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MANGROVE ECOSYSTEM CONSERVATION AS NATURE-BASED SOLUTIONS FOR ADDRESSING GLOBAL CHALLENGES

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Global mangrove trends and the drivers of loss

Mangrove is the generic term for plants that inhabit intertidal zones in tropical and subtropical coastal areas. Sixty-nine species from 18 plant families are recognized as mangrove plants worldwide.¹ Mangroves have unique forms, especially in their aerial roots and viviparous propagules, as a result of their adaptation to the intertidal environment. There are four types of roots that tangle on the forest bed: stilt, knee, cone, and buttress. They also develop uniquely shaped viviparous propagules, hanging down from branches. Mangroves have succeeded in physiological adaptation to saline brackish water. Their roots filter out over 90% of salt content in seawater entering their roots, and also exchange gas, absorbing oxygen and giving off carbon dioxide, at the surface of roots, and store the absorbed gas in their roots under inundation and oxygen-poor soil.² Thanks to their adaptation to the intertidal zone, mangroves develop green belts along coastal areas, which protect coastal people from storm waves and coastal erosion.

¹ Duke (2017), 18.

² Scholander (1968); Krishnamurthy et al. (2014).

Mangroves' adaptation abilities, however, have not spared them from decline. The global mangrove extent drastically decreased by 3.76 million hectares (ha) over 20 years from 1980 (18.8 million ha) to 2000 (15.04 million ha), at a rate of 0.19 million ha/year.³ However, the reduction rate slowed to around 11,300 ha/year from 2000 (15.04 million ha) to 2015 (14.87 million ha), then reversed, increasing through 2025 (15.53 million ha) due to growing efforts in the protection and restoration of mangrove forests.⁴

Goldberg et al. analyzed the causes of mangrove reduction. Between 2000 and 2016, 2.1% (3,363 km²) of global mangrove area was lost, an average loss of 0.13% per year.⁵ Conversion to commodities, such as aquaculture ponds, rice paddies, and oil palm plantations, served as the primary driver of mangrove loss, resulting in 47% (1,596 ± 42 km²) of global losses during the period.⁶ Shoreline erosion represented the second driver of global mangrove loss at 27% (912 ± 41 km²), followed by extreme weather events contributing 11% of their loss (361 ± 31 km²).⁷ The main drivers of mangrove loss were different among regions. As Goldberg et al. detailed, conversion to commodities was the primary driver of their loss in Asia. Shoreline erosion and extreme weather events were the main causes in North and South America, Australia, and Oceania. Africa remained the only continent where nonproductive conversion by mining activities, including petroleum extraction, was the primary cause of mangrove loss.

What mangroves provide: Four interlocking ecosystem services

Understanding what is being lost requires looking more closely at the range of services mangroves provide. Multiple mangrove ecosystem services contribute to addressing global and local challenges, such as climate change mitigation, coastal protection, enhancement of coastal communities' livelihoods, and biodiversity.

CLIMATE CHANGE MITIGATION

The amount of carbon storage per unit area of mangrove ecosystems is 1,023 ± 88 standard error of the mean (s.e.m.) megagrams of carbon/ha, which is much higher than that of terrestrial tropical forests.⁸ Therefore, the conservation and restoration of mangrove ecosystems effectively contribute to climate change mitigation. Below-ground carbon storage in soils accounted for the majority of total carbon storage at 71%-98% in estuarine mangroves and 49%-90% in oceanic mangroves.⁹ This is because the carbon in mangrove ecosystems is stored not only through carbon fixation by photosynthesis but also through their complex root systems trapping organic matter flowing from upstream rivers and the sea during high tide. This organic matter accumulates on the forest floor and is stored below ground for long periods without decomposition under anaerobic soil conditions.

3 FAO (2007), 9; FAO (2025), 41.

4 FAO (2025), 41.

5 Goldberg et al. (2020), 5846.

6 Goldberg et al. (2020), 5847.

7 Ibid.

8 Donato et al. (2011), 294.

9 Ibid.

COASTAL PROTECTION

Furthermore, mangroves not only trap organic matter but also effectively trap and accumulate sediments, which plays a significant role in protecting coastlines from sea-level rise and coastal erosion caused by climate change. The median soil accretion rates measured across various mangrove habitats—fringe, riverine, interior, and overwash island (see table 4.1)—are higher than the sea-level rise rate (3.7 mm/year between 2006 and 2018).¹⁰ Compared to sea levels between 1995 and 2014, the projected mean sea-level rise by 2100 under 1.5°C (Shared Socioeconomic Pathway SSP1-1.9) and 2.0°C (SSP1-2.6) global warming scenarios is 0.28-0.55 m and 0.32-0.62 m, respectively.¹¹ Using the midway point of 2005 as the baseline, the annual rates of sea-level rise by 2100 under SSP1-1.9 and SSP1-2.6 scenarios are projected to be 2.9-5.8 mm/year and 3.4-6.5 mm/year, respectively.

TABLE 4.1
Vertical soil accretion rates (mm/year) in different mangrove habitats

Habitat type	Accretion rate (mm/year)
Fringe	1.6-8.6
Riverine	6.5-13.0
Interior	0.7-20.8
Overwash island	4.4-6.3

SOURCE: Krauss et al. (2014).

