



Leveraging plural valuations of mangroves for climate interventions in Indonesia

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Abstract

Mangrove forests are globally significant blue carbon sinks that remain critically under-governed and under threat. In Indonesia, the rapid rate of mangrove loss over the past three decades, combined with the promise of these carbon-dense ecosystems to mitigate climate change impacts, has catalyzed the world's largest replanting program. Institutional and ideological divisions between advocates of conservation and commodification approaches to mangrove governance, however, have historically compromised Indonesia's ability to meet its climate commitments. Market valuations of mangroves as blue carbon have further complicated their governance by opening up new opportunities for environmental collaboration and resource exploitation. Drawing on the concept of leverage points, this study examines how plural valuations of mangroves might be applied to sustainability interventions in Riau Province, Indonesia. Using document analysis and interviews with public, private and societal stakeholders, we examine how sector-level values translate into collaborative actions through mangrove partnerships. We posit that integrating indigenous knowledge and place-based values into mangrove policy development could help to address the existing conservation–commodification divide. As plural values are mutually transformative, we argue that recognizing areas of strategic compatibility creates space for flexible and adaptive cross-sector cooperation. Such recognition is especially important for mangrove communities, whose marginal socioeconomic position reinforces their need to remain ideologically and tactfully open to areas of compatibility with shifting market valuations, both to sustainably develop locally important resources and to avoid livelihood capture by predatory development interests.

Keywords Blue carbon markets · Climate change · Coastal governance · Environmental partnerships · Indonesia · Mangrove conservation

Introduction

Despite scientific recognition of the global value of mangroves as among the most carbon-dense forests in the tropics (Donato et al. 2012), their governance remains subject

to ongoing debate (Sasmito et al. 2023). Governments have historically understood the utility of mangrove ecosystems very differently from coastal and riverine communities, generating divergent governance approaches. The latter have traditionally recognized the commercial and cultural value of mangroves as sources of biofuel (wood and charcoal), food (habitat protection for wild-catch fisheries), raw construction materials (wood for building boats and homes) and medicine (ash and bark infusions with antimicrobial, antioxidant and anti-diabetic properties) (Bibi et al. 2019). By contrast, governments and their representative bodies tend to prioritize either the protective (ecological) or productive (socioeconomic) functions of mangroves. Many governments seeking to implement their Nationally Determined Contributions (NDCs) to the 2015 Paris Agreement on climate change have implemented conservation policies that result in “biological successes and social failures” (Christie 2004, p. 155) by overlooking the importance of mangrove-dependent

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livelihoods (Friess et al. 2016). Conversely, growth agendas have frequently resulted in land-use choices that fail to account for the costs of mangrove deforestation in evaluations of coastal development opportunities (Vo et al. 2012). Marketized and technocratic valuations of mangroves as blue carbon have added to these governance complexities by introducing new economic opportunities that exacerbate transboundary challenges of carbon displacement and social dispossession (Song et al. 2021).

This study explores whose values become integrated into debates about mangrove sustainability and how plural value perspectives might be productively harnessed to overcome the existing conservation–commodification divide in environmental governance. We apply the concept of leverage points introduced by Meadows (2008, p. 145) to refer to “places in a system where a small change could lead to a large shift in behavior”. Our focus is on the “deep leverage points” (Abson et al. 2017, p. 33) of values and goals (system intent) that arguably lead to greater transformations of a system’s design than the shallower leverage points of feedback loops, subsidies and taxes. Building on the growing interest in sustainability science with integrating indigenous knowledge into environmental governance systems, we posit that including such under-represented valuations into mangrove partnerships creates new possibilities for targeted sectoral and socio-scientific transformations (Thompson et al. 2020). As values are continually negotiated and mutually transformative in cross-sector partnerships, recognizing areas of strategic compatibility within and between sectors could contribute to deeper, more adaptive changes in a system’s design (Leventon et al. 2021a). For example, mangrove communities could use monetized valuations of blue carbon to protect locally important resources against the solely utilitarian value systems of coastal developers.

Our geographical focus is on Riau Province on Indonesia’s western island of Sumatra (Fig. 1), where competing valuations of mangrove forests find expression in unresolved tensions between the government’s climate mitigation agenda and accumulating development pressures. As one of nine provinces included in Indonesia’s ambitious conservation agenda to replant 600,000 hectares (ha) of mangroves between 2021 and 2024 (Presidential Decree No.78/M/2020), Riau has become a focal point for national experimentation in sustainability interventions in blue carbon sinks, understood to mean mangroves, saltmarshes and tidally influenced freshwater wetlands that accumulate and store more carbon than they release (Lovelock and Duarte 2019; UNFCCC, n.d.). The province has approximately 150,000 ha of mangrove forests, characterized by many continuous tracts around coastal islands and riverine fringes (Bunting et al. 2018; Government of Riau 2019). Since 1990, however, Riau has lost 20% of its mangroves (Government of Riau 2019) through land-use change into

industrial estates, aquaculture, agriculture and the construction of ports, roads and human settlements (Mulyadi et al. 2018). Riau’s mangroves are mainly surrounded by peatlands; half of the province’s surface area is composed of peat that is most densely concentrated along the eastern coast (Kurniawan 2008). Neoliberal capitalist valuations of converted peatlands have seen the expansion of palm oil and acacia (for pulp and paper production) plantations, setting the territorial stage for further mangrove degradation as pollutants (fertilizers, pesticides and palm oil mill effluent) leak across plantation boundaries, contaminating shared water supplies (Miller 2022).

In what follows, we examine how plural valuations of mangroves might be leveraged to: (a) rethink knowledge co-production at the science–policy interface of mangrove governance; and (b) restructure the institutional relations of cross-sector cooperation in blue carbon partnerships. The methods are then described, followed by analysis of competing value constructions that have historically challenged Indonesia’s mangrove governance system. We then consider the potential for plural valuations of mangroves to enhance blue carbon partnerships in Riau. The conclusions make recommendations for future policy development to integrate conservation-based valuations of mangroves as environmental goods of international public value with sustainable commodification strategies suited to supporting the livelihoods of local communities that have long depended on them.

Conceptualizing plural valuations for mangrove governance

Grounded in systems thinking, leverage points are targeted interventions that can produce positive sector-level transformations at scale in a given system of interest (Abson et al. 2017; West et al. 2020). Our conceptual approach focuses on the human system of mangrove governance rather than on ecological systems. Although mangrove ecosystems have certain materialities that shape their governance, we are concerned with the plurality of meanings used by human actors to value mangroves that inform whose knowledge is integrated into environmental partnerships.

