Technical Report

Integrated Mangrove Aquaculture in the Indian Sundarbans: A Blue Economy Framework

November 2026

Avinandan Taron and Abinaya Sathiskumar



Authors

Avinandan Taron, Researcher - Environmental and Resource Economist, International Water Management Institute (IWMI), Colombo, Sri Lanka
Abinaya Sathiskumar, Consultant, IWMI, Colombo, Sri Lanka

Author contributions

Conceptualization: Abinaya Sathiskumar, Avinandan Taron; Methodology: Abinaya Sathiskumar; Validation: Avinandan Taron; Investigation: Abinaya Sathiskumar, Avinandan Taron; Resources: Abinaya Sathiskumar; Writing – original draft: Abinaya Sathiskumar; Writing – review & editing: Avinandan Taron; Visualization: Abinaya Sathiskumar; Supervision: Avinandan Taron; Project administration: Avinandan Taron; Funding acquisition: Avinandan Taron.

Suggested citation

Taron, Avinandan, and Abinaya Sathiskumar. 2026. *Integrated Mangrove Aquaculture in the Indian Sundarbans: A Blue Economy Framework.* International Water Management Institute (IWMI).

© 2026 International Water Management Institute. Some rights reserved. This work is licensed under a Creative Commons Attribution 4.0 International License (CC BY 4.0).

Disclaimers

This publication has been prepared as an output of the CGIAR Climate Action Program and has not been independently peer reviewed. Responsibility for editing, proofreading, and layout, opinions expressed, and any possible errors lie with the authors and not the institutions involved.

Boundaries used in maps do not imply the expression of any opinion whatsoever on the part of CGIAR concerning the legal status of any country, territory, city, or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Borders are approximate and cover some areas for which there may not yet be full agreement.

Front cover photo: Mangrove-fringed aquaculture ponds, South 24 Parganas, Indian Sundarbans, West Bengal, India (credit: Sourabh Kumar Dubey)
Back cover photo: New saplings. Biswajit Mistry

Acknowledgments

CGIAR Climate Action drives the transition to low-emission, climate-resilient, and equitable food, land, and water systems in Africa, Asia, and Latin America. It advances science-driven investments, policies, and tools across five Areas of Work, consolidating CGIAR's climate offer with harmonized data and Portfolio-wide impact.

We would like to thank all funders who supported this research through their contributions to the CGIAR Trust Fund (https://www.cgiar.org/funders/).

Contents

Executive summary 4

1. Background of the study 6

1.1. Blue carbon ecosystems and need for sustainable financing 6
1.2. The Integrated Mangrove Aquaculture (IMA) Approach 9
1.3. Objectives and scope of the study 12

2. Fundamentals of Blue Carbon Finance & Carbon Crediting 10

2.1. Core Concepts of Carbon Crediting 10
2.2. Carbon Baselines and Measurement Approaches 12
2.3. Types of Blue Carbon Credits 14
2.4. When to Use Carbon Financing 14

3. Carbon Standards, Market Structures, and Verification 15

3.1. Overview of International Carbon Standards 15
3.2. Carbon Market Structures and Financing Channels 17
3.3. Carbon Financing Project Development Process 18
3.4. Integrity Standards for IMA Projects 19

4. Fundamentals of Blue Carbon Finance & Carbon Crediting 21

4.1. India's Carbon Credit Trading Scheme and the Offset Mechanism 21
4.2. CCTS Mangrove Afforestation and Reforestation Methodology 21
4.3. Carbon Accounting under the Indian Mangrove Methodology 23
4.4. Monitoring, Reporting and Verification Requirements 24
4.5. Potential Project Development Pathway for IMA in the Indian Sundarbans 24
4.6. Companies and Technical Integrators in India for Carbon Market Integration 28

5. IMA Business Models for Carbon Credit Financing 32

6. Major Challenges and Implementation Barriers 49

7. Recommendations and Conclusion 50

8. References 52

Summary


Photo credit: Sourabh Kumar Dubey

Mangroves cover about 147,000 km² of tropical and subtropical coastlines worldwide, with one-third in Southeast Asia, and store on average around 394 tonnes of carbon per hectare, most of it in their soils (Murray et al. 2011; Leal and Spalding 2024). Between 2000 and 2020, conversion to aquaculture, oil palm and rice accounted for about 43% of global mangrove loss, and aquaculture remains the leading human driver of loss in much of South and Southeast Asia; natural retraction through erosion and other coastal dynamics accounted for a further quarter or more (Leal and Spalding 2024). Integrated mangrove aquaculture (IMA) offers a way to reconcile coastal food production with mangrove conservation: farms keep or restore mangroves on part of their area, with recommended designs aiming for about 50% mangrove cover, and combine shrimp, crab and fish production with mangrove protection and restoration. This approach offers potential benefits for both local livelihoods and climate mitigation, but limited access to finance, particularly for the upfront costs of converting existing ponds, remains a major barrier to wider adoption. This brief examines how carbon credit financing could support IMA, focusing on the Indian Sundarbans. It outlines how carbon markets operate, reviews key voluntary carbon standards, including Verra's Verified Carbon Standard (VCS), Gold Standard and Plan Vivo, and examines India's emerging Carbon Credit Trading Scheme (CCTS). The approved mangrove methodology under the CCTS provides a potential pathway for generating carbon credits from eligible mangrove restoration activities. However, only newly planted mangrove areas on degraded habitat, kept separate from ponds and embankments, can be credited under this methodology, so an IMA farm cannot be credited as a whole, and protecting existing mangroves would require a voluntary-market methodology. An illustrative assessment suggests that carbon revenue, at about USD 33–151 per hectare per year, cannot compensate farmers for converting productive ponds, but can cover project costs where several hundred hectares of planting are aggregated.

Four business models are proposed to mobilize carbon finance for IMA:

- **Forward-funded private investment:** Investors or corporate buyers provide upfront finance in exchange for future carbon credits.
- **Community-led financing:** Carbon credits are issued following verification, with revenues channeled back to participating communities.
- **Corporate supply chain insetting:** Companies finance IMA within their own sourcing landscapes to support sustainability and climate targets.

- **National results-based climate finance:** Governments receive payments upon achieving and verifying agreed climate and restoration targets.

Despite its potential, carbon finance faces several barriers, including high upfront and verification costs, delays before carbon revenues are received, uncertainty over land tenure and carbon ownership, limited technical capacity, and the challenges of long-term monitoring and verification. This report recommends clarifying land tenure and carbon ownership, combining carbon finance with grants and other sources of blended finance to cover early-stage costs, strengthening community participation and equitable benefit-sharing, and maintaining high standards of carbon integrity. Ultimately, carbon finance should complement broader public, private and community financing mechanisms rather than serve as a standalone solution for scaling up IMA.

1. Background of the study

1.1. Blue carbon ecosystems and need for sustainable financing

Coastal ecosystems are increasingly recognized as essential components of global climate mitigation and adaptation strategies. Among these ecosystems, mangrove forests have attracted particular attention because of their exceptional capacity to store carbon while simultaneously supporting biodiversity, fisheries, and coastal livelihoods. Together with salt marshes and seagrass meadows, mangroves form the foundation of blue carbon ecosystems, which are coastal and marine habitats that capture atmospheric carbon dioxide and store it within both living biomass and long-lived waterlogged sediments. Unlike many terrestrial ecosystems, mangroves continue to accumulate carbon over extended periods through the burial of organic material in oxygen-poor soils, making them among the most efficient natural carbon sinks on Earth (Murray et al. 2011).

Mangroves store an average of approximately 394 tonnes of carbon per hectare, with nearly 80% of this carbon contained within belowground soils rather than aboveground vegetation (Murray et al. 2011). However, mangrove carbon stocks vary considerably across geographical regions due to differences in ecosystem extent and carbon storage capacity. As shown in Table 1, Southeast Asia contains one of the largest concentrations of global mangrove forests. This regional importance is further reflected in the spatial distribution of mangrove blue carbon stocks, where Southeast Asia represents one of the major global reservoirs of stored mangrove carbon (Figure 1) (Leal and Spalding 2024). These patterns highlight the importance of protecting high-carbon mangrove ecosystems as part of global climate mitigation and blue carbon conservation strategies.

Table 1. Global distribution of mangroves across different regions

Region	Sum of area km^2	Sum of % global
East and Southern Africa	7,749	5.3%
Middle East	358	0.2%
South Asia	9,749	6.6%
Southeast Asia	**49,500**	**33.6%**
East Asia	221	0.2%
Australia and New Zealand	10,348	7.0%
Pacific islands	5,790	3.9%
North and Central America and the Caribbean	21,270	14.4%
South America	19,469	13.2%
West and Central Africa	22,802	15.5%
Total	147,256	100%

Source: Global Mangrove Alliance 2024

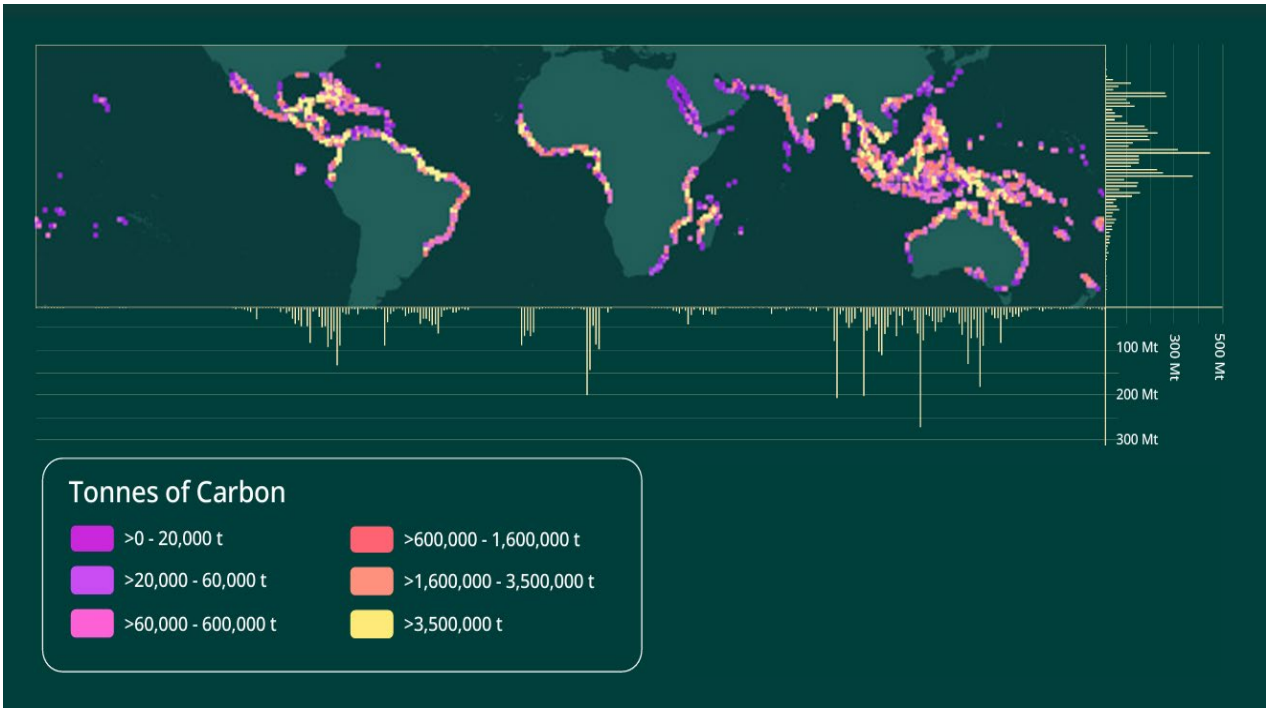


Figure 1. Spatial distribution of mangrove blue carbon stocks. Bar charts represent the total mangrove carbon by latitude and longitude, expressed in million tonnes (Mt).
Source: Global Mangrove Alliance 2024

Beyond carbon sequestration, mangroves provide multiple ecosystem services, including shoreline stabilization, storm protection, water filtration, biodiversity conservation, and habitat provision for fish and invertebrate species that support coastal food systems. These interconnected ecological functions make mangroves critical assets for both climate resilience and the sustainable development of coastal communities (Leal and Spalding 2024).

Despite their global importance, mangrove ecosystems continue to decline under increasing anthropogenic and climatic pressures. Between 2000 and 2020 (Figure 2), approximately 43.3% of global mangrove loss resulted from conversion to aquaculture, oil palm plantations, and rice cultivation, with aquaculture remaining the dominant driver (Figure 3) in many tropical coastal regions (Leal and Spalding 2024). Human-driven conversion is not, however, the only driver of loss. Natural retraction, the loss of mangroves through shoreline erosion, changes in sediment supply, extreme weather events and other natural coastal dynamics, accounted for about 24% of global mangrove loss in 2000–2010 and 29% in 2010–2020, making it the largest single driver category in the most recent decade (Figure 2; Leal and Spalding 2024). This has two implications for carbon finance. First, natural retraction is a permanence risk that projects must address through careful site selection and contributions to buffer pools. Second, it is especially relevant in dynamic deltaic systems such as the Sundarbans, where erosion, island loss and cyclone damage are well documented (World Bank 2014; Bera and Maiti 2019). Among human-driven causes, aquaculture remains the dominant driver in many tropical coastal regions (Figure 3).

