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EDITED AND REVIEWED BY
Manfred J. Lexer,
University of Natural Resources and Life
Sciences Vienna, Austria

*CORRESPONDENCE
Arbi James Sarkissian
✉ a.sarkissian@lancaster.ac.uk

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Editorial: Sustainable forest management under climate change conditions — A focus on biodiversity conservation and forest restoration

Arbi James Sarkissian^{1*} and Mykola Kutia²

¹Lancaster Environment Centre, Lancaster University, Lancaster, United Kingdom, ²School of Natural Sciences, Bangor University, Bangor, United Kingdom

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Editorial on the Research Topic

Sustainable forest management under climate change conditions — A focus on biodiversity conservation and forest restoration

Forests are among the most critical ecosystems on our planet, providing essential ecosystem services such as climate regulation, nutrient cycling, and soil stabilization, while also serving as reservoirs of biodiversity. The challenges posed by deforestation and unsustainable land-use practices continue to threaten forests globally and undermine their capacity in delivering these crucial services (Pörtner et al., 2022; Raj et al., 2022; Winkler et al., 2021). Such trends also contribute to the declining resilience of terrestrial ecosystems (Yao et al., 2024), making them more vulnerable to the impacts of climate change, including droughts, wildfires, disease outbreaks, and severe storms (Goss et al., 2020; Murphy et al., 2018; Parks and Abatzoglou, 2020; Tao et al., 2022). In response, the United Nations has declared the “Decade on Ecosystem Restoration” (2021–2030; United Nations General Assembly, 2019), recognizing the need to restore and sustainably manage global forest resources to safeguard their ecological and socio-economic benefits (Arneth et al., 2019; Sarkissian et al., 2017).

This Research Topic, “Sustainable forest management under climate change conditions—a focus on biodiversity conservation and forest restoration,” addresses the complexities of managing forests in a changing climate. The Research Topic of six articles presented here explores various strategies for forest conservation and restoration, offering new insights into how we can enhance the resilience of forest ecosystems.

Exposing the complex challenges with incentivizes for sustainable forest management are amongst the several highlights presented in this Research Topic. Zverts et al. examined the feasibility of protecting Intact Forest Landscapes (IFLs) through Forest Stewardship Council (FSC) certification, drawing attention to the delicate balance between conservation and economic viability. They explored the spatial distributions of IFLs to determine the percentage of overlap forest management units (MUs) have within them, which they express as the “conservation burden.” Their findings emphasize the need for nuanced approaches to protecting IFLs through alternative measures for generating value (e.g., payments for ecosystem services) that also consider local socio-economic contexts.

This study contributes to the broader discourse on GIS and modeling techniques, particularly with respect to fragmented landscapes shown in other recent studies (Myroniuk et al., 2020). Their study also emphasizes the need for transferring knowledge of socio-economic and ecological interactions to diverse stakeholders to facilitate broader sustainable forest management efforts globally.

China, through its government-sponsored payments for ecosystem services (PES) schemes, has contributed to one of the largest expansions of planted forests in the world over the last few decades (Salzman et al., 2018; Zhai et al., 2023). This has especially played a crucial role in storing carbon, stabilizing soils, and providing watershed services (Cheng et al., 2024; Wen and Théau, 2020). In this Research Topic, Zhang et al. provided a comprehensive analysis of the economic potential of reforestation in China as a means to achieve carbon neutrality by 2060. Their study constructs spatially disaggregated marginal abatement cost (MAC) curves to project the effects of carbon pricing on enhancing reforestation efforts across different regions in China. The key findings indicate that carbon prices of US \$20 and \$50 per ton of CO₂ could significantly increase reforestation efforts, leading to substantial carbon dioxide removals over the next four decades. The results emphasize the importance of targeting reforestation policies to regions with the highest abatement potential to maximize cost-effectiveness. This research aligns with the themes of the Research Topic by addressing the integration of economic strategies with ecological restoration efforts, particularly in mitigating climate change.