Our dual-track approach to conserving–commodifying mangroves engages with the “deepest” of Meadows’ (2008) 12 leverage points that are organized along a continuum ranging from shallowest to deepest to encompass four categories: (1) parameters, (2) feedbacks, (3) design, and (4) intent (Abson et al. 2017). We are mainly concerned with how intent, defined as “the underpinning values, goals and world views of actors” that shape a system’s direction, can reorient its design, or the “social structures and institutions” that govern feedback loops and parameters (mechanistic characteristics) (*Ibid*: 32). The uptake of plural value

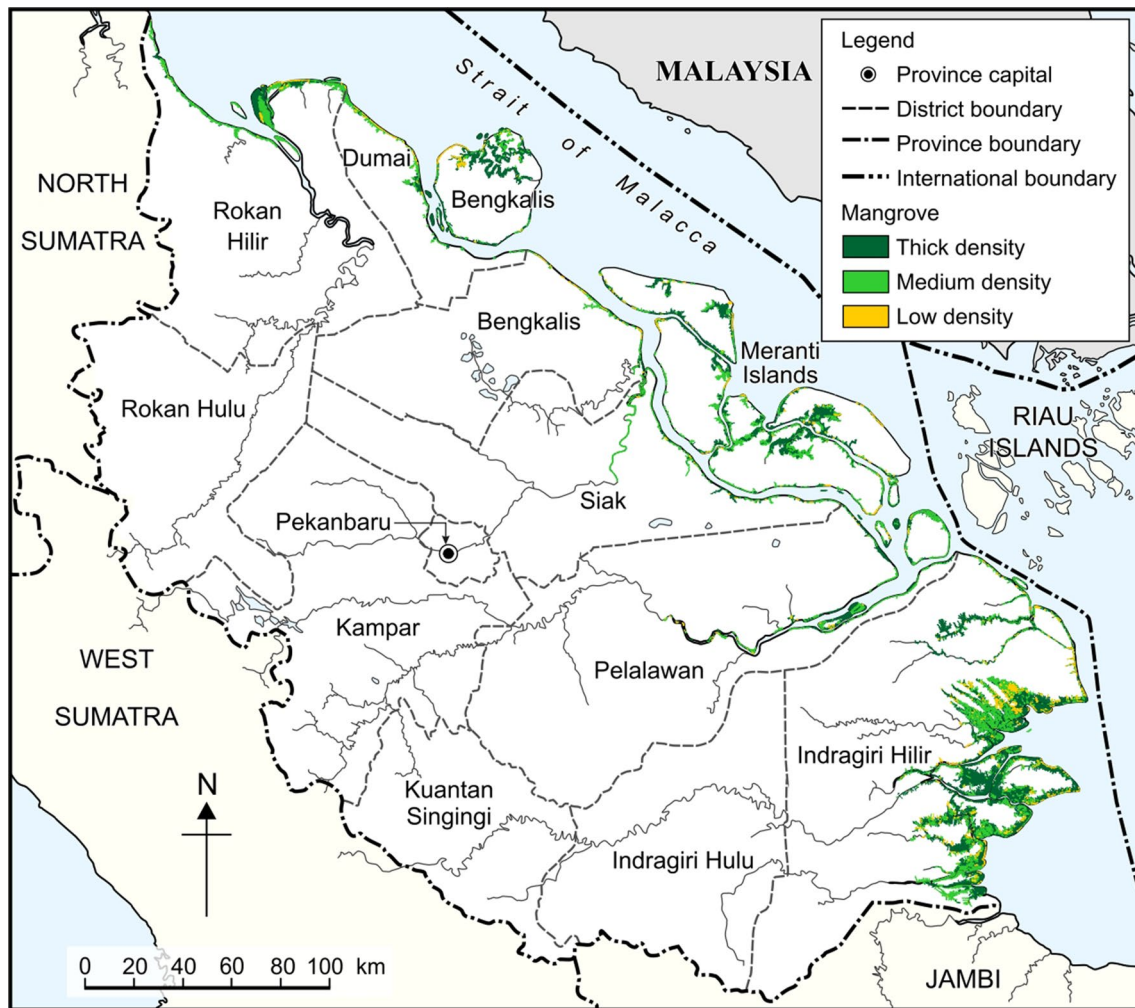


Fig. 1 Map of Riau Province showing: **a** mangrove extent and density; and **b** district boundaries that intersect mangrove ecosystems (adapted from BPS 2019; PDASRH 2021)

perspectives in sustainability science has highlighted how converging meanings of nature among public, private and societal stakeholders could be leveraged to shift the overall intent of a system to achieve more equitable and ecologically viable outcomes (Pereira et al. 2020). To facilitate such plurality, valuation processes need to be sufficiently inclusive of marginalized stakeholders (for example, by integrating participatory planning and mapping methods that recognize indigenous valuations of nature). This should entail actively challenging wider power asymmetries that erode and undermine place-based values of nature held by indigenous and local communities (Grenni et al. 2020).

Governance systems always occupy political spaces. Human constructions of value demarcate and delimit governance spaces for environmental actions, which are sites of continual negotiation, contest and compromise (Miller 2020). As boundary objects (Leventon et al. 2021b; Riechers et al. 2021), leverage points are useful for understanding

how these shifting hierarchies of sector-level valuations might be integrated into more inclusive and effective policy regimes (Fischer and Riechers 2019). Here, we emphasize the potential of plural valuations to leverage connections between *relational values*, the “manifold relationships between humans and nature” (Mattijssen et al. 2020, p. 402) that inform how different groups of people perceive and interact with particular land/waterscapes. Relational values shape sector-level priorities that tend to be underpinned by either *instrumental values* (of nature for people) or *intrinsic values* (of nature independently of people) (Chan et al. 2016). For example, biodiversity-based mangrove policies in the conservation sector are typically informed by intrinsic values (around designated protected or conservation areas) and/or instrumental values (such as payment for ecosystem services). We argue that greater recognition of plural value perspectives could protect biodiversity and reduce unsustainable practices (such as illegal logging) by creating space to

support activities that recognize other mangrove resource dependencies.