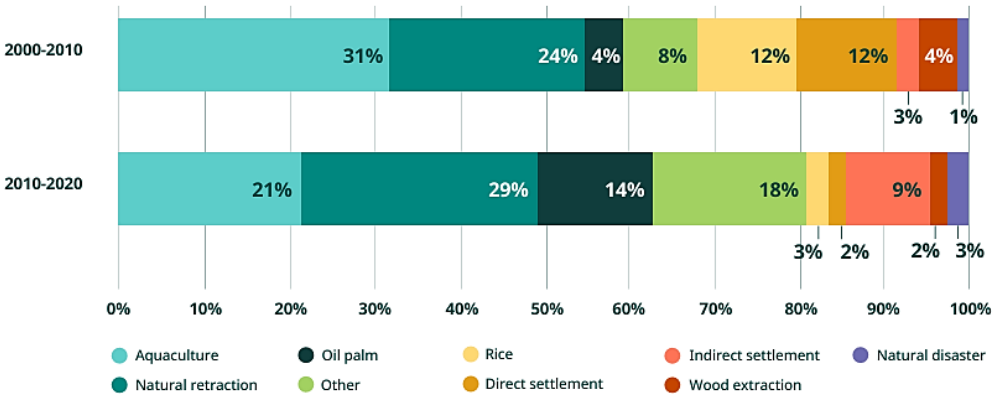


Figure 2. Global drivers of mangrove loss, 2000-2010 and 2010-2020

Source: Global Mangrove Alliance 2024

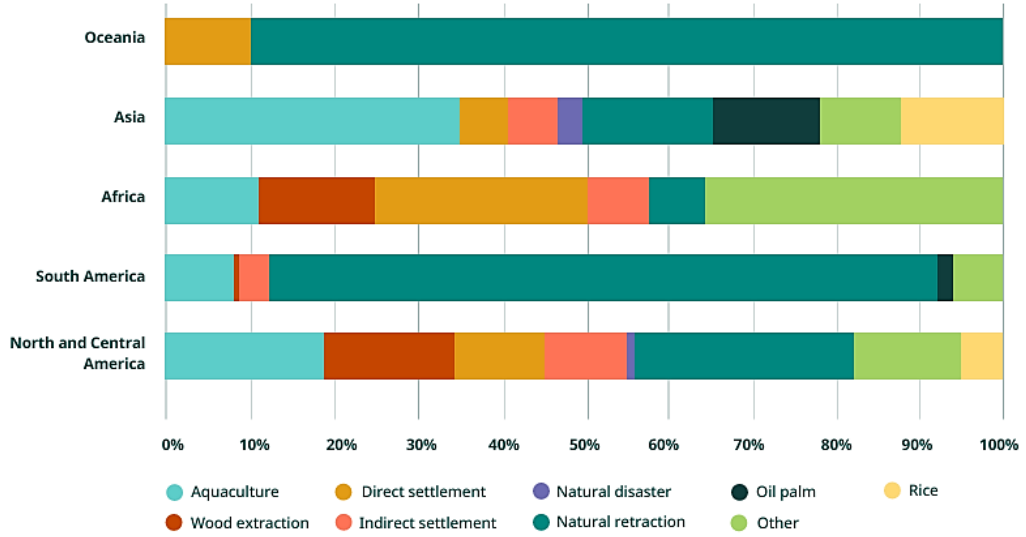


Figure 3. Regional drivers of mangrove loss, 2000-2020
Source: Global Mangrove Alliance 2024

Historically, intensive shrimp aquaculture has generated substantial economic returns but often at high environmental cost. Converting mangrove forests into aquaculture ponds disturbs carbon-rich soils, exposing previously stored organic carbon to oxidation and releasing substantial quantities of greenhouse gases. These emissions can continue for decades following land conversion, while the ecological degradation associated with intensive farming frequently reduces long-term pond productivity and leads to abandoned aquaculture landscapes (Leal and Spalding 2024; Murray et al. 2011).

Addressing these challenges requires financing mechanisms capable of supporting long-term conservation, ecological restoration, and sustainable coastal livelihoods. Blue carbon conservation and restoration are currently supported through multiple financing approaches, including public climate finance, donor-funded conservation programmes, philanthropic investment, blended finance, payments for ecosystem services, and carbon-based financing mechanisms. Each pathway plays a complementary role in mobilizing investment for coastal ecosystem protection and restoration.

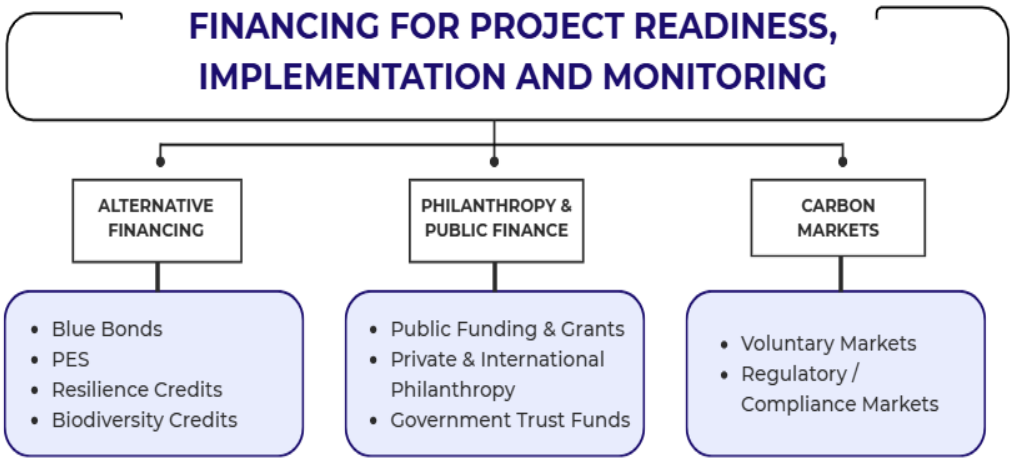


Figure 4. Overview of financing mechanisms supporting blue carbon conservation and restoration
Source: Authors' creation

Figure 4 presents an overview of the principal financing pathways available for blue carbon initiatives. Among these mechanisms, carbon credit financing has emerged as one of the most promising approaches

because it links measurable climate outcomes with long-term financial incentives for ecosystem conservation and restoration. As voluntary and compliance carbon markets continue to evolve, carbon finance is increasingly being explored as a mechanism to support integrated coastal production systems that generate both environmental and socio-economic benefits. While blue carbon finance encompasses a broad range of financing instruments, this technical brief focuses specifically on carbon credit financing as an emerging mechanism to support Integrated Mangrove aquaculture systems. The following sections examine how carbon credits can complement sustainable aquaculture by creating financial incentives for mangrove protection, restoration, and long-term management.

1.2. The Integrated Mangrove Aquaculture (IMA) Approach

Integrated Mangrove Aquaculture (IMA) has emerged as a practical nature-based solution that integrates coastal food production with mangrove restoration. Rather than treating aquaculture development and mangrove conservation as competing land uses, IMA combines both within the same production landscape, allowing restored mangroves to contribute to aquaculture productivity while recovering ecological functions within degraded coastal areas.

Degraded aquaculture landscapes, particularly former mangrove areas affected by intensive shrimp farming, provide important opportunities for ecological restoration while maintaining sustainable coastal livelihoods. IMA offers an alternative production model by transforming these landscapes into multifunctional systems where ecosystems and aquaculture activities support each other.

IMA integrates mangroves within pond embankments and production areas, allowing ecological processes to contribute directly to aquaculture productivity. Restored mangrove vegetation provides habitat complexity, natural food resources, sediment stabilization, and improved water regulation, creating favorable conditions for diverse aquatic species. Consequently, IMA systems commonly adopt polyculture approaches involving shrimp, mud crab, finfish, and filter-feeding shellfish, while reducing dependence on external feed and chemical inputs. Conceptually, IMA represents the aquatic equivalent of agroforestry, where food production occurs within a functioning ecosystem rather than replacing it (Leal and Spalding 2024).

Depending on site characteristics and hydrological conditions, well-designed IMA systems generally maintain or restore approximately 50% mangrove cover within farm boundaries. This integration enhances natural nutrient cycling, improves ecosystem functioning, and supports diversified production opportunities for farmers. Compared with intensive monoculture systems, IMA can reduce operating costs and financial risks by relying more heavily on ecosystem-based production processes rather than expensive external inputs (Leal and Spalding 2024). However, converting existing ponds requires upfront investment, the set-aside of production area and a transition period with lower output, which many farmers cannot finance on their own (see Section 4.6).

Beyond farm-level productivity, IMA generates important social and economic benefits by diversifying household income sources and reducing dependence on high-input aquaculture systems. The combination of ecological restoration and sustainable production provides opportunities to strengthen coastal livelihoods while improving resilience to environmental and market uncertainties. These characteristics position IMA as a strategy capable of advancing food security, climate resilience, biodiversity conservation, and sustainable rural development.

1.3. The Indian Sundarban: site context

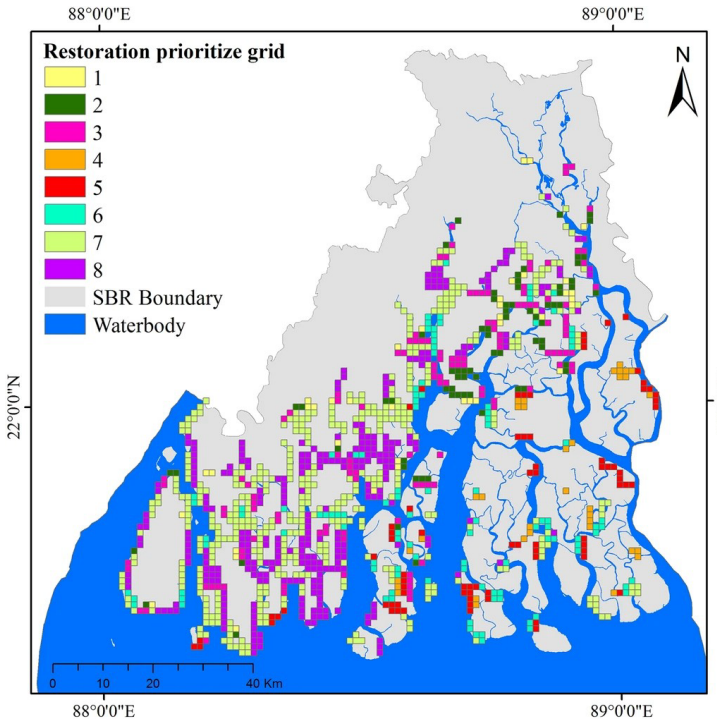
Location and extent

The Sundarbans is the world's largest single mangrove forest, covering about 10,300 km² in the Ganges–Brahmaputra–Meghna delta, of which about 60% lies in Bangladesh and the rest in India (WWF-India

2017). The Indian Sundarbans lies in the South and North 24 Parganas districts of West Bengal. The Sundarban Biosphere Reserve covers about 9,630 km², of which about 4,260 km² is reserve forest (including about 2,300 km² of protected areas). The remainder is a densely populated, embanked landscape of agriculture and aquaculture spread over 19 blocks (WWF-India 2017; World Bank 2014). West Bengal has about 2,119 km² of mangrove cover, about 42% of India's total and the largest of any state (FSI 2024).

Mangrove status and degraded habitat

A Landsat analysis of the Sundarban Biosphere Reserve found that mangrove area fell by about 341 km² between 1975 and 2020, from 22.9% to 19.8% of the reserve. Most of the lost mangrove became swamp (176 km²) or open water (121 km²), with smaller areas lost to settlements (8.6 km²), wetlands (6.5 km²) and sand bars (1.7 km²). About 85% of the loss is attributed to geomorphic, hydrological and climatic processes and about 15% to human activities, although the human share is expected to grow. Degradation hotspots include Dayapur and Annpur villages in Gosaba block and southern Hingalganj (agricultural encroachment), Bakkhali (tourism and coastal erosion) and southern Sagar Island. New mangroves have regenerated on newly accreted char islands, but more slowly than mangroves have been lost (Sahana et al. 2022). Inside the reserve forest, mangrove cover is largely intact but is affected by erosion, island submergence, rising salinity and cyclones (e.g., Aila 2009, Amphan 2020, Yaas 2021). The Indian part of the delta is starved of sediment and is a net erosional system: islands covered by dense mangroves erode at different rates from reclaimed, embanked land, and mangrove planting is recommended as an erosion-control measure (Bera and Maiti 2019). Outside the reserve forest, potential restoration sites include intertidal mudflats and newly accreted land, eroded fringes along embankments and creeks, and abandoned or low-productivity brackish-water ponds. Many of these ponds were created when rising soil salinity, aggravated by cyclone-driven saline flooding, made farmland less productive (Giri et al. 2022). Using habitat-suitability models for 18 true mangrove species on a 1 km grid, Sahana et al. (2022) identified 1,203 of the reserve's 5,609 grid cells (about 1,203 km²) as priorities for restoration. Restoration was judged feasible in highly suitable cells with less than 75% mangrove cover and low human disturbance. The two largest priority classes (431 km² of mixed Avicennia, Bruguiera, Ceriops and Rhizophora, and 314 km² of common species such as Avicennia and Aegiceras that local people use) lie mostly on inhabited islands, where IMA would take place. The authors caution that the 1 km grid overstates what can actually be planted, so these figures are an upper bound for screening sites, not a plantable area.



Code	Scientific Name	Family	Area in sq km
1	Aegialitis rotundifolia	Plumbaginaceae	38
	Aegiceras corniculatum	Myrsinaceae	
2	Avicennia alba	Acanthaceae	74
	Avicennia marina		
	Avicennia officinalis		
3	Bruguiera gymnorrhiza	Rhizophoraceae	127
	Ceriops decandra		
	Ceriops tagal		
	Rhizophora mucronate		
4	Heritiera fomes	Malvaceae	35
	Kandelia candel	Rhizophoraceae	
	Excoecaria agallocha	Euphorbiaceae	
5	Nypa fruticans	Arecaceae	77
	Phoenix paludosa		
6	Sonneratia apetala	Lythraceae	107
	Xylocarpus granatum	Meliaceae	
	Xylocarpus mekongensis		
7	Avicennia alba	Acanthaceae	431
	Avicennia marina	Rhizophoraceae	
	Avicennia officinalis		
	Bruguiera gymnorrhiza		
	Ceriops decandra		
	Ceriops tagal		
	Rhizophora mucronate		
8	Aegialitis rotundifolia	Plumbaginaceae	314
	Aegiceras corniculatum	Myrsinaceae	
	Avicennia alba	Acanthaceae	
	Avicennia marina		
	Avicennia officinalis		

Figure 5. Species wise restoration prioritized grid for selected mangroves in Indian Sundarban
Source: Sahana et al. (2022)

Land tenure and management

Tenure differs sharply between the two zones, and this determines who can own carbon rights. The reserve forest, including the Sundarban Tiger Reserve and the Sundarbans National Park (a UNESCO World Heritage Site), is state land managed by the West Bengal Forest Department, with communities involved through Joint Forest Management Committees and Eco-Development Committees. In the inhabited zone, agricultural land and ponds are mostly privately owned or leased, while embankments are maintained by the Irrigation and Waterways Department, and some intertidal and accreted land is state-owned. Activities in intertidal areas are regulated under the Coastal Regulation Zone (CRZ) Notification 2019 (MoEFCC 2019). As a result, IMA carbon projects on private ponds would need individual or cooperative agreements with landholders, whereas projects on state land would need agreements with the Forest Department or state government (see Section 5.3).

