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Editorial: The contribution of managed forestry and the driving variables in climate change mitigation and adaptation

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Editorial on the Research Topic
The contribution of managed forestry and the driving variables in climate change mitigation and adaptation

Introduction

Forests play a pivotal role in addressing the impacts of climate change due to their ability to sequester carbon, regulate water cycles, and provide essential ecosystem services (Intergovernmental Panel on Climate Change, 2021). Forest soils and vegetation act as natural carbon sinks, absorbing significant quantities of greenhouse gases (GHGs) from the atmosphere, particularly carbon dioxide (CO_2). This carbon storage helps mitigate climate change by reducing the concentration of GHGs that contribute to global warming (United Nations Framework Convention on Climate Change, 2021) and offsetting. However, it is important to note that forests can also be sources of GHGs, including CO_2, methane (CH_4), and nitrous oxide (N_2O) (Walkiewicz et al., 2024). These emissions can occur due to deforestation, forest degradation, and certain management practices.

Appropriate management practices such as reforestation, afforestation, and improved silvicultural techniques can significantly increase the carbon storage capacity, contribute to climate change mitigation and adaptation, and help offset the negative impacts of climate change (Ameray et al., 2021). By planting trees and promoting their growth, managed forests can effectively remove CO_2 from the atmosphere. Careful management can help to minimize GHG emissions from forests. This includes reducing the risk of forest fires, preventing soil erosion, and avoiding practices that lead to the release of stored carbon. Additionally, managed forests can capture and store atmospheric CH_4, a potent GHG, through soil microbial processes (Walkiewicz et al., 2024). This system can help enhance the resilience of forests to the increasingly frequent and severe weather events associated with climate change such as droughts, heatwaves, storms, and insect outbreaks (Bonan, 2008; Food and Agriculture Organization of the United Nations, 2020). This can involve diversifying species, promoting genetic diversity, and implementing appropriate thinning and pruning practices. Moreover, forests play a crucial role in regulating water flows and nutrient cycles, reducing the risk of flooding and erosion, maintaining healthy watersheds, contributing to the overall health and resilience of ecosystems, supporting biodiversity and providing essential resources for communities.

To effectively manage forests for climate change mitigation and adaptation, it is essential to have a deep understanding of ecosystem dynamics (Piao et al., 2013). This includes studying the mechanisms that influence carbon balance, as well as how forests respond to changes in edaphic and climatic factors. By gaining a better understanding of these processes, scientists and forest managers can develop more effective strategies for conserving and restoring forests, and for mitigating the impacts of climate change. The Research Topic aimed to evaluate the role of managed forestry in mitigating and adapting to climate change and investigate the impact of edaphic and climatic factors on carbon sequestration, GHG balance, and forest resilience. The topics included are the identification of key drivers of carbon sequestration, CH_4 oxidation, and N_2O emissions; the understanding of the relationship between microbial diversity and forest ecosystem processes; and the recommendation of effective management practices in various forest types.

Key themes and contributions

The Research Topic contains a collection of peer-reviewed articles that address various but key aspects and actual problems of forestry and climate change. One of the articles was focused on soil CO_2 emissions in the primary dry dipterocarp forest and secondary dry dipterocarp forest sites in Thailand, in relation to diurnal and seasonal variations in air and soil temperatures, and soil moisture (Tammadid et al.). In view of the ongoing global warming, Guo et al. assessed the long-term trend of temperature changes in Zhengzhou (China) and suggested models suitable for predicting atmospheric temperature. Zhang et al. compared normalized difference vegetation index (NDVI), enhanced vegetation index (EVI), and land surface temperature (LST) with solar-induced chlorophyll fluorescence (SIF) in six forest and grassland in different regions. The potential of the reconstructed SIF to assess by comparison with gross primary productivity (GPP) for estimating gross C fluxes has also been included. GPP is an important component in C exchange, as reported by Liao et al., that estimated the forest ecosystem GPP in Qiannan (China). Due to the important role of forest management in C sequestration, Papa et al. assessed climate-smart practices relating to forest management and wood use, that can substantially increase forest C sink strength in Maryland and Pennsylvania (USA). Also Giasson et al., based on the Canadian forest as a case study, evaluated management scenarios that contribute to reducing GHG emissions and provide a carbon sink. Bysouth et al. focused on the transparency aspect of the national reporting of GHG emissions from the forestry sector in Canada and compared their calculations with reported C amounts.