This study addresses two spheres of leverage (rethinking and restructuring) through which formal recognition of plural valuations could reorient the intent and design of Indonesia's mangrove governance system (Abson et al. 2017; Mattijssen et al. 2020). Specifically, we propose: (a) rethinking whose value perspectives become integrated into mangrove policy choices; and (b) restructuring the institutional relations of mangrove governance through cross-sector partnerships. Rethinking how values become acted upon for knowledge co-production is key to co-designing a broadly inclusive system. Here, co-production refers to participatory planning and inputs of knowledge and expertise into a system's design, especially by actively including indigenous stakeholders and local community voices and viewpoints (Latulippe and Klenk 2020). At the global level, recognition of the importance of plural valuations is evidenced in multi-sector initiatives such as the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (Zafra-Calvo et al. 2020). At the (sub)national level in Indonesia and other Southeast Asian countries, however, knowledge co-production has been stymied by the devaluation of intergenerational worldviews in environmental agendas as under-funded state agencies restructure along market lines. Scientific knowledge gaps in mapping and monitoring mangrove forests have further impeded policy development (Giri et al. 2011; Bunting et al. 2018), as have ongoing ambiguities in ownership, regulatory authority and policy coordination in dynamic coastal environments (Alongi 2011).

Overcoming these barriers to knowledge co-production is vital for restructuring the social and institutional relations of mangrove governance. Restructuring the system design should leverage the inputs of both formal institutions and informal social arrangements that shape environmental actions (Mattijssen et al. 2020). Integrating informal inputs (intergenerational knowledge and traditional value perspectives) into formal governing institutions is especially important to deliver societal and ecosystem co-benefits that are difficult to monetize. As traditional communities face accumulating climate and development uncertainties, scientific knowledge and private sector expertise and funding are also needed to support these place-based valuations of mangroves for adaptive livelihood transformations. In Indonesia, knowledge co-production is urgently needed to develop legislation to protect investments into mangrove ecosystem services (Vanderklift et al. 2019) that produce indirect and intangible benefits not valued by markets (for example, storm surge protection and water pollution filtration) (Thomas 2014). Leveraging plural valuations could bridge these knowledge gaps and redesign cross-sector partnerships

that better account for hidden, but vitally important mangrove ecosystem services and functions.

Methods

This study combines structured interviews with qualitative documentary analysis. Structured interviews have proven useful in earlier studies to understand how mangrove resources are used, and hence valued, by local communities (Kovacs 1999; Kaplowitz 2001). Between October and November 2021, 16 respondents were selected using a combination of purposive (selective) and snowball sampling (recruiting people recommended by interviewees). The selection process aimed to capture sectoral diversity in mangrove valuations by interviewing public (six government officials), private (one global agribusiness in Singapore and one Riau-based business) and societal (six NGOs and two community group representatives) stakeholders invested in mangrove governance in Riau (Appendix 1). Although the majority of interviews were conducted online, some in-person interviews were possible, despite the progression of the COVID-19 pandemic, as our second author's work in Riau necessitated ongoing travel between mangrove communities.

Questions that guided our interviews were grounded in two unifying themes: (1) identifying sector-level valuations of mangrove functions and services; and (2) gauging perceptions of the types of interventions needed to restore or sustain these values. Our questions to Riau government officials focused on decisions and programs aimed at developing mangrove forests as blue carbon sinks in the context of expanding aquaculture and wet agriculture. Questions to NGO and community representatives concentrated on institutional arrangements and funding to support continuity in human-mangrove relations. We were only able to interview two private business representatives, reflecting the nascent stage of blue carbon partnerships in Riau.

Our use of qualitative document analysis is suited to triangulating and contextualizing interviews. Qualitative document analysis—an umbrella descriptor of thematic analysis, content analysis and discourse analysis—is conducive to comparing subjective valuations of nature that do not lend toward statistical analysis (Wood et al. 2020). It is also useful for organizing interview data that cannot be easily codified. The mutually transformative nature of plural valuations resists categorical certainty and stasis. Value perspectives also require an “openness of interpretation” on account of their multiple or conflictual meanings (Lee and Martin 2015, p. 3). For instance, keywords like “charcoal” defy equal numerical weighting because they signify different meanings at various points in time (such as traditional livelihood destruction and employment creation in charcoal mills) and where patronage relations may lead the same individual to

represent competing sectoral interests (such as local state officials with investments in charcoal mills, Antara 2010).

We selected secondary documents (journal articles, government legislation, NGO and agribusiness reports and media articles) that focused on: (1) recent policy debates about mangrove governance, especially in Indonesia; (2) value to action pathways in cross-sector partnerships, and (3) interventions to conserve or sustainably commodify mangroves, including as blue carbon. These documents were supplemented with unpublished materials (base maps, reports and PowerPoint presentations) provided by the Riau headquarters of Indonesia's Peatland and Mangrove Restoration Agency (*Badan Restorasi Gambut dan Mangrove*, BRGM). From a leverage point perspective, qualitative document analysis is additionally useful for bridging boundaries in interdisciplinary knowledge to identify where targeted actions might be taken to initiate sustainability transformations (Fischer and Riechers 2019). This study, as one such interdisciplinary collaboration, required active work in applying content analysis to interpreting and reframing the study design according to the social science and hydrological backgrounds of our authors.

Competing mangrove valuations in Indonesia

The world's largest mangrove replanting program, launched by the Indonesian government in 2021 in partial fulfillment of its contributions to the Paris Agreement (Law No.16/2016), is set against a backdrop of growth-based valuations and related exploitation activities dating back to the early 1800s (Ilman et al. 2016). Indonesia contains the most extensive and biodiverse mangrove forests globally, representing 22% (Sidik et al. 2018) of the world's mangrove carbon stocks, or 3.14 billion metric tons of carbon (Murdiyarso et al. 2015; Fig. 2). However, decades of policies prioritizing economic valuations of shrimp aquaculture, timber harvesting, wet rice agriculture and palm oil production (World Bank 2021a) have left only 31% of Indonesia's 3.2 million hectares (mha) of mangroves intact, while 27% are moderately degraded and 42% are severely damaged (Alongi et al. 2016). In the past three decades alone, Indonesia has lost 40% of its mangroves, or nearly 800,000 ha (Ilman et al. 2016), generating between 0.07 and 0.21 petagrams of carbon emissions annually (Murdiyarso et al. 2015).