Mangroves also have a tsunami reduction effect. Yanagisawa et al. analyzed the tsunami reduction effect of mangrove ecosystems based on their field surveys and numerical models conducted in Banda Aceh, Indonesia, after the 2004 Indian Ocean tsunami. Compared to the areas without mangrove forests, the presence of mangrove forests in their study effectively reduced tsunami force. When comparing the tsunami reduction effects among 10-, 20-, and 30-year-old mangrove forests, the tsunami reduction performance (inundation depth and hydrodynamic force) of “20-year-old or 30-year-old mangrove forest is more effective than 10-year-old when the tsunami inundation depth exceeds approximately 4m because 10-year-old mangroves were largely destroyed by the more than 4m tsunami and its reduction performance decreased.”¹² This suggests that young forests are less effective against large tsunamis, demonstrating the importance of long-term conservation of mangrove forests.¹³ However, when tsunami heights exceeded 9m, mangrove forests of all ages were toppled, and their reduction effect was lost.¹⁴

10 IPCC (2023), 5.
11 IPCC (2021), 21.
12 Yanagisawa et al. (2010).
13 Yanagisawa et al. (2008).
14 Yanagisawa et al. (2010).

PROVIDING LIVELIHOODS FOR COASTAL COMMUNITIES

Mangroves, which serve as habitats for various marine organisms, provide abundant fishery resources to coastal communities. In addition, the unique forms and landscapes of mangroves, along with their rich biodiversity, are also utilized as tourism resources. An economic valuation based on a literature review of fisheries and tourism in mangrove forests around the world suggests a mean economic value of \$23,613/ha/year for fisheries, and a mean economic value of \$37,927/ha/year for tourism, indicating that mangroves serve as a livelihood foundation for coastal communities.¹⁵

BIODIVERSITY

Mangroves generate and provide habitats for marine organisms, especially for juvenile fish and invertebrates. Based on 481 field measurements of density for juvenile fish and juvenile and resident invertebrates across 37 commercially important mangrove-affiliated species, mangroves are estimated to support almost 735 billion juvenile fish, bivalves, prawns, and adult crabs annually. This suggests that mangroves provide nursery sites essential for the juvenile stages of fish and invertebrates in their life history, and mangroves contribute to livelihoods and global food security.¹⁶ In the comparison of meio-benthos biodiversity between undisturbed and disturbed mangrove ecosystems, the taxonomic richness and abundance of meio-benthos fauna were significantly higher in the sediments of undisturbed mangroves than in the sediments of disturbed mangroves.¹⁷

From services to solutions: Mangroves as nature-based solutions

As mentioned above, mangrove ecosystem conservation can serve as nature-based solutions (NbS), addressing not only a single challenge but also multiple challenges simultaneously, such as climate change mitigation and adaptation, natural disaster risk reduction, enhancement of local communities' livelihoods, and biodiversity. Therefore, NbS through mangrove ecosystem conservation can be considered highly effective solutions that provide multiple benefits for people.

CHALLENGES IN TROPICAL COASTAL AREAS

Coastal areas of developing countries in the tropics, especially in small island developing states (SIDS), are exposed to coastal flooding and erosion, and storm waves due to sea-level rise and frequently occurring large-scale typhoons caused by climate change. The sediment accumulation and wave-reduction effects of mangrove ecosystems, mentioned above, reduce disaster risks, and strengthen coastal resilience to climate change. In addition, since coastal communities in developing countries highly depend on mangrove ecosystems, which provide fishery and tourism resources, the mangrove loss and degradation seriously impact their livelihoods. Therefore, when we consider coastal protection measures and projected extreme events caused by climate change or natural disasters in mangrove habitats of developing countries, we have to take into account securing such multiple mangrove ecosystem services.

¹⁵ Salem and Mercer (2012), 369.

¹⁶ zu Ermgassen et al. (2025).

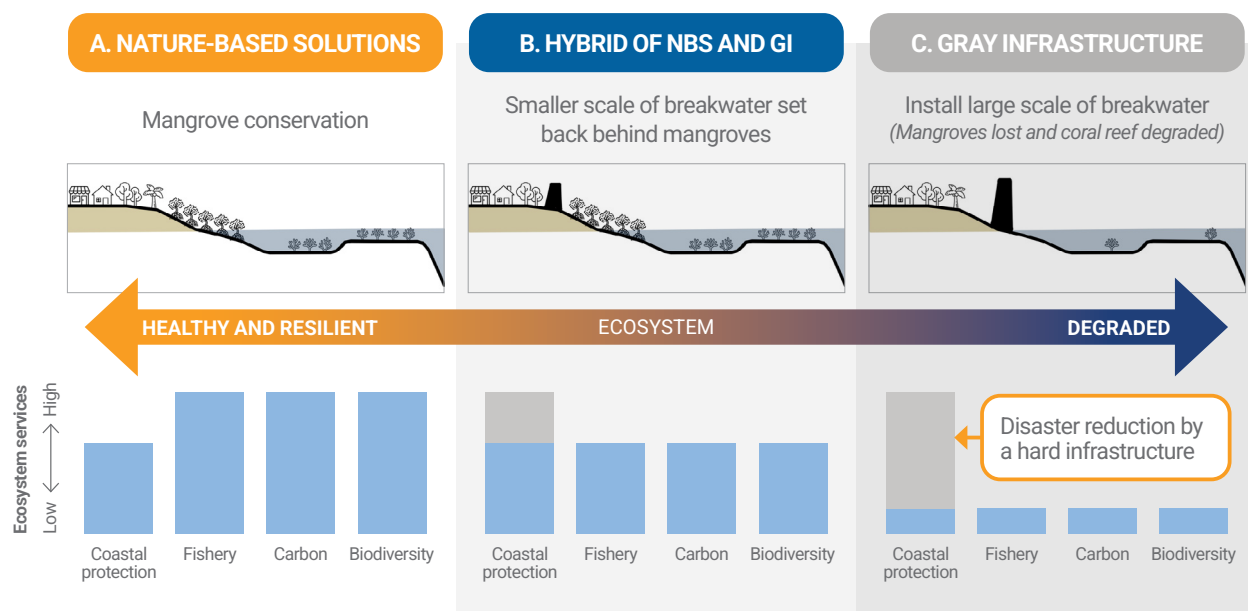
¹⁷ Carugati et al. (2018).

