are modified in conventional logging areas (CL), as a consequence of vegetation removal from the margins water bodies. Forty-nine streams in areas that differ in timber harvest practices were sampled in eastern Amazonia. As expected, aquatic systems show in RIL areas showed environmental conditions and Odonata species composition similar to CONTROL areas while CL streams differed both from CONTROL and RIL. Odonata richness and abundance were not different between CONTROL, RIL and CL treatments, however. Despite the fact that species richness and abundance changes may be masked by the presence of remaining riparian vegetation in CL areas, the use of reduced-impact logging minimizes changes in Odonata species composition and environmental conditions that remain similar to that of unlogged areas. This is possible due to planning to reduce environmental impacts in RIL. Unlike RIL, most canopy cover in the proximity of the water bodies (<10m distance) is lost in CL areas due to logging activities. L. Battico Calvao and others. Are Odonata communities impacted by conventional or reduced impact logging? [*Forest Ecology and Management* 382 143-150 2016] D

SUSTAINABILITY OF WOOD-USE IN REMOTE FOREST-DEPENDENT COMMUNITIES OF PAPUA NEW GUINEA

The impact of wood use by isolated Forest Dependent Communities (FDC) on forest conservation is not well understood. We present a study of wood use in the YUS area (combined watersheds of Yopno, Uruwa and Som rivers) in northern Papua New Guinea, where 57 communities depend on forests for their subsistence. Using a survey methodology based on the Poverty and Environment Network (PEN) survey protocol, we assess the annual volume of wood used, primary sources for this wood and evaluate the capacity of natural forest to sustainably support current rates of wood-use as well as their per capita CO_2 emissions. The primary reason for wood extraction was for fuelwood (6.4 kg person^{-1} day^{-1} or ~11.1 tonne household^{-1} year^{-1}) and housing construction (0.6 m^{-3} household^{-1} year^{-1}). Fuelwood was collected primarily from areas close to the village, in fallow (grassland) and agroforestry land types, while construction wood was being sourced primarily from secondary and primary forests. The volume of construction wood currently harvested across YUS was approximately 11% the annual increase in timber volumes in available and accessible natural forest. Under this wood use rate and projected population growth (2.5–4%) these communities can harvest construction wood at a sustainable rate for between 55 and 90 years. Nonetheless, we demonstrate that the CO_2 emissions from wood extraction, and in particular fuelwood, are high, approaching 1.15 tonnes CO_2 person^{-1} year^{-1}. Household surveys revealed that all smallholders had a strong interest in planting trees for production of wood for house construction, which could reduce pressures on forests and compensate for CO_2 emissions. T. Page and others. Sustainability of wood-use in

remote forest-dependent communities of Papua New Guinea. [*Forest Ecology and Management* 382:88-99 2016] D

CALCULATING CARBON CHANGES IN PEAT SOILS DRAINED FOR FORESTRY WITH FOUR DIFFERENT PROFILE-BASED METHODS

Boreal peatlands are an important carbon (C) sink. The effect of drainage for forestry on the soil C balance in those peatlands is a controversial debate. The Lakkasuo peatland, central Finland, comprise a minerotrophic and an ombrotrophic part, both partially drained for forestry. A pair-wise comparison was conducted and four different profile-based methods were applied to calculate the soil C balance. The first two methods used differences in ash content (I) between the upper and lower part of the profile and (II) between the drained and natural site of the peatland, respectively. The third method (III) used radiocarbon dated samples to calculate C accumulation rates at the natural site and compared these to the current C-stocks at the drained sites. The fourth method (IV) used radiocarbon dated samples to define a 1000-year layer in the profiles for comparing the C-stocks above this layer. Stable carbon isotope depth profiles, used for a qualitative assessment of the peatland status, identify both undrained sites as undisturbed. All four methods indicate a C loss at the minerotrophic drained site but of different magnitude $(0.057–0.272 \text{ kg C m}^{-2} \text{ yr}^{-1})$. At the ombrotrophic drained site both radiocarbon methods (III and IV) indicate a C gain $(0.139–0.179 \text{ kg C m}^{-2} \text{ yr}^{-1})$ whereas methods I and II suggest a C loss $(0.084–0.270 \text{ kg C m}^{-2} \text{ yr}^{-1})$. Method IV is considered the most stringent and robust one. Yet, the comparison of profile-based methods for C balance assessment suggests them to be applicable depending on site-specific conditions of nutrient status and presence of a natural reference site. J. P. Kruger and others. Calculating carbon changes in peat soils drained for forestry with four different profile-based methods. [*Forest Ecology and Management* 381:29-36 2016] D

ABOVE-GROUND CARBON STOCKS AND TIMBER VALUE OF OLD TIMBER PLANTATIONNS OF SECONDARY AND PRIMARY FORESTS IN SOUTHERN GHANA

High deforestation rates, especially in the tropics, currently result in the annual emission of large amounts of carbon, contributing to global climate change. There is therefore an urgent need to take actions to mitigate climate change both by slowing down deforestation and by initiating new sinks. Tropical forest plantations are generally thought to sequester carbon rapidly during the initial years but there is limited knowledge on their long-term potential. In this study, we assessed the carbon sequestration in old (42–47 years) timber plantations of *Aucoumea klaineana*, *Cedrela odorata*, *Tarrietia utilis*, and *Terminalia ivorensis,* and secondary forests of similar ages, by comparing their basal areas and above-ground carbon stocks (AGC) to that of nearby primary forests. Additionally, we estimated and compared timber volume and stumpage value in the three forest types. Systematic random sampling of ninety-three 20 m × 20 m plots in eleven forest sites (2 secondary forests, 2 primary forests, and 7 timber plantations) was undertaken to determine the effect of forest type on AGC, basal area, timber volume, and stumpage value. After 42 years of growth, mean AGC of the timber plantations $(159.7 \pm 14.3 \text{ Mg ha}^{-1})$ was similar to that of primary forests $(173.0 \pm 25.1 \text{ Mg ha}^{-1})$ and both were significantly higher than the mean AGC of the secondary forests $(103.6 \pm 12.3 \text{ Mg ha}^{-1})$. Mean basal area and timber volume of the timber plantations and secondary forests were similar to that of the primary forests, though in each case the timber plantations had significantly higher values compared to the secondary forests. Mean timber value of the plantations $(\$8577 \text{ ha}^{-1})$ was

significantly higher than both secondary ($1870 ha^{-1}) and primary forests ($3112 ha^{-1}). Contrary to our expectations, naturally regenerated trees (woody recruits) within the timber plantations had similar AGC levels, basal area, timber volume, and value compared to the secondary forests. Long-rotation tropical forest plantations under low-intensity management could achieve higher AGC levels and thus have higher climate change mitigation potential and timber values compared to naturally regenerated secondary forests, and are able to reach values similar to primary forests. Monoculture timber plantations could facilitate the successful colonization of their understoreys by native woody recruits that contribute considerably to stand AGC and timber values. Long-rotation forest plantations in the tropics therefore have a critical role to play in forest rehabilitation and climate change mitigation while having the potential to provide modest financial returns to landowners through selective harvesting of timber and/or payments for carbon sequestration. H. C. A. Brown and others. Above-ground carbon stocks and timber value of old timber plantations, secondary and primary forests in southern Ghana. [*Forest Ecology and Management* 472 118236 2020] D

GROWTH, MORFOLOGICAL, METABOTIC, AND PHOTOSYNTHETIC-RESPONSES OF CLONES OF *EUCALYPTUS* TO GLYPHOSATE

We hypothesized that *Eucalyptus* has clone-dependent responses to glyphosate, and such differential responses might be associated with morphological, metabolic and/or photosynthetic changes. Experiments were carried out under controlled conditions of temperature, photoperiod and nutrition, focusing on evaluating the response of *Eucalyptus x urograndis* clones (GG100 and I144) to increasing doses of glyphosate (0–1440 g ha^{-1} acid equivalent – AE) and to test whether a differential plant response would be associated to alterations in leaf morphology, plant and herbicide metabolism and photosynthesis. There was a significant reduction of plant height, stem diameter, number of leaves, leaf area and shoot dry mass caused by low doses of glyphosate ($\leq$180 g AE ha^{-1}, while a strong plant growth reduction (~60%) was caused by glyphosate field doses ($\geq$720 g AE ha^{-1}), in both clones. The GG100 clone was more susceptible to glyphosate field doses, while the I144 clone was more susceptible to glyphosate low doses. The stomatal index increased by 31% and the nervure thickness was reduced by 17% at 30 days after application of glyphosate at 180 g AE ha^{-1} (DAA) in the GG100 clone. Traces of glyphosate (<28 g mg^{-1} of dry mass) were found in leaf tissues of both clones at 1 DAA. Shikimic acid accumulated earlier (after 1 DAA) and in greater amounts (90%) in the I144 clone. Aminomethylphosphonic acid (AMPA) was not detected in either treated clone. The CO_2 assimilation rate, transpiration rate and stomatal conductance were reduced earlier (after 1 DAA) and more intensely (65%) in the I144 clone. The clone-dependent response is apparently associated with changes in plant metabolism related to glyphosate mode of action and gas exchange response differences between the clones. W. R. Cerveira Jr. and others. Growth, morphological, metabolic and photosynthetic responses of clones of eucalyptus to glyphosate. [*Forest Ecology and Management* 470 118218 2020] D

SOIL CARBON DYNAMICS IN DIFFERENT TYPES OF SUBTROPICAL FOREST AS DETERMINED BY DENSITY FRACTIONATION AND STABLE ISOTOOPE ANALYSIS

Quantifying carbon (C) dynamics with forest land-use change is essential for predicting C sequestration and stabilization. Here, we combined density fractionation and stable isotope analysis to examine soil C dynamics after primary native broadleaf forest (BF) were converted to

secondary forests (SF) and plantation forest (PF). The results showed that soil C stock at 0-30 cm depth decreased significantly from BF (70.8 MG/ha) to SF (60 MG/ha) and PF (53.9 MG/ha). Both soil C concentration and stock decreased, but soil isotope 13 C of the light and heavy fractions increased, and these increases were more evident in the topsoil (0-10 cm) than in the subsoil (10-30 cm). The decrease of the heavy fraction C stocks accounted for 52.7% and 69.7% of the reduction of bulk soil C stocks with conversion of BF to SF and PF, respectively. Analysis of isotope 13 C revealed that the input of new C into the light fraction of soil at 0-10 cm depth decreased by 13.1% with conversion of BF to SF, and by 34.0% with conversion of BF to PF. The decreases of soil C stocks in density fraction were primarily explained by soil properties (B=0.70) but also by vegetation biomass C (B=0.26) and were closely correlated with soil moisture content (0.69, the highest eigenvalue among soil properties) and floor litter biomass C (0.75, the highest eigenvalue among biomass C categories). Our findings help clarify the contrasting mechanisms explaining the dynamics of light and heavy fraction of soil C, and highlight the importance of both vegetation and soil in controlling changes in soil C dynamics in response to forest conversion. Accordingly, we recommend that management policies and actions should maximize biomass C inputs of degraded forest and minimize C losses. It follows that the preservation of primary forests might increase ecosystem C sequestration and thereby mitigates climate change. X. Luo and others. Soil carbon dynamics in different types of subtropical forests as determined by density fractionation and stable isotope analysis. [*Forest Ecology and Management* 475 118401 2020] D

POST-AGRICULTURAL SUCCESSION IN FALLOW SWIDDENS OF SOUTHERN BRAZIL

Agricultural practices have been occurring for centuries in the Brazilian Atlantic Rain Forest, which contains one of the highest levels of biodiversity in the world. The communities that still practice traditional shifting agricultural are constrained by legal, economic and social factors, which make the practice of itinerant agriculture a complex dynamic process. The long-term effect of repeated, long-fallows shifting cultivation on plant communities in secondary forest fallows of various age and slash-and- burn history was examined in a quilombola village in Southeastern Brazil. We carried out vegetations surveys in 12 cities, ten in areas of shifting cultivation and two in secondary forests formed after natural disturbances. We chose three age groups for sampling, i.e., post-harvest fallow or post-disruption times for natural area. The fallow period after cultivation ensures the continuous recovery of the composition and structure of vegetation, but even after five decades the alpha and beta diversities had not reached the values observed in mature forests. The number of species and basal area increased over time but the differences between areas in the same age group were as large as between age groups. The two disturbed natural areas had lower richness than the fallow swiddens of the same age. The data suggest that the intensive extraction of non-timber forest products to supply the market, and therefore extraneous to traditional activity, has negatively affected the stability of the system. Actions to recover stocks of these forest products together with integrated management and input of resources can maintain the sustainability of the system. E. Pereira Cabral Gomes and others. Post-agricultural succession in the fallow swiddens of Southeastern Brazil. [*Forest Ecology and Management* 475 118398 2020] D

INBREEDING DEPRESSION FROM SELFING AND MATING AMONG RELATIVES OF *HYMENAEA COURBARIL*

Inbreeding in trees can result in inbreeding depression (ID), which may affect adaptation and growth of individuals that originate from self- fertilization and mating among relatives. To investigate how inbreeding can affect seed, and seedling growth, we used microsatellite loci to determine the mating system of *Hymenaea courbaril* population and assess traits of seeds and seedlings for the expression of ID. Ninety-nine adult trees were mapped and genotyped and seeds collected from eight trees in a forest fragment Sao Paulo State, Brazil. Seed length and weight were measured and germinated seedlings that had been grown under nursery conditions were genotyped and measured for height and root collar diameter (RGD) at two-month intervals (7-17 months of age). Individual fixation index was estimated for each seedling, from which they were classified as originating from mating among unrelated parents (tu), related parents (tr), or selfing (s). This classification was confirmed using paternity analysis. Phenotypic means and ID of the measured traits were calculated for each determined s, tr, and s+tr group. Mating was not random due to the occurrence of self-fertilization (1.3%), mating among relatives (5%), and correlated mating (15.6%). Biparental inbreeding was attributed to significant spatial genetic structure up to 250 m. The mean fixation index within families was significantly higher in seedlings (0.184) than in adults (-0.035), indicating ID from seedling to adult stage. The ID varied among seed and seedling traits throughout the study and between mating groups. Self-fertilization resulted in greater ID for seed length (8.5%) and weight (21.3%) than for tr (<7%). The ID for height and RCD of selfed individuals tended to decrease over the course of the study. The values for ID for seedling height and RCD of the s group were greater (15.8-25.6% for both traits) than the tr group (3.1- 8.2%), with a total (s+tr) similar between height (7.6-9.4%) and RCD (8.1-10.5%). We recommend that seed collection is conduced across a large number of forest fragments in the region where the restoration is to be implemented, preferably in forests that are connected as possible to other remnants, to mitigate the effects of ID in future generations. Seeds must be collected from a minimum of 47 *H. courbaril* trees, respecting a minimum distance of 250 m between each tree to avoid collection of seeds from related individuals. L. C. S. M. Pereira and others. Inbreeding depression from selfing and mating among relatives of *Hymenaea courbaril* L [*Forest Ecology and Management* 475 118414 2929] D

