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# DecisionES 2025 Proceedings

DecisionES 2025
Porto Seguro
Jun 30th to Jul 4th BR
Symposium on Ecosystem Services, Forest Management and Decision Making

IPEF
INSTITUTO DE PESQUISAS E ESTUDOS FLORESTAIS

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# *Proceedings*

Luiz Carlos Estraviz Rodriguez, Silvana Ribeiro Nobre & Jordi Garcia-Gonzalo *Eds*.

Instituto de Pesquisas e Estudos Florestais – IPEF

Piracicaba, SP – Brasil


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## Funding Research Agencies

# Summary

# Welcome to DecisionES 2025

The DecisionES 2025 Symposium, hosted in Porto Seguro, Brazil, gathered over one hundred professionals and scientific experts in forest management, operations research (OR), and decision science. Set in an area recognized for its rich natural and historical heritage, the symposium provides an interdisciplinary platform for in-depth discussions on decision-making processes related to sustainable forest management and ecosystem service provision.

Organized with the support of the International Union of Forest Research Organizations (IUFRO), institutions specialized in systems analysis, and two collaborative initiatives on **Decision** Support for the Supply of **E**cosystem **S**ervices under Global Change — the **DecisionES EU** (supported by the European Marie Skłodowska-Curie Research and Innovation Staff Exchange Project #101007950) and **DecisionES BR** (supported by FAPESP Project # 2021/00833-9) — the event fosters collaboration and knowledge exchange among international researchers and practitioners.

The symposium was structured around two primary session types: technical and practical. Technical sessions address research advancements in forest management planning, covering topics such as harvest scheduling, supply chain optimization, forest health management, spatial optimization, wildland fire risk management, simulation and stochastic processes, and forest economics. Practical sessions feature applied case studies concerning ecosystem services, impacts of global changes, and strategies for restoring degraded forests.

DecisionES 2025 emphasized critical contemporary challenges, including the sustainability of ecosystem services under climate change, integrated forest and watershed management, restoration of degraded forest areas, and sustainable management of fast-growing industrial plantations.

This publication compiles abstracts of presentations delivered between July 1st and July 3rd, 2025, covering the following themes:

* Remote Sensing Applications in Forestry
* Forest Modeling
* Forest Management and Planning
* Forest Transportation and Supply Chain Optimization
* Wildfire Risk Simulation, Management, and Decision Support
* Forest Health, Invasive Species, and Wildlife Habitat Management
* Spatial Optimization
* Stochastic Process Simulation and Optimization
* Quantitative Forest and Fire Economics
* Forest and Watershed Management
* Data Science and Machine Learning
* Forest Systems Analysis under Climate Change
* Ecosystem Restoration Planning

The abstracts published in this document collectively represent the symposium's significant contributions toward advancing forest systems analysis and decision-making practices.

# General Program

**DecisionES 2025 - Porto Seguro, BA - Brazil**
**June 30 - July 04 2025**
**PROGRAM**

| Day | Start | End | Duration | Section | Content |
|---|---|---|---|---|---|
| **30-Jun** | 18:00 | 20:00 | 2:00 | **Reception Cocktail** (included in the value of the registration) | |
| **1-Jul** | 9:00 | 9:40 | 0:40 | Opening | Hosting entities |
| | 9:40 | 10:20 | 0:40 | Keynote Speaker Day1-A | **Rita Mesquita** (Brazilian Secretary of Biodiversity) |
| | | | | Keynote Speaker Day1-B | **Garo Batmanian** (Director General - Brazilian Forest Service) |
| | 10:20 | 10:50 | 0:30 | Keynote Speaker Day1-C | **Ludmila Siqueira** (Director of Landscape Restoration - CI Brazil) |
| | 10:50 | 11:20 | 0:30 | Coffee Break - Morning 1 | Refreshments (coffee and tropical juices) |
| | 11:20 | 12:20 | 1:00 | **Oral Presentations - Day1/1** | Three talks (20 minutes each) |
| | **12:20** | **14:00** | **1:40** | **Lunch** | **Lunch is included with registration and served nearby** |
| | 14:00 | 15:20 | 1:20 | **Oral Presentations - Day1/2** | Four talks (20 minutes each) |
| | 15:20 | 15:30 | 0:10 | Stretch Break | 10 minutes break |
| | 15:30 | 16:30 | 1:00 | **Oral Presentations - Day1/3** | Three talks (20 minutes each) |
| | 16:30 | 17:10 | 0:40 | Coffee Break - Afternoon 1 | Coffee, tropical juices, and light snacks + **5 minutes *flash-talks*** |
| | 17:10 | 18:50 | 1:40 | **Oral Presentations - Day1/4** | Five talks (20 minutes each) |
| **2-Jul** | 9:00 | 9:40 | 0:40 | Keynote Speaker Day2-A | **Marc McDill** (Forest Planning - Penn State) |
| | 9:40 | 10:30 | 0:50 | Keynote Speakers Day 2-B | **Caio Zanardo** (Veracel CEO) **Carolina Zonete** (Suzano Director) |
| | 10:30 | 11:00 | 0:30 | Coffee Break - Morning 2 | Refreshments (coffee and tropical juices) |
| | 11:00 | 12:20 | 1:20 | **Oral Presentations - Day2/1** | Three talks (20 minutes each) |
| | **12:20** | **14:00** | **1:40** | **Lunch** | **Lunch is included with registration and served nearby** |
| | 14:00 | 15:20 | 1:20 | **Oral Presentations - Day2/2** | Four talks (20 minutes each) |
| | 15:20 | 15:30 | 0:10 | Stretch Break | 10 minutes break |
| | 15:30 | 16:30 | 1:00 | **Oral Presentations - Day2/3** | Three talks (20 minutes each) |
| | 16:30 | 17:10 | 0:40 | Coffee Break - Afternoon 2 | Coffee, tropical juices, and light snacks + **5 minutes *flash-talks*** |
| | 17:10 | 18:50 | 1:40 | **Oral Presentations - Day2/4** | Five talks (20 minutes each) |
| | **20:00** | **22:00** | **2:00** | **Conference dinner** (included in the value of the registration) | |
| **3-Jul** | 9:00 | 9:40 | 0:40 | Keynote Speaker Day3-A | **Silvio Brienza** (Forest restoration in degraded areas - EMBRAPA) |
| | 9:40 | 10:30 | 0:50 | Keynote Speaker Day3-B | **Carlos Cerri** (Tropical sustainable agriculture CCARBON) |
| | 10:30 | 11:00 | 0:30 | Coffee Break - Morning 3 | Refreshments (coffee and tropical juices) |
| | 11:00 | 12:20 | 1:20 | **Oral Presentations - Day3/1** | Three talks (20 minutes each) |
| | **12:20** | **14:00** | **1:40** | **Lunch** | **Lunch is included with registration and served nearby** |
| | 14:00 | 15:20 | 1:20 | **Oral Presentations - Day3/2** | Four talks (20 minutes each) |
| | 15:20 | 15:30 | 0:10 | Stretch Break | 10 minutes break |
| | 15:30 | 16:30 | 1:00 | **Oral Presentations - Day3/3** | Three talks (20 minutes each) |
| | 16:30 | 17:10 | 0:40 | Coffee Break - Afternoon 3 | Coffee, tropical juices, and light snacks + **5 minutes *flash-talks*** |
| | 17:10 | 18:50 | 1:40 | **Oral Presentations - Day3/4** | Five talks (20 minutes each) |
| **4-Jul** | 8:00 | 18:00 | 10:00 | **Field Trip** (transportation and meals included in the value of the registration) | |

# Presentations Program

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| | | 16 Stand structure characterization from TLS data to assess forest management effects in protected areas | Garzas, Carolina |
| | | 13 Exploring EnMAP hyperspectral images for distinguishing forest land-cover types in Brazil | Ferreira, Matheus Pinheiro |
| | 2 | 62 Evaluating Remote Sensing-Derived Canopy Height Models for Biomass Estimation in Brazil's Atlantic Forest | Flores, Manuel |
| | | 64 Sampling Optimization for Training ALS-Based Predictive Models | Rodrigues, Leonardo Ippolito |
| | | 24 Integrating ALS data and the 3-PG model to simulate climate change impacts on Eucalyptus Management Units in Northern Portugal | Magalhaes, Jean |
| | | 34 Using LiDAR to estimate anthropogenic impacts on forest carbon stocks | Piotto, Daniel |
| | 3 | 36 Exploratory analysis of the potential of digital maps to predict the productivity of maritime pine in Portugal | Tome, Margarida |
| | | 28 Linking the 3PG model to existing empirical growth models. Application to the Portuguese production forest | Tome, Margarida |
| | | 30 Modeling Stomatal Conductance and Water-Use Efficiency in Planted Forests in Brazil | Santos, Juscelina Arcanjo dos |
| | 4 | 14 Decolonizing fire: a call for plurality in fire and forest governance | Masso-Ardila, Ana Valentina |
| | | 10 Dynamic Forest Use Suitability: towards ecosystem-services-based long-term forest management strategies | Krsnik, Goran |
| | | 60 Integrating Multifunctional Forests into the Rubber Tree Industry in São Paulo, Brazil: A Model for Balancing Resource Availability and Market Constraints | Nobre, Silvana Ribeiro |
| | | 12 From Forest to Paper: A Life Cycle Perspective on Eucalyptus-Based pulp and paper Products | Cunha, Fernanda Leite |

| Day | Session | Presentation | Author |
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| | | 20 Economic Analysis of the Pulp Value Chain in Mato Grosso do Sul: Value Generation, Employment, and Regional Sustainability | Dias, Bruna Mendes |
| | | 17 One year harvest deferrals can produce forest carbon additionality | Silva, Bruno Kanieski da |
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| | | 43 Sphere of influence: Investigating how adjacent pasture and plantation affect secondary forest structure and health at the landscape scale in Bahia, Brazil | Flores, Manuel |
| | | 18 Landscape design to support the Integrated Wildfire Risk Management Strategy for the EU | Borges, Jose Guilherme |
| | | 61 Native Species Silviculture in Brazil: Advancing Knowledge and Cutting-Edge Technologies for Sustainable Production Systems and Climate Resilience. | Calmon, Miguel |

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| | | 21 | Post-fire recovery of black pine forests: the role of fire refugia and microsite conditions | Coll, Lluis |
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| | | 19 | Planting native trees in the Cerrado accelerates carbon stock in the biomass, but contribution to soil carbon is negligible | Xavier, Marcio Venicius Barbosa |
| | | 37 | Mapping non-timber forest products and ecosystem services under climate change: A participatory methodological approach | Masso-Ardila, Ana Valentina |
| | 4 | 33 | Spatial Patterns of Fire in the Atlantic Forest of Bahia: Analysis of Driving Factors and Risk Scenarios | Nascimento, Nathalia |
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# Keynote Abstracts

**Agriculture as an option for adaptation and mitigation of global climate change**

*Carlos Eduardo Pellegrino Cerri*

Brazil is one of the world's largest producers and exporters of food, feed, fiber, and (bio)fuels. Its agricultural sector is among the main contributors to greenhouse gas (GHG) emissions across economic sectors, yet it remains highly vulnerable to the impacts of global climate change, particularly in tropical regions. However, adopting regenerative management practices and sustainable land-use strategies can significantly enhance carbon sequestration and substantially reduce GHG emissions.

This presentation aims to compile and synthesize existing literature on highly effective agricultural management practices that offer viable options for climate change adaptation and mitigation. These practices include no-till farming, crop rotation and cover cropping, integrated agricultural systems (such as crop-livestock, crop-livestock-forest, and crop-forest systems), and the restoration of degraded pastures. Each strategy contributes not only to carbon sequestration and the reduction of GHG emissions but also improves soil health and agricultural resilience.

Expanding the adoption of these strategies could position agriculture as a pivotal sector for climate change mitigation, promoting more sustainable and resilient production systems. Nevertheless, large-scale implementation requires clear policies, financial incentives, technical capacity building, and enhanced monitoring frameworks to accurately quantify carbon sequestration and GHG emission reductions.

Public policies in Brazil, such as the ABC+ Plan, provide a solid foundation for sustainable land use. However, greater investment in research, infrastructure, and education is necessary to accelerate widespread adoption. Additionally, integrating carbon markets and payment-for-ecosystem-services programs can further incentivize farmers to transition toward climate-smart agriculture.

By leveraging Brazil's vast agricultural potential, these strategies can make substantial contributions to climate change mitigation, food security, and ecological restoration, reinforcing Brazil's global leadership in sustainable agriculture.

# Oral Presentation Abstracts

**10** *Krsnik, GonzAlez-Olabarria, Reynolds*

**Dynamic Forest Use Suitability: towards ecosystem-services-based long-term forest management strategies**

Adopting a multi-criteria approach to forest management is crucial for preserving or enhancing specific benefits while minimizing adverse environmental impacts. Developing a suitable long-term management strategy for a forest necessitates considering diverse environmental and social factors, along with changes in forest characteristics over time. A strategic assessment of forest use suitability (FUS)—encompassing productive, protective, conservation-oriented, social, and multifunctional uses—at the national level can provide valuable guidance for crafting tailored management strategies and policies. This assessment takes into account the dynamics of forest ecosystem service provision and the trade-offs between different FUS alternatives.