CHOOSING AMONG GRAY, HYBRID, AND NATURE-BASED COASTAL PROTECTION

The predicted status of various ecosystem services—coastal protection, fishery resources, carbon sequestration, and biodiversity—is shown schematically in figure 4.1, corresponding to each coastal protection measure against extreme events caused by climate change or natural disasters: NbS, hybrid of NbS and gray infrastructure (GI), and gray infrastructure.

FIGURE 4.1

The predicted status of various ecosystem services corresponding to coastal protection measures



SOURCE: Author's own analysis and design.

If a large-scale breakwater is constructed along the coastline, cutting down all mangroves (figure 4.1C), a definite effect in preventing coastal erosion and storm waves can be expected. However, the construction of breakwaters would cause the loss of all mangroves inhabiting the area and degradation of ecosystem services. Since mangroves provide spawning and nursery sites as well as feeding grounds for coral fish and other organisms and trap sediment and purify the water flowing from land to coral reefs, the loss of mangroves leads to the degradation of coral reef ecosystems.

Consequently, the construction of large-scale breakwaters for coastal protection results in, as a trade-off, biodiversity loss in whole coastal ecosystems, reduction of carbon sequestration capacity for climate change mitigation, and a decrease in fishery resources important for communities' livelihoods. Building infrastructure is very costly, creates high future expenses, and lacks synergistic benefits such as nursery habitats for edible fish and recreational value.¹⁸ On the other hand, coastal protection through mangrove conservation as NbS can secure multiple ecosystem services, including not only coastal protection but also carbon storage, biodiversity, and provision of fishery resources, and, as a result, enhance the livelihoods and resilience of coastal communities (figure 4.1A).

¹⁸ IPBES (2019), 22.

When examining which approach—gray infrastructure or NbS—should be installed, the comparison should not be based solely on the coastal protection effect, but should also include the amount of each of the other services—carbon sequestration, biodiversity, and fishery resources—that people can derive from coastal ecosystems.

In the case that the coastal hinterland is densely populated and is exposed to high waves, coastal floods, and erosion with higher risks, installing gray infrastructure should be considered to protect coastal people. When the exposure and risk to such disasters are lower, one can consider installing a hybrid of NbS and gray infrastructure to maintain the multiple services of mangrove ecosystems at a certain level through sustainable mangrove management (figure 4.1B).

WHY MANGROVE NATURE-BASED SOLUTIONS ARE NOT YET MAINSTREAM IN COASTAL PROTECTION

Despite the multiple benefits of mangrove ecosystems, mangrove conservation and restoration have not yet been mainstreamed in coastal protection as NbS for climate change adaptation and disaster risk reduction. The primary reason is a lack of quantitative assessments of mangrove ecosystems' capacity for coastal protection. A review of 423 studies on mangrove ecosystem services revealed that the vast majority, 354 studies (84%), focused on carbon sequestration, highlighting the significant attention paid to the high carbon sequestration capacity of mangrove ecosystems.¹⁹ In contrast, fewer than 20 studies focused on coastal protection.²⁰ A lack of scientific data on the effectiveness of coastal protection by mangrove ecosystems hinders the application of mangroves as NbS. Meanwhile, regarding gray infrastructure, guidelines for breakwater design have been established to ensure resistance against wave heights and energy by calculating the necessary scale and strength to withstand projected storm waves and tsunamis. In Japan, the Ministry of Land, Infrastructure, Transport and Tourism developed the "Guideline on Breakwater Design for Resistance to Tsunami" in 2013.²¹

As mentioned above, the advantage of the conservation and restoration of mangrove ecosystems as NbS lies in their ability to deliver multiple benefits simultaneously, including coastal protection, carbon sequestration, biodiversity, provisioning fishery resources, and ensuring livelihoods for coastal communities. To mainstream mangrove ecosystem conservation as NbS, it is essential to simultaneously evaluate and demonstrate these multiple ecosystem benefits. However, the same review of mangrove ecosystem services revealed that only 22% (94 of 423 studies) evaluated multiple services simultaneously; and specifically, only 10 studies (2%) addressed both coastal protection and carbon sequestration, while just five (1%) covered coastal protection and fisheries, indicating a significant lack of multiple-services assessments.²² Therefore, to advance the mainstreaming of mangrove ecosystem conservation as NbS, there is an urgent need to develop indicators and methodologies for quantifying each ecosystem service and to conduct assessments of multiple ecosystem services.

