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Editorial: Agroforestry for biodiversity and ecosystem services

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Editorial on the Research Topic
Agroforestry for biodiversity and ecosystem services

Introduction

The 21st century presents humanity with a converging triad of crises: unprecedented biodiversity collapse, escalating climate disruptions, and deepening food insecurity, with over 800 million people enduring chronic hunger (IPBES, 2023; IPCC, 2023; FAO et al., 2024). These challenges are exacerbated by widespread soil degradation, affecting 33% of the Earth's land surface, threatening agricultural systems worldwide (FAO et al., 2018). While agroforestry—the intentional integration of trees with crops and/or livestock—offers a promising, nature-based solution to harmonize ecological resilience with human prosperity, its potential remains significantly underutilized (Roy et al., 2025; Mlambo and Mufandaedza, 2025).

Despite its ancient roots and evolution into a cornerstone of nature-based solutions, agroforestry faces persistent barriers to widespread adoption (Tranchina et al., 2024). Policy fragmentation, including conflicting land-use regulations, weak financial incentives for long-term investments, and gaps in locally adapted knowledge, continues to hinder its implementation (Venn et al.). Addressing these barriers is essential to unlock agroforestry's dual promise: safeguarding planetary health while advancing equitable development.

This Research Topic directly addresses this critical need by exploring agroforestry's role in harmonizing biodiversity conservation, ecosystem services, and sustainable development across diverse landscapes — from semi-arid tropics to temperate woodlands. The nine articles in this Research Topic address three interconnected dimensions: policy frameworks, ecological impacts, and socio-economic dynamics. Through policy analyses, geospatial modeling, and on-the-ground case studies, they provide actionable insights for scaling agroforestry effectively.

This editorial synthesizes key findings, underscoring agroforestry's dual capacity to strengthen agricultural productivity and ecological resilience. By integrating native trees with food crops, these systems mitigate habitat fragmentation, sequester carbon, and sustain livelihoods—a critical balance in regions facing land-use conflicts. Collectively,

these studies equip farmers, policymakers, and conservationists with evidence-based strategies to mainstream agroforestry. Their methodologies offer replicable pathways to align food security with planetary health, ensuring agroforestry transitions from a niche practice to a cornerstone of sustainable land-use policy.

Policy and governance: bridging gaps for scalable solutions

Agroforestry's potential to reconcile biodiversity conservation, climate resilience, and rural livelihoods is well-documented (Mlambo et al., 2024; Yashmita-Ulman and Singh, 2024). However, systemic policy and governance challenges continue to hinder its widespread adoption. A cross-continental narrative review by Venn et al. dissects agroforestry policies in the EU, India, Brazil, and the U.S., revealing stark contrasts in governance frameworks. While Brazil leads in jurisdictional integration—notably through its ABC+ Plan aligning agroforestry with low-carbon agriculture—the EU and U.S. lag due to misaligned financial incentives (Venn et al.). For instance, the EU's Common Agricultural Policy prioritizes monoculture subsidies, inadvertently disincentivizing tree-crop integration. In India, agroforestry relies on *ad hoc* initiatives like the Sub-Mission on Agroforestry, which struggles to harmonize with state-level forest laws, and in Brazil, despite progress, dedicated legislation remains absent. These fragmented approaches often relegate agroforestry to jurisdictional gaps between disconnected agricultural, forestry, and environmental policies, stifling its capacity to enhance carbon sequestration, soil health, and biodiversity at scale.

Complementing this analysis, Singhal et al. underscore agroforestry's dual role as both an ecological safeguard and an economic lifeline in times of crisis. Their research demonstrates that agroforestry aligns with green economy principles by generating diversified income streams (e.g., timber, fruits, non-timber forest products) while mitigating risks during global shocks, such as pandemics or climate extremes. By addressing deforestation drivers, supporting green recovery, and reducing zoonotic spillover risks through habitat restoration, their work provides a compelling case for policymakers to prioritize agroforestry. Integrating their recommendations—financial incentives, policy coherence, and community empowerment—could accelerate the transition to resilient, multifunctional landscapes that benefit both people and the planet. Together, these studies highlight the urgency of context-specific frameworks to align agroforestry with global climate and biodiversity agendas, bridging the gap between its proven potential and fragmented implementation.

Sustainable management and ecosystem services

Small forest patches embedded in agricultural landscapes serve as vital biodiversity refugia, sustaining ecological networks within human-dominated environments (Decocq et al., 2016). A study by Karamdoost Marian et al. in Iran's mixed temperate broadleaf forests demonstrates how sustainable management practices can amplify these benefits. Their research found that the single-tree selective harvesting method—targeted removal of individual trees rather than clear-cutting—led to an increase in tree species richness and diversity in managed than unmanaged patches. Crucially, this approach maintained critical ecosystem services such as carbon sequestration, with harvested patches retaining most of their baseline carbon storage capacity. These findings challenge the assumption that minimal intervention is always optimal for biodiversity, revealing that carefully designed harvesting can enhance ecological resilience without compromising agricultural productivity. By balancing human needs with conservation goals, the study underscores the potential of adaptive management to transform small forest patches into multifunctional assets within working landscapes.

Kebebew and Ozanne's study in southwest Ethiopia examines the conservation potential of coffee agroforestry systems, emphasizing their role in preserving woody plant diversity. Their research demonstrates that these systems not only sustain higher native tree species richness compared to monoculture coffee farms but also act as refuges for endangered plant species. By mapping ecological corridors and prioritizing keystone species, their findings provide actionable strategies to align agricultural productivity with biodiversity conservation in human-modified landscapes.

