Coastal area rehabilitation for climate change mitigation

The role of mangroves and subnational emissions reductions

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Executive summary

Mangrove blue carbon has significant climate change mitigation potential. This relates to the huge carbon stocks in mangrove ecosystems, which are 3–5 times higher than carbon stock in protected tropical forests. As the processes involved in storing such large volumes of carbon are lengthy and complex, emissions mitigation should have a greater focus on conservation of intact mangrove forests.

Indonesia has a target to rehabilitate more than 600,000 ha of degraded mangroves by 2024. Its accomplishment, however, remains open to question considering how little success Indonesia has experienced in carrying out rehabilitation/restoration over the last two national medium-term development plan (RPJMN) periods. A lack of available long-term records also makes verification difficult. Meanwhile, mangrove deforestation and conversion are still ongoing in numerous locations.

Nevertheless, the Government of Indonesia has had some successes in its efforts to improve degraded mangroves, such as those in Ngurah Rai Forest Park in Bali Province, where former aquaculture land has now become a mangrove forest following a restoration process that began in 1992.

Mangrove conservation for avoided greenhouse gas emissions should be considered bearing in mind its high benefit-cost ratio and better guarantee of achieving emissions reduction targets. Conservation of existing mangroves can also generate economic activities oriented towards utilization of the environmental services that mangroves provide so well.

Coastal area rehabilitation/restoration involving mangrove ecosystems for climate change mitigation is a long and risk-laden journey. It requires strong and comprehensive governance, and policies that involve stakeholders from the national to subnational levels. Involving regions in climate change mitigation through mangrove ecosystems is an important political step for increasing community participation, particularly for coastal communities whose livelihoods are highly dependent on the existence of these unique ecosystems.

Institutional complexities can become a bureaucratic hurdle and obstruct information and funding flows. These pose new challenges for the implementation of coastal area and mangrove rehabilitation/restoration both inside and outside the forest estate, particularly when they relate to aquaculture and accreted land. These complexities need to be simplified by advancing accountability and the credibility of those involved.

Foreword

Indonesia's large-scale mangrove rehabilitation programme has attracted the attention of many parties both inside and outside the country. This has happened in connection with the volume of work it entails and the time available for its implementation. To ascertain public aspirations in relation to the programme, a webinar was held on 31 March 2022. The webinar discussed three main topics: a long-term coastal region management strategy; coastal regions in climate change mitigation; and coastal regions in climate change adaptation.

This paper provides an overview of the opportunities and challenges surrounding the inclusion of coastal regions in the climate change mitigation agenda. It contains special notes gleaned from consultations with webinar participants summarized by the Coordinating Minister for Maritime and Investment Affairs relating to experiences and levels of success during the last two RPJMN periods, which are worthy of consideration when implementing large-scale mangrove rehabilitation in Indonesia.

It also provides notes relating to the institutional and ecological implications of rehabilitation/restoration programmes, and the importance of involving regional governments to prepare subnational policies on carbon trading. Challenges and opportunities identified during the webinar are highly general, but comprehensive enough for consideration.

We hope this paper, which can be considered a preliminary step in the evaluation of the rehabilitation/restoration programme plan, can also be developed in accordance with dynamics occurring on the ground and experiences learned by stakeholders. We realize it has some deficiencies and weaknesses, but effective cooperation between stakeholders will improve the quality of further evaluations.

Jakarta, late July 2022

The editors

1 Introduction

Greenhouse gases (GHGs), and particularly carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) trap heat in the atmosphere causing Earth's temperatures to rise. Steadily increasing GHG concentrations have exceeded tolerable levels and threaten the continuity of life systems on Earth. For this reason, through the Paris Agreement in 2015, all member states of the UN Framework Convention on Climate Change agreed that temperatures must not rise more than 1.5°C above 1850s, pre-industrial levels by 2030 (IPCC 2018). CO_2 is the most dominant GHG and can reach 65% of all GHGs (IPCC 2014).

Indonesia's growing population is having an impact in increasing emissions from sectors including industry, transportation and agriculture (Kurniawan and Managi 2018; Prastiyo et al. 2020). Boden et al. (2017) state that, globally, the economic sectors contributing the highest volumes of GHG emissions are electricity generation (25%), agriculture, forestry, and other land uses (24%), industry (21%), and transportation (14%). Put another way, the most dominant source of GHG emissions is the energy sector (60%) with its use of fossil fuels, followed by the land sector (24%) and the waste sector (16%).

With the increase in natural resources-based, and particularly land-based, economic growth, of Indonesia's total emissions of 1,334 million metric tons of CO_2 equivalent ($MtCO_2e$) in 2010, the land sector was the highest emitter at 56%, followed by the energy sector at 34% (Republic of Indonesia 2016). However, energy sector emissions are on an upward trend, and are expected to reach 58% of Indonesia's predicted total emissions of 2,869 $MtCO_2e$ by 2030, while land sector emissions are expected to fall to around 30% of this figure (Republic of Indonesia 2021).

Photo by Rifky/CIFOR-ICRAF

Low Carbon Development (LCD) is a new paradigm announced by the Government of Indonesia in 2017. The main aim of LCD is to undertake climate change mitigation to ensure the continuity of planet Earth. However, LCD still maintains economic growth and reduces poverty, while preserving natural resources (*Bappenas* 2020). Agendas proposed for LCD implementation in Indonesia include protecting blue carbon ecosystems (including mangroves and seagrass beds) and providing government support to ensure these programmes are properly implemented in all provinces in Indonesia. As the country with the world's largest blue carbon ecosystems, Indonesia has an opportunity to increase the economic value of blue carbon in global climate mitigation and national biodiversity protection (Murdiyarso et al. 2018).