TROPICAL FOREST MANAGEMENT ALTERED ABUNDANCES OF INDIVIDUAL TREE SPECIES BUT NOT DIVERSITY

In this study, we evaluated tree species abundance distribution in a Brazilian Amazon forest following reduced-impact logging and unlogged plots over two decades. A large body of literature shows changes in species abundance distributions (SADs) after disturbances in many systems and suggests those SADs are a useful tool for monitoring community recovery after impacts. We used Poisson lognormal distribution to described SAD, which has sigma and correlation parameters, for comparing species diversity before logging and over time. Sigma is a measure of alpha diversity and correlation expresses similarity between communities. Contrary to our expectations, we detected no changes for sigma, but correlation showed a decreasing trend, particularly after the first decade. Those changes were due to the increase in the abundance of pioneers and little recruitment of commercial species. Mortality was mainly attributed to the accidental death of non-targeted individuals. Because of the dominant role of random accidental tree deaths, the signature of logging operations was not detected immediately after logging using

sigma. Forest management did not cause changes in the abundance structure of communities if we disregard species composition. However, considering species composition, and particularly, which species were common or rare, we did not detect changes over time. The trends we have detected might be an early warning of a stronger long term tendency, which could affect abundance distributions. Due to the long lifecycle of trees and their slow growth rate, longer-term studies are needed to understand the impacts of logging tropical forests. R. Pereira Naves and others. Tropical forest management altered abundances of individual tree species but not diversity. [*Forest Ecology and Management* 475 118399 2020] D

USING LICHEN COMMUNITIES AS INDICATORS OF FOREST STAND AGE AND CONSERVATION VALUE

Evaluating the conservation value of ecological communities is critical for forest management but can be challenging because it is difficult to survey all taxonomic groups of conservation concern. Lichens have long been used as indicators of late successional habitats with particularly high conservational value because lichens are ubiquitous, sensitive to fine-scale environmental variation and some species require old substrates. However, the efficacy of such lichen indicator systems has rarely been tested beyond narrow geographic areas, and their reliability has not been established with well replicated quantitative research. Here, we develop a continuous lichen conservation index representing epiphytic macrolichen species affinities for late successional forests in the Pacific Northwest, USA. This index classifies species based on expert field experience and is similar to the "coefficient of conservation" that is widely used for evaluating vascular plant communities in the central and eastern USA. We then use a large forest survey dataset to test whether the community-level conservation index is related to forest stand age. We find that the lichen conservation index has a positive, linear relationship with forest stand age. In contrast, lichen species richness has only a weak unimodal relationship with forest stand age, and a binary indicator approach (where species are assigned as either old growth forest indicators or not) has a substantially weaker relationship with forest stand age than the continuous lichen conservation index. Our finding highlights that lichen communities can be useful indicators of late successional habitats of conservation concern at a regional scale. Quantitative lichen indicator systems provide unique information about habitat conservation value that is not capture by traditional community metrics such as lichen species richness. More broadly, indicator systems based on expert experience can have strong biological relevance. J. E. D. Miller and others. [*Forest Ecology and Management* 475 2020 118436] D

TOPMOST TREES AND FOREMOST SPECIES UNDERLIE TROPICAL FOREST STUCTURE, DIVERSITY AND BIOMASS THROUGH OPPOSING MECHANISMS

Tropical forests play a main role in the global carbon cycle, due to their higher exchange capacity of carbon dioxide with the atmosphere than any other forest type of the Earth. In this study, we aimed to explore the relative importance of foremost species and topmost trees in shaping forest structure, diversity and biomass in natural tropical forests. We hypothesized that topmost trees promote but foremost species decline tropical forest structure, diversity and biomass in a changing environment (i.e. the 'tree overtopping hypothesis'). We formulated three questions to assess the proposed hypothesis: (1) Are forest structure, diversity and biomass affected by both foremost species and topmost trees, and what is the magnitude and direction of each relative effect? (2) Are foremost species and topmost trees influenced similarly by multiple environmental factors? (3) How do foremost species and topmost trees mediate the feedbacks of forest structure, diversity and biomass to environmental factors? Using 189 plots data from Sri Lanka, we quantified 16 environmental (9 climate and 7 soil) factors, two indices of the topmost trees (i.e. top 1% large-diameter, and tall-stature) and their combination, four indices of foremost species (i.e. top 1% species' importance value index or each of its three components including either relative basal area, relative frequency or relative density), rarefied species richness, and stand density. We used structural equation modeling to test the proposed hypothesis. Strong positive effects of topmost trees whereas negative to negligible positive effects of foremost

species shaped tropical forest structure, diversity and biomass through opposing mechanisms, i.e., the promoting part of big trees and suppressing part of dominant species, respectively. Moreover, forest structure promoted biomass directly and indirectly via forest diversity. Environmental factors (i.e. high climatic water and low soil fertility) increased forest structure, diversity and biomass indirectly via topmost trees but decreased via foremost species. The main novelty or contribution of this study determines that the adverse effects of few foremost (i.e. dominant or abundant) species shaped forest structure, diversity and biomass in tropical forests when simultaneously considered the positive effects of topmost trees. Hence, encouraging topmost trees while managing foremost species might necessarily increase complementarity resource-use within a forest community, leading to positive forest diversity-structure-biomass relationships. We argue that both topmost trees and foremost species might have important influences on forest carbon stock in the context of global climate change. A. Ali and others. Topmost trees and foremost species underlie tropical forest structure, diversity and biomass through opposing mechanisms. [*Forest Ecology and Management* 473 118299 2020] D

DENDROECOLOGICAL INVESTIGATION OF THE RED-COCKADED WOODPECKER CAVITY TREE SELECTION IN ENDANGERED LONGLEAF PINE FORESTS

Old growth with longleaf (*Pinus palustris*) is a keynote/foundation species for 29 threatened or endangered species or species in the Coastal Plain of southeastern United Sates. The endangered red-cockaded woodpecker (*Dryobates borealis*; RCW) and endangered longleaf pine have an established ecological association. Here, we explore differences in climate/growth response and radial growth disturbance events in trees with RCW cavities compared to non-cavity trees in the Sandhills Gameland Reserve in North Carolina, USA. Using standard dendrochronological techniques, we collected and analyzed core samples from trees selected by RCW for their cavities (RCWC) and adjacent control trees (RCWCo) that had no visible cavity. We developed RCWC and RCWCo tree-ring chronologies that allowed us to examine if climate vulnerability is a component of the RCW selection process for their nests. Specifically, we investigated climate/growth responses, radial growth suppressions, and physical characteristics of both tree types through a comparison of tree age, latewood radial growth measurements, and number of resin ducts. For long-term climate response (1910-2018), we found no significant differences between RCWC and RCWCo trees. However, we identified temporal differences in climate/growth relationships between RCWC and RCWCo as well as significant differences in the number of suppression events and spatially-grouped suppression events. For tree physiology, we found more resin ducts during 1950-2018 in RCWC trees. Our dendroecological-based investigation examines multiple factors in addressing the question of why RCWs select specific longleaf pine trees for cavities which may help improve conservation efforts for RCW and longleaf pine. A. L. Kaiser and others. Dendroecological investigation of red-cockaded woodpecker cavity tree selection in endangered longleaf pine forests. [*Forest Ecology and Management* 473 118291 2020] D

FOREST CLEAR-CUTS AS HABITAT FOR FARMLAND BIRDS AND BUTTERFLIES.

The intensifications of agriculture has result in more homogeneous landscapes and decline of many species associated with farmland or other semi-natural open habitats. In parallel, forestry has also intensified causing declines in many species associated with old-growth forest. While intensive forestry negatively affects forest species, it inadvertently creates new habitats such as

clear-cuts, which attracts some farmland species. To understand the potential of clear-cuts as alternative habitat for farmland species, we need to know what makes clear-cuts attractive and whether they are suitable for reproductions and survival. We review literature on the occurrence of farmland birds and butterflies in forest clear-cuts and synthesize the current knowledge on factors and characteristics affecting their occurrence. Many farmland birds and butterflies do indeed use clear-cuts, and have been found in clear-cut up to ten years after felling. Clear-cut characteristic of importance include age, size, retention structures, land-use history and landscape composition. However, direct measures of resources abundance such as food and hostplants are often lacking. In addition to the potential benefit of individual clear-cut, the total clear-cut area in forested regions is often large. Together with the fact that clear-cuts may be occupied by farmland species for several years, the potential of clear-cuts as alternative habitat for farmland biodiversity is substantial. Clear-cuts with a history as meadows, the presence of species of conservation importance, or shorter distance to farmland could for example be motivations for focusing conservation efforts on farmland species instead of forest species. Gaining more knowledge on how farmland species use clear-cuts, and what characteristics they depend on, could help inform management guidelines. We are no advocates for forest clear-cuts, but given their ubiquity in forested landscapes, the potential of clear-cuts as alternative habitats for species suffering from loss of suitable farmland habitats is worth serious attention from a conservation perspective. D. Ram and others. Forest clear-cuts as habitat for farmland birds and butterflies. [*Forest Ecology and Management* 473 118239 2020] D

A COMPARATIVE ASSESMENT OF THE VERTICAL DISTRIBUTION OF FOREST COMPONENTS USING FULL-WAVEFORM AIRBORNE, DISCRETE AIRBORNE AND DISCRETE TERRESTRIAL LASER SCANNING DATA

Laser scanning has the potential to accurately detect the vertical distribution of forest vegetative components. However, limitations are present and vary according to the system's platform (i.e., terrestrial or airborne) and recording method (i.e., discrete return or full-waveform). Terrestrial configurations detect close objects (i.e., lower vegetation strata) in more detail while airborne configurations detect a more detailed upper strata, with weak backscattered signals from lower strata. Moreover, discrete lidar systems record single or multiple hits from a given pulse at intercepted features in contrast to full-waveform systems, which register the pulse's complete backscattered signal providing complete vertical profiles. In this study, we examine for a boreal and a Mediterranean forest with contrasted conifer canopy densities: (*i*) the characterization of the vertical distribution and signal occlusion from three laser scanning configurations: full-waveform airborne (ALS_{FW}), discrete airborne (ALS_D), and discrete terrestrial (TLS); (*ii*) the comparison in the detection of understory vegetation by ALS_{FW} and ALS_D using TLS as reference; and (*iii*) the use of a methodological procedure based on the Gini index concept to group understory vegetation in density classes from both ALS_{FW} and ALS_D configurations. Our results demonstrate, firstly, that signal occlusion can be quantified by the rate of pulse reduction independently for data from all three laser scanning configurations. The ALS_D configuration was the most affected by signal occlusion, leading to weak signal returns at the lower strata (z < 4 m) where the rate of pulse reduction was highest as a result of dense canopy covers. Secondly, we demonstrated the capabilities for both airborne laser scanning configurations to detect understory vegetation, albeit significantly more accurately with ALS_{FW}. Lastly, we demonstrated the use of the Gini index as an indicator to determine understory vegetation density classes, particularly for ALS_{FW} data in dense canopy cover. We proceed to explain the limitations in detecting the

vertical distribution from different configurations, and indicate that understory vegetation density classes may be successfully assigned with ALS$_{FW}$ in contrasted conifer canopy densities. P. Crespo-Peremarch and others. [*Forest Ecology and Management* 473 118268 2020] D

EFFECT OF THINNING INTENSITY ON PRODUCTIVITY AND WATER USE EFFICIENCY OF *QUERCUS ROBUR* L

Thinning intensity is an important factor affecting forest structure and density and influencing tree growth. The main objective of the study is to evaluate how the different intensity of thinning can influence, in the short and long term, the productivity and intrinsic water use efficiency (WUE$_i$) of *Quercus robur* L., a widespread European species. Three thinning types of different intensity were applied in 14-year mixed plantation of *Quercus robur* L. growing with *Alnus glutinosa* (L) Gaertn., a N-fixing species, with an initial density of 625 trees/ha. A multidisciplinary approach was applied, coupling the tree-ring analyses with the measurements of stable isotopes of carbon and oxygen. Findings highlighted how the different conditions of light and competition, determined by the type and intensity of thinning, triggered different responses of *Q. robur* species in terms of growth and WUE$_i$. Data suggested that the moderate selective thinning (31% reduction of total biomass) was not able to reduce the high competition for resources among individuals: this condition negatively influenced the trees growth. The presence of the N-fixing species, left after the thinning, was not able to counteract the negative effect of competition. A negative effect on productivity was recorded with the geometric thinning (62% reduction of total biomass). Indeed, this treatment resulted in an increase of asymmetry of the canopy (0.90 vs 0.83, respectively in pre- and post-thinning period), due to the partial crown competition from one side and with a consequent limitation of the photosynthetic activity of the trees. Finally, the very high selective thinning (75% reduction of total biomass) resulted to be the most appropriate management practice, as it guarantees positive effects both in terms of growth and intrinsic water use efficiency. The post thinning conditions determined high photosynthesis rates, an increase of productivity and a limited water loss. F. Niccoli and others. Effects of thinning intensity on productivity and water use efficiency of *Quercus robur* L. [*Forest Ecology and Management* 473 118282 2020] D

RESILIENCE OF LOWLAND ATLANTIC FOREST IN A HIGHLY FRAGMENTED LANDSCAPE: INSIGHTS ON THE TEMPORAL SCALE OF LANDSCAPE RESTORATION

The Atlantic forest is one of the most threatened tropical forest ecosystems in the world, and despite current knowledge, its ability to recover structure and diversity after a disturbance is still a matter of debate. Quantifying carbon stocks and species diversity in forests at different successional stages and assessing their recovery capacity is important for designing local conservation and restoration strategies. We investigated the resilience potential of lowland Atlantic forests at landscape-scale using a chronosequence approach in 160, 0.1-ha permanent plots, three old-growth and 13 second-growth forests at various stages of recovery. We assessed whether tree species richness, including species with high conservation values (endemic and threatened), composition and aboveground carbon stock recover along succession; and estimated how much of the old-growth forest values the 20-yr-old secondary forests had attained and the time needed to reach old-growth forests levels. Species richness, composition and carbon stock tended to recover along the chronosequence, while endemic and threatened species showed no relationship with forest age. After 20 yr of succession, the secondary forests recovered on

average 52% of total species richness, 21% of species composition and only 16% of carbon stock of old-growth forests. We predicted that the absolute recovery of lowland Atlantic forests would take eight decades to thousands of years, much longer than the 10–40 years targeted by national efforts to restore degraded ecosystems. Despite slow recovery, these regenerating forests are important for climate mitigation and biodiversity conservation as they potentially sequester 1.78 Mg C ha^{-1} yr^{-1} and harbor a number of species comparable to old-growth forests. Our findings indicate that achieving landscape restoration and conservation goals through passive restoration can be a challenge, highlighting the need to invest in management plans in areas with relatively low resilience and high biodiversity and carbon conservation values. N. Viera Hissa Safar and others. Resilience of lowland Atlantic forests in a highly fragmented landscape: Insights on the temporal scale of landscape restoration. [*Forest Ecology and Management* 470 118183 2020] D