In this study, we assess the supply and temporal dynamics of diverse ecosystem services in Pinus sylvestris stands across Spain. Using a decision model, we identify the most suitable FUS alternative that optimizes the delivery of these services. This process aims to support informed decision-making and facilitate the selection of appropriate management strategies.

To achieve this, we leverage the latest version of the Ecosystem Management Decision Support (EMDS) system, a spatially focused decision-support tool capable of delivering precise multi-criteria assessment results. Participatory planning methods based on the Delphi principles, combined with Analytic Hierarchy Process (AHP) analysis, were integrated with geospatial logic-based modelling. The findings reveal that the protective FUS is dominant, followed by the productive alternative, demonstrating high levels of multifunctionality.

**12** *Cunha, Lopes, Pulls, Cook, Baker, Campoe*

**From Forest to Paper: A Life Cycle Perspective on Eucalyptus-Based pulp and paper Products**

Processed wood products (HWPs) play a crucial role in climate change mitigation strategies. HWPs continue to store carbon post-harvest, retaining ~335 $MtCO_2e$ annually worldwide. This study aims to provide a comprehensive analysis of the carbon dynamics of Eucalyptus-derived HWPs in Brazil, assessing their contribution to atmospheric carbon removal and their long-term storage potential. The LobWISE model, designed for inventorying, storage, and emissions of wood products, was adapted to reflect forest management and product conditions in Brazil. The model generates results over a 120-year period following the initial harvest. It integrates elements of Life Cycle Assessment (LCA) to create a system, developed in R, that tracks carbon flows through five phases: 1-silviculture, 2-transportation, 3-milling, manufacturing, and use, 4-recycling, downcycling, and landfilling, and 5-emissions. This framework produces multiple outputs, including carbon stored in different applications and landfills over time, biogenic $CO_2$ emissions, methane emissions, and fossil fuel, and chemicals emissions associated with pulp and paper production. The analysis includes five paper categories based on Brazilian Tree Industry data: Cardboard (6%), Sanitary products (13%), Packaging (56%), Printing and writing (20%), and Miscellaneous paper products (5%). The model was applied using input data from a one-hectare Eucalyptus plantation at six years of age, sourced from 25 sites of the TECHS (Tolerance of Eucalyptus Clones to Hydric, Thermal and Biotic Stresses). These sites span ~4,000 km across Brazil, including nine subtropical and 17 tropical locations. We use the most widely planted clone in Brazil, E. urophylla, characterized by high productivity and plasticity. With the stock emission outputs of LobWise, we applied Inverse Distance Weighted (IDW) interpolation to spatially analyze the data. Results indicate that subtropical sites stored and emitted 50% more carbon than tropical sites, mainly due to higher biomass production. The average carbon stocks in subtropicais plantations were ~406, ~166, and ~135 $tCO2eqha^{-1}$, with emissions of ~208, ~132, and ~81 $tCO2eq^{-1}$ at 0, 15, and 120 years respectively. In contrast, tropical plantations stored ~270, ~110, and ~90 $tCO2eqha^{-1}$, with emissions of ~138, ~88, and ~54 $tCO2eqha^{-1}$ over the same periods. Carbon storage was lowest in water-deficit regions. These differences underscore the influence of climate, decomposition rates, and product longevity on carbon retention. The average lifespan of paper products was 15 years, representing 42% of total stored carbon within the first decade. Landfills were the primary carbon reservoir, as anaerobic conditions slow decomposition, allowing long-term storage. Pulp-paper production emerged as the largest emissions source, highlighting this cycle stage as the main challenge in reducing emissions within the sector. The findings demonstrate that HWPs function as a significant carbon sink over time. These findings reinforce the importance of integrating long-term HWP carbon storage into climate policies, aiding forest industries in aligning with net-zero targets. Future research should explore alternative management strategies, extended product lifespans, and recycling improvements to enhance carbon retention.

**13** *Ferreira*

**Exploring EnMAP hyperspectral images for distinguishing forest land-cover types in Brazil**

Spatially explicit information on forest land-cover types is critical for effectively managing and conserving forest ecosystems and monitoring restoration initiatives. This study delves into the potential of the Environmental Mapping and Analysis Program (EnMAP) hyperspectral satellite for distinguishing between tropical forest land-cover types in São Paulo, Brazil. We evaluated the impact of band selection on the classification accuracy and the impact of spectral resolution by simulating the spectral bands of the Landsat 8 and Sentinel-2A satellites to compare with EnMAP's higher spectral resolution data. The study focused on mapping forest land-cover types, including conserved remnants, natural regeneration, restoration plantations, and monocultures. We compared the classification performance of pixel-wise deep learning approaches against that achieved by conventional machine learning methods, including support vector machines (SVM). Our findings reveal significant distinctions in spectral responses across these forest land-cover types, highlighting the efficacy of deep learning models, especially an optimized recurrent neural network (RNN), which outperformed SVM in classification performance. Misclassification rates of 6% or lower were noted when distinguishing between plantation and natural forest land-cover types. This study provides valuable insights into the effective use of space-borne hyperspectral imagery and deep learning for forest land-cover type mapping in tropical regions, demonstrating the importance of band selection and spectral resolution in improving classification accuracy.

**14** *Cuartas, Masso-Ardila, Cacais, Machado, Florez, Villafane, Vasquez, Walker*

**DECOLONIZING FIRE: A CALL FOR PLURALITY IN FIRE AND FOREST GOVERNANCE**

Conventional fire governance in native forest management is predominantly shaped by Western scientific paradigms emphasizing suppression and control. However, Indigenous communities have long maintained fire as an integral tool for ecosystem stewardship, demonstrating knowledge systems that sustain biodiversity, mitigate wildfire risks, and promote resilience. This study explores fire and forest management through the perspectives of five Indigenous groups in Colombia: Arhuaco, Pijao, Embera Chamí, Tikuna, and Uitoto, who conceptualize fire not merely as a physical phenomenon but as a sacred force regulating ecological balance, social structures, and spiritual well-being.
Drawing from participatory dialogues and narrative interviews with Indigenous knowledge holders, this research challenges the dichotomy between current Western fire suppression strategies and Indigenous fire governance. A decolonial approach to fire governance in forest areas necessitates recognizing that fire is not an adversary, but a dynamic ecological force that Indigenous and local communities have managed sustainably for centuries. Indigenous fire management practices reveal a sophisticated understanding of ecological cycles. This dynamic ecological force works with other forces such as water, wind, and soil. Importantly, the research highlights that each territory's unique context must inform fire and forest management, cautioning against generalized management strategies.
By critically analyzing the exclusion of Indigenous perspectives in fire and forest management policies, this research advocates for a pluralistic approach integrating Indigenous epistemologies into decision-making frameworks. Recognizing fire as more than a destructive force, one that heals, transforms, and regenerates landscapes, can promote more sustainable, equitable, and climate-resilient forest governance. The findings contribute to broader discussions on decolonizing forest science and reimagining fire governance in the face of escalating global wildfire risks.
Examining fire and its management cannot be isolated from all other forces and systems converging in landscape design and management. To recommend strategies that use or manage fire independent of scale, it is crucial to understand, recognize, and manage water, vegetation, soil, and genetic flows collectively.
Therefore, this study calls for a paradigm shift in fire and forest governance that embraces plurality. By dismantling colonial structures in environmental policy and amplifying Indigenous voices, we can develop fire management strategies that are not only scientifically robust but also socially just and ecologically sustainable. The findings of this research underscore the urgency of decolonizing fire governance to address contemporary fire crises while ensuring equity and resilience in forest landscapes.

**16** *Garzas, Benito, Parras, Aulló, Cruz, Vazquez, Cabo, Montes, Canellas, Hernandez, Pardos, Marino*

**Stand structure characterization from TLS data to assess forest management effects in protected areas**

The future of protected forest areas is uncertain considering the current climate and land use change scenario. The stand structure, which can be shaped through forest management, constitutes a key factor determining the forest dynamics and potential wildfire behaviour. New LiDAR technologies have been incorporated in the monitoring of forest systems in order to optimize data collection and provide information for forest research and management. The aim of WHAT-IF project is to characterize the effects of different forest management and conservation strategies on forest structure through Terrestrial Laser Scanner (TLS) data considering their implications for wildfires behaviour and stand dynamics.

Our study has been carried out in Spanish National Parks, in which are represented a wide range of forest types. Two plots of 0.5 ha covering unmanaged and managed stands were stablished in each forest type. Plots were scanned with Leica BLK 360 TLS, co-registered and preprocessed in multi-scan 3D point clouds. The open-source Cloud Compare 3DFin plugin, which applies voxel based geometrical segmentation, was used to locate the trees and measure diameter and height. Vertical structure and spatial pattern of stand features were analyzed using second order moment techniques with the purpose of characterizing forest fuels and forest species dynamics.

This study shows the potential of operational focused tools such as 3DFin for stand structure retrieval. Our results show the effects of forest management on forest structure, modulating forest composition and modifying vertical structure. Proximal sensing techniques provide valuable information for decision support in the management of protected forests areas.

I101 WHAT-IF project is supported by Fundación Biodiversidad from the Ministry for the Ecological Transition and the Demographic Challenge (MITECO) within the framework of the Recovery, Transformation and Resilience Plan (PRTR), funded by European Union – NextGenerationEU.

**17** *Silva, Henderson, Tanger, Tilman, Chizmar, Marufuzzaman, Fortuin*

**One year harvest deferrals can produce forest carbon additionality**

The growing demand for nature-based solutions to mitigate climate change has heightened interest in forest carbon programs, particularly in the southeastern United States, a region with abundant forest resources. Challenges such as additionality, leakage effects, and competition between timber and carbon markets are among the complexities of implementing effective carbon forest programs. This study examines the impacts of one-year harvest deferral programs on carbon sequestration and timber market dynamics using an agent-based simulation model. The model incorporates interactions between landowners, a wood-consuming mill, and a carbon aggregator. The simulation experiment we developed explored varying levels of carbon demand and prices to analyze how forest landowners respond under different scenarios and to examine the outcomes for stand age structure, stumpage and delivered prices for timber, and carbon sequestration over a 100-year period. The results indicate that a one-year harvest deferral program can substantially alter timber market dynamics by increasing stumpage prices and encouraging forest aging in the aggregate, with higher carbon demand leading to greater additionality via carbon sequestration but also higher program costs. This study contributes to a growing literature by providing insights into economic and ecological trade-offs of forest carbon offset programs and their implications for sustainable forest management in the US South.

**18** *Borges*

**Landscape design to support the Integrated Wildfire Risk Management Strategy for the EU**

This talk will outline the FIRE-RES (https://fire-res.eu/) approach to landscape design and its contribution to the development of an Integrated Wildfire Risk Management Strategy for the EU. The emphasis will be on adaptive territorial management innovations that may encompass novel practices, namely fire management models and adaptive management strategies, to mitigate the impacts of wildfires on forest ecosystems, and the provision of ecosystem services. In this context, the talk will focus on innovative actions to design pre-fire (prevention and preparedness) and post fire (adaptation and restoration) landscape mosaics that are less prone to the occurrence of wildfires and that can facilitate detection and suppression when a wildfire occurs. The potential of innovative models, methods and tools to address wildfire risk and support adaptive forest management planning is illustrated by an application to a forested landscape extending over 14 thousand ha and involving multiple decision makers and stakeholders. It is illustrated further by their contribution to the development of resilient landscapes and safer communities within the Integrated Wildfire Risk Management Strategy for the EU.

**19** *Xavier, Melo, Durigan*

**Planting native trees in the Cerrado accelerates carbon stock in the biomass, but contribution to soil carbon is negligible**

The growing global demand for ecological restoration emphasizes the recovery of ecosystem services. In Brazil, this understanding was incorporated into the Native Vegetation Protection Law (12.651/2012), which establishes the rehabilitation of ecological processes as one of the objectives of restoration in Legal Reserves. In an area with a history of intensive agriculture in the Cerrado region of southeastern Brazil, we established a restoration experiment in 2015 with seven treatments (ten replicates), based on technical-scientific knowledge of the ecology and flora of the regional Cerrado. The treatments included mixed plantings with wide spacing (Cerrado Fruit Trees, Nucleation Trees) or dense spacing (Cerrado Specialists, Generalists, Conventional), pure planting (Tachigali vulgaris), and Passive Restoration (control). We compared the treatments among themselves and with two reference ecosystems: cerrado stricto sensu (s.s; savanna) and cerradão (forest). In this study, we address the effectiveness of the treatments in storing carbon (C) in biomass (aboveground and root) and soil. In each useful plot (900 $m^2$), we measured all individuals with DBH greater than or equal to 5 cm and estimated biomass and C (aboveground and root) using locally developed allometric equations. We collected soil samples at five depths (up to 1 m) to quantify soil C. Nine years after planting, C stock in biomass varied widely, from 0.6 Mg $ha^{-1}$ in Passive Restoration to 60 Mg $ha^{-1}$ in the T. vulgaris planting. All dense plantings exceeded the C stock in biomass of a cerrado s.s, and the T. vulgaris planting already reached the values of cerradão. Tree plantings with wide spacing exhibited a structure similar to that of cerrado s.s On the other hand, the effect of tree plantings on total soil C was practically negligible, with only the highest density planting, with 80 Mg $ha^{-1}$, being superior to the others, which did not differ from each other, the control, or cerrado s.s, ranging from 69 to 76 Mg $ha^{-1}$. The extremely slow recovery of biomass in Passive Restoration highlights the legacy of agricultural use, which severely compromises the resilience of the Cerrado. If rapid C sequestration is the goal of restoration in low-resilience areas, dense plantings with fast-growing native trees are recommended, although, in the long term, the total stock should not differ between treatments, being limited by the carrying capacity of the environment (approximately 55 Mg $ha^{-1}$ in aboveground and belowground biomass). Significant gains in soil C cannot be expected within the timeframe of carbon projects (20 years), so there will be no additionality resulting from restoration plantings. Furthermore, one cannot ignore the trade-offs typical of savannas in general: if restoration results in a forest structure (high C stock), this will mean decreased water recharge and loss of endemic savanna flora and fauna diversity. Additionally, high aboveground biomass in savanna regions also increases the risk of catastrophic fires, jeopardizing the premise of C permanence in the restored ecosystem (Fapesp support - process 2023/03670-9).