Mangroves are coastal wetland ecosystems with huge potential as a nature-based climate solution (NBCS) to the problem of climate change. Mangroves have been reported to have huge capacity to absorb and store carbon in biomass and sediment (Macreadie et al. 2019). Mangrove carbon stock in Indonesia amounts to 3.14 billion metric tons (Murdiyarso et al. 2015). This enormous carbon stock is the result of high carbon density at approximately 950 metric tons per hectare and is thought to constitute 17% of the world's blue carbon stocks (Alongi et al. 2016). Mangroves' capacity to store carbon is made possible by their permanently inundated and anoxic (dense with little dissolved oxygen) sediments that prevent organic carbon that accumulates within them from being decomposed by bacteria, thereby locking carbon in for thousands of years (Alongi 2014). Mangroves are high in lignin, which means their detritus is hard to break down in dense sediments with insufficient oxygen (Cragg et al. 2020).

Yet, the global extent of mangroves has been greatly reduced by anthropogenic activities such as land conversion, deforestation, and pollution (Alongi 2002; Kelleway et al. 2020). Around 35% of the world's mangroves in four regions (Asia, Africa, Australia, and America) are thought to have been lost since the 1950s, with the highest rate of loss in America at 38%, followed by Asia at 36%, Africa at 32%, and Australia at 14%. The area of mangroves remaining in the world in 2001 was estimated at 1.7×10^5 km^2 (Valiela et al. 2001). This area of mangroves has continued to fall, where around 10,000 km^2 of mangroves was reported to have been lost in the 20 years from 1996 to 2016 (Thomas et al. 2017). Specifically, around 2.1% of the world's mangroves, or 3,363 km^2, were estimated to have been lost over the period from 2000 to 2016, at a rate of 0.13% annually. Around 62% of this loss was the result of mangrove forests being converted for aquaculture and agricultural land (Goldberg et al. 2020).

2 Mangrove management in Indonesia

2.1 Mangrove area and categories

The area of mangroves has fallen sharply in Indonesia, where mangrove cover prior to 1989 was estimated at 7,700,000 ha (Ilman et al. 2016). In 1990, Indonesia's mangroves were estimated to cover 4,250,000 ha (equivalent to 20% of the world's mangroves), with 2,940,000 ha in Papua and West Papua being relatively undisturbed. Meanwhile, 1,310,000 ha distributed throughout more densely populated regions such as Java, Sumatra, and Kalimantan were exploited on a large scale (Choong et al. 1990). Mapping of Indonesia's mangroves in 2000 using satellite data showed an area of 3,100,000 ha (Giri et al. 2011).

Meanwhile, in 2007, the Ministry of Forestry's Directorate General of Land Rehabilitation and Social Forestry reported Indonesia's mangrove area to be 7,758,411 ha, with 30.7% in good condition, 27.4% moderately degraded, and 41.9% heavily degraded. Then, in 2009, the National Surveys and Mapping Coordination Agency reported Indonesia's mangrove area to be 3,244,018 ha (Kusmana 2014). In 2012, the Geospatial Information Agency put mangrove cover at 3,200,000 ha, while the following year, Ministry of Forestry data estimated the extent to be 2,800,000 ha.

These data, obtained using various methods, show that from 1800 to 2013, approximately 1,000,000 ha of mangroves were lost (Ilman et al. 2016). Disparate data on the extent of mangroves in Indonesia needed to be aligned by applying a single, standardized method of calculation. Accordingly, it was important to designate a custodian of data on the extent of mangroves in Indonesia.

Photo by Yayan Indriatmoko/CIFOR

Custodianship of thematic geospatial information (TGI) data on mangroves was mandated to KLHK's Directorate of Soil and Water Conservation based on Head of Geospatial Information Agency (BIG) Decree No. 27/2019. As custodian of data on Indonesia's mangroves, KLHK subsequently issued the National Mangrove Map in 2019 (KLHK 2019) with various mangrove categories covering a total area of 3,311,207 ha, as detailed in Table 1.

It showed mangroves covering 637,624 ha, or 19% of Indonesia's total mangrove area being in critical condition with 'sparse' or 'very sparse' vegetation cover. Around 460,244 ha of these critical mangroves were inside the forest estate, while 177,380 ha were outside. It was this data that formed the basis for the mangrove rehabilitation programme launched by the Government of Indonesia in 2021.

Table 1. Mangrove area inside and outside the forest estate and condition according to the National Mangrove Map

	Mangroves inside the forest estate (ha)	Mangroves outside the forest estate (ha)	Total
Non-critical	2,057,295	616,287	2,673,583 (81%)
Critical	460,244	177,380	637,624 (19%)
Total	**2,533,488**	**777,719**	**3,311,207**

Source: Ministry of Environment and Forestry (KLHK 2019)

Table 2. Area of 'existing' mangroves by canopy density category

Canopy density	Area (ha)	%
Dense	3,121,240	92.8
Moderate	188,366	5.6
Sparse	54,474	1.6
Total	**3,364,080**	**100**

Source: Ministry of Environment and Forestry (KLHK 2021)

Table 3. Area of 'potential' mangrove habitat by land cover category

Land use	Area (ha)	%
Area affected by abrasion	4,129	0.6
Open land	55,889	7.4
Mangrove affected by abrasion	8,200	1.1
Aquaculture	631,802	83.5
Accreted land	56,162	7.4
Total	**756,183**	**100**