Aquaculture

Brackish-water aquaculture, mainly black tiger shrimp (Penaeus monodon) together with mud crab and finfish, has expanded rapidly in the inhabited zone since the early 2000s. It ranges from traditional tide-fed "bheri" systems to more intensive ponds and is steadily replacing agricultural land, driven mainly by its higher economic returns (Giri et al. 2021; Giri et al. 2022). It has been estimated that more than 50,000 ha were under shrimp cultivation (Giri et al. 2021) with average farm size of 1-2 ha (Ghosal et al. 2019). A survey of 67 aquaculture farmers across all 19 blocks of the reserve found that most farms were small and many were on leased land, with lease rents of INR 45,000–150,000 (USD 607–2,023) per hectare per year. Net profits ranged from INR 150,000–225,000 (USD 2,023–3,034) per hectare per year in traditional brackish-water polyculture and INR 300,000–485,000 (USD 4,045–6,540) in improved-traditional systems, up to INR 2.2–3.6 million (USD 29,665–48,542) in semi-intensive culture of the exotic whiteleg shrimp (Litopenaeus vannamei), whereas the farmers' remaining farmland earned only INR 7,500–67,500 (USD 98–878) (Giri et al. 2022). Mangrove–aquaculture integration has already been piloted locally. Under the Sustainable Aquaculture in Mangrove Ecosystems (SAIME) initiative, NEWS and its partners have worked since 2020 with 42 farmers on 29.48 ha at Chaital (North 24 Parganas) and Madhabpur (South 24 Parganas). These farms keep 5–25% of their area under mangroves, report average yields of 535 kg/ha (200 kg/ha of black tiger shrimp) and have raised farmer incomes by 7–12% (NEWS 2023). The pilot also shows that in practice mangrove cover on Sundarbans farms is well below the 50% design benchmark. A 2019–2020 survey of 28 tide-fed farms in Kultali block, also carried out under SAIME, found an average farm size of 1.21 ha and an average net profit of INR 122,934 per hectare. The 24 farms within 50 m of a mangrove creek earned INR 129,602 per hectare against INR 70,158 for farms farther away, mainly because their operating costs were lower; yields also declined significantly with distance from the creek (Sinha et al. 2024). According to the 2011 Census, more than 4.4 million people live in the Indian Sundarbans, many of them heavily dependent on agriculture, fisheries and aquaculture and highly exposed to climate hazards (WWF-India 2017; World Bank 2014). More than 85% of people in the biosphere reserve depend directly or indirectly on the mangrove ecosystem (Sahana et al. 2022).

Beyond habitat loss, shrimp farming systems in Bangladesh and India are increasingly exposed to cyclones, flooding, salinity intrusion, sea-level rise, and temperature fluctuations that threaten production and livelihoods (Ahmed et al. 2018; Ahmed and Diana 2015). Similar vulnerabilities affect the Sundarbans region shared by Bangladesh and India. Such vulnerabilities are especially evident in the Sundarbans region, where the combined pressures of environmental degradation and climate change pose significant challenges to the long-term sustainability of shrimp farming. These challenges highlight the limitations of conventional production systems and reinforce the need for alternative business models that can maintain profitability while enhancing ecological resilience. In this context, approaches such as IMA offer promising pathways by combining shrimp production with mangrove conservation, ecosystem restoration, and improved resource efficiency (Ahmed et al. 2018; Ahmed and Troell 2010; Chopin et al. 2012).

Existing carbon experience

The Sundarbans already hosts a mangrove carbon project: the Livelihoods Fund–NEWS restoration project, which planted over 16 million mangroves on about 4,400 ha under the VCS (Case Study 9; Livelihoods Funds 2020). NEWS's SAIME pilot, described above, adds direct local experience of integrating mangroves into shrimp farms (NEWS 2023). It shows that community-based mangrove planting can be certified and financed in this landscape, and it is a reference point for the CCTS pathway discussed in Section 4.

1.4. Objectives and scope of the study

Growing international recognition of blue carbon ecosystems has created new opportunities to mobilize finance for coastal conservation and restoration. Among the available financing mechanisms, carbon credit financing has received increasing attention because it generates performance-based financial incentives linked to measurable greenhouse gas emission reductions and carbon removals. When appropriately designed, carbon finance can help bridge funding gaps for mangrove restoration while supporting sustainable aquaculture, biodiversity conservation, and improved livelihoods.

However, realizing these opportunities require robust project design, credible carbon accounting, transparent governance, and equitable benefit-sharing arrangements that ensure local communities receive meaningful economic returns. The environmental integrity of carbon credits depends not only on measurable climate outcomes but also on long-term ecosystem protection and strong social safeguards.

Against this background, this technical brief examines how carbon credit financing can be integrated into Integrated Mangrove Aquaculture systems as part of a broader blue economy framework, with a particular focus on the Indian Sundarbans. The brief introduces the fundamentals of carbon crediting, international carbon standards and market structures, and the integrity requirements that apply to IMA projects. It then examines India's Carbon Credit Trading Scheme (CCTS), including the approved mangrove afforestation and reforestation methodology, its carbon accounting and monitoring, reporting and verification (MRV) requirements, a potential project development pathway for IMA in the Indian Sundarbans, and the technical partners available to support carbon-market integration in India. The present study draws on four business models for financing mangrove restoration through carbon credits that are described in the literature: (i) pre-financing against future credit sales, (ii) community-governed projects, (iii) corporate investment linked to companies' own supply chains (insetting), and (iv) non-market, results-based climate finance (Wylie et al. 2016; Vanderklift et al. 2019; IFC 2023; WEF 2025). To show how these models work in practice, it reviews ten mangrove carbon projects from eight countries in the Global South (Senegal, Thailand, Indonesia, Pakistan, Kenya, Madagascar, Myanmar and India). These are summarized in Table 7 and presented as Case Studies 1–10 in Section 5 and include an existing project in the Indian Sundarbans (Case Study 9). The case studies were purposively selected, not as a representative sample, so that each business model is illustrated by at least one operational project with publicly documented financing and benefit-sharing arrangements, across a range of certification standards, scales and governance settings relevant to the Indian Sundarbans. Drawing on these lessons, the brief then assesses how each model could apply to integrated mangrove–aquaculture (IMA) in the Indian Sundarbans under both India's Carbon Credit Trading Scheme (CCTS) and the voluntary carbon market. It further identifies the technical, financial, and policy challenges associated with implementing carbon-financed mangrove aquaculture projects and provides recommendations for developing high-integrity financing mechanisms that generate lasting climate, biodiversity, and livelihood benefits.

2. Fundamentals of Blue Carbon Finance & Carbon Crediting

2.1. Core Concepts of Carbon Crediting

Carbon crediting is a market-based mechanism that assigns financial value to verified greenhouse gas (GHG) emission reductions or removals. One carbon credit represents one tonne of carbon dioxide equivalent (tCO_2e) that has either been avoided or removed from the atmosphere. Since the climate benefit of reducing or removing one tonne of carbon dioxide is equivalent regardless of where it occurs, carbon credits provide a standardized and tradable instrument for mobilizing finance towards climate mitigation activities (Procton 2024). Credit markets have become one of the most mature and recognizable financing mechanisms for directing private investment into climate mitigation and nature-based solutions, including blue carbon ecosystems (World Economic Forum 2026).

Carbon credits may be generated through international mechanisms administered under the United Nations Framework Convention on Climate Change (UNFCCC), national or subnational government crediting mechanisms, or independent carbon standards such as Verra, Gold Standard and Plan Vivo. Depending on the source of demand, credits may be traded in compliance carbon markets to meet regulatory obligations or in voluntary carbon markets (VCMs), where companies, organizations and other entities purchase credits to achieve voluntary climate commitments or net-zero targets (Procton 2024). Table 2 provides an overview of voluntary carbon market transactions by major project category, while Table 3 presents the breakdown of Forestry and Land Use project types, including blue carbon projects.

Table 2. Voluntary carbon market transactions by project category (2022–2023)

	2022			2023			Percent Change		
Category	**Volume ($MtCO_2e$)**	**Value (Million USD)**	**Price (USD/tCO_2e)**	**Volume (MtCO2e)**	**Value (Million USD)**	**Price (USD/tCO_2e)**	**Volume**	**Value**	**Price**
Forestry & Land Use	113.0	1,100.0	10.14	36.2	353.1	9.72	-68%	-69%	-4%
Renewable Energy	92.7	386.1	4.16	28.6	111.1	3.88	-69%	-71%	-7%
Chemical Processes / Industrial Manufacturing	13.3	68.5	5.14	12.2	50.2	4.10	-8%	-27%	-20%
Household / Community Devices	9.1	77.6	8.55	9.9	76.6	7.70	+10%	-1%	-10%
Energy Efficiency / Fuel Switching	6.6	35.6	5.39	9.4	34.4	3.65	+43%	-3%	-32%
Agriculture	3.8	41.7	11.02	4.7	30.6	6.51	+24%	-26%	-41%
Waste Disposal	6.2	44.9	7.23	1.5	10.9	7.48	-77%	-76%	+3%
Transportation	0.18	0.77	4.37	–	–	–	–	–	–
Forestry & Land Use	113.0	1,100.0	10.14	36.2	353.1	9.72	-68%	-69%	-4%
Renewable Energy	92.7	386.1	4.16	28.6	111.1	3.88	-69%	-71%	-7%
Chemical Processes / Industrial Manufacturing	13.3	68.5	5.14	12.2	50.2	4.10	-8%	-27%	-20%
Household / Community Devices	9.1	77.6	8.55	9.9	76.6	7.70	+10%	-1%	-10%
Energy Efficiency / Fuel Switching	6.6	35.6	5.39	9.4	34.4	3.65	+43%	-3%	-32%
Agriculture	3.8	41.7	11.02	4.7	30.6	6.51	+24%	-26%	-41%
Waste Disposal	6.2	44.9	7.23	1.5	10.9	7.48	-77%	-76%	+3%
Transportation	0.18	0.77	4.37	–	–	–	–	–	–

Source: Procton 2024

Although the Forestry and Land Use category remains the largest within the voluntary carbon market (Table 2), blue carbon projects account for only a small share of total transactions (Table 3). This reflects the relatively early stage of blue carbon market development compared with more established forestry activities such as REDD+ and afforestation/reforestation. Blue carbon projects generally require higher upfront investment, specialized carbon accounting methodologies, long-term ecological monitoring, and robust Monitoring, Reporting and Verification (MRV) systems, making project development more complex and costly. In addition, uncertainties surrounding Article 6 implementation, national carbon market regulations, and corresponding adjustment requirements have slowed the expansion of new projects in many countries. Blue carbon prices have also been volatile. In 2022 blue carbon credits

averaged USD 11.58/tCO_2e, above the Forestry and Land Use average, but in 2023 they fell to USD 8.33/tCO_2e, below the prices paid for afforestation, reforestation and revegetation (ARR; USD 15.74) and improved forest management (IFM; USD 16.21) credits (Table 3). Three factors help explain this. First, the voluntary market as a whole contracted sharply in 2023, with Forestry and Land Use volumes down 68% (Table 2), as buyers responded to integrity concerns, particularly about avoided-deforestation credits. Second, because blue carbon volumes are so small (0.38 $MtCO_2e$ in 2023), average prices depend on a few transactions and on the mix of avoidance and removal credits traded in a given year. Third, buyers are increasingly willing to pay more for removal credits than for avoidance credits, as the higher ARR and IFM prices suggest (Procton 2024). The evidence therefore does not support a general price premium for blue carbon. Higher prices are more likely for removal-based mangrove restoration credits with verified biodiversity, coastal-protection and community co-benefits (World Economic Forum 2026). IMA projects built around mangrove restoration could fall into this segment, but financial planning should not assume a premium. The illustrative assessment in Section 4.6 uses a range of USD 8–16/tCO_2e.

Table 3. Voluntary carbon market transactions by forestry and land use project types (2022–2023)

	2022			2023		
Category	**Volume ($MtCO_2e$)**	**Value (Million USD)**	**Price (USD/tCO_2e)**	**Volume (MtCO2e)**	**Value (Million USD)**	**Price (USD/tCO_2e)**
REDD+ (ALL)	57.4	584.2	10.19	28.2	222.3	7.87
Afforestation-Reforestation and Revegetation (ARR)	10.8	129.8	12.05	4.1	64.8	15.74
Improved Forest Management (IFM)	4.5	66.2	14.67	2.4	38.9	16.21
Blue Carbon	3.4	39.3	11.58	0.38	3.2	8.33

Source: Procton 2024

Irrespective of the financing mechanism or project category, carbon credits must demonstrate that the claimed climate benefits are real, measurable, and verifiable. This is achieved through key principles such as additionality, credible baseline setting, and robust monitoring, reporting, and verification (MRV). Additionally, it ensures that emission reductions or removals would not have occurred in the absence of the carbon finance provided by the project. In other words, carbon finance should enable climate actions that would otherwise be financially, technically or institutionally unfeasible. Closely related to additionality is the establishment of a credible carbon baseline, against which project performance is assessed. If baselines are overestimated, credits may be issued for emission reductions that would have occurred anyway, compromising the environmental integrity of carbon markets (Gold Standard 2026).

The Kyoto Protocol established the first international carbon market mechanisms, including the Clean Development Mechanism (CDM), which allowed emission reduction projects in developing countries to generate Certified Emission Reductions (CERs) that could be used by countries with emission reduction commitments. However, CDM operated largely through a project-based approach, with concerns regarding additionality, baseline inflation, and uneven participation across regions. Under the Paris Agreement, carbon market approaches were redesigned to align with national climate commitments under Nationally Determined Contributions (NDCs). Article 6 of the Paris Agreement provides the framework for international cooperation through both market and non-market approaches. Article 6.2 allows countries to directly cooperate through the transfer of Internationally Transferred Mitigation Outcomes (ITMOs), where transferred emission reductions must be accompanied by corresponding adjustments to avoid double counting against national climate targets. Article 6.4 establishes a new

centralized UN-supervised crediting mechanism intended to replace the CDM, with stricter requirements for baseline setting, additionality, monitoring, reporting and verification (MRV), and alignment with the Paris Agreement's long-term temperature goals (Gold Standard 2026; ; UNFCCC 2015, 2022).