**20** *Dias*

**Economic Analysis of the Pulp Value Chain in Mato Grosso do Sul: Value Generation, Employment, and Regional Sustainability**

Mato Grosso do Sul has established itself as one of Brazil's leading hubs for pulp production, driven by large-scale eucalyptus plantations and public policies that promote sustainable development. This study presents an economic analysis of the pulp value chain in the state, using data from Regional Accounts, RAIS, CAGED, investment records, foreign trade statistics, and socioeconomic indicators from the Mato Grosso do Sul Statistical Profile.

Between 2010 and 2023, the sector experienced remarkable growth, particularly in the municipality of Três Lagoas, which has become the country’s top pulp exporter. The industrial sector accounted for 14.7% of formal employment in 2023, with an average wage of R$ 3,547.95. Although forestry is a capital-intensive sector, it generates significant multiplier effects in transportation, logistics, trade, and services.

A central indicator of this transformation is the expansion of eucalyptus plantation area. According to data from SIGA-MS, the planted area increased by over 500% from 2009/2010 to the 2023/2024 crop year, growing from 242 to 1,453 thousand hectares. This exponential growth reflects the strong synergy between industrial demand, land availability, and investment policies in the state. It also strengthens the region’s position in the global pulp market.

The study also discusses challenges related to local workforce qualification and the need to expand technical education and forestry engineering programs. Furthermore, the strategic role of eucalyptus pulp in meeting global demand for renewable, low-carbon materials is emphasized, along with its potential to generate carbon credits and support ecosystem services.

The findings suggest that the pulp industry in Mato Grosso do Sul is a powerful driver of inclusive and sustainable development, contributing to industrial modernization, regional integration, and environmental resilience in the face of global challenges.

**21** *Mendez-Cartin, Coll, Krawchuk, Gelabert, Fontova, Ameztegui*

**Post-fire recovery of black pine forests: the role of fire refugia and microsite conditions**

The recovery capacity of Pinu nigra in Catalonia has been challenged by new fire regimes, which have led to a reduction of its populations. Here we aim to understand the biophysical drivers – seed source availability, plant community interactions, water/nutritional constraints – affecting the post-fire regeneration patterns of P. nigra in Catalonia. We quantified fire refugia through PNOA orthoimages, ALS-LiDAR and SVM classification models. We calculated the distance-weighed refugia density (DWD) across the landscape, to have a multidimensional distance to the seed source. We sampled 270 five-meter-radius-plots across our DWD gradient, having samples both inside and outside refugia. For each plot we obtained information on regeneration levels, % shrub cover, basal area, annual precipitation and calculated the heat load index (aridity). We built two identical zero inflated negative binomial models – inside and outside refugia. We found that fire refugia had a sheltering effect over the regeneration, reducing the negative effect of aridity. Higher DWD levels promoted P. nigra recovery, mainly outside refugia. Shrub cover negatively impacted regeneration inside refugia and in the driest sites outside refugia, however, outside refugia, it exerted a facilitative effect at the milder sites.

Seed source abundance is an important driver to ensure black pine's post-fire recovery. However, within the current climate change context biophysical site conditions have a stronger effect, increasing or diminishing the regeneration; hinting that seed availability alone is not enough to ensure its recovery.

**23** *Pedro, Ferreira, Oliveira, Ferraz*

**Predicting the effects of land use on stream drying through remote sensing and deep learning algorithm**

Land-use changes can result in reduction of base flow, and ultimately on drying perennial reaches, threatening aquatic biodiversity, stream regulation and ecosystem services. This is especially relevant in the global climate change context where increased drought occurrence is expected in many world regions. However, we are currently unable to accurately predict when, where, and how streams dry in order to better mitigate and adapt to negative effects. Remote Sensing (RS) associated with Deep Learning (DL) models is a promising approach for this task, offering a scalable and consistent solution across space and time. Therefore, we asked the following scientific question: Can stream drying be effectively assessed using only geospatial data? Our study area is Corumbataí river basin in São Paulo, Brazil, impacted by intensive agriculture, particularly sugarcane crops and cattle ranching. To predict the probability of a stream to dry, we used RS and DL. We applied a convolutional neural network (CNN) to extract data from 699 catchments (1–8 $km^2$) automatically delineated using a 30 m resolution Digital Elevation Model (DEM). RS data included high-resolution Planet imagery (RGB, NIR; 5 m), vegetation indices (NDVI, NDWI), DEM-derived terrain attributes, and climatic variables. We classified the catchments in three categories of stream drying probability (low, medium, and high). This classification was made by analyzing RS data and incorporating researchers' opinions to train the DL algorithm. The next step is field validation. By identifying high-risk drying areas, our approach offers a cost-effective, scalable tool for forest and water resource management, helping prioritize conservation efforts and mitigate water scarcity impacts on aquatic ecosystems and ecosystem services. [Funded by FAPESP, Process nº 2024/13393-5]

**24** *Magalhaes, Guerra-Hernandez, Marques, Borges, Tome*

**Integrating ALS data and the 3-PG model to simulate climate change impacts on Eucalyptus Management Units in Northern Portugal**

The characterization of forest stands across large areas using Airborne Laser Scanning (ALS) data is essential for a detailed understanding of forest structure, providing technical support for sustainable management and informed decision-making. This study focuses on Management Units (MUs) dominated by eucalyptus stands, located within a Forest Intervention Zone in northern Portugal — a region frequently affected by wildfires. The high recurrence of forest fires underscores the urgent need for forest management strategies adapted to future climate conditions. While process-based models such as the Physiological Principles Predicting Growth (3-PG) model are widely used, their integration with ALS data remains limited in the literature. This study addresses this gap by combining ALS-derived metrics and field data to estimate the input variables required to initialize the 3-PG model. Driven by intercepted radiation, the 3-PG model simulates stand growth and development under user-defined forest management and climate scenarios. The primary objective of this study is to assess the potential impacts of climate change on stand development, particularly regarding wood production and carbon sequestration. Based on a predefined management scenario, simulations were conducted under three climate scenarios: BAU, RCP4.5, and RCP8.5. The results provide projections of the future performance of eucalyptus stands, supporting the identification of more climate-resilient management strategies that can assist forest managers and policymakers in developing more effective and adaptive plans in the face of increasing wildfire threats.

**27** *Brienza Junior, Yared, Ruschel, Siviero, Vieira, Sales*

**Human-Modified Forests and Precision Forest Restoration: a new frontier for the Amazon**

For over 45 years, research conducted in the Tapajós National Forest has enabled pioneering small enterprises to incorporate innovative forest technologies. In 2010, the State Secretariat for Science and Technology of Pará supported a pilot-business project (involving Grupo Arboris, Embrapa, UFRA, and UFPA) focused on intensively exploited forests along the eastern edge of Pará State. The project included botanical identification, pre-exploratory inventories, harvesting criteria, infrastructure planning, and tests of wood technologies for commercially lesser-known species. After 15 years of studies, managed and enriched/densified anthropogenic forests can maintain high species diversity, biomass stocks, and growth rates 5 to 8 times higher than those of first-cycle managed forests. The new technique allows for the management of intensively exploited forests with cycles of 12 to 15 years, harvesting trees with DBH (Diameter at Breast Height) starting from 25 cm, and growth increments of 5 to 8 m3/ha/year. However, existing regulations (IBAMA IN-5/2006 and SEMAS-PA IN-5/2015) mandate management with a harvesting intensity of 30 m3/ha, cycles of 35 years, harvesting trees with DBH exceeding 50 cm, and an average annual increment of 0.86 m3/ha/year. The innovative alternatives studied lack legal support as they deviate from traditional standards, i.e., first-cycle forest management and large areas such as forest concessions. They also do not consider the dynamics of smaller areas and Legal Reserves (ARL). This situation generates a notable contradiction, as environmental licensing for the management of natural forests seems stringent, while other forms of land use (partial suppression in ecological zoning areas) are often subject to less stringent requirements. Forests managed under traditional cycles may, in the future, exhibit characteristics similar to the intensively exploited areas of today, with challenges and opportunities projected for the next 50 to 100 years. According to Law No. 11,284 of 2006, particularly regarding the principles of promoting and disseminating forest research (Art. 2, paragraphs VI and VII), it is imperative to foster knowledge and raise awareness about the importance of conserving, restoring, and sustainably using forest resources, thereby also encompassing private forests and Legal Reserves. In summary, for the dissemination and scaling of intensive management technological innovations, it is urgent that legislation incorporates specific guidelines for forest management and reflects the reality of anthropogenic forests, thereby ensuring the maintenance and recovery of these ecosystems, which are vital for environmental balance.

**28** *Tome, Barreiro, Baptista-Coelho, Jorge, Magalhaes, Nunes, Paulo, Soares*

**Linking the 3PG model to existing empirical growth models. Application to the Portuguese production forest**

Forests cover 36% of Portugal mainland, and the majority of this forest is based on eucalyptus (26.2%), maritime pine (22.1%) and cork oak (22.3%) as pure stands or mixed-species stands with the species as dominant. The impact of climate change on the wood/cork production from those forests is of the major importance for Portugal, giving impetus to the need to use process-based models. Such models, integrating the main physical, biogeochemical and physiological processes involved in forest growth and development, give a mechanistic description of the interactions between the living plants and their environment and are able to assess the energy balance and the cycling of water, carbon and nutrients within a given ecosystem. At present, empirical tree models based on the simulation of each of the individual trees within the stand are well established in the country (see the website thttps://www.isa.ulisboa.pt/cef/forchange/fctools/pt/inicio) and are the ones used to support management decisions. Process-based models are complex and require very detailed information for the model parameters and also for the characterization of the site and stand to initialize the simulations, mainly if using individual trees as the unit of simulation. The 3PG model is a simple process-based stand model, based on the light-use efficiency principles, that was developed to bridge the gap between conventional, mensuration-based growth and yield, and process-based carbon balance models. The output variables it produces are of interest and relevance to forest managers but they are stand level variables which are not enough for the simulation of different management alternatives. This presentation discusses the application of a methodology to link the 3PG model to the existing individual tree models in order to make those sensitive to climate change but keep the information on the individual trees along the projection horizon.

**30** *Santos, Campoe, Cunha*

**Modeling Stomatal Conductance and Water-Use Efficiency in Planted Forests in Brazil**

Modeling photosynthetic capacity and stomatal conductance is essential for predicting vegetation responses and developing strategies for selecting species and genotypes in forestry under current and future scenarios. Several leaf-level models have been developed to describe stomatal conductance (gs) as a function of environmental factors such as $CO_2$ concentration, light, temperature, relative humidity, vapor pressure deficit (VPD), and soil hydraulic potential. In this study, we aimed to evaluate the applicability of three commonly used stomatal conductance models: the Ball-Woodrow-Berry (BB) model, the Ball-Berry-Leuning (BBL) model, and the Unified Stomatal Optimization (USO) model. Our objective was to identify the most suitable model using data collected from planted forests of Pinus, Corymbia, and Eucalyptus in Brazil. Additionally, we analyzed how stomatal conductance and water-use efficiency vary among genera (Pinus, Corymbia, and Eucalyptus) and among different Eucalyptus genotypes.

Our results indicate that the BBL and USO models performed better than the BB model. Both USO and BBL models showed good fits ($R^2$ ranging from 0.41 to 0.95) based on the evaluated metrics. Among the 22 Eucalyptus genotypes tested, three did not fit the BBL model. The USO model demonstrated good fits for stomatal conductance across all datasets.

The USO model estimated the highest slope parameter ($g_1$) for Pinus taeda ($g_1 = 4.96 \pm 0.09$) and the lowest $g_1$ for the E. grandis × E. urophylla hybrid ($g_1 = 1.42 \pm 0.04$). In Eucalyptus species, $g_1$ ranged from 1.42 to 4.87, while in the Pinus genus, it varied from 4.30 to 4.96. Pinus species exhibited higher $g_1$ values, which translated into lower water-use efficiency compared to Eucalyptus species.

Overall, our results highlight significant differences in $g_1$ between the evaluated groups. The Pinus genus exhibited the highest $g_1$ values, whereas Eucalyptus and Corymbia presented lower values, with no significant difference between them. This study provides a comprehensive database of $g_1$ values obtained through three widely used models in Earth System Models (ESMs) and Process-Based Models (PBMs). Additionally, our findings offer insights into the next steps for improving stomatal conductance modeling in planted forests in Brazil.