Source: Ministry of Environment and Forestry (KLHK 2021)

Table 4. 'Existing' and 'potential' mangrove habitat inside and outside the forest estate

Category	'Existing' mangroves (ha)	'Potential' mangrove habitat (ha)	Total (ha)
Protection forest	911,397	83,737	995,134
Conservation forest	748,271	48,837	797,108
Production forest	1,001,614	142,961	1,144,575
Other use areas (APL)	701,798	480,648	1,183,446
Total	**3,364,080**	**756,183**	**4,120,263**

Source: Ministry of Environment and Forestry (KLHK 2021)

However, a weakness of this 2019 map was that data on mangrove condition was not collected in one year, but blended from a long mapping process that took place from 2013 to 2019, with different implementation times in each location. Mapping in Java took place in 2013; Sumatra in 2014; Sulawesi in 2015; Bali and Nusa Tenggara in 2016; the Maluku Archipelago in 2017; Kalimantan in 2018; and Papua and West Papua in 2019. This resulted in criticism from many circles questioning the accuracy of data included in the 2019 map.

Consequently, the map and its categories were updated in the National Mangrove Map 2021 (KLHK 2021), in which mangroves are categorized as 'existing' with categories based on canopy cover density (see Table 2), and 'potential' mangrove habitats with categories based on land cover/use (see Table 3).

Then, 'existing' mangroves and 'potential' mangrove habitats were plotted into a map by forest estate category, the results of which are shown in Table 4.

Until now, there has been no clarity over whether mangrove rehabilitation/restoration uses data and mangrove classifications according to the 2019 or 2021 map. One thing that is certain is the extent of mangroves in the two maps changing from 3,311,207 ha to 4,120,263 ha. This additional mangrove extent was caused by the inclusion of mangrove conservation and rehabilitation efforts from various parties.

Despite differences in the extent of mangroves in Indonesia reported by different institutions over a short space of time with inconsistent patterns of change as listed above, it is safe to conclude that the area of mangroves in Indonesia has fallen. The loss rate for Indonesia's mangroves from 1980 to 2005 was reported to be 1.24% annually, from 4.2 million ha in 1980 to 2.9 million ha in 2005 (FAO 2007). A major cause of this loss of mangroves in Indonesia was their conversion to shrimp and fishponds, where land clearing for aquaculture involved massive deforestation through the large-scale felling and uprooting of mangrove trees (Ilman et al. 2016; Goldberg et al. 2020).

Mangrove deforestation reduces carbon stock and mangroves' capacity to absorb carbon emissions, and conversely, mangrove deforestation that has already occurred results in annual carbon emissions of 70–210 $MtCO_2e$, which is 10%–35% of all emissions caused by land conversion (Murdiyarso et al. 2015). Mangrove forest conversion for aquaculture is estimated to release carbon emissions of 120 $MtCO_2e$ $year^{-1}$ into the atmosphere (Arifanti et al. 2019).

Programmes to protect remaining mangroves and rehabilitate/restore degraded mangroves can be seen as nature-based solutions for overcoming the problem of climate change (Alongi et al. 2016). Mangrove rehabilitation is an effective measure for returning various important functions to mangrove ecosystems, including their capacity to absorb atmospheric carbon and reduce GHG emissions into the atmosphere by storing carbon in biomass and burying it in sediment as carbon stock (Cameron et al. 2019a).

As a country with a large extent of mangroves that play important roles in various aspects of community life, Indonesia requires institutionalized mangrove management from the central to regional levels to support sustainable mangrove ecosystem management.

The Government of Indonesia has taken various steps to restore and rehabilitate mangrove ecosystems, one of which was its establishment of the Peatland and Mangrove Restoration Agency (BRGM) through Presidential Regulation No. 120/2020 on the Peatland and Mangrove Restoration Agency. In addition to establishing BRGM, the government has also improved mangroves in Ngurah Rai Forest Park in Bali Province, where former aquaculture land has now become a mangrove forest following a restoration process that began in 1992.

2.2 Legal and institutional aspects

According to Kusmana (2014), prior 1990, five ministries and agencies play roles in mangrove ecosystem management in Indonesia: the Ministry of Environment and Forestry (KLHK), which is responsible for the management of mangroves inside the forest estate; the Ministry of Marine Affairs and Fisheries (KKP), which plays a role in enhancing mangrove ecosystem benefits outside the forest estate for the fields of marine affairs and fisheries; the Ministry of Home Affairs, which regulates government affairs; and the Ministry of Agrarian Affairs and Spatial Planning/ National Land Agency, which formulates and establishes spatial and land use arrangements.

Basically, legal aspects relating to mangrove management strategies and implementation cover:

1. Mangrove forest silvicultural enterprises following Forestry Department Regulation No. 13062/465/ BIR dated 1 July 1938: silviculture methods have continually been renewed with subsequent rulings such as Forest Research Institute Recommendation No. 2854/42 dated 30 June 1956 on the Standard Clear Cutting System; then in 1972, the Directorate General of Forestry recommended the Strip-wise Selective Felling System; and in 1978, the same institution issued Decree No. 60/ Kpts/DI/ 1978 on Mangrove Forest Silviculture System Guidelines, where the silviculture system changed to become the Seed Tree Method.
2. Mangrove protection according to Presidential Decree No. 32/1990.
3. Mangrove rehabilitation/restoration (reforestation and afforestation) – reforestation applies to land that was previously forested, whereas afforestation applies to land that has been without forest for 50 or more years – by following Minister of Forestry Regulation No. P.14/Menhut-II/2004 on Afforestation and Reforestation Procedures.
4. The annual updating of the National Mangrove Map provided in Presidential Regulation No. 23/2021 on Acceleration of One Map Policy Implementation at a Mapping Precision Scale of 1:50,000.
5. Mangrove rehabilitation on small islands, which are important in mangrove ecosystem management and regulated under Minister of Marine Affairs and Fisheries Regulation No. 24/2016 on Rehabilitation Procedures for Coastal Regions and Small Islands.