THE LONG-TERM PERFORMANCE OF 35 TREE SPECIES OF SUDANIAN WEST AFRICA IN PURE AND MIXED PLANTINGS

The rapidly growing human population in Sudanian West Africa has generated increasing demand for agricultural land and forest products so that most of the original vegetation cover has disappeared and the remainder is highly degraded, meaning that it is urgent to draw up a long-term assessment of the potential of local species to be promoted in pure and mixed plantings as contribution to global forest restoration efforts. We inventoried the survival and growth of 5817 trees belonging to 35 species planted more than 25 years ago in pure and mixed plantings. For a subset of individuals, we estimated heights and volumes of standing timber. We found that (i) the long-term survival (from 50 to 99%.yr^{-1}) and diameter growth (from 1 to 10 mm.yr^{-1}) are highly diverse between species and not correlated to each other, (ii) the annual increase in biomass per tree averages 2.22 kg while the annual increase in stand biomass may be over 6 Mg. ha^{-1} for three highly-productive species (*Khaya senegalensis*, *Pterocarpus erinaceus* and *Anogeissus leïocarpa*) (iii) the effect of mixture on annual growth is significantly positive with an across-species gain of 0.7 mm.yr^{-1} while there is no effect on the survival probability. Considering a potential productivity of 10 m^3 of timber wood per hectare at 30 years, 13 species have been retained in the list of woody species of interest for planting in the Sudanese zone of West Africa. B. Hérault and others. The long-term performance of 35 tree species of sudanian West Africa in pure and mixed plantings. [*Forest Ecology and Management* 468 118171 2020] D

QUANTIFYING LOSSES IN PRODUCTIVITY BY THE RUST IN EUCALYPT PLANTATIONS IN BRAZIL

The eucalyptus plantations in Brazil have been great importance in economy with 1.3% of the Gross Domestic Product, so their productivity has recently been extensively researched by the forestry. This productivity is affected by abiotic and biotic factors. Among the biotic factors we can highlight the rust, which attacks and generates large long-term losses in large scale. The aim of this paper is to measure the effect of the rust disease in eucalyptus stand by the statistical-models approach. Firstly, a new index named Rust Severity Index – R S I has been proposed. The index is a weighted average of the severity scale by the inverse of age in days. The generalized linear model has been used to model the effect of region/farm and severity of disease in maximum sample volume (m3) of the plantations. We also fit a generalized linear regression model to maximum sample volume (m^3) of the plantations by the rust severity index. Finally, Gompertz nonlinear regressions models were fitted to the volume growth according to region/farm and rust severity. Then, it has been possible to measure the losses in volume (m^3)

due the rust severity by the percentage difference between the rust severity categories at 51st and 72nd months. A. Passos dos Santos and others. Quantifying losses in productivity by the rust in eucalypt plantations in Brazil. [*Forest Ecology and Management* 468 118170 2020] D

TROPICAL FORESTRY NOTES (56)

PLANT TRAITS AS INDICATORS OF RECOVERY OF RECLAIMED WELL SITED IN FORESTED AREAS: SLOW BUT DIRECTIONAL SUCCESSION TRAJECTORY

Trait-based approaches can provide a generalizable mechanistic understanding of complex post-disturbance succession dynamics of plant communities. Much of our knowledge regarding successional trajectories of functional trait composition come from observations of natural disturbances that leave physical and biological legacy on site for self-regeneration. We lack, however, understanding of the long-term recovery in severely degraded lands following reclamation through active vegetation. To address this gap, we examined changes in trait composition of forest understory plant communities in reclaimed oil and gas wellsites using chronosequence data (7-48 years since reclamation) to assess recovery towards that post-harvest and natural post-fire reference forest sites. We used multiple traits associated with resource acquisition (i.e., fast growth and performance ability metrics (i.e., shade-tolerance) with putative environmental factors to evaluate the trait-environment relationships underlying plant community recovery in reclaimed sites. We found an overall directional change in functional composition with time since reclamation towards that observed in reference sites, but even older reclaimed sites remained significantly different from reference sites. This could be related to differential trajectory patterns among traits where some trait values progressed towards those of reference (long distance dispersal by wind decreased with time since reclamation) whereas some fast-resource acquisition traits and exotic species showed no change and remained dominant in older reclaimed sites. The strong link between traits and environment suggest a significant influence of time and subsequent developing site conditions (e.g., canopy cover) as well as enduring legacies of wellsite operation/reclamation (e.g., high soil bulk density and exotic species) on functional composition. Knowledge of functional composition trajectories in severely degraded ecosystems, such as wellsites, could improve our understanding of recovery processes and inform more effective reclamation practices by identifying putative underlying environmental factors and specific ecological attributes that may delay successful recovery. E. T. Azeria and others. Plant traits as indicators of recovery of reclaimed wellsites in forested areas: Slow but directional succession trajectory. [*Forest Ecology and Management* 468 118180 2020] D

DROUGHT RESISTANCE TRAITS PREDICT TREE SPECIES PERFORMANCE IN A HUMID TROPICAL LANDSCAPE, BUT THEIR IMPORTANCE SHIFTS BETWEEN MANAGED COVER TYPES

In the humid tropics, the substitution of forest cover by open pastures generates hotter and dryer conditions limiting the establishment of native plants. In this context reforestation of pastures using fast-growing tree species is commonly used to improve the environmental conditions, however, contrary to expected this strategy may lead to drier soil conditions due to the elevated transpiration rates of large trees, overall generating landscape mosaics with high variation in light and water availability. Despite the high sensitivity of tree species from the humid tropics to drought, efforts to predict species performance in reforestation campaigns have been focused mostly on carbon gain traits, while ignoring the drought resistance traits. In this study we addressed the hypothesis that both carbon gain and drought resistance traits are good predictors of growth rate and survival of species under contrasting vegetation cover types in a managed landscape. To test this hypothesis, the growth and survival over 38 months, and 17 physiological

and morphological leaf traits related to carbon economy and drought resistance were measured in ten tree species planted in pastures and tree plantations. Plantations showed higher soil water depletion than pastures and the relative growth rate and survival of species were higher in pastures. Carbon economy and drought resistance traits together predicted interspecific growth rate and survival; however, the importance of functional traits as predictors depended on the cover type. Carbon acquisition traits (Am and AFE) were the best predictors in pastures, while drought resistance traits ($RWC_{tlp,}$ LDMC and ε) had the lowest magnitude of interspecific variation, but were the best predictors in plantations. This suggests that, despite its restricted variation, drought tolerance traits may be of paramount importance in defining tree performance and long-term success of managed species in the humid tropics, particularly under fast-growing tree covertures. This study shows that soil water might act as a limiting factor on plant performance in managed landscapes in the humid tropics, and challenges the common assumption that using a low diversity of fast-growing and highly resource-demanding species is the best strategy to reforest abandoned pastures and improve the environmental conditions for other species. L. Cifuentes and others. Drought resistance traits predict tree species performance in a humid tropical landscape, but their importance shifts between managed cover types. [*Forest Ecology and Management* 468 118160 2020] D

WHERE CAN PALATEBLE YOUNG TREES ESCAPE HERBIVORE PRESSURE IN A PROTECTED FOREST?

Browsing damage by ungulates is among the most decisive factors affecting the establishment and growth of young trees. In recent decades, ungulate populations have been expanding in the Northern Hemisphere; impairment of tree regeneration by their activity is an increasing problem. Herbivore-induced changes in tree regeneration may alter the composition and biodiversity of the future tree stand. In this study we determined where young trees can leave the seedling bank and succeed to higher forest strata in a protected natural forest that is under strong herbivore pressure. We studied rowan (*Sorbus aucuparia*) regeneration in a subalpine spruce forest growing in a strictly protected area of Babia Góra National Park (Western Carpathians). Rowan is one of the most palatable forest species, so browsing can significantly limit its growth. We predicted that factors, that restrict the movement of red deer (*Cervus elaphus*), decrease their visits in some forest patches, which will result in a higher share of rowan saplings. We also considered two other factors that can affect the distribution of rowan saplings: light availability and distance to maternal trees. In particular, we tested whether the occurrence of rowan saplings was related to: (i) slope angle, amount of logs lying on the forest floor, and distance to the hiking trails; (ii) distance to fruit-bearing trees; and (iii) canopy openness. The results confirmed our main predictions concerning the relation between the occurrence of palatable tree saplings and the availability of a forest area to ungulates. Factors related to the availability of terrain to red deer significantly influenced the distribution of rowan saplings taller than 1 m. The probability of rowan sapling occurrence increased when the amount of logs was higher and the distance to hiking trails was shorter. Slope had a significant negative impact on sapling occurrence. We found no effect of proximity of fruit-bearing rowan trees or canopy gap area. Thus, in the natural forest, the likelihood that young palatable trees will make the transition from seedlings to taller saplings seems to be determined mainly by factors related to ungulate activity. This suggests that the increase of ungulate populations and their browsing behavior will affect the species composition and spatial structure of future tree stands. F. Milne-Rostkowska and others. Where

can palatable young trees escape herbivore pressure in a protected forest? [*Forest Ecology and Management* 472 118221 2020] D

THE EFFECT OF WILDFIRE ON THE STRUCTURE AND WATER BALANCE OF A HIGH CONSERVATION VALUE (*NOTHOFAGUS GLAUCA* (PHIL.) KRASSER) FOREST IN CENTRAL CHILE

The structure and water balance of an *Nothofagus glauca* forest were measured in the year before and for two years after the wildfires of January 2017. The aim was to investigate the relationship between changes in structure and in transpiration, canopy interception, soil evaporation and their proportional contribution to evapotranspiration. This forest recovered rapidly after the fire. After two months there was evidence of resprouting from ground level in all species and after four months regrowth was visible in the crown of *N. glauca*. One year after the fire the leaf area index of the overstorey had recovered by about 1.5 units and about 70% of all the trees were supporting live growth either at the base or in the crown. The overstorey sapwood area was 5 m^2 ha^{-1} after the fire, down 60% from the 13 m^2 ha^{-1} measured before the fire. In the year before the fire the total transpiration, canopy interception and soil evaporation were respectively 210 mm, 258 mm and 46 mm (evapotranspiration of 514 mm). In the first and second year after fire transpiration was 78 and 127, canopy interception was 145 and 85 mm and soil evaporation was 125 and 143 mm. Compared to before the fire, transpiration after the fire was reduced by 63%, canopy interception was reduced by 44% and soil evaporation increased approximately three-fold. The combined effect of all these changes in the partitioning of rainfall was a 33% reduction in evapotranspiration. The reduction in transpiration was in proportion with the reduction in sapwood area and was partially offset by a threefold increase in soil evaporation. Two years after the fire the water balance of this forest had substantially recovered and at the current rate of recovery will be at pre-fire levels in 2021. D. A. White and others. The effect of wildfire on the structure and water balance of a high conservation value Hualo (*Nothofagus glauca* (Phil.) Krasser.) forest in central Chile. [*Forest Ecology and Management* 472 118219 2020] D

THE LONG-TERM EFFECTS OF ACTIVE MANAGEMENT AND LANDSCAPE CHARACTERISTICS ON CARBON ACCUMULATION AND DIVERSITY WITHIN A SEASONAL DRY TROPICAL ECOSYSTEM

Reforestation is the largest natural climate solution, while potentially reversing the biodiversity crisis, especially in tropical countries. Dry tropical forests are of particular interest because they experienced greater historic loss, and offer large reforestation opportunities. This study addressed the potential of secondary forests in dry tropical systems regenerating after 60 + years in cattle pasture to accumulate carbon while increasing floristic diversity. Total carbon and woody species diversity were quantified within experimental treatments established 15 years ago. Initial active management practices included removing exotic grass with herbicide, excluding cattle by constructing live fences, and monitoring succession relative to proximity to forested riparian zones and slope position. Overall, carbon accumulated relatively slowly in this landscape (1.30 MgC ha^{-1} yr^{-1}). Differences were seen between management practices and landscape characteristics. Lower slope plots, adjacent to forested zones, had significantly more carbon than upper slope plots, isolated from riparian zones. The initial application of herbicide decreased total carbon. However, natural regeneration of two valuable timber species with small seeds, *Astronium graveolens* and *Cedrela odorata*, benefited from this initial treatment. Live fences that were initially planted to exclude cattle significantly increased carbon of regenerating

woody species. Lianas were abundant at this successional stage. Almost half of all inventoried trees (44%) had at least one liana climbing through them, with the most common species being *Bauhinia glabra* and *Macherium microfolium*. Some valuable timber tree species found within older, protected riparian forests were not yet regenerating in any treatment, such as the wind-dispersed species, *Cieba pentandra*, and the animal dispersed species, *Hymenaea coubaril.* These species may need to be actively planted at the mid-successional stage (~15–20 years) to restore biodiversity. A trade-off between timber value, diversity, and carbon sequestration must be considered in reforestation programs and this depends on landscape characteristics and management. Passive management, even with invasive grass species, is a practical option when sites are located near forested riparian zones due to low cost and high timber value of a suite of native species that naturally regenerate. No intervention is needed other than continual protection from fire and grazing. However, low-cost management, such cutting lianas and enrichment planting at the mid-successional stage, is likely to increase carbon accumulation and diversity. More active management, such as planting drought-tolerant, higher timber value tree species, is recommended at sites isolated from forested riparian zones on upper slopes where carbon accumulation is lower. Tropical forest regeneration mechanisms in proximity to forest fragments can be surprisingly resilient if chronic human impacts are removed. H. P. Griscom. The long-term effects of active management and landscape characteristics on carbon accumulation and diversity within a seasonal dry tropical ecosystem. [*Forest Ecology and Management* 473 118296 2020] D

THE EFFECT OF OVERWOOD COMPETITION ON THE LONG-TERM SURVIVAL, GROWTH AND STOCKING OF UNDERPLANTED TREE SPECIES IN LOGGED TROPICAL RAIN FOREST IN NORTH QUEENSLAND, AUSTRALIA

Enrichment of selectively logged rainforest by planting seedlings of commercially valuable species is often recommended to improve productivity, ecological functioning, and biodiversity. However, the survival and subsequent growth of enrichment plantings depend on how they respond to competition from neighbours. For successful forest restoration or commercial forest management, the challenge is to determine appropriate frequencies and intensities of silvicultural interventions, principally competition reduction. In this study, we use long-term data (49–60 years) from four enrichment planting experiments established after selective logging and girdling of non-commercial trees in a tropical rainforest in north Queensland, Australia, to assess the effects of competition on the survival and growth of enrichment plantings. We found that residual overwood development severely reduced the survival, diameter and volume growth of two widely planted rainforest species - *Flindersia brayleyana* (Rutaceae) and *Agathis robusta* (Araucariaceae). Both species responded well to overstory removal, either as an initial treatment or thereafter. Use of Hegyi's competition index confirmed the strong suppressive effect of neighbours. The most abundant competitor was the fast-growing, early-secondary species *Acacia aulacocarpa*, which only became apparent after cessation of silvicultural treatments, 7 years after planting. Our results reaffirm the importance of an initial or early-age removal of the competing overstory for the success of enrichment planting. Further silvicultural treatments may be required for extended periods to control excessively increased overwood basal area and to remove late emerging pioneer or early secondary species. P. M. Quang and others. The effect of overwood competition on the long-term survival, growth and stocking of underplanted tree species in logged tropical rainforest in north Queensland, Australia. [*Forest Ecology and Management* 472 118241 2020] D