Furthermore, while global guidelines for mangrove restoration are already in place, there is also a need to develop NbS guidelines for strengthening coastal resilience while securing multiple ecosystem services based on quantitative assessments.²³

19 Lee et al. (2025), 2, 4.

20 Lee et al. (2025), 5.

21 Japan, MLIT (2013).

22 Lee et al. (2025), 5.

23 For more on global guidelines for mangrove restoration see Beeston et al. (2023).

Global efforts for mangrove conservation

The Convention on Biological Diversity (CBD) adopted the Kunming-Montreal Global Biodiversity Framework for 2030 at the 15th Conference of the Parties (COP15) to achieve a world of living in harmony with nature by 2050. The framework's mission is to mobilize urgent action to halt and reverse biodiversity loss and place nature on a trajectory toward recovery by 2030. To achieve the mission, the framework set up 23 targets that include not only targets for conserving biodiversity itself, such as restoring at least 30% of areas of degraded ecosystems (target 2) and conserving and managing at least 30% of particularly important areas for biodiversity (target 3), but also those for leveraging NbS, such as minimizing the impact of climate change on biodiversity through NbS (target 8) and enhancing nature's contributions to people, including ecosystem services, through NbS for the benefit of all people and nature (target 11).²⁴

To move toward a transition to sustainable climate action, the conservation and restoration of mangrove ecosystems is important for ecosystem-based adaptation and disaster risk reduction.²⁵ Numerous research results have found that mangrove ecosystem services effectively contribute to climate change mitigation and adaptation, disaster risk reduction, and the enhancement of communities' livelihoods through providing fishery and tourism resources as mentioned above. In response to widespread understanding of the importance of mangrove ecosystems' contribution to addressing global challenges, the international community has recently established global initiatives or frameworks to strengthen and accelerate the conservation of mangroves, as follows:

GLOBAL MANGROVE ALLIANCE AND MANGROVE BREAKTHROUGH

At the World Ocean Summit in 2018, the Global Mangrove Alliance (GMA) was established with the participation of nongovernmental organizations (NGOs), international organizations, research institutes, and countries.²⁶ At the 27th Conference of the Parties (COP27) to the United Nations Framework Convention on Climate Change (UNFCCC) held in Sharm El-Sheikh, Egypt, in 2022, Mangrove Breakthrough was launched as a global mangrove conservation initiative with the GMA.²⁷ Mangrove Breakthrough sets the following goals to be achieved by 2030: (1) halt loss and degradation, (2) recover half of the recent loss, (3) double the protected areas, (4) conserve 15 million ha, and (5) mobilize \$4 billion to achieve the targets.²⁸ These initiatives have produced deliverables to be used for the protection, restoration, and sustainable management of mangroves at global and local levels. For example, "The State of the World's Mangroves" has been published annually by the GMA to report the changes in global mangrove areas and their drivers. The report utilizes and analyzes the data and information from the platform "Global Mangrove Watch," which provides remote sensing data and tools for monitoring mangrove conservation.²⁹

²⁴ CBD (2022).

²⁵ CBD (2020).

²⁶ See more on the Global Mangrove Alliance at <https://www.mangrovealliance.org/about-us>.

²⁷ See more on Mangrove Breakthrough at <https://www.mangrovebreakthrough.com/about>.

²⁸ Mangrove Breakthrough (n.d.).

²⁹ See "The State of the World's Mangroves 2026" at <https://www.mangrovealliance.org/news/the-state-of-the-world-s-mangroves-2026>; see more on the "Global Mangrove Watch" at <https://www.globalmangrovewatch.org/>.

MANGROVE ALLIANCE FOR CLIMATE

The Mangrove Alliance for Climate (MAC) was also established as a government-led mangrove conservation framework at the UNFCCC summit at COP27 in 2022.³⁰ The Standing Committee, co-chaired by the United Arab Emirates (UAE) and Indonesia, is responsible, as the highest body, for providing strategic guidance and making decisions.³¹ The UAE serves as the secretariat to implement and monitor MAC-convened activities in coordination with member states. There are 30 countries with mangroves that are partners with the MAC and whose mangrove area exceeds 60% of the total mangrove area in the world.³²

The mission of the MAC strategy is to conserve and restore mangrove ecosystems through international cooperation, blue carbon solutions, local community engagement, collaborative research, and knowledge exchange, supported by the private sector and nonprofits to achieve a sustainable future. The strategy sets up four strategic initiatives: (1) knowledge exchange, (2) policy development, (3) restoration and rehabilitation, and (4) capacity building.³³

COLLABORATION BETWEEN MANGROVE BREAKTHROUGH AND THE MAC

Mangrove Breakthrough and the MAC, both established in 2022, are deepening their collaboration. Mangrove Breakthrough, led by international NGOs, has published numerous scientific findings, information, and technical guidelines through extensive mangrove conservation activities at the local level, and has developed its financial roadmap up to 2030. However, the involvement of national governments is essential in order to implement mangrove conservation in alignment with national policies and legislation while mobilizing public funds. Since the MAC is a government-led framework, the collaboration between Mangrove Breakthrough and the MAC is considered to effectively function to implement mangrove conservation at the national level.