In 2014, the two main ministries involved with mangrove management, i.e., the Ministry of Forestry and the Ministry of Environment, were merged to become the Ministry of Environment and Forestry (KLHK). Later, the Peatland and Mangrove Restoration Agency (BRGM) was established through Presidential Regulation No. 20/2020. BRGM is a non-structural agency under and answering to the president. In regard to mangrove management, BRGM is tasked with facilitating the accelerated implementation of mangrove rehabilitation/restoration in nine target provinces: North Sumatra, Riau, Riau Archipelago, Bangka Belitung, West Kalimantan, East Kalimantan, North Kalimantan, Papua, and West Papua. The agency, in its former incarnation as the Peatland Restoration Agency, was established in 2016 to restore peatland ecosystems in seven target provinces: Riau, Jambi, South Sumatra, Central Kalimantan, South Kalimantan, West Kalimantan, and Papua. BRGM's current mandate is to restore these two ecosystem types simultaneously in mostly different target regions, with only three overlapping provinces: Riau, West Kalimantan, and Papua. This government step to make institutional improvements in mangrove ecosystem management illustrates its attention to ensuring the continuity of these important ecosystems. BRGM is already furthering communications with several non-governmental organizations (NGOs), companies, and donor institutions.

The Coordinating Ministry for Maritime and Investment Affairs (*Kemenkomarves*) plays a role in coordinating acceleration of the rehabilitation/restoration programme on 600,000 ha of mangroves (2021–2024) with non-budgetary funds, multi-donor trust funds (MDTFs), and so on. Guidance to communities on the ground on implementing mangrove rehabilitation/restoration is provided by KLHK and KKP technical implementation units (UPTs).

Then, the Ministry of National Development Planning/National Development Planning Agency (PPN/*Bappenas*) plays a role in providing strategic direction in long-term planning and management of peatland and mangrove ecosystems. Other ministries and institutions also involved in this programme are the Ministry of Finance; Ministry of Home Affairs; Ministry of Villages, Disadvantaged Regions and Transmigration; and regional governments.

3 Mangrove rehabilitation/restoration commitments

Indonesia's commitments to reducing GHG emissions are laid out in the Nationally Determined Contribution (NDC) it handed to the United Nations Framework Convention on Climate Change (UNFCCC) Secretariat in July 2021, where it committed to reducing emissions independently by 29% of a business-as-usual scenario or 834 $MtCO_2e$ by 2030, and by 41% or 1,185 $MtCO_2e$ with international support. Presidential Regulation No. 98/2021 has outlined the implementation of these commitments, where the national baseline used as the basis for GHG emissions reductions is 2,869 $MtCO_2e$ by 2030, with the involvement of all sectors at the national, subnational, and sectoral levels. The forestry and other land uses (FOLU) sector is expected to no longer be a source of GHG emissions (a carbon source) and become a carbon sink by 2030.

As blue carbon ecosystems with enormous carbon stocks and vast coverage, Indonesia's mangroves have huge climate change mitigation potential if carbon emissions into the atmosphere can be avoided by preventing deforestation and increasing conservation efforts (Murdiyarso et al. 2015; Alongi et al. 2016; Macreadie et al. 2019). BRGM has categorized 19% of the existing mangrove extent (according to the National Mangrove Map 2019), as 'potential mangroves' that will be rehabilitated/restored. Research shows that rehabilitated/restored mangroves with good growth have the same capacity as natural mangroves to absorb carbon emissions (Cameron et al. 2019a). This provides evidence to suggest that now is the time to start thinking about a mechanism for funding mangrove rehabilitation/restoration from the proceeds of carbon sales. Then, Kusumaningtyas et al. (2021) reported that despite their carbon accumulation rates being lower, rehabilitated/restored mangroves have higher carbon stocks compared to natural mangroves.

Photo by Donny Iqbal/CIFOR-ICRAF

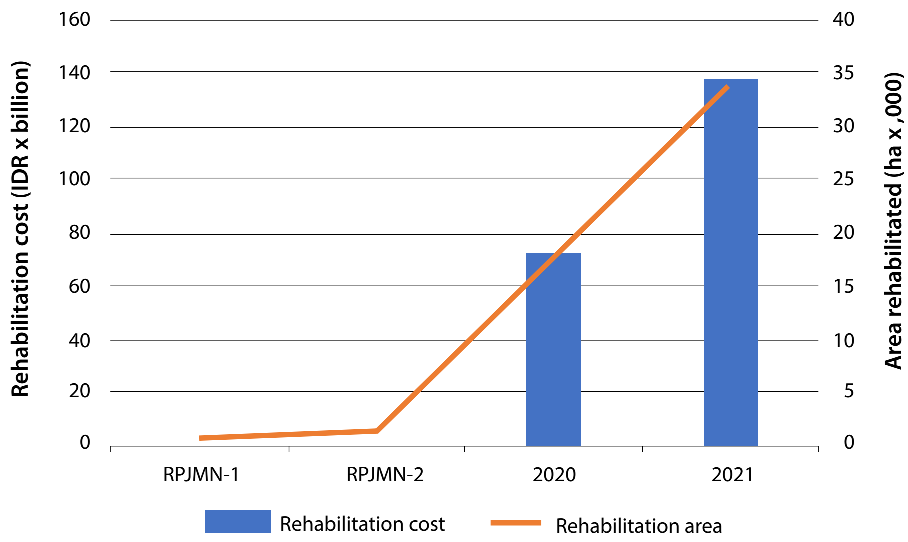

Figure 1. Realization of mangrove rehabilitation using public funds over the last seven years since the commencement of RPJMN 2015–2019

This is likely due to the role played by the environment – in this case hydrology – which is thought to play an important role in achieving such results. So hydrological modification could become an alternative mangrove rehabilitation technique for increasing carbon stocks and accumulation rates in the sediments of rehabilitated/restored mangroves.

