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Agroforestry systems in Latin America

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Introduction

Latin America (LAC) is a megadiverse region in terms of landscapes, soils, climates, cultures, and production systems (Rojas and Banerjee 2019). This region contains approximately 57% of the world's primary forests, storing approximately 104 Pg of carbon and hosting between 40 and 50% of the world's biodiversity and a third of all plant species (Morris and Sebastian 2020). It is also rich in various ecosystems, ranging from humid and dry broadleaved forests, temperate forests, tropical and subtropical coniferous forests, pastures, savannas, and shrublands.

LAC region is not exempted from the impact of climate change, with extreme weather conditions affecting millions of people, mainly due to heatwaves, droughts, hurricanes, forest fires, regional sea level rise flooding, and crop yield decrease (WMO 2021). Other threats include deforestation, forest and land degradation, and low productivity with severe consequences in the entire subcontinent (Branthomme et al. 2023, Rojas and Banerjee 2019). Hopefully, well-designed and well-managed agroforestry systems can be a viable land-use option to counteract these societal, productive, and environmental problems. Agroforestry systems in the region cover around 200–500 million hectares, mainly in silvopastoral systems and tree-shaded crops (Somarriba et al. 2012).

This special issue seeks to concentrate on the most relevant outcomes of agroforestry systems in LAC. It is intended to be a transdisciplinary issue, where articles on the region's biophysical, economic, social, and cultural aspects of agroforestry will converge.

Papers contained in this special issue

This special issue includes 15 articles depicting examples of agroforestry practices in different contexts and spatial arrangements, their impact on environmental services provision and the state of their adoption process. Articles are derived from research conducted in Argentina, Brazil, Colombia, Uruguay and México. The evaluated agroforestry practices range from multi-strata agroforestry systems with perennial crops to silvopastoral systems, homegardens, and Taungya. The papers summarized findings on the effect of different agroforestry systems on soil quality and soil organic carbon, animal behavior, forest cover, tree growth, adoption and education.

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Silvopastoral systems

In Latin America, livestock is a major land use with both environmental and socio-economic impacts. This special issue highlights the benefits of silvopastoral systems (SPS) in different aspects of livestock production. Da Silva Morenz et al. (2023) evaluated different shade level regimes on cow behavior, finding that the behavior of crossbred dairy cows subjected to climatic stress benefitted from microclimatic conditions provided by trees. Providing at least moderate shade around the paddocks alleviates the stress and regulates the vital activities of the animals. Rivera et al. (2023) assess the effect of SPS with *Tithonia diversifolia* (Hemsl.) A. Gray in reducing greenhouse gas emissions from cattle manure. They evidence that such SPS emit lower amounts of greenhouse gases (CH_4 and N_2O–N) from manure, contributing to the mitigation of the climate warming resulting from bovine manure under tropical humid conditions. López-Hernández et al. (2023) evaluate the carbon stocks and accrual rates in a SPS of *Leucaena leucocephala* + *Cynadon plectostachyus*, and *Brachiaria decumbens* grass and compare them with conventional open grazing lands in Chiapas. The study finds that the average tree biomass stock in SPS was 5.5 Mg C ha^{-1} and differed with SPS age. Mean annual carbon sequestration rates range from 0.25 to 2.57 Mg C ha^{-1} $year^{-1}$ in biomass and 0.14 Mg C ha^{-1} $year^{-1}$ in soils down to 50 cm depth. This shows the importance of this type of AFS in climate change mitigation through carbon sequestration or capture. Similarly, in Mexico, the opportunities of local SPS practices in retaining tree cover to intensify livestock landscapes and reduce negative outcomes on forest cover is discussed by Špirić and Ramírez (2023). They identify seven types of SPS in this area, six of which are local/traditional practices. Adopting or maintaining such AFS is an important strategy to improve livestock production while contributing to preventing forest degradation and deforestation.

Soil quality and soil organic carbon

Suárez et al. (2024) investigate the stock and vertical distribution of SOC fractions and the SOC sequestration of different agroforestry systems (AFS) and other land uses in the Colombian Amazon. Forest plantations, crops in forest plantations and alley cropping arrangements show the highest values of SOC in the 0–100 cm layers (174.0 to 199.0 Mg ha^{-1}). In contrast, homegardens, pastureland, and multistrata systems with perennial crops show the lowest values of SOC with 134.0, 116.0, and 96.2 Mg ha^{-1}, respectively. Some AFS increase both the amount and stability of SOC compared to pastures, which is an indicator of climate change mitigation. Similarly, González et al. (2024) evaluate the soil's physical, chemical, and biological properties of the five most common land-use scenarios in the Colombian Andes. They find that soil properties varied among the five evaluated land uses, indicating that the use significantly affects the properties and behavior of soils. According to these authors, restoration activities improve soil quality indicators, such as soil organic carbon, a deep root system and nutrient cycling. Macedo et al. (2023) investigate the effects of land use on the soil fertility and dynamics of aggregates and associated cementing agents (SOC and iron oxides) under three land uses (forest, agroforestry system, and pasture). The study indicates that agroforestry practices had an important effect on soil fertility, significantly increasing the content and cycling of Ca and P in the soils. Agroforestry practices increase the potential of soils as SOC sinks in micro aggregates, suggesting higher storage and stabilization of SOC in the long term.