**32** *Nascimento, Ferreira*

**Prioritizing Areas for Forest Restoration in São Paulo State: Degradation, Connectivity, and Decision-Making**

Forest restoration is one of the most effective strategies for mitigating and adapting to climate change. However, large-scale implementation in Brazil faces significant challenges, including high costs and resistance from landowners to adopt restoration initiatives. The state of São Paulo has set a goal of restoring 1.5 million hectares by 2030. However, achieving this target requires overcoming these barriers and strategically identifying priority areas for restoration.

In this study, we identified forest areas in the state of São Paulo that exhibit some level of degradation or are affected by multiple degradation drivers, such as fire, edge effects, and isolation. These areas are considered priorities for cost-effective conservation actions and have high potential for providing ecosystem services. We applied a multicriteria assessment methodology to identify degraded forest remnants with connectivity potential to healthy forest fragments, aiming to establish ecological corridors. This process can facilitate natural regeneration through seed rain and wildlife movement.

Additionally, we cross-referenced this information with the database of private property boundaries in the state of São Paulo to understand the profile of landowners with the largest areas available for restoration. Based on this analysis, we propose alternative restoration models tailored to different types of rural landowners and provide insights for policymakers on the most effective mechanisms to support restoration efforts according to each group's specific needs.

Our results indicate that, of the 5% of remaining forest cover in São Paulo, approximately 2.5% show signs of degradation. Furthermore, forest isolation levels are high, with fragments located more than 10 km apart in some regions, posing a significant challenge for ecological connectivity. We found that the most suitable areas for restoration are predominantly located within large rural properties. These findings can contribute to improving policies and incentives that promote large-scale forest restoration, enhancing both its economic and environmental feasibility.

**33** *Nascimento*

**Spatial Patterns of Fire in the Atlantic Forest of Bahia: Analysis of Driving Factors and Risk Scenarios**

Fire is one of the main drivers of tropical forest degradation, often surpassing the total deforested area in certain periods and regions. In the Atlantic Forest, a biome historically pressured by land-use conversion, wildfires represent an increasing threat. In addition to the recurrent use of fire in agricultural and land management practices, climate change has intensified extreme weather events, such as prolonged droughts and rising temperatures. These conditions can increase the frequency and severity of wildfires, compromising biodiversity, ecosystem services, and forest regeneration capacity. Furthermore, wildfires have significant impacts on human health, agricultural systems, and water security.

In this study, we investigated the spatial and temporal patterns of fire in the Atlantic Forest of Bahia, Brazil, over the past decade. We used remote sensing and geoprocessing techniques to map fire frequency and correlate it with different environmental and anthropogenic factors. The analyzed variables included land tenure categories, proximity to rivers and roads, and climatic factors such as maximum temperature, precipitation, humidity, radiation, and water deficit. We applied the weight of evidence method to assess the contribution of each variable to fire occurrence and frequency. Based on these data, we developed predictive models to project future fire risk scenarios in the state.

Our results indicate that approximately 40% of Bahia's remaining forests are at high or very high fire risk. The most vulnerable areas are concentrated in the western region of the state, where drier climatic conditions prevail, and continuous forest cover is reduced. The factors most strongly correlated with fire occurrence include proximity to previously burned areas, proximity to agricultural lands and highways, as well as high temperatures and low relative humidity. The spatial modeling of these factors not only helps identify critical areas but also supports strategic actions for fire prevention and suppression.

Understanding fire spatial patterns and their key driving factors is essential for policy planning and mitigation strategies. Our findings highlight the importance of preventive measures, such as the implementation of early warning systems, sustainable landscape management, and the creation of natural barriers to fire spread. Additionally, integrating environmental conservation with low-impact agricultural practices can help reduce fire incidence and enhance the resilience of Atlantic Forest ecosystems in the face of climate change.

**34** *Coelho, Piotto, Camargos, Dalmolin, Magnago*

**Using LiDAR to estimate anthropogenic impacts on forest carbon stocks**

Tropical forests are expected to play a key role in mitigating climate change and achieving the global temperature rise target set in the Paris Agreement. However, to support climate mitigation policies and operationalize targets, information about the carbon storage potential in these forests must be clear and spatially detailed due to the heterogeneity of tropical forests. Tropical forest carbon stocks are vulnerable to changes in land use and land cover, and their estimates rarely include variability in the particularities of each site. Forest fragmentation, edge effects, logging, fires events, biological invasion and defaunation, can alter the species composition leading to loss of carbon storage potential even if no deforestation occurs. Thus, the application of technologies to optimize tree carbon stocks measurements and anthropogenic impacts on forestry functioning are crucial to implementing nature-based solutions. Because of the need for more detailed spatial information on how degradation in carbon stocks due to anthropogenic disturbances occurs, we aimed (a) to verify if there is a significant difference and to accurately estimate the average carbon per hectare of secondary and matures using airborne LiDAR, (b) to assess the edge effect on carbon stock variability and the threshold of this effect. Our results showed significant differences between the carbon stocks of primary and secondary forests ($p>0.001$) even after a long time since the end of the disturbance. The relationship between terrain slope and carbon stock may be related to land use history. We also found that edge effects influence forest degradation: in primary forests, the first 182 meters impact 25.07% of the carbon stock, and after this threshold carbon stocks tend to stabilize, while in the secondary forest, the first 48 meters impact 56.63% of the carbon stocks. Our results show a clear spatial relationship between edge effects and forest carbon stocks in the Atlantic Forest. As local-scale field information is rarely available, the use of airborne LiDAR has the potential to reduce uncertainty between regional carbon maps of the Atlantic Forest and its true climate mitigation potential. They can help the implementation of global climate commitments at local levels. The results presented here, using LiDAR to with degradation as a function of edge distance. In addition, it provides an quantify carbon stocks in forests, provide consistent insight into how these stocks vary at the local scale by forest type (primary and secondary forest area), including patterns associated alternative to support decision-making to identify priority areas for management. The analysis and results presented here, can allow governments and other stakeholders to develop their conservation and restoration goals for carbon, biodiversity, and ecosystem services with more precise geospatial terms operationalizing existing targets, support long-term goals, and implement nature-based solutions such as REDD+.

**35** *Pintado, Knoke*

**Optimizing the configuration of a tropical forest landscape: A two-stage framework integrating robust and metaheuristic methods**

Designing multifunctional landscapes that balance the needs of human populations while enhancing the provision of ecosystem services is essential for the sustainable management of land resources. This is particularly relevant in tropical regions, where growing resource demands and rapid socio-environmental changes constantly threaten the forest ecosystems. While research on landscape multifunctionality has increased in recent decades, most of studies have focused on analyzing changes in the landscape composition. Meanwhile, the landscape configuration has received considerably less attention despite its significant role in shaping ecological processes and influencing the ecosystem service supply. Addressing the spatial aspects of land management is a critical step in practical decision-making, as it can enhance conservation efforts and improve resource allocation strategies.

Optimization models are powerful tools to support land-use allocation decisions, which often involve multiple conflicting objectives. For example, non-stochastic robust optimization approaches have been used to determine the optimal landscape composition of a tropical mountain forest in southern Ecuador. However, such optimization models do not specify where these allocations should occur within the landscape, limiting their applicability to real-world decision-making. To address this spatial limitation, we integrated the results of a previous optimization study into the metaheuristic-based software CoMOLA (Constrained Multi-objective Optimization of Land Use Allocation, Strauch et al. 2019), an optimization model developed for solving spatial allocation problems. This metaheuristic approach facilitates the consideration of inherent biophysical constraints and spatial interactions by further integrating spatially explicit objectives. The proposed two-stage optimization framework enhances the spatial precision of robust optimization techniques, facilitating the effective allocation of land resources in a multifunctional tropical forest landscape. Moreover, it provides decision-makers with reliable, site-specific data to better navigate the uncertainties of forest management.

**36** *Coelho, Tome*

**Exploratory analysis of the potential of digital maps to predict the productivity of maritime pine in Portugal**

With the aim of conducting an exploratory analysis of the potential of digital maps to predict the productivity of maritime pine in Portugal, the coordinates of plots located in pure maritime pine stands—where dominant height and known age were available—were matched with climatic, topographic, and soil data obtained from various sources (Atlas do Ambiente, EPIC, Clipick, and MDT). These variables were then used to estimate the Site Quality Index (SI) through both traditional linear regression and quantile regression (adjusted at the 0.05, 0.25, 0.50, 0.75, and 0.90 quantiles).

Preliminary analysis showed low correlations between the measured IQE and the numerical environmental variables, and no clear differences were detected among groups of categorical variables. The final linear model, even after successive variable selections, achieved a coefficient of determination ($R^2$) below 20%. The introduction of two principal climatic components, obtained from prior analyses, did not improve the fit. Furthermore, when grouping the plots by climatic regions defined in previous studies, no clear trend was observed in IQE values, reinforcing the hypothesis that local factors—such as soil depth, slope, or hillside position—may have a greater impact than the large-scale variables available in digital maps.

Quantile regression allowed the identification of variations in the coefficients at different quantiles, suggesting that the environmental variables exert different effects in areas of higher or lower productivity, where different limiting factors come into play. Despite this, the results indicate that the information contained in digital maps is not sufficient to adequately explain the variation in IQE for maritime pine. The conclusion is that, for a more robust model, more specific local data will be needed to account for the substantial local variability affecting the productivity of this species.

**37** *Masso-Ardila, Cuartas, Condori*

**Mapping non-timber forest products and ecosystem services under climate change: A participatory methodological approach**

Forests play a critical role in supporting rural livelihoods and ecological resilience through the provision of non-timber forest products (NTFPs), including food, medicinal plants, and raw materials. Understanding the impacts of climate change on these resources and associated ecosystem services is essential for effective forest management and community adaptation.

This work introduces a participatory methodological framework adapted from the agricultural livelihood vulnerability methodology originally proposed by Uniendo Saberes (CATIE, 2025). The expanded framework specifically addresses the assessment and mapping of NTFPs and ecosystem services.

The methodology involves structured participatory steps:

1. Stakeholder Engagement: Forest-dependent communities and diverse actors (forest owners, experts) collaboratively identify and prioritize key NTFPs, integrating traditional ecological knowledge (TEK), cultural significance, and current management practices.
2. Climate Impact Assessment: Communities assess perceived impacts of climate variability on the availability and quality of NTFPs, considering both provisioning services (such as food and medicinal plants) and cultural services (including spiritual and cultural values).
3. Participatory Mapping: The mapping of NTFPs in nearby native forests is an essential component of the participatory mapping process, as it makes it possible to visualize the spatial distribution of wild harvesting systems in the study area.
4. Local seasonal Calendars: The development of forestry calendars is a fundamental tool for understanding production practices throughout the year and how they are and how they are influenced by climatic and seasonal conditions. Utilization of seasonal calendars demonstrates the influence of climate variability on harvesting cycles and resource availability, supporting adaptive planning.

By actively involving diverse community members, this participatory framework integrates local ecological knowledge with scientific insights, fostering inclusive and informed decision-making. The methodology provides a comprehensive tool for incorporating NTFPs into broader forest management and climate adaptation strategies, thereby enhancing sustainable livelihoods and the resilience of forest ecosystems.

**39** *Nobre, McDill, Rodriguez*

**Defining Adequately the Decision Space for Maximizing Carbon Removals in Eucalyptus Industrial Plantations**

The efficacy of optimization in forest management is heavily contingent upon the definition and density of the decision space. This study illustrates the critical importance of expressing the possible alternates to more accurately mirror real-world complexities, using carbon sequestration in Eucalyptus plantations in Brazil as a case study. Effective forest management for carbon sequestration requires precise optimization of the decision space to approach the theoretical optimum in operational scenarios. This study presents an optimization exercise centered on Eucalyptus plantations in Brazil, demonstrating the pivotal role of a well-defined decision space in enhancing carbon removal from the atmosphere. Using carbon removal as the primary optimization variable, we explore a 'Business as Usual' (BAU) scenario of Eucalyptus cultivation alongside several scenarios. Each scenario progressively refines the granularity of decision-making inputs, including variations in age ranges, coppicing alternatives, and cycle combinations. This methodical enhancement in scenario design aims to encapsulate a broader spectrum of potential management strategies, thereby densifying the decision space. The scenarios were calculated and analyzed using iGen and iMath from Romero®, which facilitated the calculation and comparison of carbon sequestration across different management alternatives. Initial results indicate a direct correlation between the density of the decision space and the efficacy of carbon sequestration: as more diverse management alternatives are considered, the amount of carbon removed from the atmosphere increases significantly. Our findings underscore the importance of expanding the decision space in forest management plans. By incorporating a wider array of management alternatives, it becomes feasible to not only approach but potentially reach the optimum levels of carbon sequestration. This study contributes to the ongoing discourse on optimizing ecosystem services in forest management, offering actionable insights into strategic decision-making processes that maximize environmental benefits. This approach underlines the significance of detailed scenario planning in forest management, suggesting that the key to achieving superior ecosystem services and operational objectives lies in accurately representing the manifold possibilities of real-world conditions.

