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Editorial: Carbon cycle vulnerability across coastal and forested wetlands in response to anthropogenic perturbations

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Editorial on the Research Topic
Carbon cycle vulnerability across coastal and forested wetlands in response to anthropogenic perturbations

Introduction

Coastal wetlands, including mangroves, seagrasses, and riparian zones, are vital ecosystems for carbon storage and climate change mitigation. As highlighted in this Research Topic of studies, these ecosystems face mounting challenges from climate change and human activities, necessitating innovative strategies for their restoration, management, and conservation. The contributions in this Research Topic span experimental, observational, and computational approaches, offering critical insights into the interplay between wetland ecology, greenhouse gas fluxes, and climate change mitigation strategies. The articles address knowledge gaps in restoration assessment, carbon sequestration mechanisms, and management practices, providing a foundation for future research.

From evaluating restoration outcomes in Carolina Bay wetlands (Moritz et al.) to investigating photochemical enrichment of dissolved organic matter in tidal systems (Zhou et al.), and from assessing blue carbon potential in the Maldives (Macreadie et al.) to examining riparian zone dynamics in China's river systems (Arif et al.), this Research Topic advances our understanding of coastal carbon dynamics. Additionally, Li et al. highlight the potential of young mangroves in carbon storage, emphasizing the importance of targeted restoration strategies, while Kang et al. evaluated the carbon storage potential of planted mangroves in Kaozhouyang, Guangdong Province, focusing on key factors like species, age, and tidal gradients to determine their role in restoring blue carbon ecosystems. Collectively, these studies underscore the urgent need for integrated conservation policies and adaptive management approaches to safeguard coastal wetlands as critical carbon reservoirs in the face of rapid environmental change.

Overview

Restoring wetlands is a critical environmental endeavor that mitigates habitat loss and supports ecological resilience. However, restoration efforts remain expensive, necessitating the development of robust scientific methods to evaluate various restoration projects. To that end, Moritz et al. focuses heavily on developing chronosequences (timelines) as an environmental assessment tool to evaluate restoration outcomes for Carolina Bay wetlands (CBWs) in the Southeastern US, previously converted for agricultural use. By establishing timelines for key indicators such as litter thickness, tree basal area, and potential tree height across Hydrologic Groups defined by saturation levels, the authors address the lack of standardized criteria for assessing wetland recovery. Their integration of empirical methods to estimate saturation periods showcases a balanced focus on field practicality and scientific rigor. This approach not only facilitates consistent evaluation across diverse restoration sites but also supports adaptive management strategies tailored to site-specific needs. Significantly, the study underscores that achieving reference conditions may require decades, emphasizing the importance of long-term monitoring and adaptive practices. The proposed methods empower restoration projects with measurable standards, ensuring accountability and fostering confidence in investments aimed at ecological restoration. The insights from this study will be instrumental in advancing restoration methodologies for wetlands in the Carolina Bay area, though further validation is needed to generalize the findings to other wetland types and regions.

Zhou et al. investigated how photochemical processes contribute to the enrichment of dissolved organic matter (DOM) in tidal river systems, focusing on the Dagu River, an essential estuarine environment near Jiaozhou Bay. The study highlights soil photodissolution as a key mechanism driving estuarine carbon cycling. Laboratory experiments reveal that light exposure significantly enhances the release of DOM, particularly humic-like substances, from resuspended soils, with salinity playing a regulatory role in this process. Additionally, the research underscores how soil characteristics, including organic carbon content and isotopic composition, affect the extent of DOM release. Aged soils with higher organic carbon levels were particularly responsive to photochemical activity, underscoring their substantial role in sustaining DOM pools. This work offers valuable insights into the role of photochemical reactions in mediating carbon transfer from terrestrial to marine systems, with broader implications for understanding estuarine carbon cycles and enhancing the predictive capabilities for carbon transport processes.