The authors have used a variety of approaches in the articles, making the Research Topic multi-level and complementary. Given the methodology applied, the use of modeling predominated (Giasson et al.; Guo et al.; Liao et al.; Papa et al.; Zhang et al.), although direct measurements (Tammadid et al.) and calculation methods (Bysouth et al.) based on available data were also carried out. Liao et al. presented the spatiotemporal changes in GPP in Qiannan state (China) over the past 20 years (from 2000 to 2020), showing its increase (especially during the non-growing season), significant spatial heterogeneity and positive correlation with both temperature and precipitation. Tammadid et al. based on CO_2 *in situ* measurements reported that soil and air temperatures were the main drivers of diurnal variation, while the combination of soil moisture and soil and air temperatures determined the seasonal variations. Guo et al. showed the annual average and minimum atmospheric temperatures from 1950 to 2022 in Zhengzhou City (China), and based on values from the previous 22 months prepared a projection of future climate change between 2030 and 2040. Two articles (Giasson et al.; Papa et al.) focused specifically on predicting the C-balance following different forest management practices. Focusing on the reduction of GHG emissions to the atmosphere, Papa et al. assessed how different climate-smart management practices affect future land surface C balance in both forest ecosystems and wood products in the period from 2020 to 2100. The authors indicated the following key climate-smart management activities: maintaining and increasing forest extent, fostering forest resiliency and natural regeneration, encouraging sustainable harvest practices, balancing timber supply and wood utilization with tree growth, and preparing for future climate impacts. Similarly, Giasson et al. identified optimal management and wood production solutions in the short and long term. Based on the boreal balsam fir-white birch landscapes of Quebec, the authors suggested a reduction in harvest levels combined with an increase in the use of partial cut (instead of clearcut) and planting (instead of natural regeneration) can significantly increase the C sink even in the long term. However, implementing proper mitigation and adaptation practices in forestry requires accurate GHG reporting. Bysouth et al. focused on GHG emissions from the forestry sector at the national level in Canada, and based on analysis revealed that between 2005 and 2021 forestry was a source of C while the national GHG inventory report showed a small net C sink. The authors explained that the discrepancy results from approaching the classification of GHG emissions from wildfires as natural, but GHG removals from forests at the age of commercial maturity as anthropogenic.

Challenges and limitations of managed forestry as a climate change solution

It has been revealed that managed forestry faces several challenges and limitations. One significant hurdle is the potential for unintended consequences such as large-scale afforestation can lead to habitat fragmentation and biodiversity loss, particularly in tropical regions (Cooper and MacFarlane, 2023). Its effectiveness can vary widely depending on factors such as forest type, management practices, and regional climate conditions. For example, in some regions, increased forest biomass may lead to higher temperatures due to the darkening effect of trees, known as the albedo effect. The long-term sustainability of managed forestry is contingent on factors like disease outbreaks, pest infestations, and changes in land use patterns. Research highlights how native and non-native insect and disease disturbances can significantly reduce carbon sequestration, potentially transforming forests from carbon sinks into sources due to decomposition emissions. This adds long-term challenges to maintaining forest productivity and carbon balance for example difficulty in accurately assessing carbon sequestration (Quirion et al., 2021).

Another challenge is the difficulty in quantifying and verifying carbon sequestration accurately (Cooper and MacFarlane, 2023). While remote sensing technologies and field measurements have improved in recent years, there remains uncertainty in assessing the net carbon balance of forests, particularly in complex ecosystems. Moreover, the economic viability of managed forestry as a climate change mitigation strategy can be constrained by factors such as market volatility for forest products, government policies, and the costs associated with sustainable management practices. There seems to be ongoing uncertainties and complexities in implementing forestry as a reliable carbon management solution.

Opportunities for further research and innovation

To address the challenges and limitations of managed forestry, further research and innovation are essential. One promising area is the development of advanced modeling tools and data analytics techniques to improve our understanding of forest carbon dynamics, N_2O emissions, CH_4 oxidation and their response to climate change. This could involve integrating remote sensing data, field measurements, and climate models to provide more accurate estimates of carbon sequestration and GHG emissions and the overall total/net carbon balance. Additionally, research on innovative forest management practices, such as silvicultural systems that promote biodiversity and enhance carbon storage, is crucial. Exploring the potential of agroforestry and forest-based climate-smart agriculture can also contribute to more sustainable and climate-resilient forest ecosystems.

There is a need for increased investment in research and development to support the development of new forest products and markets that can generate additional revenue for forest owners and incentivise sustainable management practices. This could include exploring the potential of bioenergy, forest-based pharmaceuticals, and other value-added products. Finally, strengthening international cooperation and collaboration is essential for addressing the global challenges including sharing knowledge, best practices, and resources among countries and fostering partnerships between governments, businesses, and civil society organizations.

Conclusion

Forests play a crucial role in mitigating climate change (and adaptation) by sequestering carbon and regulating water cycles. They can also be sources of GHG emissions. Proper forest management practices could promote carbon sequestration, reduce emissions, and increase resilience. This Research Topic highlights the importance of understanding ecosystem dynamics and the impact of edaphic and climatic factors on forest processes. The articles presented in this Research Topic provide valuable insights into the potential of managed forestry to mitigate and adapt to climate change. However, challenges such as the quantification of carbon sequestration, the impact of disturbances, and the economic viability of sustainable forestry practices remain. To fully realize the potential of forests as a climate solution, further research is needed to address these challenges. By advancing our understanding of forest ecosystems and developing innovative management strategies, we can ensure the long-term health and sustainability of forests and their vital contributions to a climate-resilient future.

Author contributions

MK: Writing – original draft, Writing – review & editing. AW: 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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