**40** *Torres-Celi, Knoke, Castro*

**Dry forest land-use strategies: a multicriteria approach to enhance socioeconomic benefits and ecosystem services under uncertainty**

This research provides an in-depth analysis of the complex land-use decision-making processes faced by farmers within dry forest ecosystems. Employing robust Pareto frontiers to examine inherent trade-offs between competing socioeconomic and ecological objectives. Using a multiobjective robust optimization approach, we integrated two indicator bundles to compare observed land-use compositions with optimized portfolios, emphasizing the influence of uncertainty on decision-making. The current farm-level land use in the dry forest region of southern Ecuador was identified through secondary data and GIS analysis, which is dominated by three agroforestry systems (silvopasture: 57%, shade coffee: 7%, and shade cocoa: 4%) and a monoculture system of maize (32%). The multiobjective optimization model prioritized agroforestry systems, increasing the shares of shade cocoa and shade coffee while reducing silvopasture (25%, 23%, and 15%, respectively) alongside a slight increase in maize (37%). This optimized land-use composition improved the guaranteed performance across different uncertainty levels (22% to 48% under low uncertainty, 10% to 32% under moderate uncertainty, and 16% to 33% under high uncertainty). The robust Pareto frontier analysis explicitly revealed trade-offs between socioeconomic and ecological indicator bundles, demonstrating that improvements in ecological performance may negatively impact socioeconomic performance and subsequently change land use composition. For example, prioritizing ecological indicators may favor agroforestry systems (particularly shade cocoa and shade coffee), potentially leading to decreased area allocated for more economically productive crops like maize. These findings provide valuable insights for sustainable land-use planning in dryland ecosystems, highlighting the importance of balancing competing objectives under uncertainty.

**41** *Poudel, Borges, Marques*

**Multi-Criteria Decision Analysis for Evaluating Forest Management Strategies in Vale do Sousa, Portugal**

Forest ecosystem management involves addressing a range of economic, social, and ecological objectives, often involving multiple stakeholders with conflicting interests. The decision-making among these wide ranges of competing forest management objectives is one of the key challenges for forest managers. This study focuses on the evaluation and prioritization of forest management alternatives/strategies in Vale do Sousa, a region in northwestern Portugal, in accordance with stakeholders' preferences. These forest management alternatives/strategies include maximizing biodiversity, maximizing carbon stock, maximizing wildfire resistance, maximizing timber production, and minimizing soil erosion. To achieve this, Linear Programming (LP) is used to quantify the contribution of each management alternative to the targeted ecosystem services. Similarly, stakeholder preferences are incorporated through a questionnaire survey and analyzed using the Criterium Decision Plus (CDP) software to perform a Multi-Criteria Decision Analysis (MCDA). The expected results will identify the top-ranked forest management alternative, considering both ecosystem services provision and stakeholder preferences. In addition, a sensitivity analysis will be conducted to assess the robustness of the decision model by determining how changes in stakeholder preferences could influence the ranking of management alternatives. The findings aim to provide guidance for developing forest management strategies that are both effective and acceptable to the region in a complex decision-making environment.

**42** *Lopez, Mielke, Cerqueira*

**Monitoring of forest restoration: A review of approaches and strategies for global assessment**

Forest restoration is a fundamental for recovering degraded areas and mitigating climate change. Here we conducted a literature review to analyze how forest restoration projects are monitored, identifying advances and gaps in current knowledge to guide future research. We conducted our survey on the Scopus, Web of Science, and Science Direct platforms, using eight keywords related to restoration monitoring. This search yielded 2.630 articles, of which 348 were included in the study. The articles were published in 126 scientific journals between 1995 and 2024, with peaks in quantity of publications in 2019 and 2022. We classified the articles by their biogeographical kingdom and we categorized the disturbances identified in the studies into eight groups, with deforestation and land use change being the most frequent, appearing in 116 studies. Regarding monitoring methodologies, 290 of the 348 articles involved in situ monitoring, and there has been a notable increase in studies incorporating remote sensing as an efficient method for evaluating restoration processes. Among the types of restoration, active restoration through seedling planting was the most studied. Notably, there are knowledge gaps, particularly concerning the lack of data on survival rates and stress monitoring in planted seedlings. Focusing evaluations on these aspects, reporting functional traits, and monitoring stress will help in selecting appropriate species at each stage of the restoration process, could improve increasing the efficiency of forest recovery efforts. Closing these gaps will contribute significantly to advancing restoration practices and improving outcomes, ultimately supporting global efforts to restore forests and combat climate change.

**43** *Flores, Peters, Harris, Ashton, Piotto*

**Sphere of influence: Investigating how adjacent pasture and plantation affect secondary forest structure and health at the landscape scale in Bahia, Brazil**

Forest fragmentation and its associated edge effects have been found to drastically alter microclimate and increase tree mortality in the neotropics. However, most of this work has been focused on primary tropical forests that are being disturbed through encroaching agriculture or urban development. In contrast, there is less work analyzing secondary forest recovery within tropical regions that have undergone largescale conversion and are now regenerating in complex human modified landscapes. Thus, exploring the influence that different land uses have on regenerating secondary forest fragments is critical to understanding forest recovery and their potential role in carbon capture solutions. To address this, our study uses satellite remote sensing data to address how surrounding land uses (forest plantation and pasture) influence the health and structure of secondary forests within 11 municipalities in the Brazilian Atlantic Forest in which over 90,000 ha have been converted to Eucalyptus plantations. Using MapBiomas landcover classification data, all secondary forests were identified. A 100 m buffer was generated outside of each secondary forest fragment and the percentage of land use comprising of Eucalyptus plantation or pastureland was calculated and related to average forest values of Enhanced Vegetation Index (EVI) and lidar canopy height, two variables used to approximate forest health and structure respectively. Using linear regression that accounted for vapor pressure deficit, elevation, secondary forest age, and perimeter-to-area ratio (PA), our analysis revealed a significant interaction effect between plantation-pasture ratio and PA ($p < 0.001$, $F = 12.2$) on canopy height. It was found that forests surrounded by more plantations had higher canopy heights but primarily for high PA forests (i.e. more forest edge present). For EVI, there were significant relationships with plantation-pasture ratio and PA interactions ($p = 0.001$, $F = 6.9$) yet changes were of extremely low magnitude and there was low coefficient of variation (CV) in measurements of EVI (7.4) across forest fragments compared to lidar (20). This work shows the divergent edge effects that two land-uses have on secondary forests and is necessary for understanding how they shape tropical forest recovery.

**44** *Balocchi, Fernandez, Olmedo, Garate, Arellano*

**The role of forest plantations on soils protection using RUSLE: the case of Chile.**

From the middle of the 19th century to the early 20th century, the expansion of agricultural land, mainly for cereals production and cattle grazing, resulted in significant degradation of native forests. The inadequate agricultural soil management, winter rains coinciding with bare soil, and cultivation on slopes triggered serious erosion problems in the central region of Chile. Consequently, during the first decades of the 20th century, the country initially conceived the forestry sector as an urgent response to control erosion through reforestation of degraded soils, using fast-growing species such as Pinus radiata and Eucalyptus spp. In the 1950s, approximately 19 million hectares were under high erosion rates. This research addresses the contribution of forested areas, particularly forest plantations, to soil protection in Central Chile. We evaluated the contribution of these forested areas to soil protection using the Revised Universal Soil Loss Equation (RUSLE) along a latitudinal gradient of around 500 km in the Coastal Range, which was particularly affected by erosion. We evaluated different soils, slopes, and rainfall conditions (from 700 to 2200 mm year-1) using different scenarios of soil cover, including no cover, different agricultural systems, and native and plantation forests. In a long-term comparison, we included the effect of plantation harvest and brief soil exposure until the next rotation crown closure. The results confirm the long-term positive contribution of forested areas to erosion prevention as an ecosystem service often ignored by public opinion.

**45** *Soares, Kanieski*

**Carbon stock in the state of Santa Catarina from the perspective of ecosystem services**

The state of Santa Catarina has great potential for Payment for Ecosystem Services programs, with its forest areas, water resources, etc. Furthermore, at a time when the issue of climate change is becoming more and more relevant, the study of ecosystem services related to the potential for carbon sequestration and storage is becoming increasingly important. In this context, we sought to estimate the carbon stock for the state of Santa Catarina. To do this, we used the Land Use Land Cover (LULC) map provided by the Floristic-Forest Inventory of Santa Catarina, as well as bibliographic research to determine the carbon density of belowgroung and aboveground biomass, of the soil and dead matter, for the different land use classes. We processed the data in the softwares QGIS and then in the InVEST. For data processing, we used the Carbon Storage and Sequestration and Forest Carbon Edge Effect modules. The total amount of carbon stored in the different uses ranged from 7.69 to 21.38 tons per pixel, with native and planted forest areas standing out. As expected, urban areas have a lower carbon stock, however, it is important to highlight the potential of these areas for ecosystem services, including those related to carbon. In total terms, the state's carbon stock is 1,783,533,734.71 tons. These data show the Santa Catarina's great potential for carbon stocks and sequestration, especially in its areas with forest cover.

**47** *Zakia, Guerin, Fritz, Silva, Guerrini, Pereira, Andre*

**A Landscape-Based Protocol for Measuring Biodiversity Net Gain in the Atlantic Forest**

Contemporary conservation challenges demand robust, scalable tools to quantify genuine biodiversity recovery beyond traditional carbon-focused metrics. This study presents an innovative protocol that uses landscape ecology principles to measure biodiversity net gain through habitat quality assessment in Brazil's critically endangered Atlantic Forest. Recognizing that habitat quantity and quality serve as reliable proxies for biodiversity potential - where larger, well-connected fragments with optimal shapes and aquatic resources support greater species diversity - our framework evaluates six key indicators: (1) native vegetation coverage (percentage of property under natural cover), (2) fragment size (total area in hectares), (3) fragment shape (measured by shape index, with lower values indicating better edge-to-area ratios), (4) spatial heterogeneity (number of vegetation physiognomies), (5) landscape connectivity (percentage of natural habitat within a 1500-meter radius), and (6) aquatic resource presence (drainage density). Each indicator (scored 1-4 points) reflects well-established landscape ecology principles: larger fragments maintain more species (species-area relationship), connected landscapes enhance metacommunity dynamics, compact shapes minimize edge effects, and aquatic features significantly increase habitat value. The resulting composite score (6-24 points) provides a standardized, data-driven measure of habitat potential for biodiversity recovery. Three innovative features distinguish our approach: First, it utilizes existing geospatial datasets, enabling rapid implementation without costly field surveys. Second, it establishes a transparent metric system for biodiversity-positive market mechanisms, complementing carbon markets. By transforming landscape ecology principles into practical management tools, this protocol enables: Quantification of biodiversity gains using habitat as a measurable proxy; Cost-effective monitoring through remote sensing and open-access data; Market-based incentives for habitat restoration and connectivity; Adaptive management across different conservation contexts. The system's scientific foundation in landscape ecology (supporting habitat-biodiversity relationships) combined with digital verification creates a replicable model for tropical forest conservation. This approach bridges critical gaps between ecological theory, conservation practice, and financial mechanisms, offering a scalable solution for achieving measurable biodiversity outcomes in human-modified landscapes. Additionally, there is an opportunity to integrate the protocol with a blockchain, creating tamper-proof records of habitat gains and addressing verification challenges in conservation accounting.

**48** *Felippe, Luciano, Marin, Ferraz*

**Vapor Pressure Deficit can be used as an indicator of ecosystem services for tropical forests under restoration**

Tropical forest restoration is essential for mitigating climate change, yet assessing forests' potential effects on climate regulation remains incipient. This study investigates the potential of vapor pressure deficit (VPD) as a microclimatic index to inform environmental services in tropical riparian forests. VPD, a measure of the atmosphere's capacity to draw moisture, directly affects plant transpiration and overall ecosystem functioning.

This research examines how VPD varies across a gradient of riparian forest restoration sites, ranging from early-stage passive restoration (10-14 years) to mid-stage natural forest regeneration (26-29 years) and old-growth forests. Fifty systematically allocated 3-meter subsections were distributed along a 150-meter stream reach. Five measurements were taken repeatedly between 9 AM and 4 PM. Air temperature and relative humidity were measured using a thermo-hygrometer and data logger. VPD was calculated from these measurements following the methodology of Jucker et al. (2018). A two-way ANOVA was applied, considering time and site to analyze the VPD in each headwater stream. Tukey's test was used to compare forest structure and VPD between sites, assuming a 5 % significance level.

Results showed a significant decrease in VPD levels with increasing forest ages. Old-growth forests exhibited mean VPD values of 0.19 kPa. In comparison, younger forests consistently presented VPD values exceeding 1.0 kPa. Additionally, VPD in the reference forest (REF) showed significantly lower mean VPD compared to that presented in older stands. This indicates a stable microclimate and effective regulation of atmospheric water demand by older forests. In contrast, younger restoration sites consistently presented higher VPD values, exceeding a critical threshold associated with plant water stress.