Indonesia: A case study for policy and rehabilitation in the world's largest mangrove nation

How countries address mangrove decline is best seen through a country example. Although Indonesia has the largest mangrove extent in the world, it saw a reduction from 4.2 million ha in 1980 to 2.31 million ha in 2014.³⁴ From 2000 to 2012, mangrove loss in Indonesia was mainly caused by the conversion to aquaculture in Kalimantan and Sulawesi, and the conversion to oil palm plantations in Sumatra and Kalimantan.³⁵ However, the mangrove extent increased to 3.40 million ha in 2025 thanks to its rehabilitation and conservation efforts.³⁶

30 See more on the Mangrove Alliance for Climate at <https://mangrovealliance4climate.org/about/>.

31 The Gulf Observer (2026).

32 MAC (n.d.-b).

33 MAC (n.d.-a).

34 Ilman et al. (2016); Rahadian et al. (2019), 167.

35 Richards and Friess (2016).

36 FAO (2025), 40.

POLICIES TO ADDRESS CLIMATE CHANGE MITIGATION AND MANGROVE REHABILITATION

According to the “2024 Biennial Transparency Report,” greenhouse gas (GHG) emissions from the Land Use, Land-Use Change, and Forestry (LUCF) sector in 2022 were the second highest at 22.58% of total emissions, following the GHG emissions from the energy sector (53.42%).³⁷ In the second nationally determined contribution (NDC) plan submitted to the UNFCCC in 2025, Indonesia set a net-zero GHG emissions target by 2060.³⁸ In the Forestry and Other Land Use (FOLU) sector, efforts to reduce GHG emissions through the suppression of forest loss and degradation and the restoration of degraded forests are expected to turn the FOLU sector from a GHG emission source into a GHG sink by 2030. Since healthy mangrove ecosystems have higher carbon sequestration capacity, Indonesia identifies mangrove restoration as one of the key measures to increase carbon sequestration and suppress emissions from soil as a mitigation action in the FOLU sector.

The Indonesian government committed to accelerating the restoration of mangroves targeting 600,000 ha by 2024 through Presidential Regulation No. 120 of 2020.³⁹ As the concrete implementation plan, Indonesia developed the National Mangrove Rehabilitation Roadmap 2021-2030 in 2021, aiming to accelerate the rehabilitation of 600,000 ha of degraded mangrove forests, ensure the sustainable management of rehabilitated mangrove forests, and achieve a GHG net sink in mangrove ecosystems by 2030.⁴⁰ Since 2022, the Indonesian government, supported by the World Bank, has been conducting the “Mangroves for Coastal Resilience (M4CR) Project” as an NbS.⁴¹ The project serves not only to conserve biodiversity but also to strengthen coastal resilience against coastal flooding and abrasion as adaptation measures, increase carbon sequestration as a mitigation measure, and enhance communities’ livelihoods through the rehabilitation of 41,428 ha of lost or degraded mangrove areas in the four target provinces—North Kalimantan, East Kalimantan, North Sumatra, and Riau—by April 2027.⁴² The M4CR Project rehabilitated 13,344 ha, involving 162 community groups in 52 villages, as of April 2025.⁴³

In 2024, the Ministry of Environment and Forestry of Indonesia established the World Mangrove Center (WMC). The WMC functions as an integrated global hub for promoting research, capacity building, knowledge sharing, and policy dialogues on the conservation of mangrove ecosystems, all important to addressing global challenges such as climate change mitigation and adaptation, and biodiversity conservation.⁴⁴ The WMC is based in Bali and consists of at least three institutions/facilities: (1) the President Joko Widodo Mangrove Nursery Center developed in 2022 for the G20 Summit; (2) the Mangrove Information Center (MIC) established in 2003, supported by the Japan International Cooperation Agency (JICA); and (3) the Mohamed bin Zayed-Joko Widodo International Mangrove Research Center, whose establishment the UAE committed to support in 2024. Thus, the WMC is established and managed in cooperation with international partners.

37 Republic of Indonesia (2025a), 2.

38 Republic of Indonesia (2025c).

39 Republic of Indonesia (2020).

40 Republic of Indonesia, Ministry of Environment and Forestry, Ministry of Marine Affairs and Fisheries, and Peatland and Mangrove Restoration Agency (2021).

41 See more on M4CR at <https://documents.worldbank.org/en/publication/documents-reports/documentdetail/793041653404341879>.

42 World Bank (2025), 5.

43 World Bank (2025), 2.

44 See more on the World Mangrove Center at <https://worldmangrovecenter.org/en/about-us>.

International cooperation for mangrove conservation—the JICA/Indonesia example

JICA has extensive cooperation with Indonesia in mangrove conservation, spanning 34 years since 1992, as shown in table 4.2.