Ongoing confusion about mangrove boundaries has primarily benefited neoliberal valuations of mangroves while impeding cooperation among the key institutions responsible for their governance. Mangroves are defined in Indonesian legislation as transition areas in between land and coastal ecosystems (Lukman et al. 2019; Laws No.26 and 27/2007;



Fig. 2 Map showing extent and density of mangrove forests in Indonesia (adapted from PDASRH 2021)

Law No.1/2014). Reflecting this legal ambiguity, Indonesia's mangroves have historically been co-governed by the Ministry for Maritime Affairs and Fisheries (*Kementerian Kelautan dan Perikanan*, KKP), which deals with marine and coastal ecosystems, and the Ministry for the Environment and Forestry (*Kementerian Lingkungan Hidup dan Kehutanan*, KLHK), responsible for land-based ecosystems. Inter- and intra-departmental differences in mangrove valuations, however, manifest as competition over funding and business opportunities and in the lack of political will to legislatively resolve overlapping areas of authority (Sunyowati et al. 2016; Lukman et al. 2019).

Even within the same department, biodiversity value perspectives jostle against growth-based valuations of aquaculture and timber within the KKP and KLHK, respectively. For example, the KKP has overseen Indonesia's transition into Southeast Asia's biggest aquaculture producer that generates total revenues of US\$13 billion annually (MarketLine 2020) and is responsible for around half of the country's mangrove loss in the past three decades (Ilman et al. 2016; Oudenhoven et al. 2015). Alongside its development priorities, the ministry has sought to maintain mangrove conservation areas established by a 1975 Fisheries Directorate General ban on aquaculture activities within protected 400 m-wide mangrove green belts (Kusmana 2011). The KKP has also tried to protect existing mangroves using blue carbon aquasilviculture, the farming of fish and shrimp in enclosed nets without felling mangroves (Suriyani and Ambari 2022).

The KLHK has similarly sought to enhance the profitability of timber production while concurrently limiting mangrove deforestation. Yet, timber over-harvesting has persisted since the introduction in 1978 of a Forestry Directorate General ban on mangrove logging in protected green belts and the subsequent revocation of new mangrove timber permits (Ilman et al. 2016). Illegal logging and weak law enforcement in loosely surveilled and unclear mangrove boundaries have undermined silviculture initiatives that restrict mangrove harvesting through selective logging and replanting in felled areas (Kusmana 2014).

In Riau, these institutional barriers to co-governance jeopardize place-based knowledge and mangrove-dependent livelihoods. Riau's indigenous Sea Tribes (*Suku Laut*) have traditionally relied on mangroves to make eco-friendly fishing equipment (rods, cages and traps), boats, mooring poles, bridges, medicine (for abortions, menstruation, vaginal discharge and male virility) and seafood (starfish, crabs, shellfish, tilapia fish, eels, pufferfish and stingrays), as well as to protect their villages against storm surges, landslides and coastal abrasion (Swistantoro and Syamsulbahri 2020). However, accumulating mangrove damage linked to the area expansion of peatland plantations and brackish-water shrimp farming has compelled indigenous fishers to take up day-wage labor in mangrove charcoal mills, reinforcing

their already socioeconomically marginal positions (*Ibid*; Soerianto 2016). Mangrove over-harvesting for charcoal and timber production in Riau has been shown to destroy marine life habitats that provide food security for indigenous coastal communities, while adding to coastal land loss through saltwater intrusion and peat subsidence (Rosmasita et al. 2020; Thorburn 2013). This unsustainable conversion of mangroves in turn threatens coastal eco-tourism and community-based (aqua)silviculture activities supported by the KLHK and KKP (Effendi et al. 2018).

Leverage points, as places where opportunities exist to change the design of a system, often manifest when the pace of ecological change exceeds the ability of key stakeholders to adapt (Birney 2021). Such "critical junctures" (Linner and Wibeck 2021, p. 897) allow stakeholders to reassess the terms of their engagements in a system, including by rethinking the value of particular resources, to adjust their institutional priorities and capacities in pursuit of new goals (Grenni et al. 2020). The expansion of Indonesia's auxiliary Peatland Restoration Agency (*Badan Restorasi Gambut*, BRG) in December 2021 to encompass mangrove governance under the renamed BRGM reflected a national priority to address climate mitigation challenges by revaluing mangroves in both non-monetary terms (as public environmental goods) and using monetary valuations (within the blue economy) (Murdiyarso et al. 2015). Under this reconfigured system, the mangrove programs of the BRGM, KKP and KLHK fell under the Strategic Coordination Team for Wetlands Management, created by Indonesia's Ministry of National Development Planning (Bappenas) (Ministerial Decree No. 89/M.PPN/HK/10/2020). Formed as part of Indonesia's efforts to meet its NDCs, the strategic coordination team sought to leverage donor funding for blue carbon development in line with Indonesia's National Medium Term Development Plan 2020–2024. Private sector value perspectives were thus actively integrated into the design of Indonesia's mangrove replanting program, which was estimated to cost US\$2.7 trillion by its third year alone (Reuters 2021). In these ways, mangrove rehabilitation became tied to the perceived profitability of blue carbon credits. One 2021 study estimated that protecting 0.33 mha of imminently threatened mangrove forests could generate US\$513 million in annual investment returns and achieve 1.8% of Indonesia's NDCs (Zeng et al. 2021).

For mangrove-rich provinces like Riau, these realigned valuations at the national level incentivized private and societal partners to engage in blue carbon stewardship. They also opened a window of opportunity to address jurisdictional confusion about contested land–water mangrove boundaries and competing commercial–conservation priorities within and between the KKP and KLHK. That these two more powerful line ministries were prepared to cede responsibility and funding for mangrove replanting to the BRGM could

either be interpreted as an admission that leaders within each department functioned on an assumption of limited capacity to work cooperatively, or, that the problem of mangrove degradation was ultimately too hard for any individual department to deal with. At the very least, the creation of the Strategic Coordination Team for Wetlands Management signaled a collective interest in sustaining mangroves, including by enhancing their monetary value as blue carbon.

Results and discussion

The tremendous challenges facing the BRGM in implementing its mangrove mandate have begun to manifest in its Riau operations. The results of our interviews show a lack of cross-sector cooperation, contrasting valuations of mangrove ecosystem functions and services, inadequate knowledge about how to monetize their blue carbon potential, and confusion about mangrove boundaries that hampers law enforcement. These vexing issues contain important lessons about key areas of mangrove governance that might be leveraged to: (a) rethink whose ecological knowledge becomes embedded into policy choices; and (b) restructure

cross-sector partnerships to integrate plural value perspectives (Table 1).