These findings highlight the importance of forest canopy in regulating microclimate and providing the ecosystem service of microclimate regulation. To be successful, forest restoration initiatives require a holistic approach that integrates ecological, economic, and social considerations. Vapor Pressure Deficit (VPD) emerges as a valuable indicator in this context, offering a simple yet effective means of assessing restoration success and ecosystem integrity. By monitoring VPD we can identify vulnerable areas where vegetation is more susceptible to atmospheric water demand and potential water stress. This is especially critical for isolated trees and early-successional forests, which lack the buffering capacity of mature stands and are more prone to the coupling effect of high VPD. Recognizing the ecosystem service of microclimate regulation, as reflected in lower VPD values in healthy, mature forests, opens avenues for innovative financing mechanisms such as payment for environmental services (PES). By considering the positive effects of forests on VPD, PES schemes can incentivize landholders to adopt sustainable practices that promote forest restoration, enhance ecosystem resilience, and ensure the long-term provision of ecological functions related to microclimatic regulation service.

**49** *Piotto, Freitas, Reis, Calmon, Rolim, Brienza Junior, Pina-Rodrigues, Viani, Silva, Amaral*

**Reference Hubs: Revisiting Old Native Species Silvicultural Trials in Brazil**

The establishment of Reference Hubs through the revitalization of old experimental trials is essential for advancing sustainable silviculture and increasing the economic potential of native species' silviculture in Brazil. These research hubs serve as centers of innovation, enabling the short-term development of growth equations as well as selecting material for genetic improvement, and wood quality and processing studies. The Research and Development (R&D) Program in Native Species Silviculture has been working in two of the most significant experimental trials for native species silviculture in Brazil. The Belterra experimental field of Embrapa (state of Pará) is a reference for planting Amazonian native species, with experiments lasting over 45 years involving species such as Carapa guianensis, Bertholletia excelsa, Dipteryx odorata, Schefflera morototoni, among others, while the Paubrasilia echinata experimental field in Porto Seguro (state of Bahia) is a reference for planting Atlantic forest native species, with experiments lasting over 50 years involving species such as Dalbergia nigra, P. echinata, Cariniana legalis, Platymenia reticulata, among others. Both hubs play a crucial role in studying the growth dynamics, productivity, and environmental impact of native tree plantations, generating valuable data that supports large-scale reforestation and sustainable wood production. Research conducted in Belterra and Porto Seguro aims to integrate biometric modeling, silvicultural management strategies, and wood properties of planted trees to optimize species selection and planting practices. By bridging, in the short-term, the gap between scientific research and commercial application, the sites provide critical insights for policymakers, industry stakeholders, and conservationists, demonstrating the viability of transitioning wood production from natural forests to managed plantations. Furthermore, as part of a broader network of Reference Hubs, these experimental trials exemplifies how research-driven approaches can promote a resilient native wood economy while ensuring ecological sustainability. Expanding and strengthening such initiatives through multi-sectoral collaboration is essential for establishing Brazil as a global leader in sustainable forest management and native species cultivation.

**50** *Fernandez, Murphy, Reynolds, Borges, Gonzalez-Olabarria*

**Integrating Stakeholder Preferences into Multi-Criteria Decision Analysis for Strategic Forest Management**

Effective wildfire prevention and suppression require strategic prioritization of fuel management efforts, particularly in fire-prone regions. This study develops a Multi-Criteria Decision Analysis (MCDA) framework to integrate stakeholder preferences into spatial decision-making, ensuring that fuel management strategies align with expert knowledge and local priorities. The approach is applied to Vale do Sousa, a wildfire-prone region in northwestern Portugal, where fragmented forest ownership and diverse stakeholder interests present significant management challenges.
A participatory approach was employed to engage stakeholders in defining and weighting key criteria. Through Analytic Hierarchy Process (AHP) pairwise comparisons, participants assigned relative importance to criteria and sub criteria. To refine these weightings and ultimately arrive at the fairest possible consensus, we explored several statistical approaches, including Spearman's rank correlation, Euclidean distance, and consistency ratio analysis. These allowed us to assess the level of agreement between stakeholders and to potentially down-weight outlier contributions.
The methodology was implemented using the Ecosystem Management Decision Support (EMDS) system and Criterium Decision Plus (CDP), enabling spatially explicit prioritization of management units. Beyond this case study, ongoing research is exploring the application of these decision-support techniques at a pan-European scale, leveraging geospatial tools to incorporate homogeneous continental-scale datasets on fuels and fire behaviour. This approach facilitates large-scale assessments of wildfire prevention strategies and resource distribution needs.
This methodology provides a structured way to incorporate stakeholder perspectives into spatial decision-making, offering a replicable framework for optimizing wildfire management strategies at multiple scales.

**52** *Rolim, Barberena, Ribeiro, Piotto, Calmon, Silva, Amaral, Pina-Rodrigues, Brienza, Viani, Silva, Rocha, Tronco, Batista*

**Advancing Sustainable Forestry: The Role of Research Sites in Native Species Silviculture and the Case of Rioterra Studies Center and Symbiosis Investimentos.**

The establishment of research sites is crucial for advancing sustainable silviculture, particularly in the cultivation of native tree species, as they provide essential data to improve silvicultural practices, genetic improvement, and wood technology. In Brazil, the Research and Development Program for Native Species Silviculture (PP&D-SEN) has been key to promoting innovation and economic viability in native species silviculture. The first initiative of this program was the establishment of a long-term research site in partnership with the Rioterra Studies Center, set up in 2023, and with Symbiosis Investimentos in 2024, serving as a hub for scientific experimentation and data collection. Each site has 8 priority native tree species for R&D, following the experimental design created and validated by experts on the subject in Brazil. The research sites play a critical role in testing and refining sustainable forest models. The Rioterra Studies Center site, located in the Amazon, and the Symbiosis Investimentos site, in Atlantic Forest biome, focus on evaluating the growth, productivity, and ecological impact of native tree plantations. By providing empirical evidence on the viability and benefits of cultivating native species, the research sites exemplify how dedicated research infrastructures can bridge the gap between scientific knowledge and practical implementation. As part of a broader strategy to shift wood production from natural forests to managed plantations, these research sites are essential for ensuring the economic viability and sustainability of native tree-based silviculture, aligning conservation efforts with market demands. Through continuous investment in research and collaboration between educational and research institutions and private companies, the expansion of such initiatives will significantly contribute to develop a resilient and competitive native species-based forest market in Brazil.

**53** *Fernandez, Alzamora, Chateau, Elissetche, Munoz, Pinto*

**Increasing small landowners' opportunities by improving wood recovery from native forests discarded logs.**

Chile possesses 1.6 million hectares of Nothofagus forests, primarily consisting of N. obliqua, N. alpina, and N. dombeyi species, with valuable timber. Many correspond to secondary-growth stands with smaller diameters or degraded conditions; a significant proportion of these forests belong to small landowners. In this context, increasingly small and low-quality logs remain in the ground or are sold as fuelwood after silvicultural management. We analyzed the yield of commercial lumber from these logs and potential products to increase the benefits to the forest owners, giving them more reason to protect and manage their already degraded forest.

A sample of 177 logs from several species from discarded wood on managed stands was classified after size and quality, adjusting a log classification standard; a subsample of 67 logs was processed. Log sizes varied between 3 to 11.7 inches in diameter (average of 6 inches) and between 20 and 57 inches in length (average of 43 inches). Curved logs were split into two shorter sections, considerably improving wood recovery. For sawing, only one first cut was applied to the logs, and with this surface as a support face, the rest of the cuts were standardized at one or 2-inch thickness parallel cuts. Each obtained plank was cut in pieces of variable width and length to maximize wood recovery, discarding sections with severe defects. Average wood yield varied between species from 20% to 43% (Nothofagus dombeyi).

As products, we propose the market of cutstocks that correspond to small planed timber obtained from larger pieces with defects. They are used in finger-jointed or glued products. Cutstocks are offered in the market in thicknesses of 1 to 4 inches, widths of 2 to 6 inches, and variable lengths. 85% of the obtained pieces correspond to cut stock dimensions, with 71% in dimensions of 1-inch thickness x 2 to 5 inches width. We are also testing glued panels as products. The potential supply chain from the forest to the market and the economic feasibility are under study, and possible customers such as architects, designers, artisans, and furniture workshop's receptivity of the products are discussed based on discussion groups and surveys.

**56** *Barra, Badilla, Fernandez, Kutchartt, Garcia-Gonzalo, Cardil, Navarrete, Borges, Pirotti, Weintraub, Gonzalez*

**A Decision-Support Tool for Prioritizing Wildfire Mitigation Efforts in Europe**

Wildfires are increasingly impacting both the environment and society. Effectively mitigating their effects requires an integrated approach that considers the factors influencing fire behavior and the values at risk. However, integrating these factors is challenging due to data availability issues and the varying measurement units.

This work presents a tool designed to obtain, standardize and analyze fire-related factors, helping prioritize the most efficient areas for treatment based on user-defined preferences. The factors are categorized into three groups: landscape characteristics, fire behavior, and values at risk. These datasets are available for the whole of Europe and stored in a cloud service and made accessible through QGIS Server. Each factor is standardized using utility functions and user-specified parameters, enabling a weighted analysis to determine the most critical areas for intervention.

A case study in the Iberian Peninsula demonstrates the tool's functionality and effectiveness.

**57** *Fabrin, Zakia*

**Prediction of Sediment Export in a Public Water Supply Watershed Using the InVEST SDR Model**

Quantifying sediment export in watersheds that serve as public water sources is crucial for evidence-based environmental management, water security strategies, and the valuation of hydrological ecosystem services. This study applied the Sediment Delivery Ratio (SDR) model of the InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) software to simulate sediment export in the Tijuco Preto watershed, located in southeastern Brazil that supplies water for municipal use. The watershed covers 423.41 hectares and presents a diversified land use matrix, including pastures, native vegetation, annual and perennial crops, silviculture, urban zones, and non-vegetated areas such as unpaved roads and exposed soil. The SDR model produces several spatially explicit outputs, including the RUSLE-based potential soil loss (tons per hectare per yr), the sediment actually exported to the watershed outlet, the sediment retained within the landscape, and the spatial distribution of sediment retention and priority areas for intervention, by integrating a digital elevation model (DEM), land use/land cover (LULC) data, soil erodibility and rainfall erosivity indices, and management and support practice factors. Results indicate a total estimated sediment export of 9.81 t/ha/yr. Despite occupying the largest proportion of the landscape (44.04%), pastures showed a moderate erosion potential of 5.14 t/ha/yr. Annual crops, especially soybean (12.66 t/ha/yr) and corn (8.92 t/ha.yr), covering together 116.91 ha (27.6% of the area), contributed significantly to the sediment dynamics, due to low vegetative cover during rainfall events. Perennial crops such as coffee and others had intermediate values (6.52 and 1.34 t/ha.yr, respectively), while silviculture (0.42 t/ha.yr) and native forests (0.49 t/ha.yr) displayed low erosion intensities, reinforcing their protective role. Urban zones, occupying only 2.68% of the watershed, showed high erosion rates (9.50 t/ha.yr). This elevated value is primarily associated with the recent development of a residential subdivision. The most critical contributors were the non-vegetated and degraded areas, covering 16.22 ha (3.83%), with an extreme erosion rate of 104.83 t/ha.yr, accounting for more than one-third of total potential loss. In contrast, riparian vegetation and other natural non-forest formations exhibited lower yet non-negligible values (0.88 and 1.56 t/ha/yr, respectively). The spatialized outputs reveal that a relatively small portion of the landscape is responsible for a disproportionately high sediment export, especially where vegetative cover is minimal or degraded. Conversely, areas with structured vegetation—forests, silviculture, and perennial crops—demonstrated greater capacity for sediment retention. These findings highlight the utility of the SDR model in supporting watershed management decisions by identifying sediment source hotspots, evaluating the effectiveness of land cover in controlling erosion, and mapping ecosystem service provision zones. Furthermore, the quantification of sediment export serves as a foundation for the economic valuation of hydrological services, particularly by estimating avoided costs in water treatment due to improved sediment retention across the landscape.

**60** *Nobre, Nobre, McDill, Rodriguez*

**Integrating Multifunctional Forests into the Rubber Tree Industry in São Paulo, Brazil: A Model for Balancing Resource Availability and Market Constraints**

In São Paulo, under the ReflorestaSP Program, researchers have identified optimal regions for developing industry clusters based on Multifunctional Forests. The western and northwestern parts of the state have been recognized as suitable for supporting the expansion of the Rubber Tree-based industry. Critical to this expansion is identifying adequate land that not only adheres to the maximum economic distance for transport but also supports the production levels required for a profitable mill operation.

These Multifunctional Forests, comprising Rubber Trees and other native species, are proposed to be established on 20% of private lands designated as Legal Reserves (RL), where Brazilian regulations mandate the planting of native species. Additionally, the model considers the availability of labor within the region during harvest periods essential for latex collection.

Cost considerations are integral to the model, ensuring that the expenses incurred from forest management are aligned with what the industry can afford for raw materials. The optimization model developed for this purpose seeks to maximize the ecosystem services provided, specifically enhancing water provision and soil protection.

This approach not only facilitates the sustainable expansion of the rubber tree industry but also aligns with environmental regulations and market demands, illustrating a viable model for industry-driven reforestation efforts.