A rehabilitation report covering the 2015–2019 national medium-term development plan (RPJMN) period showed only 3,600 ha being rehabilitated (700 ha year^{-1} of the targeted 1,000 ha year^{-1}). Meanwhile, for RPJMN 2019–2024 (which is still ongoing), achievement to date is 6,000 ha, or 1,500 ha year^{-1}.

Meanwhile, funds from state budget (APBN) used over the two periods have been around IDR 17 billion and IDR 9.5 billion (to 2021), respectively. It is interesting to note that during the Covid-19 pandemic, the government also provided funds for mangrove rehabilitation through the National Economic Recovery (PEN) scheme amounting to IDR 71.6 billion in 2020 and IDR 137.7 billion in 2021, achieving 17,600 ha and 34,000 ha, respectively.

Figure 1 illustrates rehabilitation achievement trends with increases in rehabilitation funds, where extents of areas rehabilitated using APBN funds are directly proportional to funds used, with costs of around IDR 4 million to 5 million ha^{-1}. It is important to emphasize here that the area figures above are those at the time of planting. The current condition of plants has yet to be reported, and survival rates have yet to be quantified, so the extents of rehabilitated areas cannot yet be considered successes.

A mangrove rehabilitation/restoration monitoring, reporting, and verification (MRV) system needs to be developed and implemented transparently so the public can know how effectively public funds are being used. Compared with experiences over these two RPJMN periods, the plan to accelerate the rehabilitation/restoration of more than 600,000 ha by 2024 (150,000 ha year^{-1}) is a huge target (10 times the realization for 2021). Irrespective of technologies used, the programme needs to be accompanied by an MRV system that is applied continuously, both for rehabilitation/restoration successes and costs expended. Numbers of working days and planting costs do not entirely reflect rehabilitation successes, so ecosystem functions are key for gauging the overall success of mangrove rehabilitation and restoration (Cadier et al. 2020).

4 Opportunities and challenges in mangrove rehabilitation and restoration

4.1 Blue carbon economic value

Mangrove restoration, like other forms of ecosystem restoration, aims to restore ecosystem functions and biodiversity as close as possible to their original state so ecological processes can recommence and provide direct benefits for local communities. These benefits include enhancing their food security and well-being through the creation of alternative sources of income. Accordingly, evaluating and monitoring successes covers various aspects of mangrove restoration projects: ecological aspects (vegetation structure, diversity, and abundance of associated species, and ecosystem functions); as well as social and economic aspects (community participation, alternative livelihoods, and community earnings) (Biswas et al. 2009; Wortley et al. 2013). As success indicators for mangrove rehabilitation/restoration, these social and economic aspects take more time than ecological aspects to gauge.

In 2020 and 2021, Indonesia's mangrove rehabilitation/restoration programme was aligned with the Ministry of Finance's National Economic Recovery (PEN) programme to provide employment through labour intensive projects for people who had lost jobs as a result of the Covid-19 pandemic. The number of workers involved in planting 15,200 ha of mangroves in 2020 was 17,226 people, and the 84,873 ha of mangroves planted in 2021 involved an even greater number of workers. The aims of and benefits from this labour-intensive mangrove rehabilitation/restoration programme were still dependent on the ministries/institutions implementing the programme, with: (1) KLHK and BRGM being responsible for coordinating mangrove rehabilitation/restoration in protection forest and conservation forest estates to ensure they recover, are restored to health, bring conservation and ecological benefits, become habitats for wildlife to thrive and reproduce, absorb and store carbon, and prevent coastal abrasion;

Photo by Aulia Erlangga/CIFOR-ICRAF

(2) KKP being responsible for coordinating rehabilitated mangroves in coastal areas and small islands with the expectation that they bring ecological and economic benefits, prevent coastal abrasion around fishing villages, and become fishing and crabbing grounds for fishers; and (3) the Ministry of Villages, Disadvantaged Regions and Transmigration being responsible for planting mangroves by focusing on disadvantaged villages with targets to bring economic and social benefits through the establishment of mangrove ecotourism/ educational tourism as revenue sources for village enterprises and communities (Sukmono 2022)

Rehabilitation/restoration projects in several locations have succeeded in restoring ecosystem composition, functions and formations to their original state. Debrot et al. (2022) reported the establishment of fishing grounds from 2015 near rehabilitated mangroves in a coastal area in Demak Regency of Central Java, where mangrove rehabilitation and restoration had commenced in 2005. This indicates the ecological function of providing habitat for fish returning to rehabilitated/restored mangroves in less than 10 years. Nevertheless, fishing activities need to be monitored and managed, as observations in the area indicate most fish caught being juvenile. This makes them highly vulnerable to rapid population decline through overfishing, and if this happens, communities will not enjoy the direct benefit of mangroves as sources of food and income for very long.