In contrast, Comolli et al. shift the focus to economic scalability, analyzing integrated agroforestry systems for cultivating *Ilex paraguariensis* (yerba mate) in Argentina. Their model combines this high-value crop with native timber trees and forage plants, enhancing carbon sequestration and soil organic matter, while diversifying farmer income streams. By addressing challenges like shade tolerance and market access, the study offers a replicable blueprint for balancing ecological resilience (e.g., reduced pesticide use) with profitability—proving that biodiverse agroforestry systems can outperform conventional monocultures in both environmental and economic outcomes. Together, these studies underscore agroforestry's dual capacity to safeguard biodiversity and drive sustainable development. Kebebew and Ozanne highlight its conservation value in ecologically sensitive regions, while Comolli et al. demonstrate its viability as a scalable, income-generating alternative to extractive land use. Their combined insights reinforce the need for context-specific frameworks that harmonize species preservation, climate goals, and rural livelihoods.

Climate resilience: mitigating risks and enhancing stability

In the face of increasingly volatile climate conditions, Dobhal et al. provide a compelling synthesis of global data, reaffirming agroforestry's dual role in safeguarding agricultural productivity while enhancing ecosystem resilience against extreme weather events. Their meta-analysis underscores four critical findings that position agroforestry as a cornerstone of climate adaptation strategies. First, agroforestry systems significantly mitigate vulnerability to droughts, floods, and heatwaves, offering stability in regions disrupted by climate-induced pressures. Second, during heavy rainfall, agroforestry landscapes reduce surface runoff by 20–50% and enhance soil water infiltration, bolstering flood resilience and improving long-term soil health. Third, agroforestry

moderates microclimates by enhancing soil moisture retention, providing shade, and reducing wind exposure—key factors in sustaining crop yields under climatic stress. Finally, tree shelterbelts function as natural bio-shields, protecting coastal regions from high wind speeds and storm surges while reducing landscape degradation and infrastructure damage. These insights reinforce agroforestry's pivotal role in climate adaptation, demonstrating how nature-based solutions can foster resilient agricultural systems. Dobhal et al.'s findings offer actionable insights for policymakers, conservationists, and practitioners seeking to integrate agroforestry into sustainable land-use strategies, paving the way for a climate-resilient future

Ghanbari et al. assessed the impact of climate change on agroforestry practices in Iran, examining semi-arid, semi-humid, and humid climates. Their study found that farmers in semi-arid regions relied more heavily on climate-resilient species compared to those in humid environments, highlighting the urgent need for adaptation in response to the climate crisis.

Soil health: the foundation of sustainable systems

Studies by Rathore et al. and Uthappa et al. provide critical insights into the synergistic effects of agroforestry and conservation practices in enhancing soil quality and ecosystem resilience in India's semi-arid regions. Together, their research underscores the transformative potential of integrating ecological stewardship into sustainable land management. Rathore et al. demonstrate that conservation-focused agroforestry systems outperform conventional non-conservation approaches in improving soil quality. Key interventions include microsite improvements (e.g., removing boulders to optimize planting pits), integrated nutrient management that combines organic and inorganic fertilizers, mulching with crop residues and tree leaf litter to retain moisture and suppress weeds, and incorporating deep-rooted nitrogen-fixing species to enhance soil stability and nutrient cycling.

Building on this framework, Uthappa et al. analyze soil quality indices across diverse tree-based land-use systems. Their findings reveal that agroforestry significantly enhances key soil health parameters, including soil organic carbon (critical for fertility in arid regions), nutrient retention (particularly nitrogen and phosphorus), and microbial biomass, which drives nutrient mineralization and overall soil health. This work highlights agroforestry's role in mitigating the harsh conditions of semi-arid climates, where soil degradation poses a significant threat to food security. Together, these studies reinforce agroforestry's dual capacity to restore degraded landscapes and sustain agricultural livelihoods. Their complementary findings advocate for policy frameworks that incentivize conservation agroforestry, particularly in regions vulnerable to climate-induced desertification.

Conclusion

Collectively, the nine articles in this Research Topic highlight the multi-functionality of agroforestry—not merely as a farming practice but as a holistic strategy for ecological and socioeconomic resilience. These studies underscore its fundamental role in fostering biodiversity, enhancing ecosystem services, and strengthening agricultural landscapes in the face of environmental challenges. Moving forward, embracing agroforestry offers a tangible pathway to a more sustainable future—one that integrates agricultural productivity with ecological integrity. The evidence presented in this Research Topic demonstrates that through proactive policy-making, community engagement, and innovative research, agroforestry can significantly contribute to biodiversity conservation and the provisioning of critical ecosystem services.

We hope this Research Topic inspires further inquiry and collaboration in agroforestry, driving the development of scalable, effective solutions that support both food security and environmental sustainability. By bridging science, governance, and practice, agroforestry can evolve from a promising concept into a cornerstone of sustainable land-use strategies worldwide. As editors, we urge policymakers, farmers, and researchers to recognize agroforestry as a vital nexus between conservation and productivity. Beyond policy and economic factors, agroforestry adoption is significantly influenced by socio-cultural contexts. Integrating gender-sensitive approaches, addressing resistance to change, improving training, and incorporating indigenous knowledge are essential for its sustainable success, supported by quantitative assessments.

Author contributions

DM: Writing – original draft. Y-U: Writing – review & editing. PÁ-Á: Writing – review & editing. SC: Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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