2.2. Carbon Baselines and Measurement Approaches

Carbon crediting relies on robust methodologies for quantifying emission reductions and removals. At the core of these methodologies is the carbon baseline, which represents the expected level of greenhouse gas emissions or carbon stocks in the absence of the project. Emission reductions or removals are calculated by comparing actual project performance against this reference scenario. Consequently, conservative and scientifically robust baseline setting is essential to ensure that issued carbon credits represent genuine climate benefits.

Recent guidance under the Paris Agreement has strengthened baseline requirements to ensure that carbon credits represent genuine climate benefits. Baselines must consider existing and planned policies of the host country, including actions already committed under Nationally Determined Contributions (NDCs), to avoid crediting emission reductions that would have occurred through government action alone. They are expected to be set conservatively below business-as-usual (BAU) emission projections, meaning that the assumed emissions without the project should not be overstated. In addition, baselines should be periodically reviewed and updated to reflect changes in policies, technologies, economic conditions, and sectoral emission trends, ensuring that credit issuance remains aligned with actual mitigation potential (Gold Standard 2026; UNFCCC 2022).

Carbon benefits are estimated using two complementary measurement approaches. Ex-ante estimates are developed during project design to forecast expected emission reductions or carbon removals based on baseline assumptions, carbon models, and project activities. These projections support project feasibility assessments, investment decisions and financial planning. In contrast, ex-post measurements quantify the actual carbon outcomes achieved during project implementation through field measurements, monitoring data and independent verification. Carbon credits are generally issued only after ex-post verification confirms that emission reductions or removals have occurred.

Reliable Measurement, Reporting and Verification (MRV) systems underpin both ex-ante projections and ex-post verification of carbon credits. MRV involves the systematic measurement of greenhouse gas emissions, emission reductions, and carbon removals using approved methodologies, reporting of monitoring data, assumptions, and project activities, and independent verification by accredited third parties to confirm that claimed climate benefits have been achieved. In blue carbon projects, MRV may include assessing ecosystem boundaries, measuring above- and below-ground carbon stocks, monitoring changes in land cover and ecosystem conditions, tracking project interventions, and accounting for potential leakage and permanence risks. These processes ensure that issued credits represent real, measurable, and additional climate benefits. Beyond supporting credit issuance, MRV systems strengthen transparency, improve accountability, and enable countries to report progress towards their Nationally Determined Contributions (NDCs), national greenhouse gas inventories, and Biennial Transparency Reports (BTRs) required under the Paris Agreement (UNFCCC 2015). Robust MRV data also supports investment decisions by reducing uncertainty around carbon sequestration potential, project performance, and long-term climate outcomes.

The effectiveness of carbon crediting programmes depends not only on technical methodologies but also on institutional readiness. Country readiness can vary considerably depending on governance capacity, regulatory frameworks and technical expertise. Establishing effective carbon markets often requires upfront investments in governance systems, market infrastructure, social safeguards, registry systems and institutional arrangements. Similarly, project developers require functional MRV systems, stakeholder engagement processes, risk management frameworks and transparent transaction systems

before projects can participate effectively in carbon markets. Although significant progress has been made, technical capacity constraints, particularly in monitoring coastal and marine ecosystems and generating high-quality MRV data, remain important challenges in many developing countries (Breithaupt et al. 2023; Farzanmanesh et al. 2021).

2.3. Types of Blue Carbon Credits

Blue carbon projects generate carbon credits through two principal climate mitigation approaches: avoided emissions and carbon removals.

Avoided emission credits, sometimes referred to as avoidance credits, are generated by preventing greenhouse gas emissions that would otherwise occur under a defined baseline scenario. These projects protect existing carbon-rich coastal ecosystems from degradation, conversion or unsustainable management. Examples include conserving mangrove forests threatened by aquaculture expansion or coastal development, preventing wetland degradation, or improving the management of existing coastal ecosystems to reduce greenhouse gas emissions. The climate benefit arises from avoiding future emissions that would have resulted from ecosystem disturbance or carbon stock loss.

In contrast, carbon removal credits, also known as Carbon Dioxide Removal (CDR) credits, are generated through activities that actively remove atmospheric carbon dioxide and store it in long-term biological or geological reservoirs. Typical blue carbon removal activities include mangrove restoration, rehabilitation of degraded coastal wetlands, restoration of abandoned aquaculture ponds to mangrove-based systems, seagrass restoration, and other ecosystem rehabilitation measures that increase long-term carbon sequestration.

Blue carbon ecosystems are increasingly recognized within international climate policy and carbon markets. The Intergovernmental Panel on Climate Change (IPCC) has developed internationally accepted methodologies that enable countries to account for blue carbon ecosystems within their national greenhouse gas inventories and NDCs. Consequently, blue carbon has become an actionable component of climate mitigation policy, with both countries and independent carbon standards supporting the development of verified blue carbon projects for voluntary and emerging compliance markets (IPCC 2014).

2.4. When to Use Carbon Financing

Carbon financing is most appropriate when projects can generate measurable, additional and verifiable emission reductions or removals over sufficiently long time horizons to justify the costs associated with project development, monitoring, validation and verification. Project feasibility should therefore consider factors such as expected carbon revenues, project scale, implementation costs, permanence of carbon storage, monitoring requirements and long-term management commitments.

Credit markets have become one of the most advanced financing avenues for blue carbon ecosystems because they provide established accounting methodologies, internationally recognized standards and functioning market infrastructure capable of generating revenue through verified carbon credits (World Economic Forum 2026). For investors, high-quality blue carbon projects represent an emerging investment opportunity capable of delivering both measurable environmental impacts and financial returns, particularly where robust MRV systems, credible governance arrangements and long-term carbon purchase agreements are in place. In practice, concessional and philanthropic funding often plays an important catalytic role during early project development, while blended finance approaches that combine private investment with results-based payments or advance purchase agreements are increasingly viewed as effective mechanisms for scaling blue carbon investments (World Economic Forum 2026).

3. Carbon Standards, Market Structures, and Verification

Despite these opportunities, carbon financing is not appropriate for every project. High transaction costs associated with project registration, monitoring, and independent verification may limit the feasibility of smaller projects unless aggregation approaches or community-based standards are used. Project success also depends on secure land and resource tenure, supportive national policies, effective governance systems, stakeholder participation and adequate institutional capacity. Furthermore, countries must consider how participation in international carbon markets interacts with their own NDC commitments, particularly where corresponding adjustments are required under Article 6 of the Paris Agreement. Consequently, carbon finance should be viewed as one component of a broader blue carbon financing strategy rather than a standalone funding solution.

3.1. Overview of International Carbon Standards

Carbon standards define the rules, methodologies, and verification requirements used to determine whether a climate mitigation activity can generate credible carbon credits. They establish criteria for project eligibility, baseline development, additionality assessment, monitoring, reporting and verification (MRV), and credit issuance. These standards are essential for ensuring that carbon credits represent real, measurable, additional, and permanent emission reductions or removals.

Historically, carbon crediting developed through international mechanisms established under the Kyoto Protocol, particularly the Clean Development Mechanism (CDM), which enabled emission reduction projects in developing countries to generate Certified Emission Reductions (CERs). However, concerns regarding additionality, baseline inflation, and the ability of some projects to generate emission reductions beyond business-as-usual scenarios highlighted the need for stronger approaches. Under the Paris Agreement, carbon crediting has shifted towards more rigorous approaches aligned with national climate commitments, including the mechanisms established under Article 6. Article 6.2 enables countries to cooperate through internationally transferred mitigation outcomes (ITMOs), while Article 6.4 establishes a centralized UN-supervised crediting mechanism designed to replace the CDM with stronger requirements for conservative baselines, transparency, and alignment with Nationally Determined Contributions (NDCs) (UNFCCC 2022; Procton 2024).

Alongside these international mechanisms, independent carbon standards have continued to play a major role in the development of carbon markets, particularly within voluntary carbon markets and nature-based climate solutions. While Article 6 mechanisms operate through government authorization and national accounting frameworks, independent standards provide project-level frameworks that allow non-state actors, including companies and project developers, to generate and trade carbon credits. These standards establish approved methodologies for quantifying emission reductions and removals, define project eligibility requirements, and require validation and verification procedures before credits can be issued.

The Verified Carbon Standard (VCS), administered by Verra, is currently the most widely used independent carbon standard globally. Verra provides methodologies for a wide range of land use and ecosystem restoration activities, including blue carbon projects. Relevant methodologies include

VM0007 REDD+ Methodology Framework and VM0033 Methodology for Tidal Wetland and Seagrass Restoration, which provide approaches for quantifying avoided emissions and carbon removals from coastal ecosystems. Verra methodologies require robust baseline assessment, monitoring systems, leakage assessment, and third-party verification to ensure the credibility of issued credits (Verra 2023a, 2024).

Gold Standard focuses not only on climate mitigation but also on sustainable development outcomes. Gold Standard projects are designed to demonstrate measurable contributions towards the Sustainable Development Goals (SDGs), including improved livelihoods, biodiversity conservation, and community benefits. For blue carbon and other nature-based projects, this emphasis on social safeguards and sustainable development outcomes strengthens project credibility by demonstrating benefits beyond carbon sequestration. Projects that effectively integrate community participation, biodiversity protection, and livelihood improvements may attract greater buyer interest and achieve higher-value credits due to their stronger environmental and social integrity (Gold Standard 2026).

Plan Vivo follows a community-centered approach and is particularly relevant for smallholders, community forestry, and locally managed ecosystem projects. It supports smaller-scale projects by emphasizing participatory design, equitable benefit sharing, and community ownership of carbon activities. This approach can be suitable where local communities are directly involved in ecosystem restoration and conservation activities. Table 4 presents a comparison of major voluntary carbon market standards, including their focus areas, methodologies, verification requirements, and suitability for different project scales.

Table 4. Overview of voluntary carbon market standards

Standard	Methodology Focus	MRV Requirements	Typical Project Scale	Community Engagement	Gender & Social Safeguards	Governance & Benefit Sharing
Verra (VCS)	Robust methodologies for forest conservation, emission reductions, and blue carbon (e.g., VM0007, VM0033).	Highly rigorous MRV with detailed carbon accounting and uncertainty assessment.	Medium to large-scale forestry, land use, and coastal restoration projects.	Stakeholder consultation and Free, Prior and Informed Consent (FPIC).	Inclusive stakeholder participation, including gender considerations.	Independent third-party validation, audits, and benefit-sharing arrangements.
Gold Standard	High-integrity carbon accounting linked to Sustainable Development Goals (SDGs).	Rigorous MRV integrating carbon accounting with SDG impact monitoring.	Small to medium-scale agriculture, forestry, and nature-based projects.	Continuous stakeholder engagement and long-term community participation.	Strong social safeguards promoting gender equality and inclusion.	Independent verification with mandatory community benefit requirements.
Plan Vivo	Community-based carbon accounting for sustainable land management and ecosystem restoration.	Practical, community-based MRV using conservative estimates.	Small to medium-scale community and smallholder projects.	Communities lead project design, implementation, and monitoring.	Strong emphasis on gender equity and local participation.	Independent technical review with equitable benefit-sharing mechanisms.

Source: Authors' creation

3.2. Carbon Market Structures and Financing Channels

Carbon markets provide mechanisms for converting verified emission reductions and removals into financial assets. A carbon credit generally represents one tonne of carbon dioxide equivalent (tCO_2e) reduced or removed from the atmosphere. Credits are generated when a project demonstrates climate benefits beyond what would have occurred under a baseline scenario. The credibility of carbon markets therefore depends on the accuracy of carbon accounting methodologies, additionality assessment, verification systems, and safeguards against double counting.

Carbon finance operates through three main channels: compliance carbon markets, voluntary carbon markets (VCMs), and results-based climate finance (RBCF).

Compliance carbon markets operate under mandatory regulatory systems established by governments or international agreements. These markets enable regulated companies or sectors to meet legally binding emission reduction obligations through emission allowances or approved carbon credits. International mechanisms have evolved from the Kyoto Protocol's CDM towards the Paris Agreement's Article 6 framework. Under Article 6.2, countries may transfer mitigation outcomes through bilateral agreements, while Article 6.4 provides a centralized mechanism for generating internationally recognized mitigation credits. These approaches require stronger accounting rules, including corresponding adjustments, to prevent emission reductions from being counted simultaneously by both the buyer and host country towards their climate targets (Procton 2024).

Voluntary carbon markets (VCMs) allow private companies, organizations, and individuals to purchase carbon credits voluntarily to meet climate commitments, including net-zero strategies. The VCM has become a major source of finance for nature-based solutions, including mangrove conservation, coastal restoration, and other blue carbon projects. Independent standards such as Verra, Gold Standard, and Plan Vivo provide the methodologies and verification frameworks required for generating voluntary credits. Demand for high-quality credits is increasing, particularly for projects that demonstrate additional climate benefits alongside biodiversity conservation and community development outcomes (World Economic Forum 2026).

Results-Based Climate Finance (RBCF) provides payments after predefined climate results have been achieved and independently verified. Unlike carbon offset transactions, emission reductions generated through RBCF generally remain with the host country and contribute towards its NDC targets. RBCF aims to improve accountability and effectiveness by linking financial support directly to measurable outcomes rather than only project implementation. Payments may be provided by governments, multilateral institutions, or development partners after achieving agreed milestones, such as verified emission reductions or ecosystem restoration targets. RBCF programmes depend on strong carbon accounting methodologies, institutional capacity, and reliable MRV systems. The effectiveness of RBCF is influenced by the ability of programmes to establish credible methodologies, engage stakeholders, manage risks, and ensure that verified results reflect genuine climate benefits (BioCarbon Fund 2026).