In regard to mangrove rehabilitation/restoration projects aiming to mitigate climate change through the reduction of GHG emissions, the mangrove restoration project in Tiwoho, Bunaken National Marine Park showed pleasing results after 10 years (Cameron et al. 2019b). The project was implemented on an abandoned aquaculture area that had previously been mangroves by improving the area's hydrology to facilitate mangrove recruitment, with small numbers of additional mangrove seedlings also being planted. The collaborative project, implemented from November 2004 to February 2005 on an area of 14 ha, involved local communities and education institutions, NGOs, and international partners.

The rehabilitated/restored mangroves are estimated to reduce emissions amounting to 27.6 ± 1.7 Mg CO_2e ha^{-1} $year^{-1}$. Assuming a carbon price of USD 8.1 Mg CO_2e^{-1} ha^{-1} for afforestation/reforestation projects, then 76.2% of restoration costs had already been recouped after 10 years.

This success is gauged only from its carbon aspect; reviewing other ecosystem services such as biodiversity, food provisioning, fish production, and improved water quality would surely attract private and government investors to the mangrove rehabilitation/restoration programme.

4.2 Institutional challenges

In 2021, the government launched a restoration and rehabilitation programme for 600,000 ha of mangroves to 2024 based on data on the extent of degraded mangroves in 2019. KLHK, KKP and BRGM received mandates to implement the programme, whereby mangrove areas categorized as having moderate or sparse cover would be rehabilitated/restored, and those that had experienced deforestation and empty areas with potential would undergo restoration. KLHK is tasked with implementing the programme inside the forest estate with a 14% portion of the overall budget using funds from the national APBN; KKP implements the programme outside the forest estate with a 10% portion using funds from the APBN; whereas BRGM implements the programme inside the forest estate in nine priority provinces with a 76% portion using non-APBN funds from various national and international sources. Funds required by BRGM alone are estimated to be around IDR 18.4 trillion in preliminary funds for preparation, preconditioning, planning, and building a database, and where necessary constructing wave and abrasion barriers to protect newly planted mangrove seedlings. Facilitation and strengthening community economies requires an additional IDR 5.8 trillion. The programme commenced with a target to rehabilitate/restore 33,000 ha of degraded mangroves in

2021. BRGM stated it exceeded the 2021 target by restoring 34,991 ha with the involvement of 34,596 workers (BRGM 2021). The subsequent aim of rehabilitating/restoring 150,000 ha of mangroves per year until 2024 is an enormous target.

This programme will certainly have to be planned properly and consider many factors other than mangrove rehabilitation and restoration techniques, including changes in land use status and conflicts of interest over land use in mangrove areas. According to Sidik et al. (2018), only 22% of mangroves in Indonesia are in converted areas, while most of the remainder are in utilization areas. Despite their climate change mitigation objective, this situation will pose various social and economic challenges to mangrove conservation and rehabilitation/restoration programmes, particularly in regard to competing land uses. Therefore, a solid regulatory framework is necessary, as is involving various stakeholders and especially local communities, in every project being undertaken. Febriano et al. (2015) stated that to date, too many actors and power relations have been playing a part in mangrove management in Indonesia, which ultimately marginalizes local communities. Government policies side more with sectors that increase regional own-source revenue (PAD), while caring less about environmental preservation. An example of this is the large-scale conversion of mangrove forests for shrimp farming. Mangroves are converted on a large scale for aquaculture, because doing so provides large profits (Armitage 2002). Some successfully restored mangrove areas have even been reconverted to shrimp farms (Brown 2017). To provide opportunities for other actors who wish to develop the economic aspect, licences for aquaculture in mangroves in other use areas (APL) should be supplemented with obligations to allocate their aquaculture areas for mangrove planting.

The conflict of interest between short-term economic growth and environmental conservation – which will also provide economic benefits, but over the long-term – is a challenge in its own right to environmental programmes such as mangrove restoration projects. Several studies already show huge economic losses will be incurred if uncontrolled felling of forests, including mangroves continues. Mangrove ecosystems provide manifold environmental services for society: as homes and spawning grounds for numerous economically valuable marine creatures (Uddin et al. 2013); as sources of wood for building and fuel for communities; as providers of raw materials for traditional medicines (Alongi 2002; Palacios and Cantera 2017; Sadeer et al. 2022); in protecting coastlines from environmental hazards like abrasion, tsunamis and tall waves; and in mitigating global climate change (Alongi 2008; Spalding et al. 2014; Takagi 2019). The loss of mangrove forests will of course also result in the loss of the ecosystem services they provide, including those listed above. If these losses are monetized in rupiah terms, then society could bear enormous economic losses. The economic value of mangroves in Indonesia is estimated to range from IDR 52 million to 384 million per hectare per year (Rizal et al. 2018). Further, mangrove deforestation will contribute to climate change from the resulting carbon emissions, and this will cause economic losses of IDR 82–600 trillion per year (Pendleton et al. 2012).

Based on KLHK data, mangrove area according to the 2019 National Mangrove Map was 3.31 million ha (see Table 1), where 80.74% or 2.67 million ha was in good condition, and 19.26% or 637,524 ha was in critical condition. This area of critical mangroves formed the basis for the mangrove rehabilitation target to 2024. According to the 2021 National Mangrove Map, mangrove land cover was 4.12 million ha (see Table 3). This huge difference poses a challenge – especially in terms of institutional accountability – for KLHK, which is the custodian of national mangrove data.