Biodiversity

Badillo-Saldaña et al. (2024) evaluate the functional and species diversities of lizards in a tropical forest, a lime crop, and a coconut crop in southeastern Mexico. The results show that both the functional diversity and the diversity of species decrease when the tropical forest was transformed into either one of these agroecological systems. These authors argue that maintaining forest fragments in modified landscapes is an important strategy to conserve highly susceptible species.

Tree growth and tree cover

Flumignan et al. (2023) evaluate the diameter growth of eucalyptus in agroforestry systems and planted

forests and the influence of microclimate conditions on diameter growth. The results show that eucalyptus diameter growth is higher when cultivated in agroforestry systems and the higher the distance between eucalyptus rows, the larger the growth. Precipitation proves to influence the diameter growth strongly and positively, especially when cultivated in agroforestry systems. Air temperature shows little or no correlation with eucalyptus diameter growth. Lucena et al. (2023) evaluate the growth and economic return of *Khaya ivorensis* grown on Taungya systems compared to *Khaya ivorensis* monoculture in a degraded area in the humid tropics. Three planting systems were studied: T1, monoculture (*K. ivorensis*); T2, *K. ivorensis* + 1st cycle with *Zea mays* + 2nd cycle with *Manihot esculenta*; T3, *K. ivorensis* + 1st cycle with *Vigna unguiculata* + 2nd cycle with *Zea mays*. The Taungya system with bean and corn crops results in a faster growth of *K. ivorensis*, in addition to a higher density of total bacteria in the soil and an improved level of soil conditioning. In addition, these authors argue that the cultivation and sale of crops can amortize the total cost of planting and maintenance of plantations with forest species. Bolívar-Santamaria and Reu (2023) present how six important state variables of canopy structure can be predicted across a canopy gradient from AFS with cacao and coffee to a natural forest. They use data extracted from 3D point clouds derived from images obtained from unmanned aerial vehicles (UAV) and multiple linear regression. The approach presented in this study allows an accurate characterization of the canopy structure of AFS using UAVs. This method can be useful for assessing above-ground biomass and biodiversity to monitor sustainable management practices and assess ecosystem services.

Adoption and education

The slow adoption of agroforestry systems is an obstacle to scaling out the benefits of AFS practices. Schinato et al. (2024) study the willingness of farmers to adopt SPS in Uruguay, specifically assessing the valuation of local farmers for the environmental services (ES) of SPS and their willingness to incorporate areas of silvopasture. The results indicate that farmers gave significant valuation for animal thermal regulation, and the provision of this ES increases the preference for silvopastoral production scenarios. The study also highlights that reductions in livestock productivity are identified as barriers to the adoption of SPS. The results suggest a 20% reduction in the stocking rate as a threshold beyond which farmers reduce their perception of utility from SPS. Adegbeye et al. (2024) present a review of how the successful SPS employed in the Latin America context can be effectively introduced in Nigeria, offering potential advantages to livestock owners. The review confirms that the utilization of silvopastoral systems in ruminant farming can contribute to achieving several sustainable development goals, including enhancing food security, increasing milk and meat yields, supporting conservation efforts, bolstering biodiversity, and reducing GHG emissions. Gelabert et al. (2024) investigate the farms adopting silvopastoral systems in the Upper Atlantic Forest of Argentina and whether their management practices are related to the farm's structural characteristics. The variability of farms and management practices can be grouped into three categories: specialist silvopastoral farms, agricultural farms with silvopastoral management and forest plantation, and livestock farms with silvopastoral management sectors. Specialist silvopastoral farms adopt most of the technical recommendations for this land use. However, some gaps need to be investigated to increase the adoption of silvopastoral systems in this area. Oliveira e Silva Neves et al. (2024) present the viability of the establishment of an agroforestry system as a non-formal teaching space in secondary schools. The study shows that the AFS provided interesting lessons outside the classroom, promoting interaction between members of the school community (teachers, students, staff, and parents) and fulfilling the lessons of the cross-cutting theme of environmental education. It also stimulates participation in practical activities, boosts curiosity, encourages research and a sense of belonging, facilitates the production of knowledge, and makes students active subjects in the teaching–learning process.

Conclusions

This Special Issue presents 15 articles covering topics related to biophysical, environmental, and social aspects of agroforestry practices. The articles also addressed the issues of adoption and the potential of

agroforestry in maintaining tree cover and soil quality in working landscapes. The scientific knowledge and experiences shared in this issue can help farmers, NGOs, and decision-makers make informed decisions and develop policies to promote the wider implementation of agroforestry systems. The diverse range of topics showcases the multifunctional nature of agroforestry and its potential to address various challenges faced by agricultural communities. From practices involving silvopastoral systems, homegardens, taungya to multi-strata agroforestry, the articles provide an understanding of the complex dynamic of agroforestry landscapes. The findings are particularly timely, as global efforts to combat climate change, ensure food security, and protect natural resources increasingly recognize the role of agroforestry in providing sustainable and resilient solutions.

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Data availability No datasets were generated or analysed during the current study.

Declarations

Competing interests The authors declare no competing interests.

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