RESILIENCE OF A SUBTROPICAL RAINFOREST TO ANNUAL TYPHOON DISTRUBANCE: LESSONS FROM 25 YEAR DATA OF LEAF AREA INDEX

Quantifying ecosystem resilience is critical for predicting how shifts in disturbance regime affect ecosystem structure and function as a result of recent climate change. Studies of disturbance-ecosystem interactions often focus on one or a few disturbance events, but the interactions may vary considerably among disturbance events. We used a 25-year LAI (leaf area index) record of the Fushan Experimental Forest (FEF) of northeastern Taiwan to explore forest LAI resilience to annual typhoon disturbance. The four typhoons of 1994 caused the most dramatic change of LAI in both the magnitude and the rate, as well as the longest time for a full recovery. However, typhoons varied in their effects, and not all intense typhoons caused major impact suggesting that result derived from one or a few disturbance events is unlikely to capture the full spectrum of disturbance effect. Using LAI of 4.26 measured following a non-typical year of no typhoon occurrence as a reference, it took 11─16 years before the predicted LAI to return to the reference level, which represents the resilience (time to return) of the forest LAI under minimal typhoon effects. Using the event-based analyses, the average degree of return was 0.86, with values as low as 0.45, suggesting that the LAI of the FEF is not always able to fully recover within the inter-typhoon time period (<1 year). Once returned to the reference state, the LAI of the FEF stayed at the reference state for several months to several years. With annual typhoon disturbance and a return time longer than one year and may be up to more than one decade, the LAI of the FEF is constantly undergoing the disturbance-recovery process and rarely reaches an equilibrium state. Therefore, a system experiencing frequent disturbance such as FEF might be better characterized by non-equilibrium temporal dynamics of its key functions. C.-T. Chang and others. Resilience of a subtropical rainforest to annual typhoon disturbance: Lessons from 25-year data of leaf area index. [*Forest Ecology and Management* 470 118210 2020] D

PRECIPITATION INFLUENCES ON THE NET PRIMARY PRODUCTIVITY OF A TROPICAL SEASONAL RAINFOREST IN SOUTHWEST CHINA: A 9-YEAR CASE STUDY

The net primary productivity (NPP) of tropical forests is a key part of the global carbon cycle. Numerous studies have estimated tropical forest NPP, yet most of them focus on how annual NPP dynamics vary over several years. Little is known about how NPP responds to long-term climatic variation at the monthly or seasonal scales. We estimated NPP at three-month intervals from 2009 to 2017 for a tropical seasonal rainforest in Xishuangbanna, Southwest China using data from >2000 dendrometer bands and litter fall traps within a 20-ha permanent forest dynamics plot. We asked which climatic factor has the greatest effect on forest NPP at the sub annual scale, and how the relationships vary with seasonality. Calculations showed that NPP ranged from 12 to 20 t ha^{-1} yr^{-1}, and that forest productivity showed a slight, but insignificant increase from 2009 to 2017. NPP was significantly higher in the wet season than that in the dry season and was significantly related to precipitation only when all data were concerned. During the dry season, precipitation had a significant positive influence on NPP, but no effect during the wet season. We further identified that there was a threshold effect of precipitation on NPP. Specifically, productivity increased more rapidly when monthly precipitation below 229 mm. In summary, we conclude that periods of low rainfall strongly regulate the productivity in this tropical seasonal rainforest which could guide the management design of water use efficiency in tree based land-use system, like agroforestry ecosystems. E. Linger and others. Precipitation

influences on the net primary productivity of a tropical seasonal rainforest in Southwest China: A 9-year case study. [*Forest Ecology and Management* 467 118153 2020] D

TROPICAL FORESTRY NOTES (57)

BIOCLIMATIC DISTANCE AND PERFORMANCE OF APICAL SHOOT EXTENSION: DISENTANGLING THE ROLE OF GROWTH RATE AND DURATION IN ECOTYPIC DIFFERENTIATION

Under the same environmental conditions, southern and northern populations of temperate and boreal ecosystems exhibit different growth performance. However, which growth trait drives this difference is still unresolved. This study aimed to disentangle the effect of duration and rate of growth on shoot extension of five black spruce [*Picea mariana* (Mill.)] populations originating from a latitudinal gradient in Quebec, Canada, and growing in a common garden at the southern border of the boreal forest to simulate warming conditions. Bud phenology was monitored weekly during the growing seasons 2017-2019, and shoot length was recorded in autumn, representing annual growth of the primary meristem. Populations originating from the colder sites showed lower annual shoot increment compared to those originating from the warmer sites. Despite similar durations of bud phenology, the period of shoot extension occurred between the beginning of June and the beginning of July and was longer in the provenances originating from the colder sites. The period of shoot extension, on average, was shortened by 0.9 days for each degree Celsius of increase in annual mean temperature of the site of origin. Moreover, the populations originating from warmer sites showed higher growth rates, which increased by 0.1 cm day for each degree Celsius of increase in the annual mean temperature of the site of origin. Our results confirmed ecotypic variation in growth performance among black spruce population and demonstrated that differences in shoot length are related to both rate and duration of growth. In the context of a warming climate, northern populations may be unable to reach the current growth performance of southern ones because of their adaptations to harsh local conditions and low intrinsic growth rates. R. Silvestro and others. Bioclimatic distance and performance of apical shoot extension: Disentangling the role of growth rate and duration in ecotypic differentiation. [*Forest Ecology and Management* 477 118483 20 20] D

IMPROVING THE KNOWLEDTGE BASE FOR TROPICAL DRY FOREST MANAGEMENT IN SOUTHERN AFRICA: REGIONAL VOLUME MODELS FOR *PTEROCARPUS ANGOLENSIS*

The development of site-specific allometric models for tree species of natural tropical forests is hampered by limited resources while there is little quality control of the models developed. This study compares site- and species-specific models with generic and regional or pantropical models for *Pterocarpus angolensis*, the most widely exploited timber tree of southern Africa. We developed regional models with diameter at breast height (*DBH*) and tree height for the total and merchantable wood volume of *P. angolensis* with a dataset of 415 trees collected by destructive and non-destructive methods at 14 different sites in the *Baikiaea-Pterocarpus* woodlands of Namibia and southern Angola. Sources of data heterogeneity, such as site, collector and method, were investigated using mixed models and climate variables as model predictors. The study compared the ability of the new models with ten other site and species-specific volume models and nine generic volume and biomass models to estimate wood volume at tree and stand level. Stand data of 129 sample plots, representing a rainfall gradient from 480 mm to 750 mm, were used. Results showed that the three best performing models with *DBH* as single predictor (error 28% − 30%), including our new model, were developed for Namibia and Zambia. Adding tree height as predictor to our model removed the heterogeneity caused by site and reduced the error

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to 22%. One regional generic and one pantropical generic model, both with tree height, performed as well and outperformed other *Pterocarpus* specific models. Our models showed that the mean portion of merchantable wood was 35% of the total wood volume, of which 58% was heartwood. Although addition of climate variables improved our models, they did not perform well at stand level. Estimated merchantable volume of *P. angolensis* at stand level varied from 1.9 to 2.7 m^3 ha^{-1}, depending on the models employed. Total growing stock is estimated between 36 and 52 m^3 ha^{-1} in our study area, depending on the model, with the contribution of *P. angolensis* approximately 13%. Our results suggest that site-specificity of models is needed when they only include *DBH*. The use of pantropical and regional *DBH*-height based models that are adapted to site conditions through the collection of accurate height and wood density data for biomass conversion factors, is advised rather than developing site-specific *DBH* based allometric models. V. De Cauwer and others. Improving the knowledge base for tropical dry forest management in southern Africa: Regional volume models for *Pterocarpus angolensis*. [*Forest Ecology and Management* 477 118485 2020] D

STAND STRUCTURAL ATTRIBUTES AND FUNCTIONAL TRAIT CCOMPOSITION OVERRULE THE EFFECTS OF FUNTIONAL DIVERGENCE ON ABOVEGROUND BIOMASS DURING AMAZON FOREST SUCCESSION

Two competing ecological hypotheses, i.e., the niche complementarity (NGH) and the mass ratio (MRH) hypotheses, have been proposed to explain how standard structural complexity, functional trait diversity and composition simultaneously determine aboveground biomass in natural forests. Here, we hypothesized that the effects of stand structural attributes and functional trait composition overrule the effects of functional diversity on aboveground biomass during tropical forest succession. We tested different linear mixed-effects models to determine the effects of abiotic (i.e. nutrients and soil texture), taxonomic (i.e. woody species richness and composition), stand structural (i.e. stem count and maximum tree diameter), and functional attributes (functional divergence and composition). The functional attributes were based on functional divergence (FDvar) and community-weighted mean (CWM) trait values of wood density (WD). We collected data using 45 sample plots (20 m x 50 m) established in four old-growth and second- growth forests with varied stand stages from three sites in northern region of Amazonas State, Venezuela. The MRH model showed that CWM-WD had a strong direct positive effect on aboveground biomass, followed by a positive effect of maximum tree diameter, but had a weak positive relationship with soil fertility and FDvar-WD. Our study suggests that low trait diversity and high CWM-WD and maximum tree diameter determined high levels of aboveground biomass, which could be concentrate in species with larger diameters and high wood density. We conclude that stand structural attributes and functional dominance override the effects of FDvar of WD on aboveground biomass, and hence, it is important to test the mutual effects of functional diversity and composition when exploring the effects of functional traits on forest functioning. P.M. Villa and others. Stand structural attributes and functional trait composition overrule the effects of functional divergence on aboveground biomass during Amazon forest succession. [*Forest Ecology and Management* 477 118481 2020] D

LINKING ABOVE-GROUND BIOMASS PRODUCTION TO BELOW-GROUND CARBON FLUXES ACROSS STOCKING, CLONE USE, FERTILIZATION, AND

UNDERSTORY ELIMINATION IN *PINUS RADIATA* D. DON PLANTATIONS, NEW ZEALAND

The linkage between above-ground biomass production and below-ground carbon fluxes as influenced by silviculture has been insufficiently studied. We tested the effects of stocking, clone, fertilization, and follow-up herbicide treatments on below-ground carbon flux (BCF), above-ground biomass production (AGB), the ratio (BCF/AGB), tree diameter (DBH), height (H), basal area (G), and leaf area index (LAI) for a *Pinus radiata* D. Don plantation trial in the Canterbury region of New Zealand. Mixed-effects analysis of variance was carried out using data at the plot and clone levels. The H, DBH, G, AGB, BCF and the BCF/AGB ratio were influenced significantly by the main effects of stocking ($p < .05$), and the follow-up herbicide ($p < .001$). The main effects of clone had significant influence on H ($p < .001$), BCF ($p < .01$) and the BCF/AGB ratio ($p < .01$). Values of AGB and G increased with stand density, while DBH and H decreased with stand density. The significant stocking $\times$ follow-up herbicide interactions observed for DBH, G and AGB, suggested that follow-up weed control alleviated understory-induced water and nutrient stresses. Significant clone $\times$ follow-up herbicide interactions for DBH and AGB ($p < .05$), and clone $\times$ stocking interactions for G ($p < .05$), and no interaction of silvicultural treatments for BCF and BCF/AGB ratio were observed. Clones 1 and 3 exhibited greater AGB and smaller BCF/AGB ratio, compared to slower growing clones (i.e., Clones 4 and 5), suggesting certain clones were more productive above-ground at the expense of less carbon partitioned below-ground. These findings highlight that stocking, follow-up herbicide, and clone, in that order, had the greatest influence on above- and below-ground variables, suggesting that those silvicultural practices shifted carbon partitioning above-and below-ground. We conclude that well-performing clone planted with appropriate stand density and with follow-up weed control treatments may increase aboveground radiata pine productivity. K. C. Mohan and others. [*Forest Ecology and Management* 477 118469 2020] D

QUANTIFYING THE FACTORS AFFECTING WOOD DECOMPOSITION ACROSS A TROPICAL FOREST DISTURBANCE GRADIENT

Woody debris represents a substantial reservoir of carbon in forests. Disentangling the effects of factors affecting wood decomposition rates is therefore important. We examined the abiotic and biotic factors affecting wood decomposition across a disturbance gradient from mature forest to open land in a tropical montane site in Xishuangbanna, SW China. Wood logs (n = 280) of two native species with contrasting wood specific gravity (WSG), *Castanopsis mekongensis* (0.75) and *Litsea cubeba* (0.42), were exposed on the ground for three years. For each log, WSG was monitored at intervals by taking cores from top-half (up) and bottom-half (down) of the log. Mass loss was measured at the end of the experiment. WSG loss rates were similar across the disturbance gradient and the species effect varied with core position. For *Castanopsis*, which had higher initial WSG and wood N concentration and much thicker bark, up-cores had consistently higher WSG loss over the study period. This species also had substantially higher WSG loss for up-cores, but interspecific difference among down-cores was small. For mass loss, there was a complex interaction between species, habitat and the presence of termites. *Litsea* with low initial WSG experienced approximately two-fold higher mass loss in the absence of termites, but the difference between species was smaller in the presence of termites. Both species experienced higher mass loss in open habitats than in forests, but the termite effect was smaller in open habitats especially for *Litsea*. There was no interspecific difference in susceptibility to termite infestation, but infestation rates were higher in regenerating forests and open land than in mature

forest. WSG loss explained 0% and 19% of mass loss variation in *Listea* and *Castanopsis*, respectively, in absence of termites and 0% for both in the presence of termites. Afterlife effects of wood functional traits interact with abiotic conditions and decomposition processes (microbial decomposition, macro-organisms (termites), photo-degradation) in a complex manner to determine wood decomposition rates. WSG loss is not a reliable predictor of mass loss. These results have important implications for understanding the carbon cycle in tropical landscapes that are undergoing anthropogenic disturbance. G. G. O. Dossa and others. Quantifying the factors affecting wood decomposition across a tropical forest disturbance gradient. [*Forest Ecology and Management* 468 118166 2020] D