A commonly used contractual mechanism under RBCF is the Emission Reduction Payment Agreement (ERPA). ERPAs establish the legal and commercial arrangements between buyers and sellers of verified emission reductions, including emission reduction volumes, payment conditions, verification procedures, and responsibilities of participating parties. Payments are made only after emission reductions are independently verified, ensuring that finance is directly linked to demonstrated climate outcomes. ERPA-based approaches have been widely applied in forest and landscape carbon programmes and provide an important model for performance-based climate finance.

The choice of financing mechanism depends on project characteristics, national policy environments, ecosystem type, scale, and institutional readiness. Developing high-integrity carbon projects requires enabling governance frameworks, technical capacity, functional MRV systems, stakeholder engagement mechanisms, and transparent market infrastructure. These requirements are particularly important for blue carbon projects, where ecosystem monitoring, carbon measurement, land tenure, and community participation can influence project feasibility and long-term success.

3.3. Carbon Financing Project Development Process

Developing an IMA carbon finance project involves multiple stages (Figure 5), beginning with assessing technical feasibility, financial viability, ecosystem suitability, and alignment with national climate priorities. Initial feasibility assessments evaluate whether the proposed IMA intervention can generate measurable emission reductions or carbon removals, whether suitable carbon accounting methodologies are available, and whether carbon finance can provide sufficient revenue to support mangrove restoration, sustainable aquaculture practices, and long-term ecosystem management. Key considerations include the potential for mangrove carbon sequestration, avoided mangrove degradation, restoration of degraded coastal areas, aquaculture management practices, project scale, and community participation.

A critical requirement for IMA carbon projects is demonstrating additionality, meaning that the climate benefits generated by mangrove restoration or improved aquaculture management would not have occurred without carbon finance or related incentives. Additionality ensures that credits represent genuine climate benefits rather than activities that would have occurred under existing practices or regulations. Projects must also establish a credible baseline scenario that represents expected carbon emissions, removals, or ecosystem conditions in the absence of the IMA intervention. Under evolving Paris Agreement requirements, baselines are expected to be conservative, consider existing national policies and climate commitments, and avoid crediting emission reductions that would have occurred without the project (Procton 2024).

Following project design, developers must establish monitoring, reporting, and verification (MRV) systems to quantify carbon outcomes and track ecosystem changes over time. In IMA projects, MRV may involve monitoring mangrove extent, above- and below-ground biomass carbon, sediment carbon stocks, land-use changes, aquaculture practices, and potential leakage risks. These systems provide the evidence required to verify carbon removals or avoided emissions and support transparency under national greenhouse gas inventories and Paris Agreement reporting frameworks. However, developing effective MRV systems can be challenging due to technical requirements, financial costs, and limited capacity among local stakeholders, particularly in coastal and marine ecosystems where carbon measurement and monitoring remain complex (Breithaupt et al. 2023; Farzanmanesh et al. 2021).

Once project documentation is prepared, projects undergo independent validation by accredited auditors to assess compliance with the requirements of the selected carbon standard. Following implementation, periodic verification confirms whether the claimed emission reductions or removals have been achieved. Verified outcomes are then issued as carbon credits or used to trigger results-based payments depending on the financing mechanism. For IMA projects, verification may also assess compliance with social and environmental safeguards, including community participation, biodiversity protection, and sustainable resource management (Gold Standard 2026; Murray et al. 2011).

For results-based climate finance (RBCF) programmes, verified climate results are often linked to contractual agreements such as Emission Reduction Payment Agreements (ERPAs), where payments are released after achieving and independently verifying agreed emission reduction targets. For

voluntary carbon market projects, verified emission reductions or removals are issued as carbon credits that can be purchased by companies or organizations seeking to address residual emissions and support climate action. In both cases, the quality of the carbon outcome depends on robust methodologies, reliable MRV systems, and effective project governance (BioCarbon Fund 2026; Procton 2024; World Bank Group 2026).

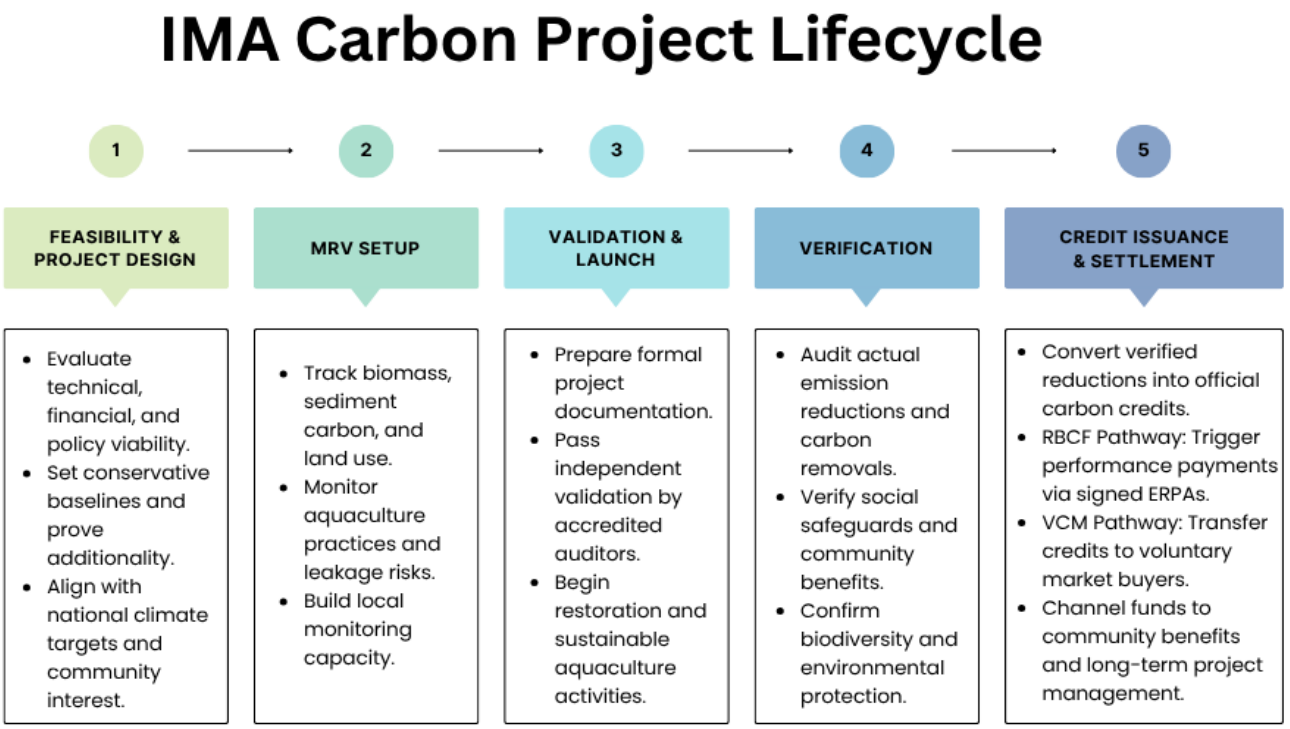


Figure 5. Stages of an IMA Carbon Financing Project
Source: Authors' creation

3.4. Integrity Standards for IMA Projects

High-integrity IMA carbon projects require more than carbon accounting alone. Environmental, social, and governance safeguards are essential to ensure that carbon finance generates durable climate benefits while supporting mangrove ecosystem resilience, sustainable aquaculture production, and coastal community livelihoods (Gold Standard 2026; Procton 2024).

Permanence is a key consideration for IMA projects because stored carbon in mangrove biomass and sediments can be released if ecosystems are degraded or disturbed. Coastal development, conversion of mangroves, extreme weather events, and unsustainable aquaculture expansion can threaten long-term carbon storage. Therefore, IMA projects require long-term management strategies, restoration monitoring, and risk mitigation measures to maintain carbon benefits over time (Gold Standard 2026; Murray et al. 2011).

Leakage prevention is also critical. Leakage occurs when emission reductions within the project area lead to increased emissions outside the project boundary, such as displacement of mangrove clearing or unsustainable aquaculture activities to neighboring areas. Credible carbon methodologies require projects to identify potential leakage pathways and implement measures to minimize these risks through effective land-use planning, stakeholder engagement, and sustainable livelihood alternatives (Gold Standard 2026; Procton 2024).

Land tenure, governance arrangements, and community rights strongly influence the success of IMA projects. Clear ownership or access rights, transparent benefit-sharing mechanisms, and meaningful participation of local communities are essential to ensure equitable outcomes and avoid conflicts. Since many coastal communities depend on mangroves and aquaculture for their livelihoods, IMA projects should integrate local knowledge, strengthen community capacity, and ensure that carbon revenues contribute to sustainable development outcomes. However, local stakeholders may face limitations in technical capacity for carbon monitoring, reporting, and project management, highlighting the importance of capacity-building and inclusive governance approaches (Breithaupt et al. 2023).

Monitoring, Reporting and Verification (MRV) systems are central to maintaining credibility and investor confidence. Reliable MRV enables accurate estimation of carbon stocks, tracks ecosystem recovery, supports national climate reporting, and reduces uncertainty associated with investment decisions. For IMA systems, MRV approaches must account for the dynamic interactions between mangrove ecosystems and aquaculture activities, including changes in vegetation cover, carbon storage, and management practices. Improving monitoring approaches remains a priority due to challenges associated with measuring below-ground carbon stocks and coastal ecosystem dynamics (Farzanmanesh et al. 2021; Murray et al. 2011).

Finally, successful IMA carbon projects depend on broader country and institutional readiness. Governance systems, regulatory frameworks, technical capacity, market infrastructure, and stakeholder engagement mechanisms influence the time, cost, and feasibility of developing carbon projects. Establishing these enabling conditions is essential for scaling high-integrity IMA investments and ensuring that carbon finance contributes not only to climate mitigation but also to coastal resilience, biodiversity conservation, sustainable aquaculture development, and improved livelihoods.

4. India’s Carbon Credit Trading Scheme: A Pathway for IMA in the Sundarbans

4.1. India’s Carbon Credit Trading Scheme and the Offset Mechanism

India is developing a domestic carbon market through the Carbon Credit Trading Scheme (CCTS), which provides a national framework for generating and trading carbon credits. The scheme consists of a compliance mechanism for obligated industrial entities and an offset mechanism through which non-obligated entities can voluntarily develop eligible climate mitigation projects and generate Carbon Credit Certificates (CCCs). The offset mechanism therefore creates a potential entry point for nature-based projects, including mangrove restoration and afforestation, that fall outside the mandatory emissions-intensity obligations applicable to designated industrial installations (Reclimatize 2026).

The Government of India approved the first phase of methodologies for the CCTS Offset Mechanism in March 2025. The initial group comprises eight methodologies covering activities including renewable energy, green hydrogen, industrial energy efficiency, landfill gas capture, mangrove afforestation and reforestation, energy storage, offshore wind, and compressed biogas. The inclusion of mangrove afforestation and reforestation represents an important development for coastal nature-based solutions because it establishes a nationally recognized methodology for quantifying carbon removals associated with the restoration of degraded mangrove habitats (BEE 2025a; Reclimatize 2026).

Although IMA is fundamentally a combined ecosystem restoration and sustainable aquaculture approach, the approved CCTS methodology provides a potential carbon-financing pathway specifically for the mangrove restoration component. Under such an approach, carbon revenue generated from eligible mangrove restoration activities could complement income generated through shrimp, crab, fish, and other aquaculture activities, thereby creating a diversified financial model for coastal communities.

The Offset Mechanism is voluntary and allows non-obligated entities to register eligible projects and generate CCCs after demonstrating compliance with the applicable methodology and completing the required validation, monitoring, and verification processes. The resulting credits may potentially serve both compliance-related demand and voluntary corporate demand within India's emerging carbon market, creating opportunities for project developers to connect nature-based climate projects with domestic buyers (Reclimatize 2026).

4.2. CCTS Mangrove Afforestation and Reforestation Methodology

The CCTS methodology for mangrove afforestation and reforestation (BM FR05.001) is specifically applicable to degraded mangrove habitats. The methodology was adopted with an effective date of 27 March 2025 and is based on the latest approved version of the UNFCCC Clean Development Mechanism methodology AR-AM0014. The methodology permits afforestation and reforestation

activities in wetlands constituting degraded mangrove habitat and establishes specific conditions governing vegetation composition, hydrology, soil disturbance, carbon pools, baseline development, additionality, leakage, and monitoring (United Nations 2026).

For a project to apply the methodology, the land must qualify as degraded mangrove habitat. The methodology defines degraded mangrove habitat as wetlands where mangrove vegetation can naturally occur, where soils or sediments are generally waterlogged with saline or brackish water, and where previous impacts have resulted in a reduction in forest cover relative to the level reported by the host party. This requirement is particularly relevant when identifying potential IMA intervention sites, as the carbon-crediting component would need to be located within areas that satisfy the methodology's definition rather than simply within any coastal aquaculture landscape (BEE 2025a).

The methodology also establishes specific requirements regarding vegetation composition and hydrology. More than 90% of the project area must be planted with mangrove species. If non-mangrove species are planted on more than 10% of the project area, the project activity must not alter the hydrology of the project area or of any connected wetland areas located upstream or downstream. In addition, soil disturbance attributable to the project activity must not exceed 10% of the project area. These requirements are particularly important for IMA design because aquaculture infrastructure, pond excavation, embankment construction, or other interventions must be planned so that activities associated with the production system do not compromise the eligibility conditions of the mangrove carbon project (United Nations 2026).

Implications for IMA eligibility. These conditions mean that a typical IMA farm, which keeps about half its area in mangroves and the rest in ponds, cannot be credited as a single unit. Pond excavation and embankment maintenance would exceed the 10% soil-disturbance limit, and the pond area would not meet the requirement that more than 90% of the project area be planted with mangroves (BEE 2025a). Under BM FR05.001, crediting is possible only if the project boundary is drawn around the mangrove planting areas alone (for example, consolidated planted blocks or broad intertidal fringes). These areas must qualify as degraded mangrove habitat, meaning saline or brackish waterlogged land whose forest cover has fallen below India’s forest definition (15% crown cover, 0.05 ha, 2 m tree height; GoI 2008). They must also remain undisturbed by farming. Ponds, embankments and active production areas would lie outside the carbon boundary. Where pond area is converted to mangroves, any loss of aquaculture production must not simply move to new ponds elsewhere. The CCTS leakage tool addresses only displaced crop cultivation and grazing, whereas VM0033 explicitly requires that displaced aquaculture does not degrade other wetlands (Verra 2023a).