Referencing Indonesian national standard SNI: 7717/2020 on Specification of Geospatial Information – Mangroves, dense mangroves are those with canopy cover exceeding 70%; moderate mangroves have canopy cover of 30%–70%; and sparse mangroves have canopy cover below 30%. Table 2 shows 93% of Indonesia's mangroves being dense, 5.6% being moderate, and 1.6% being sparse. The density or percentage of canopy cover is not always an indicator of the level of degradation. Pioneer mangroves such as *Avicennia* sp. may well have moderate or sparse densities, but due to their physiognomic characteristics, their canopies are probably already fully formed.

Irrespective of criteria used to determine mangrove criticality, the 54,474 ha of areas with sparse canopy cover indeed require attention. Still, the mangrove rehabilitation target for open and accreted land (around 112,000 ha) could give rise to ecological issues for wildlife habitats, particularly for waterfowl; whereas the rehabilitation of all aquaculture areas, which exceed 630,000 ha, can give rise to social and economic problems for communities.

A study of literature on mangrove restoration programmes implemented in Indonesia from 2000 to 2020 showed the area of mangroves being 2,930,353 ha in 2000, and 2,736,986 ha in 2020, indicating only 193,367 ha of mangroves being lost. Therefore, mangrove rehabilitation/restoration should only prioritize this extent. An area of this extent has potential for emissions reductions of 12%. Ambitions to restore 637,524 ha will encounter many problems relating to land ownership status and the potential for conflicts.

Data in Table 1 show 22% of Indonesia's mangroves being inside conservation forest (HK) estate; 27% in protection forest (HL), 30% in production forest (HP), and 21% in other use areas (APL) outside the forest estate. As we can only say with any certainty that mangrove conservation and rehabilitation/ restoration activities can be conducted without fear of significant conflict in conservation forest and protection forest estates, the data above should form a basis for consideration in determining appropriate planting locations, species, and programme allocations.

Development of a mangrove rehabilitation/restoration roadmap should afford more detailed attention to critical areas. Of the full extent of critical mangroves based on the National Mangrove Map 2021 (54,474 ha), 29,910 ha (around 55%) is outside the forest estate, which makes their rehabilitation the responsibility of KKP. This extent differs wildly from the 117,413 ha reported in the National Mangrove Map 2019 as critical mangroves outside the forest estate. As East Kalimantan and North Kalimantan are the provinces with the most critical mangroves, the government should focus mangrove restoration programmes and activities on these regions.

Data from mangrove mapping by KLHK in 2019 showed 637,524 ha of critical mangroves requiring rehabilitation/restoration; 460,211 ha of which was inside the forest estate, and 117,413 ha was outside. Restoration of critical mangroves inside the forest estate is entrusted to KLHK, whereas restoration outside the forest estate is undertaken by KKP. From this information it is apparent that there have been many irregularities in information from programme implementers themselves and from stakeholders concerned with these essential ecosystems, particularly in regard to data on areas of mangroves included in the 600,000 ha under this huge programme.

Certainly, information and perceptions need to be aligned for those involved in this huge programme as data on the land area it includes is essential for determining the funds required, including for technical planning of work implementation. The rehabilitation/restoration of marine ecosystems, including mangroves, is highly labour intensive and can necessitate expenditures of billions of rupiah per hectare (Bayraktarov et al. 2016). The larger the scale of a project, the greater the institutional and financial support it will require (Eger et al. 2020).

Mangrove rehabilitation/restoration costs in 2001 were reported to be IDR 1.5–3 million ha^{-1} for projects that only involved planting, but the success rates of these projects were extremely low, and some of those that were successful, but had involved planting on seagrass beds, ended up killing other productive ecosystems.

So, mangrove rehabilitation/restoration projects that have succeeded in terms of both cover and restoring ecological functions have required a wide range of costs starting from IDR 3 million ha^{-1} up to IDR 3 billion ha^{-1} (Lewis 2001). For comparison, costs for mangrove rehabilitation/restoration on 1,411 ha in 11 provinces in Indonesia conducted by the Ministry of Marine Affairs and Fisheries in 2021 were IDR 25,223,593,493 (or more than IDR 25 billion), including IDR 6,621,309,500 in wages for 3,860 workers for 64 working days. According to Susilo et al. (2017), mangrove rehabilitation/restoration programmes in Indonesia are actually very affordable if they involve local communities, as their outlay is very low at around only IDR 400,000 per person per month, which can keep mangrove restoration costs down.

4.3 Ecological challenges

Lee et al. (2019) stressed that incorrect choices of species, location, and allocation have caused many mangrove rehabilitation/restoration programmes to fail and have wasted huge budgets. A major cause of this has been programme managers failing to resolve social conflicts on the ground over land use and ownership and taking short cuts and opting instead to plant areas where such conflicts are absent but are ecologically unsuited to mangrove growth. Therefore, measures for gauging mangrove rehabilitation/restoration programme success and performance must cover sustainability indicators for community socioeconomic aspects, and not only numbers of mangrove propagules or area planted (Lovelock and Brown 2019).

The successes or failures of mangrove restoration in other places can also provide lessons for mangrove rehabilitation/restoration programme preparations in Indonesia. An example is a mangrove planting programme in Sri Lanka, where of 23 projects planting a total area of 1,000–1,200 ha, only around 200–220 ha, or 18%, showed successful mangrove growth. The programme's poor performance was the result of selecting planting locations that were unsuited to supporting mangrove growth in terms of their topography and hydrology. Further factors causing the failure of this mangrove planting programme included poor planning; an absence of technical guidelines for planting; the selection of only one dominant species (97% *Rhizophora sp.*); the choice of species unsuited to local hydrological conditions and salinity levels in planting locations; the choice of overly dry planting locations; the absence of any post-planting maintenance; and a lack of coordination between programme implementing institutions, regional governments, and local communities (Kodikara et al. 2017). Similar problems have blighted numerous mangrove rehabilitation/restoration projects in Indonesia (Brown 2017).