TABLE 4.2

Long-term cooperation for mangrove conservation between Indonesia and JICA

Year	Project title and main activities
1992-1999	Project on the Development of Sustainable Mangrove Management • Developed techniques for rehabilitation and sustainable management. • Published nursery and rehabilitation manuals. • Rehabilitated degraded mangroves (256 ha) in Bali and Lombok.
2001-2006	Project on the Mangrove Information Center (MIC) • Established the MIC as an information-sharing hub. • Developed and implemented training programs and dissemination strategies. • Developed and implemented environmental education and ecotourism programs using the MIC and relevant facilities.
2007-2010	Project on the Sub-Sectoral Program on Mangroves • Developed guidelines for sustainable management and monitoring. • Developed five demonstration sites to disseminate knowledge, techniques, and lessons for sustainable mangrove management.
2011-2014	Project on Mangrove Ecosystem Conservation and Sustainable Use in the Association of Southeast Asian Nations (ASEAN) Region • Shared good practices and lessons learned in the ASEAN region. • The ASEAN Mangrove Network (AMNET) was approved as a cooperation mechanism for mangrove conservation in ASEAN.
2022-2023	Follow-up Project on the Mangrove Information Center • Renovated MIC exhibition and training facilities.
2026-2029	Project on Strengthening Capacity of Sustainable Management of Mangrove for Ecosystem-based Adaptation to Climate Change • Strengthen MIC functions for capacity enhancement and CEPA (communication, capacity building, education, participation, and awareness). • Develop models for rehabilitation and sustainable management. • Enable the WMC to function as a global hub for capacity building and knowledge sharing.

SOURCE: Author's own compilation of JICA and Indonesia's collaborations.

Recently, Indonesia's Ministry of Forestry and JICA started a "Project on Strengthening Capacity of Sustainable Management of Mangrove for Ecosystem-based Adaptation to Climate Change." The project aims to strengthen capacity for sustainable mangrove management through an ecosystem-based adaptation to climate change approach and strengthen environmental and social resilience in coastal areas through developing community-based sustainable mangrove business models on silvofishery and ecotourism.⁴⁵

According to Indonesia's 2021 National Mangrove Map, 756,183 ha have been identified as potential mangrove areas, and 83.55% (631,802 ha) of the area consisted of aquaculture ponds.⁴⁶ In order to achieve the 600,000 ha restoration target in the National Mangrove Rehabilitation Roadmap 2021-2030, it is essential to rehabilitate mangroves within these aquaculture ponds. Since such aquaculture ponds serve as a source of livelihood for local communities, it is crucial to ensure that aquaculture and mangrove restoration coexist through the understanding and cooperation of local communities.

Silvofishery is one of the approaches that enables the coexistence of aquaculture and mangrove rehabilitation. This method involves planting mangroves within a portion of the aquaculture pond. Planted mangroves in a pond provide natural feed—various plankton and benthic organisms—for farmed shrimp and fish, thereby reportedly enhancing productivity. Silvofishery systems also maintain water quality within acceptable ranges for aquaculture operations.⁴⁷ Introducing silvofishery into ponds that are classified as potential mangrove forest areas enables the conversion of a certain portion of the pond area into mangrove forests. The current Indonesia and JICA project aims to develop a silvofishery model that balances mangrove restoration with aquaculture while contributing to the improvement of local livelihoods. Furthermore, given the significant value of mangroves' unique landscapes and rich biodiversity as tourism assets, the project also develops a community-based ecotourism model that utilizes the restored mangrove ecosystems, thereby promoting a balance between mangrove conservation and sustainable use.

By deploying the silvofishery and ecotourism models as sustainable social forestry businesses that contribute to enhancing the livelihoods of local communities, the project aims to scale up mangrove rehabilitation and sustainable management, thereby contributing to the achievement of the 600,000 ha restoration target in Indonesia's National Mangrove Rehabilitation Roadmap 2021-2030 and the GHG net sink by 2030 in the FOLU sector as the NDC target.

The project will also support the enhancement of the WMC as a global hub for capacity building and knowledge sharing for mangrove conservation targeting mangroves inhabiting the Association of Southeast Asian Nations (ASEAN) member states, collaborating with the ASEAN Mangrove Network (AMNET). AMNET, as a cooperation mechanism for mangrove conservation in the ASEAN region, formulated the "ASEAN Strategy on Sustainable Mangrove Ecosystem Management 2024-2030."⁴⁸ This ASEAN strategy aims to achieve the conservation and sustainable management of mangrove ecosystems to ensure ecosystem health and coastal resilience by 2030 while contributing to international commitments to address global challenges. Strategy 2, specifically, among the five strategies to achieve this objective, promotes capacity enhancement for the protection, restoration, and sustainable management of mangrove ecosystems.⁴⁹ Collaborating with AMNET, the project contributes to capacity enhancement and the promotion of knowledge and experience sharing for mangrove conservation in the ASEAN region.

45 JICA (2024).

46 Republic of Indonesia (2021a); Nurhati and Murdiyarso (2023), 13; Noviar (2023).

47 Harefa et al. (2025).

48 ASEAN (2024).

49 ASEAN (2024), 50.

Scaling mangrove restoration and conservation: Mobilizing capital to ensure ecosystem services

Projects such as these cannot be sustained or replicated at scale without addressing the question of finance. To ensure the multifaceted services of the mangrove ecosystem, and to scale up sustainable management such as mangrove restoration, silvofishery, and ecotourism, sufficient funding, as well as the establishment of systems and guidelines to appropriately guarantee ecosystem services, are necessary.