Two consequences follow. First, the creditable area is at most the share of each farm that is newly planted with mangroves: roughly up to half of a farm converted under a 50% design, and less where mangroves are planted on raised embankments that may not meet the waterlogged-soil criterion. Second, the methodology credits only removals from new planting: tree and shrub biomass, plus optional dead wood and soil organic carbon. Soil carbon is credited at a default 0.50 t C/ha/yr for 20 years unless site data justify another value (BEE 2025a). Measurements on Satjelia Island suggest that soil carbon in young Sundarbans plantations can accumulate much faster: organic carbon density in the top 30 cm rose from 54–69 t/ha at planting to 83–132 t/ha within five years (Chowdhury et al. 2018). Part of this gain is likely to be sediment-derived (allochthonous) carbon, which crediting methodologies discount, but it indicates that site-specific measurement could justify more than the default. Mangroves already on farms, or protected from clearing by the project, earn no credits under the CCTS. Protecting them could be credited only in the voluntary market, through the Conservation of Intact Wetlands activity under Verra’s VM0007 framework (module VMD0051; Verra 2023b, 2024). Restoration with measured soil carbon and avoided soil-carbon loss could use VM0033 (Verra 2023a). A parcel cannot be registered under both the CCTS and a voluntary standard at the same time (BEE 2025b).

Feasibility studies for IMA in the Sundarbans should therefore (i) map, farm by farm, the eligible degraded habitat available for new planting, and combine parcels into a grouped project or Programme of Activities to reduce transaction costs, noting that the CCTS fixes a group's make-up at registration (BEE 2025b); (ii) design farm layouts so that planted mangroves form consolidated, undisturbed blocks of at least 0.05 ha that can be monitored on their own; and (iii) decide parcel by parcel whether the CCTS or a voluntary standard fits better, using the voluntary market where protecting existing mangroves or measured soil-carbon gains are the main climate benefit.

Accordingly, an IMA project should not be considered a conventional aquaculture project with carbon credits added as an additional revenue stream. Instead, the project could be structured around an eligible mangrove restoration or afforestation activity, with sustainable aquaculture integrated within the wider landscape in a manner that is compatible with the requirements of the carbon methodology. The carbon component would therefore provide climate-finance revenue, while aquaculture would provide direct production and livelihood income. .This distinction is important for the financial assessment in Section 4.6 and for the business models in Section 5; Section 5.3 shows how each model could use the CCTS pathway.

4.3. Carbon Accounting under the Indian Mangrove Methodology

The CCTS methodology requires project developers to establish a credible baseline and demonstrate additionality using the approved CCTS tool BM-T-AR-0001: Combined Tool to Identify the Baseline Scenario and Demonstrate Additionality in A/R ICM Project Activities. The baseline represents the expected carbon stock changes in the project area in the absence of the proposed project activity. Demonstrating additionality is therefore necessary to establish that the carbon removals associated with the project represent mitigation outcomes attributable to the intervention rather than changes that would have occurred without the project (BEE 2025a).

Carbon accounting under the methodology focuses primarily on changes in biomass carbon stocks. Above-ground biomass and below-ground biomass are included as carbon pools, while the litter pool is excluded. Accounting for dead wood and soil organic carbon (SOC) is optional. The methodology also provides procedures for accounting for relevant non-CO_2 emissions, including methane (CH_4) and nitrous oxide (N_2O) associated with the burning of woody biomass where such activities occur (BEE 2025a).

For the soil organic carbon pool, the methodology assumes a default annual increase of 0.50 t C ha^{-1} for up to 20 years after planting. However, a different rate may be used if it is supported by transparent and verifiable data. The methodology also requires carbon losses associated with the displacement of agricultural activities from the project area to be accounted for as leakage. Therefore, the carbon removal credited by the project is not simply the total amount of carbon stored in the restored area. Instead, net anthropogenic greenhouse gas removals are calculated by accounting for the carbon removed by the project, the removals that would have occurred under the baseline scenario, and any applicable leakage (BEE 2025a).

For IMA projects, this distinction is important when estimating potential carbon revenues. Carbon credits should be calculated only from the net carbon removals that are eligible for crediting under the methodology and can be attributed to the mangrove restoration activity. The total carbon stored across the entire IMA landscape should not be treated as carbon-creditable by default. Therefore, financial assessments should clearly distinguish between (i) the portion of the project area and associated activities eligible for carbon crediting and (ii) the wider IMA area that supports aquaculture and other

livelihood activities. This distinction helps avoid overestimating the carbon revenue that an IMA project could generate.

4.4. Monitoring, Reporting and Verification Requirements

Robust Monitoring, Reporting and Verification (MRV) is essential for demonstrating that a project continues to meet the requirements of the CCTS Offset Mechanism and that its reported carbon removals are reliable. Under the mangrove methodology, project proponents must establish a monitoring system that can: (i) demonstrate continued compliance with the methodology's applicability conditions; (ii) measure changes in relevant carbon pools; and (iii) account for emissions from the project and any leakage. Monitoring data must also be properly recorded and retained for at least two years after the end of the project's final crediting period (BEE 2025a).

The methodology also requires project proponents to describe their forest inventory and management practices in the Project Design Document (PDD). This means that the project must clearly explain how information on vegetation, biomass, and carbon stocks will be collected and managed. Where no suitable nationally accepted procedures are available, the project must establish Standard Operating Procedures (SOPs) and Quality Assurance/Quality Control (QA/QC) procedures for field measurements and data management. If biomass is not evenly distributed across the project area, the area may need to be divided into different strata so that biomass and carbon stocks can be estimated more accurately (BEE 2025a).

For IMA projects, these requirements mean that the MRV system should cover both the mangrove restoration component and its interaction with the wider aquaculture landscape. For example, satellite imagery and GIS can be used to track changes in mangrove extent, vegetation cover and land use over time. Field surveys are then needed to measure parameters such as tree survival, tree growth, species composition and biomass, which provide the information required for carbon-stock estimation. The monitoring system should also record restoration activities, changes in vegetation, soil disturbance and other factors that could affect the project's eligibility or carbon-removal estimates.

The MRV system therefore needs to combine spatial monitoring, field measurements, carbon accounting and proper documentation. Remote sensing can provide regular information on changes across the wider project area, while field measurements can provide the detailed data needed to estimate biomass and carbon stocks. Together, these sources can provide evidence that the reported carbon removals are based on actual and measurable changes.

Finally, validation and verification provide an independent check on the project's claims. Under the CCTS framework, the non-obligated entity and the Accredited Carbon Verification Agency (ACVA) have responsibilities for ensuring that the approved methodology is correctly applied and that the project's activities and reported results are appropriately validated and/or verified. Therefore, IMA project proponents may require support from organizations with expertise in carbon accounting, MRV, project documentation, and verification preparation to ensure that the project is adequately prepared for the validation and verification process (BEE 2025a).

4.5. Potential Project Development Pathway for IMA in the Indian Sundarbans

The Indian Carbon Credit Trading Scheme (CCTS) provides a structured pathway through which Integrated Mangrove Aquaculture (IMA) projects can potentially access carbon-market finance. As illustrated in Figure 7, the CCTS Offset Mechanism follows a seven-step process organized into four

phases: Pre-Registration, Registration, Pre-Issuance, and Issuance. The process begins with project account registration and preparation of the Project Design Document (PDD), followed by independent validation, formal project registration, project implementation and monitoring, independent verification, and, finally, issuance of Carbon Credit Certificates (CCCs).

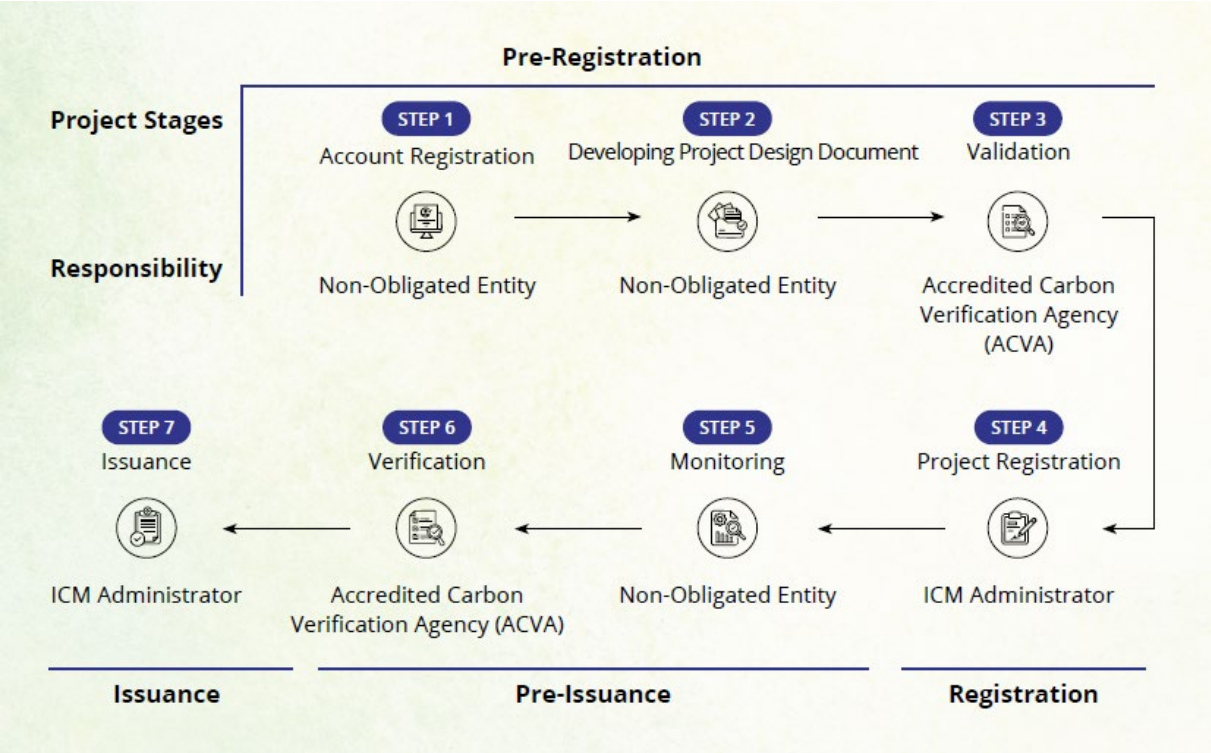


Figure 6. The seven-step project lifecycle and entity responsibilities under the CCTS Offset Mechanism. Source: BEE 2025a

During the pre-registration phase, the project proponent first registers as a Non-Obligated Entity on the Indian Carbon Market (ICM) platform and prepares the PDD. For an IMA project, the PDD development stage is particularly important because it establishes whether the proposed site and activities meet the approved mangrove methodology and other CCTS requirements. This includes assessing whether the site qualifies as degraded mangrove habitat, confirming compliance with requirements related to mangrove species, hydrology and soil disturbance, and establishing the baseline and additionality of the project. These assessments should be undertaken alongside ecological, socio-economic and aquaculture feasibility assessments to determine whether mangrove restoration and aquaculture activities can be implemented together without compromising either carbon eligibility or livelihood objectives.

The completed PDD is then independently validated by an Accredited Carbon Verification Agency (ACVA). Validation provides an external assessment of the proposed project's baseline, carbon accounting approach, and conformity with the applicable CCTS methodology. Following successful validation, the project enters the Registration phase, during which the project documentation is submitted to the ICM Administrator for review and formal registration under the CCTS Offset Mechanism.

After registration, the project enters the pre-issuance phase. The Non-Obligated Entity implements the approved mangrove restoration and compatible IMA activities and conducts ongoing monitoring in accordance with the approved monitoring plan. Monitoring should generate both field-based and geospatial evidence of changes in vegetation, biomass, and carbon stocks, while also demonstrating continued compliance with the methodology. The monitoring results are subsequently assessed through

independent verification by an ACVA, which examines the monitoring reports and supporting evidence to determine whether the reported net carbon removals have actually been achieved.

The final Issuance phase follows successful verification. Once the ACVA's verification report has been accepted and the applicable procedural requirements have been completed, the ICM Administrator issues CCCs to the project entity for the eligible and verified carbon outcomes. These certificates can then provide a potential source of carbon-market revenue, subject to applicable CCTS rules, market arrangements and buyer demand.

For IMA systems, the significance of this pathway extends beyond carbon-credit generation. It creates a potential link between three mutually reinforcing components: (i) mangrove restoration and carbon sequestration, (ii) sustainable aquaculture and livelihood generation, and (iii) carbon-market finance. Mangrove restoration generates ecological and carbon benefits, while compatible aquaculture activities provide livelihood and income opportunities. The resulting carbon revenues can potentially diversify household or project-level income and create an additional economic incentive for maintaining restored mangrove ecosystems over the long term.

Thus, the CCTS pathway should be viewed not simply as a mechanism for selling carbon credits, but as a potential financing framework that links verified ecosystem restoration with sustainable livelihood activities. For IMA projects, however, the financial viability of this model will depend on the area and activities that are actually eligible for crediting, the quantity of net carbon removals achieved, the costs of project development and MRV, and the eventual price and marketability of the issued CCCs.

4.6. Illustrative Financial Assessment for IMA Carbon Projects

This section illustrates the order of magnitude of carbon revenue an IMA project might generate. It is a desk-based assessment that uses published values only; it is not a feasibility study, and site-level data should replace these values before any investment decision.

Carbon revenue depends on three factors: the eligible planted area (Section 4.2), net creditable removals per hectare, and the credit price. Under BM FR05.001, soil organic carbon accrues by default at 0.5 t C ha^{-1} yr^{-1} (about 1.8 tCO_2 ha^{-1} yr^{-1}) for 20 years after planting and is added to biomass growth (BEE 2025a). The Sundarbans restoration project (Case Study 9) expects about 1.02 million credits from 4,403 ha over 2010–2030 (ID-RECCO 2022), which implies about 11.6 tCO_2e ha^{-1} yr^{-1}. We therefore use a range of 5–12 tCO_2e ha^{-1} yr^{-1} and deduct 20% for uncertainty and leakage. Prices range from the 2023 blue carbon average (USD 8.33) to the 2023 ARR average (USD 15.74), with the 2022 blue carbon average (USD 11.58) as the central case (Table 3). Prices for CCCs under the CCTS are not yet known. Because the CCTS limits crediting to 15 years at most (BEE 2025b), all fixed costs are spread over 15 years. Transaction costs come from FAO (2010), the most detailed published breakdown for land-use carbon projects. Its 2010 euro values are converted to 2025 US dollars at the 2010 average exchange rate of USD 1.3257 per euro (ECB 2011) and adjusted for US consumer price inflation between 2010 and 2025 (CPI-U 218.056 to 321.943; BLS 2026), a combined factor of about 1.96.