Rethinking knowledge co-production

Indonesia's ambitious mangrove replanting program has revealed conflicting sectoral knowledge about *when* to plant, *where* to plant and *why*, or for what purpose, mangroves should be replanted. In Riau, government responses to the first two of these questions have excluded traditional community knowledge from official planning and policy programs. Ongoing uncertainty regarding the third question points to a lack of consensus about mangrove values among public, private and societal sector stakeholders.

Knowledge about *when* to (re)plant mangrove seedlings and saplings fundamentally shapes ecological outcomes. In Indonesia, transplanting cycles are not aligned with budgetary cycles, dramatically reducing survival rates. Although climate change has introduced temporal uncertainties and new forms of risk into human-mangrove relations, the inter-generational knowledge of Riau's Sea Tribes about optimal mangrove planting conditions remains unsurpassed at the provincial level (Swistantoro and Syamsulbahri 2020).

Table 1 Leverage points for rethinking and restructuring mangrove governance in Riau

Realm of leverage	Existing barrier	Plural value opportunity
Rethinking knowledge production	<ul style="list-style-type: none"> Indigenous knowledge excluded from formal policy choices Spatial data inconsistencies in thematic maps reflect diverging values of mangrove ecosystem services and functions Technocratic and financialized valuations of blue carbon inaccessible to mangrove communities Uncertainty about how to measure different valuations of sustainability interventions 	<ul style="list-style-type: none"> Integrate indigenous knowledge about suitable planting sites and conditions and place-based values of mangrove resources into formal policy choices Mobilize citizen science to bridge knowledge gaps about mangrove boundaries and biophysical properties Link technocratic knowledge about blue carbon with community-based sustainability stewards Encourage donors to fund community-based mapping to value mangrove carbon credits Knowledge of measurements of plural mangrove valuations can maximize future value of specific ecological and social co-benefits
Restructuring governance system design	<ul style="list-style-type: none"> Growth-driven agendas take precedence over carbon-based conservation and sustainable commodification Hegemonic monetarized valuations of charcoal and timber products compromise ecosystem sustainability Unclear boundaries perpetuate tenurial disputes in mixed land-use regimes 	<ul style="list-style-type: none"> Combine conservation activities with sustainable commodification in low-carbon partnerships Introduce regulatory mechanisms to link sustainably grown mangrove products with eco-concerned markets Institutionalize strategies for addressing tenurial disputes about mangrove land-use boundaries Cross-sectoral partnerships underpinned by plural valuations of biodiversity needed to coordinate sustainable stewardship of overlapping mangrove resources Incentivize follow-up monitoring and care of transplanted seedlings

Integrating their place-based knowledge and cultural values into formal policy choices could thus spearhead sustainability transformations that immediately improve ecological outcomes by aligning with changing seasonal, wind, weather and tidal conditions. By contrast, the BRGM lacks strong institutional knowledge of mangroves, having only been responsible for their rehabilitation since December 2021. Consequently, BRGM offices in Riau outsource replanting activities to decentralized Watershed Management Agencies (*Balai Pengelolaan Daerah Aliran Sungai*, BPDAS), the body responsible for this task before the formation of the BRGM. BPDAS in turn pays local community groups to replant mangroves before reporting back to the BRGM (interview 6). To pay BPDAS for its services, the BRGM, which only functions at the sub-provincial level, must first return its annual mangrove budget to the KLHK in Jakarta for reallocation to provincial-level BPDAS headquarters, which distributes these funds downward to sub-provincial BPDAS offices and community groups (*ibid*).

The exclusion of local knowledge about seasonal temporalities from existing legislation undermines the overall design of Indonesia's mangrove governance system. We see this in a KHLK decree that stipulates mangrove seedlings must be transplanted during the monsoon season months of November and December (No.353/1/8/2020). Strong winds and high waves during this period, however, uproot the great majority of newly planted trees. The planned construction of wave-breaking concrete pillars along the coastline to provide a buffer against these harsh weather conditions has thus far proven too costly to complete (Wiradji 2021). By February, when the onset of the dry season creates calmer weather conducive to transplanting seedlings, the BRGM lacks sufficient funds to pay the salaries of around 400,000 mostly women workers employed in mangrove nurseries nationwide (interview 12; Subagyo 2021). Compounding these challenges, in 2021, the KLHK released its reduced mangrove budget of 1.5 trillion rupiah (US\$105 million) several months late amidst COVID-19 pandemic disruptions, compelling the BRGM to scale down its annual replanting targets from 150,000 to 34,500 ha, of which, 6,345 ha were replanted in Riau (Reuters 2021; BPDAS 2021). As one Riau government official explained:

Sea waves are strong when the budget drops at the end of the year. In January to June there is no budget; the budget is only released after July, sometimes as late as October, so expenditure in government departments is highest in the final quarter of each year. When you spend money in December, the seas are high and the wind is strong, making it difficult to plant mangroves in the ocean. This is why the survival rate is so low. Even if there are seedlings prepared in advance, nobody will plant them because

they will not be paid in February or March (interview 11).

Co-producing knowledge about *where* to plant mangrove seedlings is equally important to ensure their viability, as different types of mangroves are suited to varying coastal or riverine conditions. The introduction in 2021 of Indonesia's National Mangrove Map provided the spatial blueprint for consolidating multi-sectoral knowledge into a single, publicly accessible platform (PDASRH 2021). Nascent KLHK efforts to compile and integrate thematic mangrove maps into Indonesia's One Map Policy (OMP), however, have encountered similar problems to earlier OMP initiatives for peatlands and terrestrial forests. Developed by different government departments for specific land-use purposes, thematic landscape maps are known to be inaccurate, incomplete and contested (Astuti et al. 2022). Unresolved land–sea boundaries in mangrove forests add another layer to this complexity. In Riau, like elsewhere in Indonesia, further cartographical challenges arise from overlapping public, private and customary law ownership structures and patron–client relationships. The different value perspectives associated with these tenurial arrangements need to be reconciled to ensure that replanting sites are not captured by competing entitlement claims (Sahputra 2021a).