FUNDING MOBILIZATION

In 2023, Mangrove Breakthrough published “The Mangrove Breakthrough Financial Roadmap” to achieve the target of 15 million ha of mangrove area conservation by 2030.⁵⁰ As mentioned previously, Mangrove Breakthrough recommended that \$4 billion be mobilized to implement the projects under the initiative and achieve the target. It is expected that \$2.8 billion will come from public finance and the remaining \$1.2 billion from private or commercial finance.⁵¹

Regarding public funding mobilization, while it is fundamental to raise funds according to the circumstances of each implementation country, since mangrove ecosystem conservation significantly contributes to climate change mitigation and adaptation, it is recommended to utilize the large-scale Green Climate Fund (GCF). As shown in table 4.3, nine projects that include mangrove restoration and sustainable management have been conducted to date with funding from the GCF. Most of these projects aim to strengthen coastal communities’ resilience against climate change through mangrove restoration. The project in Vietnam, completed in 2024, restored a total of 4,028 ha of mangroves.⁵² Projects in India and Cuba are targeting the restoration of 10,575 ha and 11,427 ha of mangroves, respectively, by the end of their projects.⁵³ If all the projects in table 4.3 achieve their mangrove restoration targets, more than 32,880 ha of mangroves will be restored.

Driven by intercorporate competition to achieve carbon neutrality by 2050, the global voluntary carbon market is projected to grow to \$50 billion by 2030.⁵⁴ Consequently, mobilizing private capital to develop mangrove conservation and restoration projects, which generate higher carbon sequestration, offers an effective pathway to scaling up these efforts. One example of a mangrove restoration project within the voluntary carbon market is the “Mangrove Restoration and Coastal Greenbelt Protection Project” underway since 2011 in Aceh and North Sumatra, Indonesia.⁵⁵ Implemented by the local Indonesian NGO Yagasu, this project aims to restore 10,000 ha of mangrove areas, previously lost to conversion into aquaculture ponds, while simultaneously improving the livelihoods of local communities.⁵⁶ The project is expected to sequester a total of 4.5 million tons of carbon over a 20-year period, with carbon credits generated under Verra’s Verified Carbon Standard scheme.⁵⁷ The project has secured investment from the France-based Livelihoods Carbon Fund, in which numerous major companies have invested, including Hermès, Chanel, Danone, MCB, and Michelin.⁵⁸

50 Ring et al. (2023).

51 Ring et al. (2023), 53.

52 Data is from the Vietnam project report at <https://www.greenclimate.fund/portfolio/projects/fp013>.

53 Data is from the projects’ reports. The India project’s report is at <https://www.greenclimate.fund/document/2023-annual-performance-report-fp084-enhancing-climate-resilience-india-s-coastal>; the Cuba project’s report is at <https://www.greenclimate.fund/document/coastal-resilience-climate-change-cuba-through-ecosystem-based-adaptation-mi-costa>.

54 Blaufelder et al. (2021).

55 WWF (2022).

56 Ibid.

57 Ibid.

58 WWF (2022); Livelihoods Funds (2026).

TABLE 4.3

Climate action projects including mangrove conservation, funded by the Green Climate Fund

No.	Country	Project title	Focus	Mangrove action	Budget (in millions)	Period	AE*/EE**
FP003	Senegal	Increasing the resilience of ecosystems and communities through the restoration of the productive bases of salinized lands	Adaptation	Restoration (250 ha)	\$8.2	Feb. 2020-Feb. 2027	Centre de Suivi Écologique/Union internationale pour la conservation de la nature/ Réseau Africain pour le Développement Intégré/ Institut National de Pédologie
FP011	The Gambia	Large-scale Ecosystem-based Adaptation in The Gambia: developing a climate-resilient, natural resource-based economy	Adaptation	Restoration and sustainable management	\$25.5	Aug. 2017-Jan. 2026	United Nations Development Programme (UNDP)/ Ministry of Environment, Climate Change and Natural Resources
FP013	Vietnam	Improving the resilience of vulnerable coastal communities to climate change related impacts in Viet Nam	Cross-cutting	Restoration (4,028 ha)	\$40.5	Jul. 2017-Jul. 2024	UNDP/Ministry of Agriculture and Rural Development
FP084	India	Enhancing climate resilience of India's coastal communities	Cross-cutting	Restoration (10,575 ha)	\$130	Jun. 2019-Jun. 2027	UNDP/Ministry of Environment, Forest and Climate Change
FP157	Cuba	Coastal Resilience to Climate Change in Cuba through Ecosystem Based Adaptation – “MI COSTA”	Adaptation	Restoration (11,427 ha)	\$44.3	Sep. 2021-Sep. 2029	UNDP/Environmental Agency (AMA) of the Ministry of Science, Technology and Environment (CITMA)
FP235	Ecuador	Mangroves for climate: Public, Private and Community Partnerships for Mitigation and Adaptation in Ecuador	Cross-cutting	Restoration (4,850 ha) and sustainable management	\$45.9	Aug. 2024-Aug. 2030	Conservation International Ecuador (CI)/CI
SAP 025	Guinea-Bissau	Adaptation of agricultural production systems in Coastal Areas of Northwest Guinea-Bissau	Adaptation	Restoration (250 ha) and sustainable management	\$10.0	Sep. 2023-Sep. 2028	Sahara and Sahel Observatory/Ajuda de Desenvolvimento de Povo para Povo Guinea-Bissau
SAP 036	Sierra Leone	Sierra Leone Coastal Resilience Project	Adaptation	Restoration (1,500 ha) and sustainable management	\$26.9	Dec. 2024-Dec. 2029	Save the Children Australia/Save the Children Sierra Leone and others
SAP 049	Mexico	Sustainable Communities for Climate Action in the Yucatán Peninsula	Adaptation	Restoration and sustainable management	\$32.7	Aug. 2025-Feb. 2035	Mexican Fund for the Conservation of Nature A.C. (FMCN)/FMCN and Sureste Sostenible A.C.