Table 5. Illustrative carbon revenue and costs for an IMA carbon project in the Indian Sundarbans

Item	Low case	Central case	High case	Basis
Gross removals (tCO_2e/ha/yr)	5	8	12	Methodology default for SOC plus biomass growth (BEE 2025a); Case Study 9 implies about 11.6 (ID-RECCO 2022)

Deductions (uncertainty, leakage)	20%	20%	20%	Assumption. BM FR05.001 handles non-permanence through temporary or long-term CCCs rather than a buffer pool (BEE 2025a); the price discount for such credits is not yet known.
Net creditable (tCO_2e/ha/yr)	4.0	6.4	9.6	Calculated
Price (USD/tCO_2e)	8.33	11.58	15.74	Procton 2024 (Table 3)
Gross carbon revenue (USD/ha/yr)	≈ 33	≈ 74	≈ 151	Calculated
Project development to registration (USD 2025, one-off)	340,000	255,000	165,000	Feasibility, documentation, data collection and validation: EUR 85,000–175,000 in 2010 (FAO 2010), ≈ USD 166,000–343,000 in 2025. Consistent with USD 200,000–250,000 in 2008 for A/R CDM projects (Baalman and Schlamadinger 2008, cited in FAO 2010), ≈ USD 300,000–375,000 in 2025
Verification (USD 2025 per event, three events in 15 years)	49,000	34,000	20,000	EUR 10,000–25,000 per verification in 2010 (FAO 2010), ≈ USD 19,600–48,900 in 2025
Ongoing monitoring (USD 2025/yr, project level)	49,000	28,000	7,000	EUR 3,500–25,000 per year in 2010 (FAO 2010), ≈ USD 6,900–48,900 in 2025
Annualized fixed costs over 15 years (USD/yr)	≈ 81,500	≈ 51,800	≈ 22,000	(Development + verifications) ÷ 15 + monitoring
Break-even planted area (ha)	≈ 2,450	≈ 700	≈ 150	Fixed costs ÷ revenue per ha; excludes planting and maintenance
Revenue per household with 0.5 ha newly planted (USD/yr, gross)	≈ 17	≈ 37	≈ 76	Before costs and benefit-sharing
For comparison: net aquaculture profit (USD/ha/yr)	2,023	–	6,540	Traditional to improved-traditional brackish-water polyculture; semi-intensive L. vannamei earns USD 29,665–48,542 (Giri et al. 2022, Table 3; 2020 exchange rate)
For comparison: pond lease rent (USD/ha/yr)	607	–	2,023	INR 45,000–150,000; 23 of 41 lessees paid INR 45,000–80,000 (USD 607–1,079) (Giri et al. 2022, Table 2)
For comparison: net agricultural profit (USD/ha/yr)	98	–	878	INR 7,500–67,500, farmers' remaining farmland (Giri et al. 2022)
For comparison: net profit of extensive tide-fed farms, Kultali (USD/ha)	903	1,598 (mean)	2,141	INR 69,478–164,680/ha across farm-size groups, mean INR 122,934; farms within 50 m of a mangrove creek INR 129,602 against INR 70,158 farther away (Sinha et al. 2024; converted at USD 0.013 per INR, as in Giri et al. 2022)
For comparison: community planting cost, Satjelia Island (EUR/ha, 2012)	6	–	255	Direct propagule dibbling of Avicennia marina (71 ha) to drain-and-trench planting of Rhizophora mucronata; nursery-seedling transplanting EUR 138–152/ha. Planting only; excludes protection and maintenance (Chowdhury et al. 2018, Table 1)
For comparison: mangrove planting cost (USD/ha)	≈ 930	–	8,143	INR 77,000/ha for a 2021 West Bengal Forest Department plantation (Bhattacharya and Sen 2022); global median implementation cost (Goto et al. 2025)

Source: Authors' calculations based on the sources cited.

Three conclusions follow. First, carbon revenue cannot compensate farmers for converting productive ponds. At USD 33–151 per hectare per year, it is less than 8% of the net profit from traditional and

improved-traditional brackish-water aquaculture (USD 2,023–6,540 per hectare), less than 0.5% of the profit from semi-intensive shrimp culture, and well below the USD 607–2,023 per hectare per year that farmers pay to lease pond land (Giri et al. 2022). Even for the extensive tide-fed farms surveyed in Kultali block, whose net profits are lower, carbon revenue would be at most about one-sixth of net profit (Sinha et al. 2024). It is of the same order only as profits from the least productive, salt-affected farmland (USD 98–878 per hectare; Giri et al. 2022). A farm that newly plants half a hectare would earn a few tens of US dollars a year. Carbon finance is therefore best suited to planting on land with little or no current aquaculture value, such as abandoned or low-productivity ponds, eroded embankment fringes and mudflats (Section 1.3). Second, at an aggregated project scale carbon finance can matter. In the central case, about 700 ha of eligible planting is needed to cover development, verification and monitoring costs at 2025 prices; in the low case about 2,450 ha is needed, and even in the high case about 150 ha, so aggregation through a grouped project (Section 4.2) and grant co-financing are essential. Over a 15-year crediting period, central-case revenue of about USD 1,100 per hectare would more than cover the planting itself. Planting costs in the Sundarbans range from about EUR 6 per hectare for direct propagule dibbling to EUR 255 per hectare for labour-intensive Rhizophora planting in a community programme on Satjelia Island (2012 prices; Chowdhury et al. 2018), and about INR 77,000 (USD 930) per hectare for a 2021 government plantation (Bhattacharya and Sen 2022). All are far below the global median implementation cost of USD 8,143 per hectare (Goto et al. 2025). The larger costs are survival and protection. Survival on Satjelia ranged from 27% for direct seeding to 39–100% for transplanted seedlings, depending on species, and was higher where community committees were paid to guard the plantations (Chowdhury et al. 2018); survival of about 30% has been reported elsewhere in the Sundarbans (Bhattacharya and Sen 2022). Low survival raises effective costs and reduces credits, so a share of carbon revenue should be reserved for protection and replanting. Third, because credits are issued only after verification, typically several years after planting, revenue arrives after costs are incurred, which is why pre-financing and blended finance (Models 1 and 4) are important.

Additionality. IMA can reduce operating costs and financial risk once established (Section 1.2), but these benefits arrive only after a costly transition. Converting existing ponds requires upfront investment in earthworks and planting, the permanent set-aside of up to half the pond area, and a transition of several years with lower output before mangroves mature and their ecosystem benefits appear. Smallholders typically lack the credit, security of tenure and technical support to bear these costs, and in the short term intensive monoculture can yield higher private returns, which is why conversion to ponds has continued; in the Indian Sundarbans, higher economic returns are the main driver of the shift from agriculture to aquaculture (Giri et al. 2022). In the SAIME pilot, farmers themselves paid 30–40% of the cost of reshaping their land (NEWS 2023), which shows that conversion costs are real even where farmers are willing. The private benefits of mangroves are also poorly recognized. In Kultali, farms within 50 m of a mangrove creek earned higher net profits with lower operating costs, yet only 13% of farmers planned to invest any of their revenue in maintaining mangroves around their ponds and only 46% saw mangroves as complementary to shrimp farming (Sinha et al. 2024). This information and awareness barrier is part of the case for transition support. Carbon finance is additional where it closes this gap. This corresponds to the investment and barrier analyses required by the CCTS tool BM-T-AR-0001 (Section 4.3).

4.7. Companies and Technical Integrators in India for Carbon Market Integration

Successful development of an Integrated Mangrove Aquaculture (IMA) project for carbon-market participation requires capabilities that extend beyond mangrove restoration and aquaculture management. Project proponents must be able to demonstrate methodological eligibility, establish a credible baseline, quantify carbon removals, implement a robust Monitoring, Reporting and Verification (MRV) system, prepare the required documentation, and complete independent validation and

verification. In practice, these functions may require collaboration among several specialized organizations rather than a single service provider.

For IMA projects, the relevant service providers can broadly be grouped into four categories: (i) carbon project developers and advisory consultancies, (ii) Accredited Carbon Verification Agencies (ACVAs) and other independent verification bodies, (iii) digital MRV and geospatial technology providers, and (iv) on-ground NGOs and community-based project aggregators. Their roles are complementary and extend across different stages of the project lifecycle (BEE 2025a).

4.7.2. Carbon Project Developers and Advisory Consultancies

Carbon project developers and advisory firms can provide end-to-end technical support from initial feasibility assessment through project registration, carbon accounting and market engagement. Their services may include site and eligibility assessment, baseline development, additionality assessment, methodology selection, project design document preparation, carbon-stock estimation, monitoring-plan development, stakeholder engagement and support for carbon-credit transactions.

Examples of organizations operating in India include EKI Energy Services Ltd. (EKI), which provides carbon project development, carbon accounting and carbon-market services across sectors including forestry, agriculture, and nature-based solutions (EKI 2026). ProClime works on climate and nature-based solutions and provides support related to project development and carbon-market requirements (ProClime 2026). VNV Advisory Services is another relevant example, with a focus on nature-based solutions, ecosystem restoration and carbon-finance approaches (VNV 2026).

For an IMA project, the value of such organizations would be their ability to integrate the ecological restoration component with the carbon-market requirements. However, project proponents should assess whether a prospective developer has demonstrated experience specifically in mangrove, wetland, or blue-carbon projects, rather than relying solely on its general carbon-market experience.

4.7.3. Accredited Carbon Verification Agencies and Independent Verification Bodies

Independent validation and verification are essential components of both compliance and voluntary carbon markets. Under the CCTS Offset Mechanism, validation and verification are undertaken by Accredited Carbon Verification Agencies (ACVAs) recognized under the applicable Indian framework. In voluntary carbon markets, equivalent functions are performed by independent validation and verification bodies (VVBs) approved under the relevant carbon standard (BEE 2025a).

The role of these organizations is fundamentally different from that of a project developer. An ACVA/VVB provides an independent assessment of whether the project has been designed, implemented, monitored, and reported in accordance with the applicable methodology and standard. For an IMA project, this may include reviewing baseline assumptions, carbon-stock estimation methods, monitoring procedures, field data, QA/QC systems, leakage assessment and supporting documentation.

Potential organizations operating in the Indian carbon-verification and assurance space include VKU Certification Private Limited, Bureau Veritas India (Pvt.) Ltd, Earthood Services Limited, KBS Certification Services Limited and SustainCERT. Project proponents should confirm the current accreditation status and approved scope of any agency before engagement (BEE 2026).

4.7.4. Digital MRV and Geospatial Technology Providers

IMA projects require monitoring of both the mangrove restoration component and the surrounding aquaculture and land-use system. Digital MRV and geospatial technologies can therefore provide an important layer of evidence for project monitoring. Satellite remote sensing, GIS, GPS-based field surveys and, where appropriate, higher-resolution or LiDAR data can be used to monitor changes in mangrove extent, vegetation cover, land-use boundaries, hydrological features and other spatial characteristics of the project area.

Indian technology providers such as Satyukt Analytics Private Limited and TraceX Technologies offer digital solutions in areas relevant to Earth observation, geospatial intelligence, and environmental monitoring (Satyukt 2026; TraceX 2026). Their technologies could potentially support components of an IMA MRV system, such as spatial mapping, change detection, field-data management, and land-use monitoring.

However, remote sensing should not be regarded as a replacement for field measurements. Satellite and GIS data can demonstrate spatial changes in mangrove extent and vegetation, while field inventories are generally required to provide the detailed measurements needed for biomass and carbon-stock estimation. An effective IMA MRV system would therefore combine remote sensing, GIS and field-based measurements within a common monitoring framework.

4.7.5. On-Ground NGOs and Community Aggregators

Local NGOs, community organizations and project aggregators can play a particularly important role in IMA projects because restoration and aquaculture activities are implemented at the community and farm level. Smallholder farmers and individual aquaculture operators may lack the financial resources, technical capacity and scale required to independently develop and manage a carbon project. Aggregation can therefore reduce transaction costs and enable multiple small projects or landholdings to participate within a common carbon program.

Potential implementation partners include organizations with established experience in mangrove restoration, coastal livelihoods and community engagement. For example, the Nature Environment and Wildlife Society (NEWS) has experience in mangrove restoration and community-based conservation in the Sundarbans region (NEWS 2026).

For IMA projects, local partners can support activities such as community mobilization, restoration planning, farmer coordination, field data collection, maintenance of restored areas, livelihood monitoring, and communication with local institutions. Their involvement can also help ensure that carbon-finance interventions are aligned with local aquaculture practices and community needs.

4.7.6. Potential Integration Model for IMA Projects

Rather than relying on a single organization to perform all functions, an IMA project could adopt a multi-partner integration model. A carbon project developer or technical consultant could lead project design, methodology compliance, and carbon accounting. An independent ACVA could undertake validation and verification. A geospatial/MRV provider could support spatial monitoring and data management, and a local NGO or community aggregator could coordinate restoration and livelihood activities on the ground.

This division of responsibilities is particularly relevant for IMA projects because carbon-market eligibility depends on rigorous technical documentation and monitoring, while the long-term success of mangrove restoration depends on local participation and continued compatibility with aquaculture activities.

Table 6. Key organizations and service providers supporting carbon-market integration of IMA projects in India.