**61** *Calmon, Piotto, Pina-Rodrigues, Freitas, Verdade, Arco-Verde, Freitas, Oliveira, Viani, Rolim, Brienza, Silva, Amaral*

**Native Species Silviculture in Brazil: Advancing Knowledge and Cutting-Edge Technologies for Sustainable Production Systems and Climate Resilience.**

Commercial plantations of native tree species in Brazil hold significant potential to meet the demand for tropical sawn wood, reduce deforestation, enhance ecosystem services and biodiversity conservation, generate green jobs, increase producer income, and attract public and private investment. The key challenge lies in identifying suitable native tree species and production systems adapted to the socioeconomic realities of target stakeholders. However, crucial questions have impaired the development of large scale native species silviculture, such as growth rates, production systems, regulatory framework, harvesting timelines, timber quality, and market potential. In 2018, an initiative led by the Brazilian Coalition on Climate, Forests and Agriculture and the World Resources Institute (WRI) reviewed 3,303 studies on Brazilian native tree species. As a result, the 15 most promising species were prioritized for the Amazon biome and 15 for the Atlantic Forest biome. This effort culminated in the development of a Research and Development (R&D) Program for native species, inspired by the success of Brazil's forestry and agribusiness sectors, which together contribute over 20% of the country's GDP. The selection of 15 species per biome was intentional, as silvicultural systems for native species in Brazil, including mixed plantations and agroforestry systems, require greater species diversity than those traditionally used for exotic species. Diverse silvicultural approaches that balance ecological and social objectives can significantly improve local livelihoods, enhance forest productivity, strengthen the resilience of tree plantations to adverse climatic conditions, and, where applicable, support compliance with Brazilian Environmental Law. The R&D Program began its activities in April 2021, and has been making progress in securing strategic funding for its implementation. Significant steps have already been taken, including the establishment of two research sites within the Long-Term Research Site Network (Rede-SELD), located in the Atlantic Forest and Amazon biomes, reinforcing our commitment to cutting-edge research and innovation. Additionally, studies on older silvicultural plantations, known as Reference Hubs, are already underway.

**62** *Harris, Flores, Kinane, Piotto, Ashton*

**Evaluating Remote Sensing-Derived Canopy Height Models for Biomass Estimation in Brazil's Atlantic Forest**

For accurate estimation of forest structure, biomass, or carbon storage in trees, it is essential to have as much information as possible. It is well established that total volume or aboveground biomass is best estimated using both stem diameter and total height. However, in many regions, the practice of measuring tree heights is either uncommon or unreliable. As a result, users may rely solely on diameter at breast height (DBH) to make these predictions, at the expense of accuracy and precision. Many practitioners may therefore look to incorporate remotely sensed canopy height data alongside field measurements or published datasets to assess the tradeoffs involved. Remote sensing offers a promising alternative, yet the performance of canopy height models across varying spatial resolutions remains insufficiently evaluated.

This study assesses the utility of four gridded canopy height models for AGB estimation in the Atlantic Forest of southern Bahia, Brazil. We compare models at spatial resolutions ranging from coarse to very high: 1000 × 1000 m (Bubayah et al., 2021), 30 × 30 m (Potapov et al., 2021), 10 × 10 m (Lang & Jetz, 2023), and 0.5 × 0.5 m (Tolan et al., 2024). Our study area encompasses 1.5 million hectares across 11 municipalities in southern Bahia, Brazil, with a rainfall gradient of 1100–1800 mm/year and an annual water deficit of 50–200 mm.

Using data from 212 forest inventory plots containing over 4,000 paired diameter and height measurements, we evaluate model performance across five configurations for AGB estimation: (1) DBH only, (2) field-measured height only, (3) DBH + field-measured height, (4) DBH + remote sensing-derived canopy height, and (5) remote sensing-derived canopy height alone. These configurations assess how resolution and data source impact biomass predictions at both tree and plot levels.

Our findings show that the Lang & Jetz (2023) model overestimates canopy height, while the Bubayah et al. (2021) and Potapov et al. (2021) models tend to underestimate it. Although the Tolan et al. (2024) model offers exceptionally high resolution, it tends to saturate around 22–24 meters, underrepresenting the tallest trees observed in the field. This mismatch highlights key tradeoffs between spatial resolution, model accuracy, and the need for reliable ground-based data. We demonstrate the potential of remotely sensed canopy height to enhance or calibrate local height-diameter models, particularly when applied to legacy forest inventory data lacking height measurements.

This work provides valuable insights for Brazil's forest monitoring and carbon accounting initiatives and supports the integration of high-resolution remote sensing data into forest inventory workflows. By improving biomass estimates from forest inventory data, it helps build a clearer picture of carbon stocks and adds weight to the case for expanding forest restoration efforts in the Atlantic Forest.

**64** *Rodrigues, Araujo, Gorgens*

**Sampling Optimization for Training ALS-Based Predictive Models**

1. Introduction

Growth and yield models (GYM) are crucial for managing biological assets, enabling accurate estimation of wood volume over time. Traditionally calibrated with permanent plots, these models depend on effective sampling strategies to ensure representativeness and minimize errors.

Airborne Laser Scanning (ALS) has emerged as a powerful tool for forest measurement, enabling the acquisition of precise three-dimensional data over large areas. ALS-based inventories typically use the area-based method described by GOBBAKKEN et al. (2013), correlating ALS data with field measurements to adjust predictive models and create production maps.

However, the effectiveness of these models depends on the representative selection of plots used for training, covering a variety of forest sites. While Continuous Forest Inventory (CFI) has been widely used in Brazil for decades, the incorporation of ALS data is a more recent development, necessitating refinements in sampling strategies for initial model adjustment, similar to those outlined by Goodbody et al. (2023), which focus on structurally guided sampling.

2. Objective

This study evaluates sampling strategies for selecting permanent plots in the training of ALS-based growth and yield models, aiming to establish criteria that ensure representativeness and accuracy of volumetric estimates compared to models adjusted using continuous forest inventory.

3. Methodology

A total of 6,121 permanent plots of 300 $m^2$ were used, distributed across 15,514 hectares of commercial Eucalyptus urograndis plantations, with a 3.0 × 3.0 m spacing and ages ranging from 2 to 8 years. Measurements conducted from 2010 to 2024 revealed a stabilization of average productivity at 7 years (MAI7) at 47 $m^3$/ha/year.

To optimize the selection of ALS survey areas, four sampling approaches were tested: (a) simple random sampling, providing an overview of production; (b) simple random sampling within a confidence boundary (CB) based on the standard deviation of production at 7 years; (c) stratified random sampling, segmenting samples by age within the CB; and (d) stratified random sampling in main classes, excluding intermediate age ranges, within the CB.

The resulting models were compared to the continuous forest inventory based on statistical accuracy and sample coverage at the stand level.

4. Results and Conclusion

A total of 1,000 random simulations were performed for each planned number of plots per stratum and sampling method, totaling 576,000 simulations. The results indicate that plot selection significantly influences both the surveyed area and the quality of volumetric adjustments. The approach based on confidence intervals and main classes led to a substantial reduction in the surveyed area without compromising model accuracy. Compared to simple random sampling, for 10 samples per stratum, there was a reduction of up to 63% in the surveyed area while maintaining adherence to the growth and yield estimates based on CFI.

5. Conclusion

The careful selection of permanent plots for training LiDAR-based models is essential to ensure accurate and representative estimates. Strategies that consider confidence boundaries and stratification optimize the selection of survey areas, aligning with models adjusted through CFI and reducing the need for excessive sampling.

**65** *Moreira, Tourinho, Boscolo*

**What is the cost of the pollination deficit in the state of São Paulo?**

Valuing the ecosystem services provided by biodiversity, such as pollination, is a crucial step toward designing public policies that support the ecological transition from intensive agriculture to more sustainable practices. These practices aim to reconcile agricultural production with biodiversity conservation through the ecological intensification of agriculture. However, the valuation techniques traditionally used for this service are based on multiplying past agricultural production by its market value and the crop's dependency level, assuming that the entire cultivated area benefited from this service, disregarding the role of pollinator diversity and landscape structure in the pollination service. In this context, we employed PolLEM, a high-resolution (30m), spatially explicit model that considers supply, flow, and demand to estimate the value of pollination services. Supply is modelled as a function of climatic suitability, landscape structure (proportion of native vegetation, landscape Shannon's diversity index), and native vegetation structure. Flow is modelled using a diffusion model with distance decay, and demand is represented by the peak of photosynthetic biomass in cultivated areas, which determines the number of flowers to be pollinated in the field. This model allowed us to estimate the proportion of the main pollination-dependent crops in the state of São Paulo that received pollination services from wild pollinators, as well as the areas experiencing a pollination deficit. On average, half of the demand for pollination services was met by wild pollinators. By cross-referencing these results with municipal agricultural production data, we estimated the total value of the pollination service at R$3.9 billion and the value of the deficit at R$4.2 billion, which represents approximately 11% of the total production value of pollination-dependent crops in 2022. The crops with the highest pollination deficit were soybeans (R$1.4 billion), citrus (R$1 billion), and coffee (R$0.7 billion). Most pollination provision and deficit were concentrated in regions where large areas are dedicated to intensive agriculture of commodity crops, along the Paranapanema River basin. The high Paranapanema River basin is also a strategic region in terms of nutritional security and environmental justice, characterised by high levels of socioeconomic vulnerability and a diversity of pollination-dependent crops. In addition to being a substantial opportunity cost, usually unknown or ignored by farmers and environmental managers, this pollination service deficit can jeopardise food security by increasing crop yield variability in Brazil's most populous region. On the other hand, it offers an opportunity to increase food production by restoration and the adoption of pollinator-friendly practices. Our model also enables us to identify areas with a high pollinator deficit, where restoration could yield the maximum return to farmers, helping to offset some of its cost. This model can also be utilised to compare scenarios and estimate the impact of restoration on pollination services, thereby aiding environmental policy and planning. Ultimately, the PolLEM model offers a framework that can be adapted to model other ecosystem services provided by biodiversity, such as pest control, nutrient cycling and seed dispersion.

**66** *Santos, Moreira, Fernandes, Garibaldi, Boscolo*

**Effect of landscape heterogeneity on bee populations and communities**

The current global decline of bees is primarily attributed to the conversion of natural environments into intensive agricultural areas, which has become a growing concern. Homogenized agricultural landscapes reduce the availability of adequate breeding grounds and restrict resource availability over space and time, forcing bees to travel longer distances to find suitable food sources, thereby jeopardizing their survival and reproductive success. Therefore, understanding how landscape structures affect bees based on their movements could help us plan multifunctional landscapes that promote the conservation of these insects while improving the effectiveness of pollination services and agricultural sustainability. In this work, we develop agent-based models of the bees' foraging and dispersal behavior to evaluate the effect of agricultural landscape heterogeneity on their survival, reproduction, and population size, as well as its consequences for bee communities. With these models, we showed that overall, our findings support the hypothesis that heterogeneous landscapes—characterized by greater native vegetation, varied land cover, and more complex spatial structure—can enhance bee populations and communities, primarily by boosting their abundance. In particular, the amount of native vegetation had a positive influence on all measured variables at both the population and community scales. The number of environments is positively correlated with the amount of resources acquired by bees. The models indicate that the bees' foraging behavior is a significant predictor of their response to landscape structure, where their flight range is directly related to their ability to gather resources in heterogeneous landscapes. Moreover, landscape heterogeneity was an essential aspect that interfered with the population dynamics and the structure of the simulated communities, where bees with highly specialised nesting environment preferences were penalized in more heterogeneous landscapes, corroborating several conservation studies. These results indicate that, while landscape heterogeneity promotes the maintenance of more diverse pollinator communities, it can also serve as an environmental filter, excluding specialized species with lower flight capacities. Additionally, the models enabled the evaluation of mechanistic explanations for the causal relationships between landscape patterns and the structure of bee communities. This model can be used in scenario comparisons to identify priority areas where restoration would yield the highest benefits for bee communities and pollination services.

**68** *Hakamada, Ramos, Gonçalves, Bandeira, Pimenta, Souza, Silva, Franci, Costa, Stahl, Lamas, Teixeira, Nascimento, Dick, Mendes, Berger, Mizunati, Claudio, Tunes*

**Criteria to select stands for a coppice rotation in Eucalyptus plantation in Brazil**

Coppice management in Eucalyptus plantations is a key strategy for reducing carbon emissions and lowering costs compared to traditional seedling-based forests. One of the most important steps in ensuring the success of this silvicultural approach is identifying which stands are suitable for coppice management. There are several criteria used to make this decision, and our objective was to identify the most commonly used ones through a benchmarking survey of Brazilian forestry companies. On the other hand, using data from the PCOPPICE research program (Cooperative Program of Productivity and Ecophysiology of Coppiced Eucalyptus Clones) — a collaborative initiative involving 12 Brazilian forestry companies and eight universities — we evaluated whether some of these criteria are supported by scientific evidence. Our findings revealed that the five most frequently used variables in the decision-making process for recommending stands for coppice management are: productivity and survival in the previous rotation, genetic material, costs, and soil type. Initial data from the PCOPPICE project suggest that there is likely a relationship between productivity across rotations, but this relationship does not hold under all climate conditions or for all genotypes. However, genotype emerged as one of the most critical factors for the success of coppice rotations. The variation in productivity between rotations among different clones ranged from -70% to +30%, indicating that selecting an unsuitable genotype for coppicing can render the plantation economically unfeasible.