LEAF AREA INDEX (LAI) IS BOTH A DETERMINANT AND A CONSEQUENCE S OF IMPORTANT PROCESSES IN VEGETATION CANOPIES

Leaf Area Index, LAI, the total surface area of leaves per unit of ground area ($m^2\ m^{-2}$), is a collective measure of the foliar portion of vegetation canopy structure. The measure underscores the primacy of surface area in many fundamental processes of vegetation-environment interactions. Since its definition by Watson in 1947, LAI has been used to aggregate leaf level characteristics throughout the canopy to the crop or stand level, predict light regimes, assess the total quantity of above ground biomass and estimate the primary production in vegetation among other uses. This property is widely cited as a central parameter in ecosystem or earth system models of production, for schemes to parameterize vegetative surface interactions in climate models and for large-scale estimates of other surface properties. The value of LAI is sensitive to a variety of factors. At a global scale it is related to climate and plant functional type. At a local scale it is affected by weather and site factors such as fertility, stand age, management treatment, disturbance history. It is a difficult quantity to measure, principally because only part of the total is readily apparent. The indirect measurement approaches are affected by several distinct factors: viewpoint effects, occlusion of surfaces and the presence of material that is not green foliage. Much effort has been spent to estimate those hidden parts. Here I review the history of this measure and related ecosystem structure and process concepts, discuss how this structural characteristic has been connected to light distribution, material and energy exchange and used to model a variety of vegetation functions. Although the concept has been applied at the leaf, branch and whole-tree basis, I focus here on canopy and ecosystem scales, mostly in forests. The principal theses are that while LAI is a fundamental characteristic of vegetation and the result of considerable energetic investment by the plants: (1) the absolute value of the index is not always a clear driver of biomass or production, (2) the details of leaf area organization in space and within microclimate gradients is far more important than is the total amount of leaf area and (3) the total LAI can include leaf areas spanning a range of species, strategies and behaviors whose aggregate behavior is a challenge to model. I argue that (1) the value of LAI may be considered more of a consequence than a cause of canopy structural attributes and (2) the total LAI may be considered to have a range of functions, from ecosystem production to sustaining a diversity of biological strategies. Scaling of processes dependent on leaf area is a significant challenge and simple aggregation schemes can be misleading. I suggest that much of the total LAI (beyond about LAI ~ 3) may not be directly relevant for many ecosystem processes but have other important consequences. I illustrate this idea with several examples and suggest some questions related to LAI that might be profitably studied. G. G. Parker and others. Tamm review: Leaf Area Index (LAI) is both a determinant and a consequence of important processes in vegetation canopies. [*Forest Ecology and Management* 477 118496 2020] D

SPECIES-SPECIFIC GROWTH CAPACITY FOR FLOODPLAIN FOREST INFERRED FROM SAPWOOD EFFCIENCY AND INDIVIDUAL TREE COMPETITION

Although typically a strong determinant of site quality, the influence of flooding is not well understood for mixed-species floodplain forests. It is, however, generally assumed that growth is limited in floodplains that experience stagnant flooding because they are disconnected from river channels. Here, this assumption was tested across three connectivity levels (connected-to, partially-connected-to, and disconnected-from flowing water), using tree-ring sequences and field surveys of two dominant trees that cohabitate heavily flooded swamps but have contrasting life histories: short-lived black willow (*Salix nigra*) and long-lived baldcypress (*Taxodium distichum*). To characterize growing conditions for individual trees, we calculated sapwood efficiency (growth per sapwood area) and found that it declined in baldcypress from connected to disconnected sites; in contrast, black willow mean sapwood efficiency was lowest in the connected site. Overall, individual-tree sapwood efficiencies were highly variable, and local competition had a strong influence on baldcypress growth, independent of river-floodplain connectivity. Black willow appeared not to be sensitive to competition; however, it showed declining basal area trends that are likely attributable to age-related senescence. Black willow grows fast and indiscriminately, whereas baldcypress growth is sensitive to competition but persistent. Ring-width chronologies were used to identify species differences in growth responses to water levels; albeit similarly showing growth enhanced by flooding, baldcypress growth was consistently greatest with deep water (>3 m) whereas black willow growth was greatest with shallower water (1–2.5 m), especially in the less-connected sites. In addition to showing species-dependent growth responses to connectivity, these results show that tree growth is potentially more influenced by competition than by these degrees of connectivity, highlighting challenges in quantifying site-level growing conditions and flooding responses in disturbed, mixed stands. A. L. McAlhaney and others. Species-specific growth capacity for floodplain forest trees inferred from sapwood efficiency and individual tree competition. [*Forest Ecology and Management* 476 118427 2020] D

TROPICAL FORESTRY NOTES (58)

THE EFFECTS OF PRESCRIBED FIRE ON WILDFIRE REGIMES AND IMPACTS: A FRAMEWORK FOR COMPARISON

Prescribed fire can result in significant benefits to ecosystems and to society. Examples include improved wildlife habitat, enhanced biodiversity, reduced threat of destructive wildlife, and enhanced ecosystem resilience. Prescribed fire can also come with costs, such as reduced air quality and impacts to the fire sensitive species. To plan for appropriate use of prescribed fire, managers need information on the trasce-0ffs between prescribed fire and wildfire regimes. In this study we argue that information on trade-offs should be presented as spatial and temporal scales commensurate with the scales at which these processes occur and that simulation modeling exercises should include some realistic measure of wildfire probability. To that end we synthesized available scientific literature on relationships between prescribed fire and wildfire regimes, and their associated ecological and social effects., focusing specificity on simulation modeling studies that consider wildfire probably and empirical and modeling studies that consider prescribed fire and wildfire regimes at spatial and temporal scales beyond individual events. Both empirical and modeling studies overwhelmingly show that increasing use of prescribed fire can result in wildfire regimes of lower intent and intensity. In some studies, a consequence associated with increased use of prescribed fire can result in wildfire regimes of lower extent and intensity. In some studies a consequence associated with increased use of prescribed fire is an increase in the total cumulative amount of fire on a landscape over time. Presumably, this has cumulatively amount of fire on a landscape over time. Presumably, this has implications for emissions and ecosystem carbon. However, effects on ecosystem carbon dynamics are much less clear as results vary considerably across studies. Results likely vary because studies use various landscape models with different parameter savings for processes (e.g. , vegetation succession) and use different mythologies time frames and fire management and climate change scenarios. Future synthesis and meta-analysis would benefit from researchers providing more comprehensive and transparent documentation of model parameters. Assumptions and limitations. The literature review also revealed that studies on the implications of prescribed fire and wildfire regimes with regard to values other than carbon and emissions are scant and this represents a critical research need, Empirical studies are needed to calibrate and provide magnitude of order comparisons with simulation . Models and address trade-offs with respect to other values (e.g., Such studies should be conducted with consideration for our framework which includes the implications of prescribed fire and wildfire across broad spatial and temporal scales, comparisons with simulation models and addresses tradeoffs with respect to other values(e.g. wildland urban interface, wildland habitat) such studies should be conducted with consideration for our framework, which includes the implications of prescribed fire and wildfire across broad spatial and temporal scales. M. E. Hunter and M. D. Robles. Tamm review: The effects of prescribed fire on wildfire regimes and impacts: A framework for comparison. [*Forest Ecology and Management* 475 118435 2020] D

POST-AGRICULTURAL SUCCESSION IN THE FALLOW SWIDDENS OF SOUTHEASTERN BRAZIL

Agricultural practices have been occurring for centuries in the Brazilian Atlantic Rain Forest, which contains one of the highest levels of biodiversity in the world. The communities that still practice traditional shifting agriculture are constrained by legal, economic and social factors,

which makes the practice of itinerant agriculture a complex dynamic process. The long-term effect of repeated, long-fallow shifting cultivation on plant communities in secondary forest fallows of various age and slash-and-burn history was examined in a quilombola village in Southeastern Brazil. We carried out vegetation surveys in 12 sites, ten in areas of shifting cultivation and two in secondary forests formed after natural disturbances. We chose three age groups for sampling, i.e., post-harvest fallow or post-disruption times for natural areas. The fallow period after cultivation ensures the continuous recovery of the composition and structure of vegetation, but even after five decades the alpha and beta diversities had not reached the values observed in mature forests. The number of species and basal area increased over time but the differences between areas in the same age group were as large as between age groups. The two disturbed natural areas had lower richness than the fallow swiddens of the same age. The data suggest that the intensive extraction of non-timber forest products to supply the market, and therefore extraneous to traditional activity, has negatively affected the sustainability of the system. Actions to recover stocks of these forest products together with integrated management and input of resources can maintain the sustainability of the system. E. P. Cabral Gomes and others. Post-agricultural succession in the fallow swiddens of Southeastern Brazil. [*Forest Ecology and Management* 475 118398 2020] D

TREE GROWTH AT THE REAR EDGE OF AN ANDEAN FOREST SHOW DIFFERENT PATTERNS IN THE LAST CENTURY

Nothofagus pumilio is the dominant tree species at high elevations in the southern Andes between 35° and 55° S. Despite the number of tree-growth studies on this tree species, there is scarce information about the growth patterns and its relation with climatic variability at its lower elevation margin of distribution in the windward side of the Andes. In this study we focus on the altitudinal rear edge of a *N. pumilio* forest growing on the Pacific side of the northern Patagonian Andes to determine the main temporal patterns of tree radial growth, identify its relations with regional and large-scale climate and to assess the temporal variation of common signal in tree growth at centennial time-scales. A Principal Component Analysis (PCA) between trees for their common period 1850–2010 indicates the existence of more than one pattern of tree growth within this lower altitudinal margin, which exhibit contrasting relations with climate. The tree ring chronology and the PC1 amplitude of tree growth shows negative correlation with maximum temperature during spring-summer while the PC2 shows the contrary. Maps and correlation functions indicate that the PC1 and PC2 patterns of *N. pumilio* growth are significantly related with high latitude climate variability induced by the Antarctic Oscillation (AAO) during spring-summer in an opposite manner, with the PC1 (PC2) negatively (positively) correlated with the poleward displacement of the storm tracks driven by the mid- and high-latitude dipole pressure in the Southern Hemisphere. The running PCA between the standardized tree ring-width series shows a decreasing trend in the percentage of variance explained by the first mode of tree growth, indicating a centennial scale loss in the common signal of growth within the population, especially since mid-20th century when the behavior of the AAO was unprecedented within the context of the last millennium. Given that the future climatic scenario for northern Patagonia as predicted by models would lead to more arid conditions forced by the positive trend of the AAO, we expect that the main pattern of *N. pumilio* growth at the rear edge of Choshuenco volcano will be negatively affected. Despite the present knowledge about *N. pumilio* radial growth in treeline environments, specific research is needed to gain insights about the complexity of the climate-growth relationship at its low elevation margin, in order to

evaluate anomalies in tree growth patterns in the habitat where *N. pumilio* grows and competes with other low elevation species more tolerant to warmer conditions. H. Serrano-Leon and D. A. Christie. Tree-growth at the rear edge of a *Nothofagus pumilio* Andean forest from Northern Patagonia show different patterns and a decline in the common signal during the last century. [*Forest Ecology and Management* 475 118426 2020] D

COMPARING THE EFFECT OF EVEN-AGED THINNING AND SELECTIVE FELLING ON BOREAL FOREST BIRDS

Biodiversity is in decline and therefore alternative forest management approaches have gained interest. One of such approaches is uneven-aged silviculture, which has been suggested to better maintain mature or late-successional forest characteristics and species assemblage than even-aged silviculture. Therefore, it is assumed that uneven-aged silviculture can be a useful tool for landscape planning to benefit biodiversity. Nevertheless, there is a lack of empirical studies regarding bird responses to uneven-aged silviculture in northern European boreal ecosystems. Here we test the similarity of bird assemblage structure between mature forests within even-aged silviculture (thinning) and uneven-aged silviculture (selective felling). In spring 2018 we censused breeding birds using territory mapping in 14 thinned stands and 14 selectively felled stands. We found higher abundance and different bird assemblages in thinned stands compared to selectively felled stands. The pied flycatcher, tree pipit and great tit contributed most to the variation of bird assemblages between the two management types. None of the species were more abundant in selectively felled than in thinned stands. According to functional guilds, the abundance of ground breeders, ground feeders and generalists was higher in thinned stands than in selectively felled stands, similar results were found in the species richness of long-distance migrants, ground nesters, secondary cavity nesters and generalists. Independent of management type, time since treatment had an overall effect on assemblage structures, the mistle thrush and wren were negatively correlated with time since treatment, while the chiffchaff showed the opposite trend. Our results suggest that at these locations and given this particular type of uneven-age management, selective felling is less suitable for some abundant generalists than even-aged forest stands reaching the thinning age. However, the results from this study does not provide clear management recommendations aiming to maintain biodiversity, as management guidelines should be based on red-listed species and not on common generalists. Nevertheless, our results stress the urgent need for more long-term studies comparing the effect of these different silvicultural strategies on bird assemblages. M. Versluijs and others. Comparing the effects of even-aged thinning and selective felling on boreal forest birds. [*Forest Ecology and Management* 475 118404 2020] D

GEOGAPHIC DIISCRIPTION AND THE REPRODUCTIVE AND DEMOGRAPHIC ECOLOGY OF TWO CONGENERIC SEEDER AND RESPROUTER TREE SPECIES

The distribution limits of species are mainly related to climate but other environmental factors such as soil and fire may also play an important role in local population dynamics. Species that re-establish from seed after a severe disturbance (seeder species) should have different functional attributes from species that can survive a disturbance by vegetative regeneration (resprouters). The functional attributes will influence the establishment and survival of individuals and for trees, the stem size distributions provide a view of the history of the populations and may indicate the trajectories of the populations as they age. Two congeneric tree species – *Allocasuarina fraseriana* (a resprouter) and *A. huegeliana* (a seeder) are dominant to

subdominant trees in forest and woodland vegetation of south western Australia and illustrate useful comparisons of functional attributes and population structures. Both species occupy fire prone vegetation, bear seeds in serotinous cones and are considered to regenerate new individuals after fire events. The seeder (*Allocasuarina huegeliana*) has smaller cones and seeds and more seeds cone^{-1} than the resprouter (*A. fraseriana*). The cones of the resprouter provide more protection against heat to the contained seeds than the seeder. It is generally considered that species in fire prone environments often rely on disturbance to provide suitable conditions for regeneration and recruitment between disturbances is poor. For a species killed by disturbance population structures years after the disturbance would be expected to be unimodal while a resprouter would have a multimodal structure, as adults would survive and remain in the population with the new recruits. Unexpectedly population structures for the two species we studied were very similar when compared at an overall landscape scale. We attribute this mainly to the ability of the species to recruit interfire. Best seedling recruitment does occur after fire, as this provides an environment with more nutrients and reduced competition for the seedlings. However interfire recruitment can be abundant in some habitats. The degree to which this occurs may vary in relation to co-occurring tree species and landscape position. In general, fuel reduction fires are being used to reduce the danger of high intensity fires as the climate becomes drier and hotter in parts of southern Australia and mild fires will influence recruitment of both species. Low intensity surface fires will remove interfire recruits of the seeder species, but may increase the density of small plants of the resprouter. Adults are unlikely to be damaged but size class structures will be different from those after stand replacing fires. J. W. Schmidberger and P. G. Ladd. Geographic distribution and the reproductive and demographic ecology of two congeneric seeder and resprouter tree species. [*Forest Ecology and Management* 475 118428 2020] D