China's planted forests have been estimated to capture carbon by nearly 3-fold over the last three decades (Cheng et al., 2024). Yet the capacity of these forests to sustain carbon storage over the next several decades will largely depend on the implementation of sustainable forestry strategies (Yu et al., 2024), including harvesting of timber and replanting with diverse native species (Hua et al., 2022). Building on these recent developments, Fan et al. developed a framework for evaluating Forest Landscape Restoration (FLR) suitability in the Saihanba Nature Reserve, Hebei province, located within the "Three-Norths Shelter Belt." The study employs a matter-element model to assess the suitability of different areas for restoration based on factors such as land cover type, landscape structure, soil quality, and topography. The findings reveal that ~55.55% of the study area is suitable for restoration, predominantly comprising natural secondary forests characterized by large patch areas, close patch distances, and complex patch shapes. The study's insights are crucial for informing sustainable forest management practices that integrate ecological considerations with landscape-level restoration efforts, contributing to broader goals of biodiversity conservation and ecosystem resilience in the face of climate change.

Understanding the complex dynamics of biotic and abiotic factors influencing natural landscapes is essential for effective forest restoration and conservation efforts, which are often hampered by the impacts of climate change. Khan et al. focused on the vegetation dynamics of *Pinus gerardiana* Wallich ex. D. Don forest in South Waziristan, Pakistan, showing how aspectual variations influence species richness and abundance. They revealed critical insights into the role of microclimatic conditions in forest management, for both restoration and conservation efforts. The study underscores the

importance of sustainable management practices to conserve these ecologically valuable landscapes, contributing to our understanding of the assessment, restoration, and preservation of wood and non-wood resources.

Climate change has also imposed biotic challenges to sustainable management of forest resources. Aslam et al. investigated the effectiveness of various pesticides at different concentrations and temperatures for controlling *Odontotermes obesus*, a termite species that poses a significant threat to certain vulnerable forest ecosystems. The study evaluates the mortality rates and behavioral responses of termites when exposed to pesticides and found that chlorantraniliprole, particularly at higher temperatures, was the most effective pesticide, showing the lowest lethal time (LT50). This research aligns with the themes of the Research Topic by contributing to sustainable forest management practices. It emphasizes the importance of understanding species-specific responses to pesticide treatments in the context of integrated pest management (IPM), which is crucial for maintaining forest health and resilience.

Finally, Jin et al. investigated how climate change could affect the potential geographic distribution of three significant subtropical tree species in China: *Cunninghamia lanceolata*, *Pinus taiwanensis*, and *Quercus glauca*. Using the MaxEnt model and data on various environmental variables, their study predicts shifts in the suitable habitats of these species under current and future climate scenarios (2050 and 2090's). The findings reveal that climate factors, particularly temperature and precipitation, play a more significant role than soil and topography in determining these species' distributions. Notably, *C. lanceolata* is expected to experience a northward expansion of its habitat, while *P. taiwanensis* and *Q. glauca* may face substantial reductions in their suitable areas, with *Q. glauca* at significant risk. The study emphasizes the importance of early intervention and adaptive management to mitigate these impacts. This research is highly relevant to the themes of the Research Topic as it underscores the importance of understanding species-specific responses to climate change for effective forest management and conservation strategies. The insights provided can inform the development of adaptive management practices and contribute to global efforts in forest restoration and biodiversity conservation under changing climatic conditions.

As major drivers of biodiversity loss and degradation of ecosystem services globally (Marques et al., 2019), reconciling how to improve agriculture and forestry activities sustainably continues to be one of the hallmark challenges of our time. In this decade of ecosystem restoration, Forest Landscape Restoration (FLR) efforts must therefore consider the importance of food security (De Pinto et al., 2020), including its role in agroforestry activities broadening social, environmental, and ecological benefits (Bosshard et al., 2021). We are also reminded of the trade-offs involved in forest restoration efforts, particularly those between plantations and native forests (Hua et al., 2022), if forests are to remain resilient under a changing climate. This also points to the trade-offs between long-term benefits over short-term costs through investing in genetic diversity (e.g., species suitability, seed sourcing, and planting stocks) to achieve more resilient FLR efforts (Nef et al., 2021).

With this Research Topic, we aim to advance the understanding of sustainable forest management in the context of climate change. The articles in this Research Topic provide evidence that successful forest management requires a multifaceted approach, integrating ecological, economic, and social considerations, also echoed in recent contributions within this journal (Mantilla Contreras et al., 2023). As we continue to confront the challenges of climate change and biodiversity loss, the insights gained from these studies will be invaluable in shaping policies and practices that promote the long-term health and resilience of the world's forests.

Author contributions

AS: Supervision, Writing – original draft, Writing – review & editing. MK: Writing – review & editing.

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