# Flash Talk Abstracts

**26** *Yousefpour, Djahangard*

**Global warming levels exceeding 2°C may cause tipping point of low elevation forests in southwestern Germany**

Climate change is impacting forests in Central Europe, causing increased mortality and degradation of forest ecosystem services (FES). As global warming intensifies, these effects likely will worsen, particularly through more severe droughts and increased biotic disturbances. Understanding how forests respond to different levels of warming is essential for adaptation planning. Therefore, this study analyzed changes in forest structure and FES, including timber production, climate change mitigation, recreation, and structural diversity, under three global warming scenarios. Using the LandClim model, we compared warming levels of 1.5°C, 2°C, and 3°C above pre-industrial temperatures, based on 30-year periods from RCP data, to historical climate. Our research focused on Freiburg's forests in southwestern Germany, characterized by diverse tree species and an elevation range of 200–1250 m.a.s.l. A warming of 1.5°C could temporarily increase productivity, but at 2°C, biomass losses of up to 10% occurred below elevations of 450m due to drought mortality. Under 3°C, losses intensified below 650m up to 40%, with even drought-resistant species like Pedunculate oak experiencing mortality. At higher elevations, bark beetle outbreaks caused mortality of Norway spruce, while European beech capitalized on the changing ecological conditions. Higher warming levels significantly deteriorated FES, particularly timber production, climate change mitigation, and structural diversity, while recreation was less affected. These findings emphasize the urgency of meeting Paris Agreement targets, as limiting warming below 2°C can reduce severe impacts. If warming exceeds this threshold, adaptation strategies must be rethought, as relying on drought-resistant species like native oaks may pose high risks at lower elevations.

**55** *Nunes, Moraes, Aguiar, Moraes, Piotto, Freitas*

**Planning and operational aspects of genetic breeding initiative in the research program for silviculture with native species in the Atlantic Forest and Amazon biomes**

Silvicultural practices, particularly forest genetic improvement, play a crucial role in the economy of industrial wood products, including timber used in the construction of houses, buildings, and furniture. Beyond economic interests, the use of improved trees promotes high levels of carbon sequestration and helps preserve native forests from degradation, and supports better land use, preventing further deforestation. Brazil's native forests contain many species with high potential for inclusion in breeding programs aimed at timber production. To fully utilize this genetic resource, it is necessary to establish appropriate trials to estimate genetic components, parameters and developing strategies to select the best materials with favorable silvicultural phenotypes. The Research and Development Program for Silviculture with Native Species (PP&DSEN), led by the Brazil Climate, Forests, and Agriculture Coalition (Coalizão Brasil) aims to promote the development of a scientific foundation to support the implementation of a silviculture system with native species in Brazil on large industrial scale. This project is supported by the Bezos Earth Fund (BEF) in partnership with the Southern Bahia Science and Technology Park (PCTSul) and Coalizão Brasil. As part of this initiative, the genetic breeding program seeks to implement selection and propagation strategies for superior genetic materials, focusing on increasing productivity, wood quality, and the resilience of native species. This includes conducting rigorous genetic trials, identifying seed-trees with desirable phenotypes, and developing a sustainable system for producing improved seedlings, contributing to the economic and environmental viability of silviculture with native species in Brazil. The planning of the trial network begins with the provenance and progeny tests of 10 native timber species to be established in southern Bahia and the Amazon. Each test will include 30 families originating from seed-trees located in different regions from Atlantic Forest and Amazon biomes. The families will be arranged in a randomized complete block design, with, with five trees per plot and six replications at a spacing of 3 × 3 meters. The pioneer species Trema micrantha will be planted between the rows to provide shading for the target trees in the trial. The border will be composed of a single planting row of the same species, using the same spacing as the families in each test, totaling 1,024 trees per test (900 individuals in the test + 124 border trees). Each test will cover an area of 93 × 93 meters, occupying a total area of 0.92 hectares per species. The test trees will be evaluated for growth, silvicultural, and quality wood to ensure volume yield and quality selection of the best genotypes (individuals). Operations for implementing the tests have already begun, including seed collection and seedling production. The seed-trees selection and seed collection have been carried out by professionals from neighboring communities of the areas where each species occurs. Seedling production has also started, and the first tests are scheduled to be established in 2025. Planning and operationalizing all stages of genetic breeding initiative has been complex, requiring collaboration among various companies, researchers, and silviculture professionals.

**58** *Longo, Ribeiro, Burgui*

**Metodológia para la definición de servicioa ambientales en zonas verdes en el municipio de de Alacalá de Henares/España**

La integración de espacios verdes de diferentes tipos en los centros urbanos ha adquirido cada vez más un papel fundamental en los procesos de planificación y gestión ambiental, ya que los residentes de estas zonas urbanas dependen de jardines, bosques, parques y otros espacios verdes para sus actividades recreativas, así como para la prestación de importantes servicios ambientales, como el suministro de agua, la descomposición de los residuos orgánicos, etc. Así pues, debatir la importancia de preservar, conservar y restaurar estos ecosistemas se convierte en algo fundamental para el diseño de ciudades sostenibles. Con el fin de analizar los potenciales servicios ambientales prestados por las zonas verdes objeto de estudio, se aplicó sobre el terreno una matriz de interacción entre los principales servicios ecosistémicos y los indicadores de calidad socioambiental del paisaje. En este estudio se han considerado 10 zonas verdes en el distrito de Alcalá de Henareas (España) y sus alrededores, que abarcan tipologías que proporcionan diferentes servicios ambientales. En términos generales, puede decirse que la disponibilidad de servicios ambientales en las zonas urbanas depende directamente de la cantidad y calidad de la Infraestructura Verde Urbana existente. Por lo tanto, es necesario definir en primer lugar la calidad ambiental de estos entornos antes de definir la disponibilidad y cantidad de servicios ambientales prestados por los ecosistemas allí presentes.

**67** *Jardine, Toth, Haninovich*

**Optimal Reserve Site Selection for Western Gray Squirrel with Integer Programming**

Optimal reserve site selection models have often been proposed to support conservation projects where habitat needs of a species of concern are spatial in nature. Prior models documented in the literature were designed to prioritize sites that in aggregation were guaranteed to form networks with specific spatial characteristics such as connectivity, proximity, contiguity or proportion of interior vs edge habitat. In this paper, we propose a model, cast as an integer program, that combines multiple spatial requirements for primary as well as secondary habitat for species of conservation concern. We present a case study to demonstrate the benefits as well as the mechanics of the model in Washington State, United States for the Western gray squirrel (Sciurus griseus) that has recently been listed as a Washington State endangered species.

**69** *Mendes, Soares, Teodoro, Schimalski, Liesenberg*

**Segment Anything Model (SAM): an Approach to Tree Segmentation in Urban Environments**

Image segmentation is a widely used technique to divide an image into homogeneous regions that represent different land cover types, such as bare soil, buildings, vegetation, and water bodies. These regions are commonly referred to as objects. Recently, the Segment Anything Model (SAM), developed by Meta AI, has demonstrated a high segmentation capability across a vast and diverse image dataset. Notably, it does not require additional training to identify unknown objects, making it a promising alternative for mapping urban vegetation. SAM supports four segmentation modes: (1) segment everything automatically, (2) segmentation using bounding box input (SAM Box), (3) segmentation using point input (SAM Point), and (4) segmentation using text prompts (SAM Text). This study evaluated the effectiveness of SAM in the segmentation of urban trees using high-resolution imagery captured by remotely piloted aircraft (RPAs). The analysis was conducted in a neighborhood of Lages municipality (Southern Brazil), using three of the available SAM segmentation modes (Text, Box, and Point). The script for processing was developed in Python and executed using Google Colab. Among the methods tested, SAM Text achieved the highest accuracy for the study area, reaching values above 80%, although it also resulted in a high commission error (33%). SAM Point presented the lowest accuracy (63%), with a low commission error (12%) and a high omission rate (60%). The SAM Box method performed at an intermediate level, with 72% accuracy, 20% commission, and 40% omission. All models showed low Intersection over Union (IoU) values, ranging from 0.58 to 0.64. It was observed that SAM has difficulty in segmenting isolated trees, being more effective in identifying clusters of vegetation. Commission errors commonly occurred in shadowed areas, where shadows were mistakenly identified as trees. In conclusion, SAM shows great potential for mapping vegetation in densely vegetated regions, although it still presents limitations in sparse vegetation scenarios. Further studies with alternative prompts and model fine-tuning are recommended to improve segmentation performance in heterogeneous urban environments.

**71** *Ulloa-Fierro, Alvarez-Miranda, Garcia-Gonzalo, Gonzales-Olabarria, Mola-Yudego, Weintraub*

**Risk-averse optimization for tactical forest planning: chance constraint by a simulation-based approximation approach**

For forestry companies, tactical forest planning at the landscape level aims to define scheduling silviculture and harvesting decisions over the mid-term (e.g., from 5 to 20 years) that are most likely to achieve the desired objectives. Uncertainties related to tree growth and potential losses from wildfires are significant, particularly in plantation forests, which are intensively managed, monospecific, and evenly spaced, making them highly fire-prone. The methodology proposed in this work aims to determine a tactical plan that maximizes the net present value (NPV) of future income while ensuring sustainable and efficient productivity under wildfire uncertainty. Therefore, we propose a risk-averse approach to incorporate parametric uncertainty, expressed through a chance constraint and an associated risk-level parameter. We addressed this chance-constrained framework using a simulation-based approximation. This approach provides a simple and efficient way to incorporate wildfire risks and the dynamic growth of forests over time.

**72** *Cortes-Molino*, Gelabert Vadillo, Kutchartt, Sanahuja-Llopis, Aquilue, Garcia-Gonzalo, Gonzales-Olabarria

**The potential of hyperspectral imagery from satellites for detecting forest species**

Multispectral satellite imagery has been traditionally used in forest ecosystems studies due to its lower cost. However, the recent launches of PRISMA and EnMAP hyperspectral missions significantly enhance the potential for detailed, large-scale forest species identification. The greater spectral resolution in the Visible and Near Infrared (VNIR) and Short-Wave Infrared (SWIR) enables the detection of small variations in the photosynthetic activity reflectance, which are indicative of forest species differences. In this study, we integrated Prisma images with environmental factors such as topography, solar radiation, bioclimatic variables and canopy height to estimate the probability of presence for several forest species at a 30 x 30 m pixel resolution. The study area, located in Catalonia (North-East Spain), encompassed the most abundant tree species in the region, and validation was performed using Spanish National Forest Inventory data.

**73** *Park, Jung, Park, Choi9, Lim, Zin, Min, Kim, Cho, Toth*

**A Spatial Optimization Framework to Customize Timber Supply and Harvest Decisions for the Korean Forest Service: A Case Study**

Forest management planning in South Korea primarily depends on individual manager's personal experiences and subjective judgments, lacking clear scientific criteria and objective data-driven approaches. Consequently, decisions often exhibit arbitrariness and inefficiency. Particularly, insufficient linkage between local timber production and consumption hinders sustainable forest management and limits economic value creation. To address these issues, this study developed a spatial information-based optimization model to establish a principled, rigorous decision-making framework for timber harvesting and supply planning, using Goesan-gun, Chungcheongbuk-do, as a case study. We assessed the total forest stand volumes of Goesan-gun based on forest type maps provided by the Korean Forest Service and national forest inventory data. Harvestable forest stands were identified considering legal, environmental, physical, and harvesting constraints. These stands were categorized into sawtimber (high-value timber for construction and furniture) and woodchip & pulp (low-value timber for pulp and boards). A detailed revenue-cost analysis was conducted, incorporating timber revenue, carbon revenue, afforestation, forest tending, harvesting, and transportation costs. Transportation costs were precisely calculated by determining optimal transportation routes from each forest stand to sawmill using a Dijkstra-based closest facility network analysis. Subsequently, a 100-year sustainable harvesting plan (structured in 10-year periods) was developed utilizing the Gurobi optimization algorithm, aiming to maximize profits while considering rotation ages, harvest volume fluctuation constraints, and ending condition targets for residual growing stock volume. The optimization results indicated an average annual harvest volume of approximately 63,000 $m^3$ (ranging from a minimum of 45,000 $m^3$ to a maximum of 81,000 $m^3$). Notably, during the initial 30-year period of the management plan, timber harvesting was concentrated in stands aged between V and VII, averaging approximately 80,000 $m^3$ annually. In terms of profitability, approximately 40.4 billion KRW (70%) of the total estimated net profit of 57.8 billion KRW was realized in the first 20 years. This outcome can be attributed to the current concentration of Goesan-gun's forest stands in age classes IV and V, enabling higher early-stage timber harvesting volumes. Conversely, harvest volumes declined gradually in the later stages due to constraints on achieving target residual growing stock volumes and compliance with South Korea's legal rotation age (age class IV or higher). This study demonstrates the practical application of a spatial optimization approach, reducing subjectivity in forest management decisions and promoting efficient utilization of regional timber resources and sustainable forest management. Consequently, this can enhance economic efficiency and domestic timber utilization rates. The scientific novelty of the model lies in the integration of Dijkstra's network algorithm to account for timber hauling costs and a spatially explicit harvest scheduling model. Acknowledgement: This study was carried out with the support of the R&D Program for Forest Science Technology (RS-2024-00404388) provided by the Korea Forest Service (Korea Forestry Promotion Institute).

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