The Maldives, a hub for global tourism, faces an urgent need for innovative climate solutions. The study by Macreadie et al. brings to light the critical role of blue carbon ecosystems—specifically seagrass meadows and mangroves—in mitigating carbon emissions in this small-island nation. This research revealed that seagrasses contribute between 55% and 72% of the sediment organic carbon in the studied islands, highlighting their dominance as carbon sinks. The unexpected role of screw pines, providing significant organic matter in certain areas, underscores the untapped potential of diverse vegetation in carbon sequestration strategies. Beyond its ecological insights, this study addresses a pressing economic opportunity: integrating blue carbon projects with the Maldives' tourism sector. By protecting and restoring these ecosystems, the nation can offset the high carbon footprint of its tourism industry while enriching local communities through sustainable ecotourism initiatives. As the first study of its kind in the Maldives, the findings emphasize the need for further research into blue carbon stock mapping, sequestration rates, and restoration feasibility. By coupling conservation with carbon offset programs, the Maldives can lead the way in aligning ecological health with economic resilience in the face of climate change.

Arif et al. explore the effects of changing riparian topographies on ecological indicators (EIs) within the drawdown zones of China's extensive river systems, including the Yangtze River. This research highlights how variations in stream-channel width, riparian buffer width, and elevation impact vital EI metrics including plant cover, erosion, and regeneration. Downstream areas were found to be most affected by changes in stream-channel width, while riparian width significantly influenced upstream regions. Elevation changes had profound effects on habitat quality and exotic species proliferation. These findings underscore the necessity of region-specific management strategies that account for these nuanced interactions. This work emphasizes the importance of tailored conservation policies and the establishment of buffer strips to mitigate stressors and enhance ecosystem services. As global rivers increasingly face similar challenges, this study serves as a crucial reference for policymakers and conservationists striving to sustain riparian zones amidst shifting environmental and topographical conditions.

Mangroves play a vital role in carbon sequestration, yet the mechanisms of carbon storage in young, developing systems are not well understood. Li et al. examined patterns of sedimentary organic carbon (TOC) in the Nanliu River Delta's mangrove ecosystem, providing insights into the carbon storage potential of newly restored mangroves. Notable variations in TOC were observed across zones, from creek mudflats to interior mangroves. Stable isotope analysis identified riverine sediments and marine phytoplankton as dominant carbon sources, with minimal contributions from mangrove-derived material in this early-stage ecosystem. The findings highlight the ability of young mangroves to enhance carbon storage by trapping fine sediments, even during initial growth phases. This research underscores the promise of mangrove restoration for climate mitigation and calls for long-term monitoring to fully harness the potential of these ecosystems as mature carbon sinks. Li et al.'s work emphasizes the importance of targeted conservation policies to enhance blue carbon storage and support global climate goals.

Kang et al. provided valuable insights into the carbon storage potential of mangrove plantations in Kaozhouyang, Guangdong Province, emphasizing the influence of tree species, forest age, and tidal gradients. While the findings underscore the importance of mangrove restoration for climate change mitigation and highlight the superior carbon sequestration potential of fast-growing species like *Sonneratia apetala* compared to native species such as *Kandelia obovata*, the reliance on non-native species raises ecological concerns, such as potential impacts on biodiversity and long-term ecosystem stability. Additionally, the focus on the top 50 cm of soil carbon and the limited temporal scope may underestimate the full carbon sequestration potential and soil carbon dynamics

of mangrove ecosystems. Despite these limitations, the study offers actionable recommendations for species selection and site management, contributing to the broader understanding of mangrove restoration's role in blue carbon strategies. Future research addressing long-term impacts and deeper soil carbon storage will further enhance the reliability of these findings. Overall, the study offered a foundational understanding of the trade-offs and opportunities in mangrove afforestation and restoration, providing actionable insights for policymakers and environmental managers.

Conclusion

Collectively, these studies underscore the urgent need for targeted conservation policies and adaptive management approaches to enhance the carbon sequestration capacity of coastal wetlands while addressing the challenges posed by climate change and anthropogenic pressures. This body of work provides a foundation for future research and informed policymaking in the context of global carbon cycle management.

These findings collectively stress the importance of adaptive management, site-specific conservation policies, and further research to address existing knowledge gaps. Coastal wetlands remain indispensable for global carbon sequestration and ecological resilience, and the work presented here provides a strong basis for advancing sustainable practices and informed policy-making to protect these critical ecosystems.

Author contributions

BM: Writing – original draft, Writing – review & editing.

Conflict of interest

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

Generative AI statement

The author(s) declare that Gen AI was used in the creation of this manuscript. Author used ChatGPT (Version 4.0) to Grammar and syntax correction.

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