Questions about *why* mangroves should be planted stem from a lack of consensus regarding their value. Our interviews highlight linkages between low levels of spatial knowledge about suitable planting sites, limited public awareness of their contribution to climate mitigation, and skepticism regarding their sustainable commodification potential. We see this in reports of community groups misusing government funds for haphazard transplanting activities (Sahputra 2021b), without follow-up care to improve seedling survival rates (interviews 4, 6, 10, 11). Land scarcity and the imperative to maximize productivity in existing spaces often compels community groups to plant seedlings in places where mangroves have not previously grown, including in “wasted lands” deemed unsuitable for wet rice cultivation (interview 4). In September 2021, when Indonesia's President, Joko Widodo, visited Riau to promote his government's climate mitigation strategy (*Siaran Pers* 2021), he, too, planted mangroves on a beach in Bengkalis Island where a KLHK replanting program had failed the previous year owing to strong waves and high winds (Kumparan 2021). That this inappropriate site was chosen for the presidential visit highlights both the shortage of alternative lands (interview 4) and the ceremonial aspects of Indonesia's mangrove replanting program that often supersede attention to its substance (Iswara 2020).

This conflicting knowledge about when, where and why to plant mangroves fuels distrust among government agencies and community groups (interview 10). Government officials have complained of non-indigenous community groups not keeping accurate records of planting sites because they value the funding associated with participation in replanting programs (interview 6) rather than the technical support they receive from state agencies and environmental NGOs (interviews 10, 11). One KLHK official lamented that a community group paid to replant ten hectares of mangrove seedlings had “cheated the government” by only planting the three most visible hectares along a road embankment (interview 6). Other community groups have reportedly used poor quality seeds and/ or prematurely transplanted mangrove seedlings that lack the requisite four leaves and minimum height of 35 cm, further decreasing their survival rate (*Ibid*). Somewhat differently, NGO representatives have accused district-level brokers of capturing mangrove programs by withholding 20% of replanting budgets (interview 6). As one NGO leader explained:

Indonesia now has lots of funding available for mangrove planting, so there are brokers at the district level who call the village head to make mangrove planting proposal. The broker is from [name of party anonymised] and deals with politicians [from that party] at the village level, who get money for planting. But there is no follow up monitoring, [the brokers] take photos and then don't care about mangroves (interview 4).

The political opportunism associated with perpetuating inefficiencies in Indonesia's mangrove replanting program impedes knowledge co-production that is necessary for sustainable environmental stewardship. This situation in turn erodes societal trust in time-consuming and often experimental carbon partnerships. In the next section, we identify where flaws exist in the design of Riau's mangrove governance system and how rethinking the structure of low-carbon partnerships might help to overcome some of these barriers.

Restructuring mangrove governance

Unlike peatland governance, which, in Riau, has generated a wide variety of carbon partnerships (Miller et al. 2022), Indonesia's mangrove replanting program has yielded remarkably little cross-sector cooperation. None of our Riau-based interviewees claimed to be formally involved in blue carbon partnerships, reflecting the general deficit in knowledge about how to operationalize the blue economy in Indonesia more generally. Several interviewees, however, identified areas where plural valuations of mangroves have been, or could be, leveraged to facilitate sector-level sustainability transformations through private–societal and

hybrid (public–private–societal) co-governance partnerships, including through community-based forest management partnerships.

Nationalist narratives in Indonesia that articulate monetized understandings of nature and value environmental entrepreneurship have contributed to a surge in private–societal environmental partnerships in recent years (Miller 2022). The mandatory status of Corporate Social Responsibility (CSR) in Indonesia (Law No.40/2007) has provided a spur for agribusinesses in particular to spend their required 2.5% of net profits as CSR funds on carbon projects as a vehicle through which to explore opportunities linked to the blue economy (interview 10). In Riau, where the majority of private–societal partnerships have focused on peatlands, these have often been critiqued for imposing economic rationalist worldviews onto peatland communities, eroding place-based values and undermining intergenerational knowledge. Peatland communities in Riau have equally exploited carbon partnerships to pursue funding and advance political agendas unrelated to the environment (Miller et al. 2022).

Like peatland partnerships, the dominant actors in mangrove partnerships sometimes manipulate sustainability narratives to reinforce existing power asymmetries or introduce new socially structured vulnerabilities and inequities. Several privately owned timber and charcoal companies in Riau have only discursively embraced values of biodiversity and inclusivity with mangrove community partners. For instance, one interviewee representing a mangrove charcoal mill that has operated in Meranti Islands District since 1941 described his company's silviculture “partnership” with local mangrove communities that combines “pure conservation” in protected areas with selective felling techniques (interview 3). This particular charcoal mill, however, like around 50 others in Meranti Islands District that collectively contain over 180 furnaces, operates illegally and without the full set of requisite permits (Zainuddin 2020). The KLHK refuses to issue licenses to charcoal mills, which it claims pay illegal loggers to over-harvest mangroves in areas outside their concessions as demand outstrips sustainable supply (interview 5). Although charcoal mill owners contend that they create local employment and provide various forms of community assistance, including education scholarships (interviews 3, 13), they have been accused of perpetuating rural poverty in Riau by entrapping indigenous minorities in casual low-wage conditions (Soerianto 2016; Swistantoro and Syamsulbahri 2020). State authorities find it difficult to shut down illegal charcoal mills, many of which have operated “since Dutch colonial times” and “control the surrounding area using money lending to pay for mangrove wood” (interview 5). Moreover, sections of Riau's police force have long accrued financial benefits from illegal logging activities

connected to mill-based patronage networks (interview 12; Antara 2010).

More positively, some (inter)national businesses operating in Riau have initiated mangrove partnerships that seek to pluralize value by integrating carbon-based conservation with sustainable livelihoods. These sustainability interventions have been facilitated by the Mangrove Ecosystem Restoration Alliance (MERA), a multi-stakeholder platform initiated in 2018 by the non-profit organization Nusantara Nature Conservation Foundation (YKAN). Since 2019, two of Indonesia's largest oil and gas companies, Pertamina and PT. Chevron Pacific Indonesia, which both have operations in Riau, have channelled their CSR funds through MERA to sponsor local NGOs in transplanting mangrove seedlings and preparing mangrove restoration planning documents with coastal communities (interviews 10, 11; YKAN 2022). Asia Pulp and Paper (APP), a global timber company with acacia plantations in Riau, has similarly used its YKAN partnership within the MERA network to launch a 500 ha mangrove restoration program inside its concession areas in South Sumatra and Java, although it has yet to expand this initiative to include its Riau concessions (interview 16). Notwithstanding the leading role played by mining companies and large agribusinesses in driving Indonesia's carbon emissions, regulating their CSR activities through partnerships with MERA could help to expand carbon-based mangrove conservation into privately owned properties while providing a foundation for cooperation with adjacent communities who rely on mangrove resources.

