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Editorial: Indonesian mangrove ecology and the changing climate

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Editorial on the Research Topic

Indonesian mangrove ecology and the changing climate

Introduction

We run the Research Topic with a specific goal to assess the breadth, depth and wealth of mangrove research in Indonesia and identify gaps in knowledge to support public policy-making processes concerning climate change mitigation and adaptation. The scope of mangrove research encompasses field surveys on vegetation structure and composition, sediment characteristics, carbon stocks monitoring and greenhouse gas inventory, as well as mapping mangrove distribution across the diverse hydro-geomorphic settings characteristic of the archipelago.

Although this Research Topic was focused on Indonesia, it welcomes contributions from researchers studying mangrove ecosystems in other regions. We aimed to address a broad spectrum of issues, including but not limited to variations in vegetation structure and composition of mangrove blue carbon ecosystems across the archipelago and beyond.

We also look for the challenges and opportunities associated with blue carbon ecosystems for climate change mitigation and adaptation strategies. Additionally, the resilience of low-lying coastal landscapes and mangrove blue carbon ecosystems in the face of sea level rise. This way, we can identify knowledge gaps that can inform and support public policy-making processes in the context of a changing global climate.

Although the initial objectives of the Research Topic were not fully met, we encountered several interesting trends and facts worth considering for future research agenda and inclusion in policy discourses.

Driving factor for mangrove loss and carbon emissions

Aquaculture is one of the main drivers of mangrove loss across Southeast Asian countries (Murdiyarso et al., 2015; Sasmito et al., 2025). The conversion of mangroves to aquaculture generates substantial loss of carbon stocks and eliminates carbon storage

capacity. It was demonstrated that conversion of mangrove to aquaculture could halve total ecosystem carbon stocks (TECS) as shown in Banten province of Indonesia.

Results by Royna et al. show contrasting TECS across five land uses, with the lowest TECS of 261 Mg C ha⁻¹ in working fishpond without mangrove and the highest of 574 Mg C ha⁻¹ in undisturbed fringe mangroves dominated by *Avicennia marina*. Most of these stocks were found in the soil carbon pool (87%) in fringe and interior mangroves. However, the conversion of mangroves to aquaculture ponds resulted in soil carbon loss from 6% to 60%. In a more degraded mangroves of Central Java province, the absolute loss may reach as much as 62.58 Mg C ha⁻¹, as indicated in other assessment by (Ardhani et al.).

Whereas Analuddin et al. show that in the province of Southeast Sulawesi, Indonesia, the highest carbon storage is shown in the well-protected National Park of 706.76 Mg C ha⁻¹ and decreases with lowering level of protection in three comparative areas from 448.37 Mg C ha⁻¹ to 470.76 Mg C ha⁻¹, and 253.27 Mg C ha⁻¹.

These results presented in this Research Topic emphasize the importance of soil carbon pool in accounting for carbon additionality (emissions reduction or carbon removals) following blue carbon management and approaches (e.g., mangrove conservation for reducing emissions and mangrove restoration for carbon removals). Addressing this challenge could potentially generate substantial carbon additionality and potentially climate benefits, especially through avoiding mangrove conversion into aquaculture. Restoring degraded coastal zones could help to stem the loss of carbon (estimated by soil carbon differences). Although mangroves TECS are primarily stored in soil, however the presence of vegetation remains crucial for sustaining carbon storage function.

Limited measurements in carbon dioxide (CO₂) and methane (CH₄) effluxes were identified in Asia Pacific mangroves (Sharma et al., 2023). The study in Banten reported by Royna et al., however, revealed that the highest soil CO₂ effluxes during dry and wet seasons were observed in interior mangroves (151 ± 12 mg CO₂ m⁻² h⁻¹). The highest soil CH₄ effluxes were found in fringe mangroves (0.13 ± 0.04 mg CH₄ m⁻² h⁻¹). The highest aquatic CO₂ and CH₄ effluxes were found in densely reforested fishponds, at 118 ± 7 mg CO₂ m⁻² h⁻¹ and 0.38 ± 0.04 mg CH₄ m⁻² h⁻¹, respectively. However, it is crucial to maintain mangroves for natural carbon capture and storage through carbon stock enhancement although the flux in gaseous form is higher in vegetated areas.

The need for conservation – beyond carbon

The changing climate, which resulted in increasing sea level, is a planetary scale impacts that matters for low-lying coastal zones and small island countries. Studies documented by Ardhani et al. show that the estimated local sea-level rise of 0.45 cm yr⁻¹ led to relative sea-level rises between 1.36–10.46 cm yr⁻¹ with variation of impacts depending on the types of mangrove degradation, land use changes and coastal zonation.

However, following the enhancement of sediment accretion, only mangroves in degraded areas experienced an elevation surplus of 2.02 cm yr⁻¹. The remaining land-uses suffered elevation deficits and were inundated by up to 15 cm yr⁻¹ in abandoned ponds. Land subsidence is responsible for the collapsing surface as dead mangrove's fine roots are decomposed or eroded. These findings imply that mangroves, especially degraded ones, are highly vulnerable to sea level rise impacts.

The presence of both conserved and restored mangroves are essential in providing ecosystem services, not only in accumulating or trapping carbon but also in building land to cope with rising sea levels. Additionally, it is worth noting that northern coast of Java and eastern coast of Sumatra are part of the East Asian-Australasian Flyway. They play an important role in providing services to migratory water birds and songbirds (Yong et al., 2015).

Similarly, as demonstrated in protected mangroves areas in Guangdong Province, China, Yang et al. demonstrated that mangrove serves as a vital breeding, feeding, and resting ground for a wide range of bird species. The study documented a large bird diversity, recording 193 bird species across 17 orders and 53 families. The identified bird diversity includes 74 songbirds, 60 wading birds, 27 swimming birds, 17 climbing birds, 10 raptors, and 5 terrestrial birds. This high diversity reflects the ecological complexity of mangrove landscapes—where mangrove extent strongly influences the distribution of songbirds, climbing birds, raptors, and terrestrial birds, while the surrounding aquaculture ponds play a pivotal role in supporting wading and swimming birds.

The way forwards

To enhance mangrove roles in curbing climate change by reducing mangrove loss and storing more carbon, coping with rising sea level, and promoting bird diversity, management interventions such as protection and restoration should adopt evidence-based approaches. Planning and managing mangrove landscapes should consider ecological connectivity between remaining mangroves, natural and man-made habitats such as mudflats and aquaculture pond areas. This would prevent extensive mangrove planting in places where ecologically unsuitable, which may result in restoration failure rather than success. Additionally, improved management of aquaculture ponds should accommodate diverse bird habitats through measures, such as water level adjustments. All these parameters may be considered in the monitoring, reporting and verification (MRV) system, when high-integrity blue carbon projects scrutinized using robust standards and methodologies are to be implemented. Therefore, the future direction of mangrove conservation and restoration should not be focused on maximizing carbon outcomes alone, but must also embrace the broader co-benefits this ecosystem provides. By integrating goals for terrestrial and marine biodiversity outcomes, successful mangrove management can simultaneously strengthen climate mitigation, safeguard critical habitats, and support the ecological integrity of

coastal landscapes. Such a holistic approach ensures that mangrove conservation delivers durable climate solutions while also enhancing resilience and biodiversity across land–sea interfaces.

Author contributions

DM: Conceptualization, Funding acquisition, Supervision, Validation, Writing – original draft, Writing – review & editing. SSh: Validation, Writing – review & editing. SSa: Supervision, Validation, Writing – review & editing.

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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