*AE = Accredited Entity; **EE = Executing Entity

SOURCE: Author's own compilation of project information from the GCF website (<https://www.greenclimate.fund/portfolio/all?search=mangrove>) and the respective project reports.

THE NEED FOR NATIONAL SYSTEMS

While private companies show significant interest in the carbon market, and the mobilization of private funds for mangrove restoration is expected, mangrove plantation activities aimed at generating carbon credits may lead to trade-offs. These include the potential for reducing other ecosystem services, such as biodiversity, by focusing solely on carbon sequestration and straining the livelihoods of local communities by restricting their use of natural resources. Therefore, in the restoration and conservation of mangrove ecosystems, it is necessary to establish regulations and guidelines that properly ensure their multiple services and guarantee the livelihoods and welfare of local communities.

Also at the 2022 UNFCCC summit at COP27, the “High-Quality Blue Carbon Principles and Guidance” was published to achieve three co-benefits: people, nature, and climate.⁵⁹ Aiming to equitably and transparently improve outcomes for people, nature, and climate, five principles were created for the development and deployment of high-quality blue carbon projects and credits: “1) safeguard nature, 2) empower people, 3) employ the best information, interventions, and carbon accounting practices, 4) operate locally and contextually, and 5) mobilize high-integrity capital.”⁶⁰

To ensure that the carbon sequestration results of mangrove restoration and conservation projects, funded by private capital mobilization through the voluntary carbon market, are incorporated into national GHG inventories and contribute to achieving NDC targets, it is essential to establish national regulations, including registration, measurement, reporting, and verification (MRV), and carbon credit allocation for carbon credit generation projects, including mangrove ecosystem restoration and conservation. Without regulations like these in place, the results of GHG reduction achieved through domestically implemented projects will likely flow overseas.

In 2021, the Indonesian government established Presidential Regulation No. 98, “Implementation of Carbon Pricing to Achieve the Nationally Determined Contribution Target and the Control of Greenhouse Gas Emissions in National Development,” which promoted the achievement of NDC targets through market-based instruments consisting of carbon trading, results-based payments, and carbon tax, based on GHG emissions and reductions.⁶¹ Additionally, the government enacted its Ministry of Forestry Regulation No. 6 of 2026 concerning “Procedures for Carbon Trading through Greenhouse Gas Emission Offsets in the Forestry Sector,” to strengthen the governance of carbon trading in the forestry sector, ensuring it is credible, transparent, and inclusive, and integrate a nesting framework to prevent double-counting and align with its FOLU Net Sink 2030 target.⁶²

Few countries have developed systems like Indonesia’s. It is recommended that countries that have not yet established carbon pricing systems in the forestry sector, including mangroves, urgently develop a plan to balance the promotion of private capital mobilization with proper mangrove restoration and conservation.

59 Friends of Ocean Action et al. (2022).

60 Friends of Ocean Action et al. (2022), 10-11.

61 Republic of Indonesia (2021b); note: Presidential Regulation No. 98 has since been repealed and replaced by Presidential Regulation No. 110 of 2025 “Implementation of Carbon Economic Value Instruments and National Greenhouse Gas Emission Control” and builds upon the carbon and GHG governance goals set forth (see Republic of Indonesia (2025b)).

62 Republic of Indonesia (2026); Republic of Indonesia, Ministry of Environment and Forestry (2023).

Integrated mangrove ecosystem management

As previously mentioned, mangrove ecosystems provide multiple benefits to people, including carbon sequestration, coastal protection, disaster risk reduction, biodiversity, and provisioning fishery and tourism resources, ensuring the livelihoods and welfare of local communities. In order to optimize mangrove ecosystem services and ensure their conservation and sustainable management on the ground, it is vital to adopt an “adaptive management” approach that includes scientific monitoring of the ecosystem services and impacts of human activities, analysis of their interaction, and comprehensive assessment to guide planning, implementation, and improvement. Furthermore, given that various human activities affect the mangrove ecosystem, it is necessary to establish a management mechanism that facilitates information sharing and coordination among stakeholders representing both the conservation and utilization interests.

In the planning and implementation of projects based on the NbS approach, including ecosystem-based adaptation (EbA) and ecosystem-based disaster risk reduction (Eco-DRR), it is essential to adopt such integrated ecosystem management as a fundamental principle, across both coastal and terrestrial ecosystems.

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