Hybrid partnerships that involve state agencies in addition to private companies and local communities have been used with growing frequency in Indonesia to govern overlapping resources that are differentially valued by varying stakeholders. In Riau, the most high-profile hybrid partnership to date around mangrove governance was initiated by the state-owned oil and gas company, Pertamina (Elvira 2022). Launched in 2019, the private–state–societal partnership used Pertamina CSR funds to establish an integrated mangrove management model in Bengkalis District, co-led by government officials and coastal communities (Pertamina 2019). Although this mangrove partnership was registered as a carbon offset project, local state and societal partners received inadequate training to use the carbon credit system and lacked autonomy over Pertamina CSR funds to effectively plan, manage and implement their budgets (Nawari et al. 2021). Another study, however, found that 3 years after its inception, the partnership had succeeded in integrating mangrove biodiversity with community-based livelihoods, eco-tourism and inland aquaculture (Christian et al. 2021).

In Indonesia and elsewhere in Southeast Asia, community-based forest management (CBFM) has been promoted as the most inclusive type of hybrid partnership through which to turn plural valuations of mangroves into

place-based sustainability transformations (Sidik et al. 2018; Mollick et al. 2021; Nesperos et al. 2021). However, the insinuation of growth agendas into CBFM partnerships has frequently seen the model fail to meet its core objectives of environmental sustainability, poverty reduction and community empowerment (Tole 2010). In Riau, CBFM partnerships between mangrove communities, KLHK and the World Bank (2021b) have similarly begun to yield mixed results in realigning place-based valuations of mangrove resources away from unsustainably sourced charcoal and timber products and toward livelihoods centered on community plantation forests and mangrove ecotourism.

To date, only a handful of CBFM partnerships in Riau have succeeded in combining mangrove conservation with selective intercropping using commercially viable crops such as sago (*Metroxylon sago*) and rubber (*Hevea brasiliensis*) (Zainuddin 2020). These community plantation forests are noteworthy for their promise to deliver livelihood and ecosystem co-benefits to Riau's coastal communities. As one mangrove ecotourism manager explained:

...sago is compatible with mangroves. If mangroves are destroyed then sago won't be protected. Mangroves have a protective barrier function for existing livelihoods [including] sago, rubber, coconuts and paddy fields (interview 7).

At the same time, some respondents cited difficulties in linking their more-than-monetary valuations of sustainably grown mangrove commodities with green supply chain partners. Apart from lacking contacts with wider markets, subsistence community farmers typically lack access to processing machines for mangrove products (interview 9) and can only afford simple, "unattractive packaging" (interview 8). Sweets and syrup made from the fruits of nipah palms (*Nyipah fruticans*), perepat mangroves (*Sonneratia alba*) and berembang mangroves (*Sonneratia caseolaris*) are also virtually unknown outside Indonesia's coastal communities (interviews 7, 10). Unlike mangrove charcoal and timber products, which are readily exportable from Riau to neighboring Malaysia (interview 2), these food commodities, that are made without artificial preservatives, additionally have a short shelf life and do not travel well (interview 8).

Little wonder, then, that CBFM partnerships remain vulnerable to encroachment by utilitarian value regimes that prioritize profitability over sustainability. Coastal residents can earn three to five times more income from logging than they do from selling products obtained from healthy mangrove habitats (interview 4). Although mangrove timber harvesting is prohibited within community plantation forests, illegal logging remains a serious problem that is financially supported by charcoal mill owners and sections of the police force (interviews 1, 3, 4). According to one NGO representative:

In privately owned lands, many people replenish [mangrove] stocks, but in public areas, they log without planting and cut down mangroves without licenses but don't replant afterwards to replenish stocks. They don't care what happens in areas that don't belong to them (interview 4).

This, combined with the illegal conversion of community plantation forests into private shrimp farms and palm oil plantations (Kasim 2021), reduces the available space for operationalizing CBFM initiatives. It also prevents successful trial plots, which are usually tied to fixed-term project budgets, from being scaled up and extended.

To become more sustainable, regulatory frameworks needed to be integrated into partnership arrangements to foster longer lasting relationships with sustainably sourced mangrove products. Legal safeguards are urgently needed to ensure that biodiversity value perspectives are not subordinated to solely economic valuations that add to transboundary problems of impermanence (future carbon loss) and leakage (displaced emissions to other areas) (Sidik et al. 2018). Without such regulations, state, private and societal stakeholders alike will continue to only weakly integrate plural valuations of nature into governance systems, diluting environmental benefits in the longer term.

Blue carbon: an opportunity or obstacle to rethinking knowledge and structure?

Blue carbon value perspectives have created new forms of meaning for mangrove governance that could assist sustainability transformations at the sector level. To date, however, widespread confusion about how to operationalize the blue carbon concept has resulted in its frequent misappropriation for the exploitation of water resources (Bennett et al. 2019). In a similar vein, Indonesia's largest environmental organization, WALHI (*Wahana Lingkungan Hidup Indonesia*; Indonesian Forum for the Environment), has criticized the national government for placing the blue economy at the center of its mangrove replanting program. According to WALHI, such monetized valuations risk increasing personal enrichment opportunities for state officials and private businesses alike at the expense of meaningful advancements in integrating conservation values with sustainable livelihoods (CNN Indonesia 2020).

In Riau and globally, there is a pronounced gap in translating valuations of mangroves as blue carbon into climate programs that can deliver societal and ecological co-benefits. This value to action gap characterizes the great majority of REDD+ and payment for ecosystem services (PES) mangrove projects (Ahmed and Glaser 2016; Alongi et al. 2016) that are small scale and fixed term with outcomes

that remain largely unknown and undocumented (Locatelli et al. 2014; Miteva et al. 2015; Thompson et al. 2017). In Riau, too, the application of REDD+ to mangroves has been limited to experimental initiatives such as avoiding deforestation in fishponds (Hilmi et al. 2017) and monitoring carbon sequestration in primary mangrove forests (Romijn et al. 2013).