RETENTION OF LARGE, OLD TREES IN ALTERNATIVES TO CLEARCUTTING WITH COMPARISON OF GROUND-AND HELICOPTER-BASED ASSESSMENTS

Habitat trees (mature live and dead trees with hollows) are a keystone habitat in Australian eucalypt forests where tree hollows typically occur in large, old trees. These trees provide potential habitat for hollow-using birds, bats and arboreal marsupials, including many threatened species. Habitat trees may be felled during forest harvesting and can also be negatively affected by wildfires. Shortages of habitat trees in harvesting landscapes can be a limiting factor for populations of hollow-using vertebrates. Retention forestry systems are expected to retain a greater number of habitat trees within sites than traditional clearcutting silviculture, but there is a need to quantify how the pattern of retention (dispersed trees vs. retained clumps) will affect the numbers and types of trees retained. The method of assessment (ground-based vs. aerial surveys) may influence the estimated numbers of habitat trees. We investigated habitat tree retention at the Warra Silvicultural Systems Trial in Southern Tasmania, Australia. This trial was instrumental in developing alternatives to clearcutting in tall, wet, old-growth eucalypt forests. Our research has two objectives. Objective 1 is to assess the numbers of habitat trees retained in various alternatives to clearcutting by comparing: unlogged control areas, 0.5–1 ha clumps retained within a harvested matrix (aggregated retention), trees scattered throughout the harvested area (dispersed retention), and small ~0.08 ha machinery exclusion zones where trees were retained if they were not of commercial value (clearcutting with understorey islands). Objective 2 is to compare ground-based to aerial, helicopter-based, assessment of large live and dead trees. Although low replication of harvest treatments precluded statistical comparison of

silvicultural systems, the results, based on 1,260 trees, were clear. Of the various alternatives to clearcutting, aggregated retention retained the greatest proportion of all classes of habitat trees, primarily because of higher retention targets, but possibly also because of greater survival with reduced wind exposure in aggregates. Substantially fewer habitat trees were retained with dispersed retention, and virtually none with understorey islands in clearcutting. Aerial and ground-based assessment methods provided similar estimates of numbers of trees with visible hollows in aggregates and understorey islands ($R^2 = 0.95$). Choice of method for future studies should consider available resources and objectives, since there were advantages and disadvantages of each approach. In conclusion, aggregated retention was found to be the preferred silvicultural system for retaining habitat trees within sites for hollow-using vertebrates, and helicopter surveys provide a rapid alternative to traditional ground-based assessment. S. C. Baker and others. Retention of large, old trees in alternatives to clearcutting with a comparison of ground- and helicopter-based assessments. [*Forest Ecology and Management* 475 118390 2020] D

CHARACTERIZING SPATIAL PATTERNS OF PINE BARK BEETLE OUTBREAKS DURING THE DRY AND RAINY SEASONS IN HONDURAS WITH THE AID OF GEOGRAPHIC INFORMATION SYSTEMS AND REMOTE SENSING DATA.

Coniferous and mixed forests cover approximately 42% of Honduras forested areas, however; pine bark beetle (PBB) (*Dendroctonus* spp.) outbreaks are an environmental hazard that has caused incalculable ecological and economic impacts in Honduras. In this research, in order to plan more focalized measures for controlling the PBB outbreaks, it is essential to identify those areas that have a high susceptibility to a PBB outbreak during the dry and rainy seasons. For this purpose, we require to associate the historical PBB outbreak points (2017–2019), with a series of environmental and anthropogenic variables that according to the literature review have affected the initiation and the spread of PBB outbreaks. To assess the current climatic variables we used MODIS land surface temperature product (LST-MOD11A2), wind speed, precipitation, and temperature acquired from the WorldClim data. To assess vegetation vigor, we use the Normalized drought moisture index estimated from the MODIS surface reflectance product (MOD09A3). To give us an understanding of the density of the forest, we compare two products, the MODIS Leaf Area Index (LAI-MOD15A2H), and the MODIS Vegetation Continuous Fields (VFC-MOD44B). We included elevation, aspect, and slope as variables and acquired this data from the Global multiresolution terrain elevation data (GMTED-2010). Finally, we used geographical information systems data to derive proximity to different types of roads as anthropogenic data and wildfire density. We do a preliminary analysis of the variables and eliminated those which show the least importance. Furthermore, we integrated the most relevant variables identified with the PBB points by using the Random Forest (RF) algorithm to fit the model and then predicted the current PBB outbreak susceptibility for the dry and rainy season. Results indicated that climatic variables weigh heavily in determining high susceptibility areas. Our prediction results show high and very high susceptibility in the North-eastern and Central parts of the country especially. The results acquired, can lead to improved preventive and control measures to reduce the negative ecological effects that are caused by PBB outbreaks. M. C. Valdez Vasquez and others. Characterizing spatial patterns of pine bark beetle outbreaks during the dry and rainy season's in Honduras with the aid of geographic information systems and remote sensing data. [*Forest Ecology and Management* 467 118162 2020] D

PRESCRIBED BURN SEVERITY HAS MINIMUM EFFECT ON COMMON BIRD SPECIES IN FIRE-PRONE FOREST ECOSYSTEM

Prescribed burning is widely used to mitigate the effects of severe fires across the landscape and to maintain biodiversity. Just like wildfires, the severity of prescribed burns can vary; this study was an opportunistic investigation. In one fortnight during autumn months of 2012, several prescribed burns were carried out in heathy-dry forests of central Victoria, Australia. We used measurements of canopy scorch, bark burn and ground cover burn to calculate a severity score for each site. The severity scores across sites ranged from low (2.5) to high (10). A before-after control-impact (BACI) design was utilised to model the potential impacts of fire and fire severity on birds. We used generalised linear mixed models (GLMM's), and incorporated first- and second-year post-fire spring/summer observations from 2012 to 2014, against bird data from observations carried out in 2010. The total combined abundances of individual species showed that broadly, bird abundance rebounded to pre-burn levels by the second spring post-fire. There was little response detected in either species richness or turnover. The muted turnover result aligns to other studies that indicate a scarcity of early-successional-stage species in eucalyptus forests and woodlands that rapidly regenerate post-fire. Ten individual species were also examined, and only one species, the White-throated Treecreeper (*Cormobates leucophaea)*, responded to both fire and its severity. The BACI design was informative in illustrating that while the forest birds were resilient to small-scale prescribed burns of any severity, abundances in general may have been in decline, a result aligning with the years of reduced rainfall in the region. D. Kuchinke and others. Prescribed burn severity has minimal effect on common bird species in a fire-prone forest ecosystem. [*Forest Ecology and Management* 475 118437 2020] D

INDIVIDUAL TREE DETECTION AND SPECIES CLASSIFICATION OF AMAZON PALMS

Information regarding the spatial distribution of palm trees in tropical forests is crucial for commercial exploitation and management. However, spatially continuous knowledge of palms occurrence is scarce and difficult to obtain with conventional approaches such as field inventories. Here, we developed a new method to map Amazonian palm species at the individual tree crown (ITC) level using RGB images acquired by a low-cost unmanned aerial vehicle (UAV). Our approach is based on morphological operations performed in the score maps of palm species derived from a fully convolutional neural network model. We first constructed a labeled dataset by dividing the study area (135 ha within an old-growth Amazon forest) into 28 plots of 250 m × 150 m. Then, we manually outlined all palm trees seen in RGB images with 4 cm pixels. We identified three palm species: *Attalea butyracea*, *Euterpe precatoria* and *Iriartea deltoidea*. We randomly selected 22 plots (80%) for training and six plots (20%) for testing. We changed the plots for training and testing to evaluate the variability in the classification accuracy and assess model generalization. Our method outperformed the average producer's accuracy of conventional patch-wise semantic segmentation (CSS) in 4.7%. Moreover, our method correctly identified, on average, 34.7 percentage points more ITCs than CSS, which tended to merge trees that are close to each other. The producer's accuracy of *A. butyracea*, *E. precatoria* and *I. deltoidea* was 78.6 ± 5.5%, 98.6 ± 1.4% and 96.6 ± 3.4%, respectively. Fortunately, one of the most exploited and commercialized palm species in the Amazon (*E. precatoria*, a.k.a, Açaí) was mapped with the highest classification accuracy. Maps of *E. precatoria* derived from low-cost UAV systems can support management projects and community-based forest monitoring programs in the Amazon. M. Pinheiro Ferreira and others. Individual tree detection and species

classification of Amazonian palms using UAV images and deep learning. [*Forest Ecology and Management* 475 118397 2020] D

TROPICAL FORESTRY NOTES (59)

CROSS-SITE PATTERNS IN THE RESPONE OF *EUCALYPTUS* PLANTATIONS TO IRRIGATON, CLIMATE, AND INTRA-ANNUAL WEATHER VARIATION

Cross-site patterns for multiple sites tend to be more broadly applicable and more useful for constructing and constraining models. We examined cross-site patterns of *Eucalyptus* plantation response to water supply (including irrigation and 1/3 precipitation removal), mean annual temperature (MAT), vapor pressure deficit during the daytime (VPD), and nutrient addition in eight sites from the Brazil Eucalyptus Productivity Project (BEPP). Mean annual increment (MAI) for all treatments and sites varied from 12.7 to 37.3 Mg ha^{-1} yr^{-1} across a 1400 km latitudinal gradient where annual precipitation varied from 940 to 1430 mm yr^{-1}. MAI varied with water added across all sites, with a near linear increase of 1.42 Mg ha^{-1} yr^{-1} per 100 mm yr^{-1} between 640 and 1800 mm yr^{-1}, a MAI plateau of 30.8 Mg ha^{-1} yr^{-1} at ~2000 mm yr^{-1}, then decreasing to MAI of 27.2 Mg ha^{-1} yr^{-1} at 3060 mm yr^{-1}. Including MAT with the water response showed that MAI decreased at 1.23 Mg ha^{-1} yr^{-1} per °C. For the natural precipitation treatments, MAI decreased at 2.52 Mg ha^{-1} yr^{-1} per °C, comparable to that for the much broader TECHS Project. MAI was not related to temperature for the irrigation treatments, suggesting that some or all of the response of MAI to temperature is related to water supply. The difference between the biomass of the irrigation treatments and that of natural precipitation treatment slowed its increase or stopped increasing at age 30–60 months for five of the eight sites, but increased through the study duration for the other three sites. The difference in biomass between the fertilization and no fertilization treatments increased throughout the study for two sites. Three- and six-month growth was generally unrelated prior 3–12 month weather. Age-related decline was observed for all of the treatments at four of the eight sites. These cross-site comparisons affirm that water supply is the key resource determining levels of plantation productivity in Brazil and that individual site studies are inadequate for understanding many key responses. M. G. Ryan and others. Cross-site patterns in the response of Eucalyptus plantations to irrigation, climate and intra-annual weather variation. [*Forest Ecology and Management* 475 118444 2020] D

TIMBER HARVEST AND FREQUENT PRESCRIBED BURNING INTERACT AND AFFECT THE DEMOGRAPHY OF EUCALYPT SPECIES

Ecosystem management can negatively affect the demography of plant communities through the introduction of novel disturbance regimes. Prescribed burning and timber harvesting are two common and widely applied management strategies across forest ecosystems. Despite this, little is known about the long-term effects that these interacting disturbances have on forest demography. This study examined the effect of timber harvesting and frequent prescribed burning on the mortality, growth and regeneration of trees in a temperate eucalypt forest of south-eastern Australia. The study took place at a long-term experimental site, where experimental coupes were subjected to a one-off selective harvesting treatment (harvested, not harvested), followed by regimes of experimental burning (no fire, ~4 year burn intervals or ~2 year burn intervals) over a 22 year period. Tree communities were surveyed at permanent monitoring sites prior to the application of experimental treatments (1985 – 1989), and resurveyed post treatment (2016) to assess mortality, growth rates and ingrowth of trees >10 cm diameter at breast height. Harvesting directly removed ~40% of trees and indirectly increased the mortality of retained trees through damage (e.g. crown and bole breakage) caused during the

harvesting operation. The likelihood of harvesting damage was greater for small trees and increased with harvesting intensity (i.e. the amount of timber removed). Frequent burning increased the likelihood of tree mortality on harvested sites, with large, old trees being particularly vulnerable. Growth rate and ingrowth of trees was elevated at harvested sites, increasing almost linearly with harvesting intensity, which suggests that competitive release had occurred. Fire frequency had no effect on growth rates or ingrowth of trees. This study highlights that frequent prescribed burning and selective timber harvesting can have additive effects on the loss of large trees, reducing the availability of these keystone habitat structures in intensively managed forest ecosystems. Although the elevated rates of growth and ingrowth may hasten the replacement of lost large trees, recovery will require long time frames. G. M. Watson and others. Timber harvest and frequent prescribed burning interact to affect the demography of Eucalypt species. [*Forest Ecology and Management* 475 118463 2020] D

CONTRASTING WATER USE OF TWO *EUCALYPTUS* CLONES ACROSS A PRECIPITATION AND TEMPERATURE GRADIENT IN BRAZIL

Eucalyptus plantation productivity has increased 4-fold across Brazil as a result of improved genetic selection and intensive silviculture. However, the rate of productivity improvements is slowing and suggests increased production will require planting in areas that have never been previously planted with *Eucalyptus* with uncertain impacts on local water supplies. This study compares water use and water use efficiency between a drought resistant (*E. grandis* $\times$ *E. camaldulensis*) and high productivity *Eucalyptus* clone (*E. urophylla*) across three sites (dry, mesic and wet) spanning a two-fold precipitation gradient (~600–1350 mm y^{-1}) in Brazil. Each site included a 30% reduced rainfall treatment for each clone to investigate within site response to reduced precipitation. We found that the drought resistant clone used as much or more water than the high productivity clone at all three sites. The drought resistant clone transpired almost 20% percent more water than the high productivity clone at the dry site (3.7 vs. 3.0 m^3 y^{-1}) while water use between clones did not differ at the mesic (4.6 vs 4.0 m^3 y^{-1}) and wet site (4.0 vs 4.5 m^3 y^{-1}). The high productivity clone transpired 54, 46 and 37% of annual precipitation at the dry, mesic and wet sites respectively while the drought resistant clone consumed 67, 47 and 31% of annual precipitation from the dry to the wet site. Although the rain reduction treatments did not impact annual water use for either clone at the dry and mesic sites, there were some differences at a subannual timescale. Rain reduction treatments at the dry site lowered transpiration in the driest, hottest three months for the high productivity clone by 25–32%. Rainfall reduction led to lower water use by the drought resistant clone for only one month during the dry season (18%). The high productivity clone transpired less water (24–26%) in the rainfall reduction treatment at the mesic site during three months and the drought resistant clone transpired 18 and 20% less water in the rainfall reduction treatment during two months. Rainfall reduction reduced annual transpiration by 59% for the high productivity clone at the wet site. Average water use efficiency of the drought resistant clone was almost 70% lower than the high productivity clone at the dry and mesic sites (~5.2 vs. 1.5 kg m^{-3} y^{-1}) and was due to the combination of low growth and high water use. Higher than expected growth by the drought resistant clone at the wet site resulted in similar water use efficiency between clones (6.3 vs. 5.8 kg m^{-3} y^{-1}). We discuss potential implications of our findings and highlight several lines of evidence that suggest the drought resistant clone in this study allocates a greater proportion of gross primary productivity below ground allowing it to access deeper reserves of soil water during dry periods. Our results suggest that decisions to plant drought resistant clones in drought

prone areas should be carefully considered and also highlight the need for more research on water use and drought tolerance strategies for *Eucalyptus* clones bred for more arid areas in Brazil. R. M. Hubbard and others. Contrasting water use of two Eucalyptus clones across a precipitation and temperature gradient in Brazil. [*Forest Ecology and Management* 118407 2020] D

