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Editorial: Tropical blue carbon: challenges and opportunities

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Editorial on the Research Topic
Tropical blue carbon: challenges and opportunities

Blue carbon ecosystems - mangrove forests, seagrass meadows, and salt marshes - are essential for global organic carbon sequestration. These ecosystems serve as significant carbon sinks whilst contributing to climate change mitigation and adaptation. They provide numerous benefits, including coastal protection, water filtration, and nursery habitats (see Figure 1). However, these ecosystems are highly threatened by natural and anthropogenic stressors, with significant losses and degradation of habitats already observed. The vulnerability of these coastal ecosystems has been documented, and future climate-mitigation projects need to fully incorporate protection, restoration, and conservation of these important carbon sinks.

The bulk of published blue carbon studies originate from developed countries (e.g. Howard et al., 2017; Macreadie et al., 2019; Wylie et al., 2016), leading to an overrepresentation of certain species (salt marsh plants, temperate seagrasses) in the scientific literature. Whilst salt marshes are scarce in tropical regions, seagrass and mangroves are predominant coastal ecosystems (e.g Giri et al., 2011; Alongi, 2008). Tropical regions are particularly rich blue carbon reservoirs (Donato et al., 2011) with Indonesia hosting the largest national area of mangroves and seagrasses (Unsworth and Cullen, 2010).

Although tropical blue carbon knowledge is expanding, with research efforts in countries like Mexico, Indonesia, and Malaysia, regions such as Australia remain better represented in the literature (Zhong et al., 2023). This limited knowledge constraints, for example, effective implementation of management actions aimed at restoration. Priority areas of research that will allow countries to utilise these areas within their mitigation and adaptation targets include mapping of these ecosystems, measuring carbon stocks and fluxes, considering ecosystem services and livelihood opportunities, policy development, and assessing potential abatement activities.

A growing body of research in tropical regions is essential for advancing effective restoration practices and supporting the goals of the UN Decade of Ocean Science for Sustainable Development (2021–2030), which aims to promote the conservation and sustainable use of oceans, seas, and marine resources. The "*Tropical Blue Carbon: Challenges and Opportunities*" articles provide crucial insights into tropical ecosystems' roles in carbon dynamics and their challenges from natural and human activities. They offer a valuable foundation for shaping future policies and guiding research in underrepresented regions, helping to strengthen global efforts to conserve and restore these critical ecosystems. This editorial aims to summarise the findings of the studies within this Research Topic (Figure 1 indicates the ecosystems studied by the contributing authors), place them in a broader context, and explore challenges and opportunities for integrating ongoing research in areas such as monitoring, management, and economic activity (Pace et al., 2023).

Research topic preview

Yeemin et al. demonstrated the interconnected nature of coastal ecosystems and assessed blue carbon stocks across microhabitats in Thailand's Western Gulf. The study revealed that seagrass beds, mainly their sediments, stored the majority of carbon (8,877 Mg C across 122 ha), with shallow beds showing higher storage capacity.

Research by Herrera-Silveira et al. established that seagrass connectivity significantly influences carbon storage in reef lagoon systems. Carbon stocks ranged from 0.7 to 1.2 Mg C ha^{-1} in biomass and 19 to 117 Mg C ha^{-1} in sediment, with more connected landscapes supporting higher carbon levels.

Wang et al. utilised habitat suitability models to predict seagrass distribution in the Northern Chinese Seas. Their research identified key environmental variables affecting distribution, including sea surface temperature and substrate type, providing crucial insights for seagrass conservation amidst coastal development and climate change threats.

The complex interplay between nitrogen and organic carbon cycling in tropical coastal zones was explored by Jiang et al.. It was noted that excessive nitrogen can disrupt carbon sequestration, necessitating strategies to mitigate terrestrial nitrogen pollution to enhance blue carbon ecosystem resilience.

Microbial contributions to carbon storage in mangrove ecosystems were investigated by Liu et al.. The role of extracellular polymeric substances in enhancing carbon storage was examined, with findings suggesting that microbial processes are crucial for maintaining carbon stocks.

The impact of invasive species on carbon storage was studied by Huang et al.. It was found that *Spartina alterniflora* invasion in Beihai coastal wetlands increased soil organic carbon levels, prompting discussions on integrating carbon sequestration goals with invasive species management. However, careful