Classifying hydrological conditions is an important consideration in planning mangrove rehabilitation/restoration, as it will provide pointers on how to restore hydrological conditions that suit natural mangrove regeneration or provide information for selecting appropriate mangrove species for planting under specific hydrological conditions (van Loon et al. 2016).

Other examples given included the failed mangrove planting programme in Mahakam, Indonesia, where the choice of mangrove species was unsuited to hydrological conditions in the planting area with *Rhizophora sp.* being planted on land that was too wet. Qu et al. (2019) recommended identifying potential restoration areas by studying their mangrove biodiversity history. An area previously having a large variety of mangrove species is a good indicator of how successful restoration activities might be in that location. This can be done by tracing mangrove distribution from maps that have used remote sensing and Geographical Information System (GIS) technologies.

In addition to selecting appropriate locations, mangrove restoration methods also need to be developed, where those that to date have only involved planting mangroves should shift to ecological mangrove restoration by focusing more on the restoration of mangrove habitats themselves so they will later facilitate natural mangrove growth, and by using methods that combine mangrove habitat restoration and planting (van Bijsterveldt et al. 2022). Certainly, any restoration method choice should suit conditions in the rehabilitation/restoration location.

From a regulatory angle, the government has also established procedures for forest and land rehabilitation/restoration through Minister of Environment and Forestry Regulation No. 23/2021, which includes provisions on species selection, techniques for evaluating plant growth success rates, and implementation techniques as preconditions for minimizing failure.

5 Recommendations

After synthesizing and summarizing information from various references relating to the Government of Indonesia's huge programme to rehabilitate 600,000 ha of degraded or reportedly critical mangroves by 2024, we propose the following recommendations:

- ***MRV***: A reliable and transparent MRV system should be established to increase the credibility and accountability of the mangrove rehabilitation/restoration programme. This system should remain continuously active so that mangrove rehabilitation/restoration successes in terms of area planted can be followed by successes in regard to mangrove vegetation survival. A monitoring timeframe of five years is recommended, bearing in mind the high biophysical and other risks related to the successful growth of vegetation resulting from rehabilitation/restoration.
- ***Working days***: Community involvement, as quantified by numbers of working days, should be included in the MRV system. That way, community involvement targets can be monitored and reported transparently. Working days can also be defined as additional earnings in a framework of resurrecting local community economies, particularly for those coastal and fishing communities where degraded mangroves have had negative impacts, and rehabilitated/restored mangrove ecosystems will have positive ones.
- ***Biodiversity***: Mangrove rehabilitation/restoration programme implementation will require feasibility studies for every prospective rehabilitation/restoration location. Such studies should cover planting location and species suitability; rehabilitation/restoration methods that will be used by considering natural risks and survival rates; species variety to maintain biodiversity in the rehabilitation/restoration area; and government and local community involvement.
- ***Science***: Scientific support is vital for providing suggestions and considerations for restoration/rehabilitation on this scale. The latest findings and scientific studies should be accommodated for testing and application in accordance with scientific principles. This science should cover biophysical, social/anthropological, cultural, and economic aspects.
- ***Conservation***: Intact mangroves inside conservation areas should be afforded equal attention bearing in mind the high carbon stocks such ecosystems contain and the challenges rehabilitation programmes face in attaining such ecosystem conditions.

Photo by Kate Evans/CIFOR

6 Closing

In a framework of supporting ministries/agencies in performing their main tasks and functions and strengthening their collaboration in coastal region and mangrove ecosystem management, programmes, activities, and budgets should be synchronized and harmonized so targets can be achieved more effectively, efficiently, credibly and accountably. Specifically, government institutions with capacity to coordinate (*Kemenkomarves*), and provide strategic direction (*Bappenas*) should keep watch over implementing institutions, where programmes are designed and funds allocated (KLHK, BRGM and KKP).

APBN and non-APBN (bilateral, multilateral) funding, which falls under the remit of the Ministry of Finance, and funds from the business community, should be blended for higher interests such as climate change mitigation, not only for national agendas such as LCD and NDC, but also global agendas, including SDGs.

Climate change mitigation through blue carbon mangrove ecosystems in coastal areas has huge potential for bringing Indonesian leadership to the global stage.

Photo by Mokhamad Edliadi/CIFOR

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Coastal area rehabilitation/restoration involving mangrove ecosystems for climate change mitigation is a long and risk-laden journey. It requires strong and comprehensive governance, and policies that involve stakeholders from the national to subnational levels.

Institutional complexities can become a bureaucratic hurdle and obstruct information and funding flows. These pose new challenges for the implementation of coastal area and mangrove rehabilitation/restoration both inside and outside the forest estate, particularly when they relate to aquaculture and accreted land. Therefore, these complexities need to be simplified by advancing accountability and the credibility of those involved.

Mangrove blue carbon has significant climate change mitigation potential. This relates to the huge carbon stocks in mangrove ecosystems, which are 3–5 times higher than carbon stock in protected tropical forests. As the processes involved in storing such large volumes of carbon are lengthy and complex, emissions mitigation should have a greater focus on conservation of intact mangrove forests. Conservation has a higher benefit-cost ratio and a better guarantee of achieving emissions reduction targets. In addition, mangrove conservation can generate economic activities oriented towards utilization of the environmental services mangroves provide.

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