RELATIONSHIP BETWEEN FOREST RESIDUE MANAGEMENT AND MICRONUTRIENT FERTILIZATION WITH *EUCALYPTUS* RUST SEVERITY IN *EUCALYPTUS GRANDIS* PLANTATIONS

The average loss of stem growth caused by eucalyptus rust (*Austropuccinia psidii*) is 20% in Brazil. Micronutrients can affect the defense mechanisms of plants, such as the production of lignin, phenols, phytoalexins, and other defense molecules. Micronutrients are used in several production pathways of these molecules as cofactors and enzymatic activators. The epidemiology of eucalyptus rust was studied in a *Eucalyptus grandis* plantation with micronutrient fertilization (B, Cu, and Zn) associated with the removal or maintenance of forest residues from wood harvest, and was compared between 6 and 12 months of age. Regardless of treatment, the loss due to rust was 60% of stem volume. The forest residue management did not affect the severity of eucalyptus rust. The omission of Zn increased the Cu foliar contents and reduced the eucalyptus rust severity. Cu leaf contents showed a strong negative correlation with rust severity. Thus, nutrition was related to the severity of eucalyptus rust, emphasizing the importance of an adequate supply of Cu to reduce the susceptibility of *E. grandis*. L. Santos Masullo and others. Relationship between forest residue management and micronutrient fertilization with eucalyptus rust severity in *Eucalyptus grandis* plantations. [*Forest Ecology and Management* 475 118443 2020] D

THE EFFECT OF THE LAS MAQUINAS WILDFIRE OF 2917 ON THE HYDROLOGICAL BALANCE OF A HIGH CONSERVATION VALUE FOREST IN CENTRAL CHILE

The large wildfires of January 2017 burned more than 500,000 ha, including areas of high conservation value native forest, central Chile. Runoff, streamflow, and water balance were measured in a native forest catchment for 7 years before and 2 years after the fires. The annual peak flows and runoff coefficients decreased after the fire, as did the summer flows and total streamflow. These reductions in flow were despite rainfall being higher in the two years after the fire than in the two years before the fire. The forest resprouted vigorously after the fire and evaporation in the second year after the fire was approximately two thirds of the rate before the fire. While water use in the forest is recovering rapidly, streamflow in the two years after the fire was reduced to below that of 7 years before the fire. In the two years after the fires, more than 50% of rainfall is not accounted for by either evapotranspiration or by streamflow. Potential explanations for this gap in the water balance include recovery in storage after the fire and increased by-pass flow below the measuring weirs. F. Baloccihi and others. The effect of the 'Las Maquinas' wildfire of 2017 on the hydrologic balance of a high conservation value Hualo (*Nothofagus glauca* (Phil.) Krasser) forest in central Chile. [*Forest Ecology and Management* 477 118482 2020] D

EFFECTIVENESS OF COMPETITION INDICES FOR UNDERSTANDING GROWTH IN AN OVERSTOCKED STAND

The objective of this study was to select and discuss indices to explain competition among trees in an unmanaged stand in order to support decision-making in forest management. The work was carried out in a plantation of *Araucaria angustifolia* (Bertol.) Kuntze located in a national forest in southern Brazil. The plantation was established in 1946 in 2×2 m spacing, with only one thinning that happened sometime between 1970 and 1980. Forty-six sample plots were established using an adaptation of the Prodan method. We tested distance-independent and distance-dependent competition indices that included or excluded crown area variables. An equation was generated to describe the relation between diameter at breast height and crown diameter, since these were highly correlated ($r = 0.87$); this permitted calculation of the growth space required for the trees in the stand. It is important to carefully choose the variables and competition indices to be tested in each study case. Including crown variables did not improve prediction ability to overcome the performance of the Stage distance-independent index. In general, the distance-independent indices performed better than the distance-dependent ones, even the stand arrangement in our study area was modified through thinning, mortality, and natural regeneration. When the goal is to better understand the ecological significance of a competition index and not only its statistical ability to predict short-term growth, simpler indices are recommended. R. de Angeli Curto and others. Effectiveness of competition indices for understanding growth in an overstocked stand. [*Forest Ecology and Management* 477 118472 2020] D

SOIL ORGANIC MATTER NITROGEN AND PH DRIVEN CHANGE IN A BACTERIAL COMMUNITY

Fast expansion of forest conversion to monoculture plantations has profound effects on ecosystem structure and functions. Through altering litter and rhizodeposition composition as well as one-sided effects on soil chemical properties, monoculture plantations may tremendously decrease biodiversity and functions of soil microorganisms. We investigated the impacts of conversion of natural evergreen and deciduous broad-leaf forest (Forest) to four 5-year old monoculture plantations (plantations), such as *Camellia oleiferaAbel.*(Oil), *Amygdalus persica* (Peach), *Myrica rubra (Lour.) S. et Zucc.*(Berry) and *Cunninghamia lanceolata (Lamb.) Hook.*(Fir), on soil properties and bacterial community and its driving factors using the high-throughput sequencing technique. Soil organic carbon, and total nitrogen decreased up to 59%–83% and pH increased by 0.31 units following the forest conversion. The changes in soil properties and bacterial communities were depended on the type of the plantation. Bacterial diversity increased by 6.5% after forest conversion. The relative abundances of *Acidobacteria*, *Proteobacteria, Bacteroidetes* and *Actinobacteria* in the Forest were remarkably higher compared with all plantations, whereas that of *Chloroflexi* and *Planctomycetes* was less. All plantations had low abundance of *Acidobacteria*, while the highest abundance of *Proteobacteria, Actinobacteria* and *Planctomycetes* was observed under Peach. The co-occurrence patterns of bacterial communities identified rare taxa rather than abundant taxa as central players in bacterial network. The redundancy analysis indicated that the variation in the composition of bacterial community was mainly driven by soil pH, organic carbon and total nitrogen content. Therefore, good management practices, such as reasonable fertilization and soil erosion prevention, need to be developed for monoculture plantations to mitigate the depletion of nutrients and to enhance microbial functioning after forest conversion. T. Liu and others. [*Forest Ecology and Management* 477 118473 2020] D

HERPETOFAUNAL RESPONSES TO INTENSIFICATION OF WOODY BIOENERGY PRODUCTION IN A GLOBAL BIODIVERSITY HOTSPOT

Bioenergy produced from woody biomass in managed forest systems represents a substantial portion of the global supply of renewable energy. As societies transition to renewable energy and demand for wood-based bioenergy increases, timber-producing forests and other agricultural and marginal lands may transition to bioenergy management regimes. Limited empirical information exists regarding how wildlife communities will respond to bioenergy intensification. We investigated herpetofaunal occurrence across 75 study sites located in two types of bioenergy feedstocks (corn and pine) to evaluate effects of bioenergy alternatives in a global biodiversity hotspot in the southeastern United States: the North American Coastal Plain. We found that removing harvest residue following clearcut management in pine forests as a source of woody biomass resulted in either neutral or positive effects for six of the seven herpetofaunal species examined. Other bioenergy alternatives, such as mid-rotation thinning and short-rotation practices, resulted in highly variable effects among individual species and generally contrasting effects between amphibians and reptiles. Similarly high variability was observed when comparing species occurrence patterns between corn and managed pine bioenergy feedstocks. Our study suggests herpetofaunal community responses to changing land-use practices in the era of bioenergy may be taxa- and species-specific. Some land-use practices (e.g., residue removal following clearcuts) may be generally compatible with conservation of most species examined, but conserving herpetofaunal diversity within the Southeast as bioenergy production increases may involve promoting heterogeneous managed landscapes in which a diversity of harvest approaches are used.) G. M. Jones and others. Herpetofaunal responses to intensification of woody bioenergy production in a global biodiversity hotspot. [*Forest Ecology and Management* 477 118493 2020] D

BIOCLIMATIC MODELING OF POTENTIAL VEGETATION TYPES AS AN ALTERNATIVE TO SPECIES DISTRIBUTION MODELS FOR PROJECTING PLANT SPECIES SHIFTS UNDER CHANGING CLIMATES

Land-managers need new tools for planning novel futures due to climate change. Species distribution modeling (SDM) has been used extensively to predict future distributions of species under different climates, but their map products are often too coarse for fine-scale operational use. In this study we developed a flexible, efficient, and robust method for mapping current and future distributions and abundances of plant species and communities at the fine spatial resolutions that are germane to land management. First, we mapped Potential Vegetation Types (PVTs) using conventional statistical modeling techniques (Random Forest) that used bioclimatic ecosystem process and climate variables as predictors. We obtained over 50% accuracy across 13 mapped PVTs for our study area. We then applied future climate projections as climate input to the Random Forest model to generate future PVT maps, and used field data describing the occurrence of tree and non-tree species in each PVT category to model and map species distributions for current and future climate. These maps were then compared to two previous SDM mapping efforts with over 80% agreement and equivalent accuracy. Because PVTs represent the biophysical potential of the landscape to support vegetation communities as opposed to the vegetation that currently exists, they can be readily linked to climate forecasts and correlated with other climate-sensitive ecological processes significant in land management, such as fire regimes and site productivity. R. E. Keane and others. Bioclimatic modeling of potential

vegetation types as an alternative to species distribution models for projecting plant species shifts under changing climates. [*Forest Ecology and Management* 477 118498 2920] D

TROPICAL FORESTRY NOTES 60)

ECOSYSTEM-LEVEL CARBON STOCKS AND SEQUESTRATION RATES IN THE MANGROVES IN THE CANANEIA-IGUAPE LAGOON ESTUARINE SYSTEM, SOUTHEASTERN BRAZIL

Mangroves fringe the coastlines of 54% of the world's nations but convey ecosystem services, such as carbon sequestration, that span administrative boundaries. Despite their high carbon sequestration efficiency and long-term storage capacity, few countries have assembled detailed mangrove carbon inventories. For example, Brazil, which detains the second largest mangrove area in the world, still lacks a detailed inventory on its blue carbon resources, largely due to the scarcity of integrated ecosystem-level (that is, carbon stored in biomass and soil combined) carbon assessments. Here we combine published and unpublished data to derive an inventory on ecosystem-level carbon stocks and carbon sequestration rates in the Cananéia-Iguape lagoon estuarine system, southeastern Brazil. We find that mangroves in the study area have the largest per-unit-area ecosystem-level carbon stocks at 380 MgC ha^{-1} when compared to other Brazilian mangroves. Soil organic carbon stocks (top meter) account for 70% of this total. Annual carbon sequestration in mangrove soils and woody biomass combined with carbon fluxes via litterfall total 0.16 TgC yr^{-1}. Degradation of mangrove ecosystems in this region could lead to CO_2 emissions up to 1,395 MgCO$_2$ ha^{-1} and reduce annual carbon sequestration in soil and biomass combined, and carbon flux via litterfall by 27 and 12 MgCO$_2$ ha^{-1} yr^{-1}, respectively. Our results provide coastal wetlands managers and scientists with novel information on mangrove carbon stocks and sequestration rates in the study area, which is useful to strengthen regional blue carbon and potential CO_2 emission inventories. These estimates can also be used to establish performance measures to inform restoration targets as well as to serve as a baseline for comparison with current and future measurements of carbon stocks and fluxes in response to environmental change. A. S. Rovai and others. Ecosystem-level carbon stocks and sequestration rates in mangroves in the Cananéia-Iguape lagoon estuarine system, southeastern Brazil. [*Forest Ecology and Management* 479 118553 2020] D

PREDICTING POTENTIAL MANGROVE DISTRIBUTIONS AT THE GLOBAL NORTHERN DISTRIBUTION MARGIN USING AN ECOLOGICAL NICHE MODEL: DETERMINING CONSERVATION AND REFORESTATION INVOLVEMENT

Mangroves play an important role in maintaining coastal wetland ecosystem functions, but they are highly threatened by anthropogenic activities. Predicting the potential distribution of mangroves is vital for policy makers and stakeholders to enforce conservation and reforestation measures. China is at the global northern margin of mangrove distribution. In this study, we used the maximum entropy (MaxEnt) model to predict potentially suitable habitats for mangroves based on current data of mangrove distributions in mainland China. For modeling, we grouped the native and exotic mangrove species in China into five groups and used 30 bioclimate, topographic, substrate, and sea surface temperature variables to predict mangrove distributions. The results show that bioclimate and sea surface are both important factors that determine mangrove distribution. The largest suitable area modified for mangrove species in the coastal zone was 2705 km^2. About 14.8% of the predicted suitable habitat for the five mangrove groups is under protection in mangrove nature reserves. Along China's coastline, 15 sites were identified as hotspots for mangrove conservation and reforestation. By comparing these results with current conservation efforts, we identified that protection priority should be given to the

Beilun River Estuary to Fangcheng Harbor coastal zone in Guangxi Province, the east coast of the Leizhou Peninsula in Guangdong Province, and the Meizhou Bay to the Xinghua Bay area in Fujian Province. In addition, suitable species selection should also be considered to achieve successful mangrove reforestation. W. Hu and others. Predicting potential mangrove distributions at the global northern distribution margin using an ecological niche model: Determining conservation and reforestation involvement. [*Forest Ecology and Management* 478 118517 2020] D

EFFECTS OF CANOPY COVER AND NEIGHBORING VEGETATON ON THE EARLY DEVELOPMENT OF *AUSTROCEDRUS CHILENSIS* AND *NOTHOFAGUS DOMBEYI* IN NORTH PATAGONIAN DEGRADED FORESTS

Austrocedrus chilensis and *Nothofagus dombeyi*, are endemic forest species of ecological and productive importance in the Andean-Patagonian region of Argentina. Both species grow in pure or mixed stands. In the last decades, several *A. chilensis* stands have been degraded by different disturbances that have compromised their natural regeneration. Plantation of seedlings of both species may be an alternative to help restore degraded *A. chilensis* stands. In this study we determined, in degraded *A. chilensis* stands grown in a xeric and a mesic site, the effects of canopy cover, the presence/absence of neighboring herbaceous vegetation and the interaction between these factors, on the performance (i.e. survival and growth) of planted *N. dombeyi* and *A. chilensis* seedlings, during three growing seasons. Results showed that in both xeric and mesic sites, survival and growth of either species were reduced when canopy cover was below 30%. Removal of neighboring vegetation improved survival of both species at the xeric site, and improved growth of both species at the mesic site. Canopy cover and removal of neighboring vegetation seem to interact by improving survival and growth of *A. chilensis*, while for *N. dombeyi* the effects of these factors, when present, are independent, both improving survival and growth. *Austrocedrus chilensis* has greater capacity than *N. dombeyi* to tolerate the high radiation and low soil moisture combination, so this species is more recommendable for planting at most exposed conditions (no canopy cover at xeric sites), but both species could be successfully used for restoring degraded *A. chilensis* stands. M. Caselli and others. Effects of canopy cover and neighboring vegetation on the early development of planted *Austrocedrus chilensis* and *Nothofagus dombeyi* in north Patagonian degraded forests. [*Forest Ecology and Management* 479 118543] D