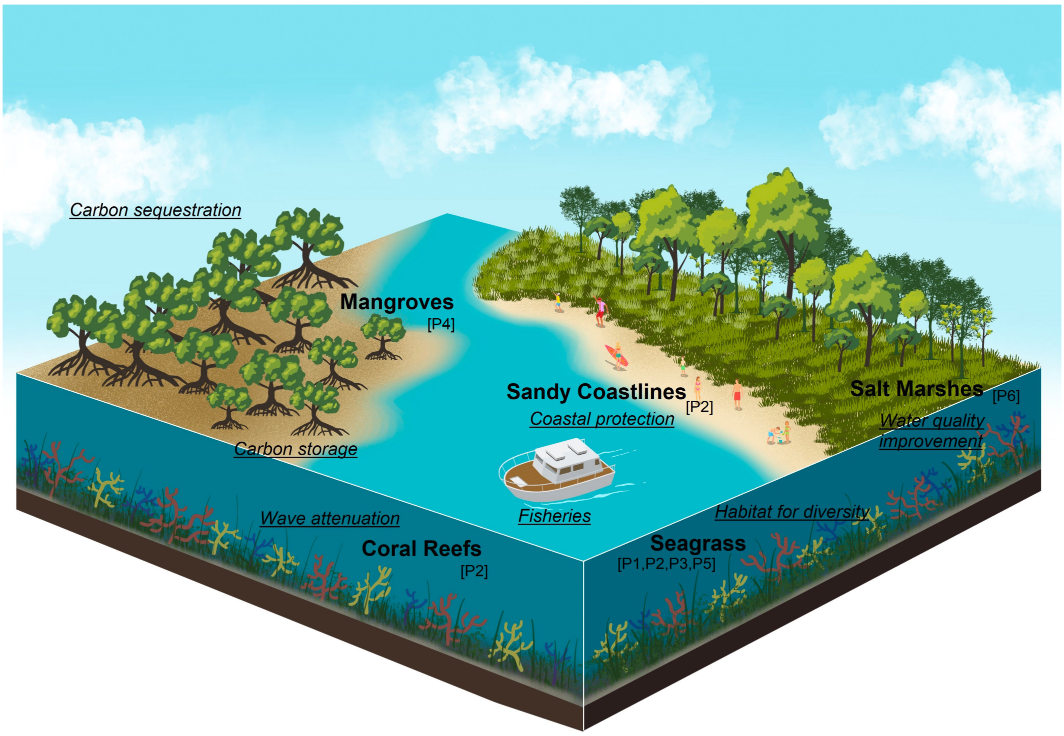

FIGURE 1
Schematic overview of tropical coastal ecosystems (mangroves, coral reefs, seagrass, salt marshes, and sandy coastlines) and their key ecosystem services (e.g. carbon sequestration and wave attenuation). Studies presented in this Research Topic are depicted as P1-P6 next to the ecosystem studied. P1: Herrera-Silveira et al.; P2: Yeemin et al.; P3: Wang et al.; P4: Liu et al.; P5: Samper-Villarreal et al.; and P6: Huang et al..

consideration is needed to balance ecosystem health and carbon storage benefits.

The effects of megaherbivore exclusion on seagrass canopy complexity and carbon pools were studied by Samper-Villarreal et al.. It was observed that grazing by large herbivores significantly reduced seagrass biomass and carbon storage while excluding grazers enhanced canopy complexity and carbon sequestration. This study underscores the delicate balance between preserving biodiversity and optimising carbon sequestration, suggesting that conservation strategies must consider trophic dynamics to maximise blue carbon outcomes.

Overall, the Research Topic '*Tropical Blue Carbon: Challenges and Opportunities*' highlights the complexities of managing blue carbon ecosystems in the tropics, which are highly valuable for climate change mitigation but threatened by multiple stressors such as habitat fragmentation and pollution. Conservation initiatives must be holistic, incorporating habitat connectivity, pollution control, and ecosystem restoration to enhance carbon sequestration. A recurring theme within the Research Topic was the interconnectedness of these ecosystems, underscoring the need for a holistic approach in future research. Expanding the scope of studies to include microbiology, invasive species, and biogeochemically active compounds like nitrogen is crucial. Given the diversity and interconnectivity of tropical coastal ecosystems, research efforts must be designed with these complexities in mind to preserve and enhance their blue carbon capacity. Adopting a seascape approach to coastal restoration (Pittman, 2017) recognises the interconnected nature of habitats like mangroves and, for example, oyster reefs (Grabowski et al., 2012) and integrates them into a single management framework. Rather than focusing on each habitat in isolation, holistic seascape restoration enhances ecological functions by reestablishing key processes such as nutrient cycling, habitat connectivity, and trophic linkages (Boström et al., 2011). Restoring multiple habitats in tandem allows coastal communities to benefit from stronger resilience to climate change—through increased blue carbon sequestration and enhanced natural protection against flooding, erosion, and other hydrodynamic risks.

Author contributions

MM: Conceptualization, Visualization, Writing – original draft, Writing – review & editing. NS: Writing – original draft, Writing – review & editing. JS-V: Writing – original draft, Writing – review & editing. SJ: Visualization, Writing – original draft, Writing – review & editing. AM: Writing – original draft, Writing – review & editing. JO: Writing – original draft, Writing – review & editing. TV: Writing – original draft, Writing – review & editing. JZ: Supervision, Writing – original draft, 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.

Publisher's note

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