In this uncertain policy context, Riau authorities have struggled to value and certify mangrove carbon stocks using international verification standards such as the Voluntary Carbon Standard (VCS) or the Gold Carbon Standard. A local KKP official explained that although his ministry is responsible for managing Indonesia's blue economy under Article 8 of Presidential Regulation No.98/2021, there has been "no socialization yet because the blue carbon rules are not clear" (interview 10). Only three interviewees, all Riau-based NGO representatives, demonstrated any knowledge of how to value mangroves using carbon accreditation (interviews 12, 13, 15). Two had received funding, training and/or technical support from Blue Forests (interviews 12, 13), a non-profit organization that aims to empower rural coastal communities to conserve and sustainably commodify mangrove and coastal resources, including through community-based voluntary blue carbon markets (blue-forests.org, n.d.). Despite this support, Riau-based NGO respondents cited bureaucratic obstacles in applying national-level documentation about carbon markets to local realities (interview 12) and gaining access to blue finance streams (interviews 13, 15). As one NGO representative explained:

Until now, the carbon market is managed by Jakarta, but money is needed by local villages to protect mangroves. Therefore, it is better to focus on the village level. The carbon market fund from Korea and Norway projects goes to Jakarta, but only 10% goes to the province level. But in Jakarta they only talk and do nothing, just make documents that can't be used in Riau. In the case of Norway, Riau didn't even receive the documents that were made in Jakarta, which stayed on a laptop in the BRG headquarters in Jakarta (interview 12).

In addition to these challenges, Riau-based environmental NGOs recounted difficulties in applying their acquired knowledge of carbon trading to field sites, where it was "difficult to convince residents to conserve mangroves" (interview 13) because of the low material value associated with carbon-based conservation (interview 12).

Rethinking the institutional relations of mangrove partnerships should therefore involve strengthening collaborations between local users of mangrove resources and eco-concerned markets. As a starting point in this pursuit, knowledge about mangrove boundaries needs to be improved. Many CBFM initiatives are unable to register for

carbon-based conservation schemes like REDD+ because they cannot verify mangrove boundaries to determine the extent and volume of carbon stocks within their project areas (Sidik et al. 2018). To provide redress for this problem, some development organizations and NGOs have begun to leverage citizen science to collect critically needed national data about the boundaries and biophysical properties of mangroves in coastal communities (World Bank 2021b). Since 2020, Indonesia's Institute of Sciences (LIPI) has also partnered with CBFM groups to roll out MONMANG, a mobile app that enables citizens to monitor and process data about the health of mangrove ecosystems in their areas (Indonesia Window 2020). Such applications of citizen science to reconnect humans with nature (Ives et al. 2018) could be leveraged to bridge gaps between intergenerational and scientific knowledge. Improving key information about mangrove carbon stocks, boundaries and properties would thus provide a basis for establishing plural values in specific places. This co-produced knowledge in turn could strengthen community-based proposals to attract blue carbon funding and support cross-sector partnerships that work to scale.

Conclusions

As a contribution to the solution-oriented field of sustainability science (Abson et al. 2017), this study has identified how plural valuations of mangrove services and functions might be leveraged for sector-level transformations at the sub-national scale. Shifting the design of Indonesia's mangrove governance system to accommodate such plurality will entail tremendous challenges. At present, activities that contribute to mangrove loss (commercial aquaculture, charcoal and timber production) have a higher monetary value than activities designed to sustain them (such as ecotourism and community-based agroforestry). The rate of mangrove deforestation is likely to continue to exceed the rate of replanting following the introduction in 2020 of Indonesia's Job Creation Law, which stipulates central government discretion in authorizing "changes to the status of 'the core zone' of National Conservation Areas" (Article 51, Law No.11/2020). This suggests a pressing need to assign a higher value to carbon-based mangrove conservation and sustainable commodification initiatives than to growth-driven forms of development that displace them.

Rethinking knowledge co-production to recognize plural valuations of mangroves could provide a firm basis for adaptive and flexible cross-sectoral transformations. Mangrove carbon sinks are unlikely to be long-lasting without targeted sustainability interventions that integrate knowledge from the full range of stakeholders (Friess et al. 2022). Including intergenerational knowledge about suitable planting sites

and conditions into formal policy choices could generate immediate improvements in the survival rates of transplanted seedlings. Bringing scientific knowledge to bear on mangrove boundaries and properties would also assist local communities in adapting to climate uncertainties and environmental transformations. Private sector knowledge about voluntary carbon payment/ credit schemes is needed too, both to incentivise users of mangrove resources to keep carbon in healthy ecosystems and to empower mangrove communities to register for blue carbon funding as a strategy to sustain their place-based valuations of nature. Further research is needed to build knowledge of measurements for these different valuations of sustainability interventions in order to maximize specific ecological and societal co-benefits.

Rethinking the structure of mangrove governance systems is equally important to ensuring representation and participation from the full range of stakeholders. Although cross-sector partnerships can easily escalate resource tensions, we have focused on their productive potential to balance competing conservation and commodification agendas and activities. For mangrove partnerships to thus flourish, coordinating mechanisms are needed to build trust by encouraging buy-in and feedback loops, particularly for indigenous and local community stakeholders. Integrating plural value perspectives into such governance arrangements should be treated as co-evolutionary and continually transformative rather than fixed and immutable. Rethinking structure as flexible, dynamic and adaptive requires periodically reassessing valuations of trade-offs and adjusting knowledge of compensation and incentives to protect perceived co-benefits over time.

Indonesia's capacity to meet its NDCs and reduce net emissions through mangrove governance will ultimately require closer attention to the invisibilities behind cross-sector partnerships. Directing attention toward the intangible realm of plural value perspectives creates room to rethink how discrete sectoral interests, which cannot be attained in isolation from each other, could be mobilized to co-produce knowledge in the service of a collective environmental good. Mangrove communities depend on CSR funds and green supply chain partners to develop sustainable livelihood pathways and export sustainably produced mangrove commodities. Private companies need societal and government partners to spend their CSR funds and offset carbon. Government agencies, unable to independently finance, map, monitor or implement their mangrove replanting programs, will continue to rely on societal and business partners to meet Indonesia's climate and sustainability goals. Unless the values that underscore these sectoral priorities can be better integrated into partnerships that prioritize public environmental goods over private profits, carbon leakage will displace mangrove co-benefits on an ever-expanding scale.

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