CONTRIBUTON OF SPECIES ABUNDANCE AND FREQUENCY TO ABOVE-GROUND FOREST BIOMASS ALONG AN ANDEAN GRADIENT

To determine whether species that contribute most to a plot's biomass are the most abundant (high local abundance at plot scale) or the most frequent (occur the most across plots at landscape scale), or both. In the tropical Andes, these patterns may change with elevation. This study assesses the contribution to plot's above-ground biomass (AGB) of the plant community abundance pattern –the prevalence of within-plot dominant species– and the over-occurrence of regionally frequent species, in an elevation gradient. We considered all trees ≥ 2.5 cm DBH from 446 0.1 ha plots in an Amazonia-Andes 260–4350 m elevation cline in N Bolivia. Plot AGB was calculated as the sum of AGBs for all stems contained. We grouped plots into four bins segregated by elevation and ran a bootstrap analysis over subsets of 58 random plots per bin with 100 iterations. Simpson evenness index (E_D) for all species in each plot was used as a measure for its species abundance. Values for each plot's species frequency was calculated as the mean of

all species' in the plot mean frequencies across the bin (i.e. the fraction of plots where each species occurs). We used linear models to correlate plot AGB with (1) elevation and mean annual precipitation (MAP), and (2) E_D, plot species frequency and elevation. We performed all analyses at the species, genus and family levels. Plot AGB was related negatively with elevation, and thus positively with MAP, and also negatively with plot E_D and plot species frequency, all significant. Plot species abundance therefore contributes positively to explain the relationship with AGB along elevational gradients, while plot species frequency does so negatively (i.e. less frequent species contribute more to a plot's AGB across elevation). AGB, for both generic and familial levels was also significantly and negatively correlated with E_D, but not related with plot species frequency biomass at these taxonomic levels. Plot AGB was mainly associated with elevation and floristic composition where species, genera and families tended to be abundant at the local (plot) scale. Species that were less frequent at the regional scale contributed with more AGB regionally, while frequency at generic and familial scales did little to explain AGB patterns. This association seems stronger at lower elevations for all taxonomic levels while decreases toward higher elevation. Our study reveals a relationship between plot structural features like C stocks –influenced by species local abundances– and the distribution of taxa across the landscape. V Sandoya and others. Contribution of species abundance and frequency to aboveground forest biomass along an Andean elevation gradient. [*Forest Ecology and Management* 479 118549 2021] D

RECOVERY OF ABOVE-GROUND BIOMASS, SPECIES RICHNESS AND COMPOSITION IN TROPICAL SECONDARY FOREST IN SW COSTA RICA

Tropical secondary forests comprise about half of the world's tropical forests and are important as carbon sinks and to conserve biodiversity. Their rate of recovery varies widely; however, particularly older secondary forests are difficult to date so that the recovery rate is uncertain. As a consequence, factors affecting recovery are difficult to analyse. We used aerial surveys going back to 1968 to date 12 secondary forests in the wet tropics of SW Costa Rica and evaluated the recovery of aboveground biomass, tree species richness and tree species composition in relation to nearby old-growth forests and previous land use. To confirm the validity of the space-for-time substitution, the plots were re-censused after four years. We found fast rates of aboveground biomass accumulation, especially in the first years of succession. After 20 years AGB had reached c. 164 Mg/ha equivalent to 52% of the biomass in old-growth forests in the region. Species richness increased at a slower pace and had reached c. 31% of old-growth forests after 20 years. Recovery rates differed substantially among forests, with biomass at least initially recovering faster in forests after clearcuts whereas species numbers increased faster in forests recovering from pastures. Biomass recovery was positively related to the forest cover in the vicinity and negatively to species richness, whereas species richness was related to soil parameters. The change during the four years between the censuses is broadly in line with the initial chronosequence. While the recovery of tropical secondary forests has been studied in many places, our study shows that various environmental parameters affect the speed of recovery, which is important to include in efforts to manage and restore tropical landscapes. F. Oberleitner and others. Recovery of aboveground biomass, species richness and composition in tropical secondary forests in SW Costa Rica. [*Forest Ecology and Management* 479 118580 2021] D

DRIVERS OF LEAF AREA INDEX IN BRAZILIAN SUBTROPICAL ATLANTIC FOREST

The Atlantic Forest, a global biodiversity hotspot, has changed dramatically due to land use pressures causing deforestation, degradation, and forest fragmentation. A major challenge is to understand and potentially mitigate the consequences of these changes, for the capacity of forests to deliver essential environmental services to rural areas. Here, we focus on unraveling the mechanisms underpinning spatial variation in forest leaf area index. Forest leaf area index can be used as an environmental indicator that controls key forest functions underlying environmental services and is also expected to respond to land use change. Specifically, we use Structural Equation Modelling to determine the direct and indirect pathways that link environmental drivers to canopy leaf area index (LAI) variation across forest types in the Atlantic Forest in Southern Brazil. We sampled 240 sample units (each 4000 m^2), from a systematic and permanent forest inventory set which covers the State of Santa Catarina in a 10 km × 10 km grid, using hemispherical photographs. Environmental variables were extracted for each sample unit, including climatic and topographic data as well as indicators of anthropogenic pressure. Our results showed that forest types differed in their leaf area index (but not all of them) and that forest canopies show complex responses to environmental drivers, encompassing direct and indirect pathways. A major pathway was the positive effect of 'Distance to city' on the 'Percentage of cropland in the matrix'. This led to a decline in the distance of the sample unit to the forest edge, indirectly reducing LAI, presumably because of elevated tree mortality at the forest edge. 'Terrain steepness' and 'Rainfall in the driest month' independently affected the 'Percentage of cropland in the matrix' and the 'Distance to forest edge'. Halting forest fragmentation and increasing fragment size by landscape planning will mitigate these anthropogenic LAI declines. This can be achieved with a combination of legal and market mechanisms, like enforcement of the Brazilian Forest Act regulation on buffer zones around water bodies and steep slopes, landscape planning, and payment for environmental services to compensate the farmers for maintaining forest cover on otherwise productive land. D. Augusto da Silva and others. Drivers of leaf area index variation in Brazilian Subtropical Atlantic Forests. [*Forest Ecology and Management* 476 118477 2020] D

EFFECT OF DIVERSITY, CLIMATE AND LITTER ON SOIL ORGANIC CARBON STORAGE IN SUBTROPICAL FOREST

Tropical and subtropical forest ecosystems play an important role in the global carbon regulation. Although positive relationships between biodiversity and soil organic carbon (SOC) storage have been found in experimental grasslands, biodiversity effects on SOC storage in natural forests remain debated. Based on a large dataset from 523 forest inventory plots across subtropical forests in China, we tested the relationship between biodiversity and SOC storage and examined whether environmental conditions (temperature, precipitation, soil properties) and litter quantity (leaf litter and root biomass) and quality (leaf litter carbon to nitrogen ratio [leaf litter C/N]) had effects on SOC storage. Furthermore, we used linear mixed-effects models to test the relative effects of biodiversity, environmental conditions, and litter quantity and quality on SOC storage. We used structural equation models to test how these variables directly or indirectly affected SOC storage. We found that species diversity, together with climatic factors (mean annual temperature and mean annual precipitation), leaf litter C/N and root biomass determined SOC storage in subtropical forests at a large spatial scale. SOC storage was most strongly affected by climatic factors, followed by leaf litter C/N. Species diversity had both direct and indirect

(through root biomass and leaf litter C/N) effects on SOC storage after accounting for environmental conditions. We also found that the positive diversity–SOC storage relationships were stronger in low and medium mean annual precipitation. Our findings highlight that higher species diversity can lead to higher SOC storage and therefore the conservation of biodiversity could play an important role in climate change mitigation. Yin Li and others. Effects of diversity, climate and litter on soil organic carbon storage in subtropical forests. [*Forest Ecology and Management* 476 118479] D

RAPID RECOVERY OF PHYLOGENETIC DIVERSITY, COMMUNITY STRUCTURE AND COMPOSITION OF BORNEAN TROPICAL FOREST A DECADE AFTER LOGGING AND POST-LOGGING SILVICULTURAL INTERVENTIONS

Logged-over forests comprise a large proportion of tropical forest landscapes, but questions remain on how to fully describe and understand the regeneration of these forests and which selective logging and silvicultural interventions are best for maintaining biological diversity. We used a phylogenetic approach to capture changes on the evolutionary diversity, structure and composition of 72-one-hectare forest subplots in East Kalimantan that were logged using conventional (CL) and reduced-impact (RIL) techniques, including post-logging silvicultural interventions by reducing stem density (thinning), shortly after (on average 18 months) and 10 years after treatments. Both CL and RIL techniques initially decreased phylogenetic diversity, but after a decade of succession the phylogenetic diversity levels were no longer different from unlogged forests (Controls). Thinning through poison-notching non-commercial trees led to an increase in phylogenetic diversity after a decade of succession. Mean evolutionary relatedness, as measured by the Net Relatedness Index, initially decreased in logged forests, possibly because of harvest of closely related dipterocarp species, but returned to initial levels after a decade. Regardless of silvicultural interventions 10 years after logging had no effect on the mean evolutionary relatedness of the trees in the communities at both time intervals.

Both CL and RIL techniques increased the phylogenetic composition dissimilarity with unlogged forest, with increasing logging intensity resulting in increasingly larger effects, although the changes were smaller for RIL. Phylogenetic composition only became dissimilar from unlogged forest after a decade of succession, when the logging intensity was above 4 m^2 ha^{-1} for both CL and RIL, equivalent to 8 trees ha^{-1} or 68 m^3 ha^{-1}. Post-logging silvicultural interventions started to cause changes in phylogenetic composition when the basal area was reduced by thinning by more than 10 m^2 ha^{-1}. The rapid recovery of phylogenetic diversity, community structure and, to a lesser extent composition after logging and thinning confirms that tropical forests are resilient to a single logging cycle. With low-intensity logging of less than 4 m^2 ha^{-1}, RIL techniques appear to facilitate phylogenetic structure and compositional recovery to levels not different from unlogged forest after 10 years of succession, especially when combined with post-logging silvicultural intervention with a basal area reduction by thinning of less than 10 m^2 ha^{-1}. However, it remains to be seen whether forests will respond similarly to a second logging cycle. Ni Putu Diana Mahayani and others. Rapid recovery of phylogenetic diversity, community structure and composition of Bornean tropical forest a decade after logging and post-logging silvicultural interventions. [*Forest Ecology and Management* 476 118467 2020] D

A DECISION SUPPORT TOOL FOR THE CONSERVATION OF TROPICAL FOREST AND NEARSHORE ENVIRONMENTS ON BABELDAOB ISLAND, PALAU

Nearshore ecosystems (e.g., mangrove forests, sea grass, beds, coral reefs) are some of the most biologically diverse and ecologically productive on Earth, while providing essential goods and services to human communities. Because these ecosystems are subject to threats from both land and sea, their conservation and management requires a ridge-to-reef approach. Here, we developed a watershed decision support tool (DST) for Babeldaob Island, Republic of Palau, aimed at prioritizing catchments for reforestation of fire degraded savanna or protection of native forest against conversion to savanna. We use a distributed hydrology model to estimate catchment-level sedimentation and water yield for three vegetation scenarios: (1) current vegetation; (2) a hypothetical fully-forested Babeldaob Island; and (3) a hypothetical Babeldaob Island that has been fully converted to savanna. Using the DST, we integrated model results with geospatial information on treatment cost, efficacy, and conservation value to identify where reforestation and forest protection investments would provide the greatest benefit to coral reef health. Modeled sediment yields were lowest for catchments >80% tropical forest cover and highest for those with <40% forest cover. Sediment hotspots were concentrated near coastal population centers. Modeled catchment-level groundwater recharge showed high variability across vegetation scenarios, while no clear relationship was identified between recharge and percentage land cover in forest or savanna. The DST identified 14% of catchments as high priority for reforestation of grassland-savanna, and 11% of catchments for protection of native tropical forest. Most high priority reforestation catchments were located near the coast, while all high protection areas were further inland. Results from the DST suggest that road access and slope will not limit reforestation, but the remoteness of inland high priority catchments may limit protection efforts. N. A. Povak and others. A decision support tool for the conservation of tropical forest and nearshore environments on Babeldaob Island, Palau. [*Forest Ecology and Management* 476 118480] D

A GLOBAL MAPPING TEMPLATE FOR NATURAL AND MODIFIED HABITAT ACROSS TERRESTRIAL EARTH

The IPBES Global Assessment proposed five key interventions to tackle the drivers of nature deterioration. One of these proposals was to take pre-emptive and precautionary actions in regulatory and management institutions and businesses. Performance standards are tools that can be used to help achieve these interventions. The most influential standard is Performance Standard 6 (PS6) of the International Finance Corporation (IFC), part of the World Bank Group. Institutions like the IFC invest in the private sector in developing countries, including in the infrastructure, agribusiness, forestry, oil, gas and mining sectors, all of which have the potential to cause large environmental impacts. A core element of PS6 outlines the need for the consideration of "natural and modified habitat" within investment screening processes. Here we use freely available data layers in combination to develop a new global layer that identifies natural and modified habitat. It is aligned with the IFC PS6 definitions of natural and modified habitat. However, we propose this layer as an output that can be used beyond the IFC and could be integrated into the investment decision making of global and regional banks, or the decision making of international corporations. J. Gosling and others. A global mapping template for natural and modified habitat across terrestrial Earth. [*Biological Conservation* 250 108674 2020] D

FOREST OUTGROWER SCHEMES IN SMALL AND MEDIUM-SIZED FARMERS IN BRAZIL

Outgrower schemes are an alternative for supplying companies and can generate benefits for both the farmers and the community. The main reasons that lead companies to adopt this type of strategy are reduced investment in land purchases, lower cost of wood at the factory, increase in diversification of sources of raw materials, and greater integration with landowners close of companies. Of the total of 7.84 million hectares of trees planted in Brazil in 2016, 34% belonged to companies in the pulp and paper industry, 29% were independent operators and participants in outgrower schemes, and 14% represented the charcoal-fired steel industry. In 2016, 19,000 people benefitted from the outgrowth programs adopted by Brazilian Trade Industry (IBA) member companies, planting 545,000 ha. For rural producers, the forest development consists of an alternative to traditional income generation to their properties, which may be unused or underused areas, with low technical risk due to production inputs and technical assistance provided by the companies. The most frequent outgrower modalities include providing forest species seedlings, revenue anticipation programs, and wood purchase guarantee at harvest time. For the community, these include the possibility of creating new wood-based forest business and generating jobs in the region. This program prevents land concentration, makes local activities feasible, creates opportunities for additional income, and assists in settling people in the countryside. Also, it greatly improves the acceptability of eucalypt plantations in the region and is positive for the certification of forest products. From the environmental standpoint, an outgrower scheme mitigates the pressure on native forests, recovers degraded soils, and promotes soil conservation. J. L. de Moraes-Gonçalves and others. Forest outgrower schemes in small and medium-sized farmers in Brazil. [*Forest Ecology and Management* 456 117654 2020] D