Service category	Primary function in an IMA project	Examples of organizations operating in India
Carbon project developers/advisory firms	Feasibility, methodology selection, PDD preparation, carbon accounting and market support	EKI Energy Services, ProClime, VNV Advisory Services
ACVAs/VVBs	Independent validation and verification of project design, monitoring and carbon outcomes	VKU Certification Private Limited, Bureau Veritas India (Pvt.) Ltd, Earthood Services Limited, KBS Certification Services Limited, SustainCERT
Digital MRV/geospatial providers	Remote sensing, GIS, spatial monitoring, data management and change detection	Satyukt Analytics Private Limited and Tracex Technologies
NGOs/community aggregators	Community mobilization, restoration implementation, farmer coordination and livelihood integration	NEWS and other location-specific coastal organizations

Source: Authors' creation

Overall, the selection of technical partners should be based not only on their general carbon-market experience but also on their demonstrated capacity in mangrove restoration, blue carbon, wetland systems, community-based implementation and the specific CCTS or voluntary carbon standard being pursued. For IMA projects, an effective integration model should bring together carbon-market expertise with ecological, geospatial, aquaculture, and community-level expertise. The following section presents global business models that demonstrate how these different components can be integrated to support carbon finance, ecosystem restoration, and local livelihoods.

5. IMA Business Models for Carbon Credit Financing

This section explores existing pathways to mobilize carbon finance for mangrove restoration and integrated mangrove aquaculture (IMA). It distinguishes four business models: (1) forward-funded private investment, in which investors or credit buyers provide capital before credits are issued; (2) community-led projects, in which communities or NGOs develop the project, usually with grant support, and sell credits after verification; (3) corporate supply-chain insetting, in which companies finance restoration within their own sourcing landscapes; and (4) national or sub-national results-based climate finance, in which governments receive payments from climate funds for verified emission reductions. The models diverge across four key dimensions: the source of upfront capital, the allocation of land and carbon rights, the timing of revenue streams, and the distribution of proceeds among investors, governments, and local communities.

Table 7 summarizes the ten case studies used to illustrate the models, showing for each its country, certification standard, business model and main lesson for IMA in the Indian Sundarbans. Some projects combine features of more than one model. Delta Blue Carbon in Pakistan (Case Study 4), for example, combines private forward finance with a provincial government partnership. It is grouped with the model it most closely resembles, and the overlap is noted in the table. Sections 5.1 and 5.2 then discuss the models in turn: how it is financed, who takes part, how carbon is measured and verified, and how revenue is distributed. Each model description ends with lessons for the Indian Sundarbans and is followed by its case studies, presented in boxes. Section 5.3 considers how each model could be applied in the Indian Sundarbans under India's Carbon Credit Trading Scheme (CCTS) and under the voluntary carbon market.

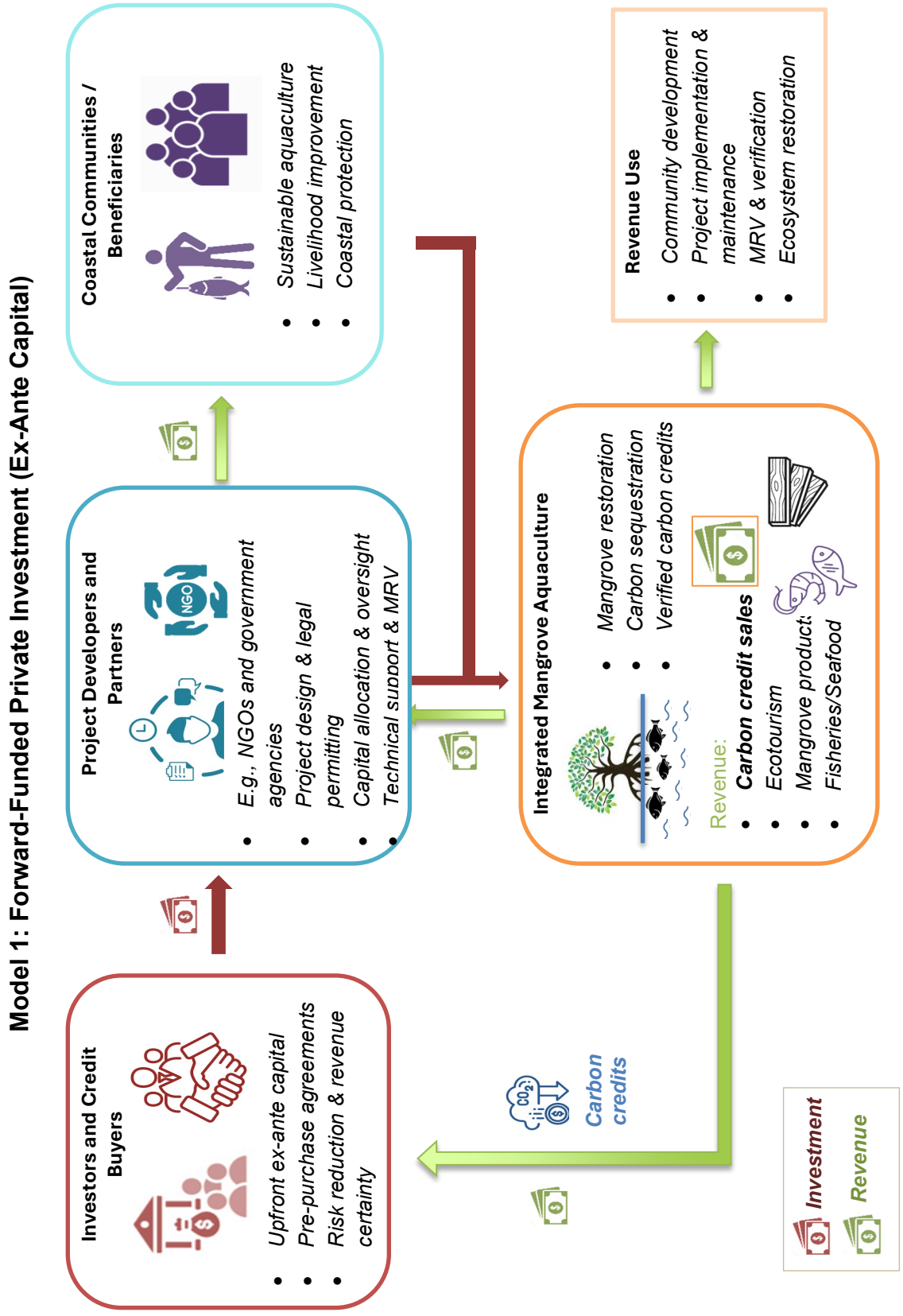
Table 7. Mangrove carbon case studies used to illustrate the business models

Case study	Country	Standard	Business model	Main lesson for IMA in the Sundarbans
1. Océanium / Livelihoods Carbon Fund mangrove restoration	Senegal	VCS	Model 1 – Forward-funded	An investor fund can pre-finance large-scale community planting (about 10,000 ha) in exchange for future credits; how much of the budget reaches communities needs attention.
2. DMCR mangrove plantation programme	Thailand	T-VER	Model 1 – Forward-funded (government-regulated)	A government agency can set the rules for sharing credits among companies (70%), communities (20%) and the state (10%).
3. Yagasu / Livelihoods Fund mangrove restoration, Aceh and North Sumatra	Indonesia	VCS	Model 1 – Forward-funded	A 70:30 mangrove-to-open-water design financed by pre-financing and offtake agreements with 12 investors; closest analogue to IMA, but also a reminder of social-licence risk.
4. Delta Blue Carbon	Pakistan	VCS (VM0033) + CCB	Model 1 – Forward-funded (public–private partnership)	A provincial government–private developer partnership can secure land access and work at landscape scale (about 350,000 ha) in a South Asian delta, financed by forward sales of credits to corporate buyers. Note: the project shares one operational feature with results-based mechanisms (Model 4): credit issuance is strictly performance-based (ex post). Under Verra's VM0033 methodology, credits are issued and delivered only after third-party verification confirms the biomass and soil carbon actually accumulated. In project-finance terms it is therefore a forward-financed, performance-

				contingent market instrument, similar to a commodity streaming or forward-offtake agreement, rather than a sovereign, non-market results-based grant.
5. Mikoko Pamoja	Kenya	Plan Vivo	Model 2 – Community-led	Small projects (117 ha) are viable with community governance, but revenues are modest (about USD 17,000/year).
6. Vanga Blue Forest	Kenya	Plan Vivo	Model 2 – Community-led	Replication and scale (460 ha) increased revenue and community funds.
7. Tahiry Honko	Madagascar	Plan Vivo	Model 2 – Community-led	Transparent benefit-sharing and the cost of verification for a small community project (about 1,200 ha).
8. WIF mangrove reforestation and restoration, Ayeyarwady (VCS 1764)	Myanmar	VCS	Model 2 – Community-led (NGO-led, ex-post)	An NGO can finance planting up front and recover costs from credit sales, with village committees holding land rights and 30% of the budget going to livelihoods.
9. Sundarbans mangrove restoration (Livelihoods Fund–NEWS)	India	VCS	Model 3 – Corporate insetting / investor fund	Proof of concept in the Sundarbans itself: a 4,403 ha VCS project area and about 1 million credits expected over 2010–2030 (ID-RECCO 2022).
10. East Kalimantan jurisdictional ER programme	Indonesia	FCPF Carbon Fund (ERPA)	Model 4 – RBCF	Province-wide results-based payments (up to USD 110 million for 22 $MtCO_2e$); mainly a forest programme, used here to show how the payment model works for state-level programmes.

Source: Authors' creation

5.1. Voluntary Carbon Market Models



Forward-funded private investment models provide upfront capital from private investors, corporate buyers, or dedicated carbon funds in exchange for future carbon credit generation. By supplying finance before credits are issued, these models reduce the financial barriers associated with establishing large-scale restoration projects while allowing investors to secure future supplies of high-quality blue carbon credits. The model brings together impact investors, project developers, NGOs, government agencies, and coastal communities through long-term partnerships. Project developers use the initial investment to establish mangrove nurseries, restore degraded coastal ecosystems, convert conventional aquaculture systems into integrated mangrove aquaculture systems, and support community participation throughout implementation. Integrated Mangrove Aquaculture (IMA) typically combines mangrove restoration with sustainable aquaculture, where mangrove cover is maintained alongside ponds for shrimp, mud crab, milkfish, and other aquatic species. Restoring mangrove ecosystems improve nursery habitats for fisheries, reduce coastal erosion, strengthens protection against storm surges, and enhances household incomes by diversifying livelihood opportunities.

Because restoration activities require substantial investment before carbon credits can be generated, projects often rely on blended finance arrangements that combine concessional finance, philanthropic grants, impact investment, and corporate carbon credit pre-purchase agreements. For example, the first credits from Delta Blue Carbon in Pakistan (Case Study 4) were sold to corporate buyers; such purchase agreements provide revenue certainty and help projects secure working capital before credits are issued. These agreements reduce investment risk while supporting long-term project implementation. Once carbon credits are issued over crediting periods that typically extend from 10 to 20 years, revenues are distributed according to pre-agreed contractual arrangements among investors, project developers, government agencies, and local communities. Additional income may also be generated through sustainable aquaculture production, ecotourism, and non-timber mangrove products such as honey and seafood.

Carbon accounting follows internationally recognized standards such as Verra's Verified Carbon Standard (VCS), Gold Standard, Plan Vivo, or relevant national standards. Measurement, Reporting and Verification (MRV) combines remote sensing, field inventories, and independent third-party verification to quantify carbon stored in above-ground biomass, below-ground biomass, dead wood, and soil organic carbon, while also accounting for greenhouse gas emissions such as methane (CH_4) and nitrous oxide (N_2O) where appropriate. These verification processes ensure that issued carbon credits represent real, measurable, and verifiable climate benefits throughout the project lifecycle.

Lessons for the Indian Sundarbans. Case Studies 1–4 show that forward finance works where a developer can aggregate a large restoration area and offer buyers a credible future supply of credits. Delta Blue Carbon (Case Study 4) is especially relevant for a South Asian delta: a partnership with the provincial forest department secured access to land at landscape scale, while forward sales to corporate buyers provided the capital. Because credits are issued only after verification, investors bear the risk of under-delivery, much as in a forward-offtake agreement. In the Sundarbans this would require aggregating many small farms. The Livelihoods Fund–NEWS project (Case Study 9) shows that this is achievable, but under the CCTS, forward agreements would depend on domestic demand for Carbon Credit Certificates, which is still developing (Section 5.3).

Case Study 1: Mangrove Restoration Senegal

The project is in the **Casamance and Sine Saloum regions, Senegal**.

The project restores about 104 km² of mangroves in the Casamance and Sine Saloum regions of Senegal, engaging 450 villages and over 200,000 people in replanting native Rhizophora species. Implemented by OCEANIUM with support from the Livelihoods Carbon Fund (LCF) since 2009, the project enhances fisheries, protects agricultural land from salinization, and restores mangrove ecosystems through community participation. The project fosters sustainable populations of fish, oysters, and shrimp through restored mangrove habitats (Livelihoods Funds 2019).

The project is registered under Verra's Verified Carbon Standard (VCS).

Carbon Credit Financing and Revenue

- Carbon finance supports community-led mangrove restoration through investment from private companies via the Livelihoods Carbon Fund, which provides funding to Océanium for restoration activities, monitoring, and evaluation over a 20-year period (2009–2029).
- Investors in the Livelihoods Carbon Fund receive high-quality carbon credits generated by the project to offset CO_2 emissions (Livelihoods Funds 2019).

Case Study 2: DMCR Mangrove Plantation Programme, Thailand

The project is in **Thailand.**

By 2024, 34,456 ha of community mangroves had been registered across 98 communities in coastal provinces including Trat, Nakhon Si Thammarat, Phang Nga, Trang, Satun, Pattani, Krabi and Phuket. Credits are issued under the Thailand Voluntary Emission Reduction Program (T-VER), which generally uses a 10-year crediting period for mangrove planting. Sustainable crab fishing provides a vital economic lifeline for local communities (DMCR 2022; Wachpanich 2024).

The project is registered under Thailand's T-VER programme.

Carbon Credit Financing and Revenue

- In 2022, Thailand's Department of Marine and Coastal Resources (DMCR) invited private companies, including oil and gas firms, to fund community mangrove planting in return for carbon credits.
-

Case Study 3: Mangrove Restoration and Coastal Greenbelt Protection

The project is in the **Aceh and North Sumatra** provinces, **Indonesia.**

Yagasu's blue carbon projects combine 70% mangrove vegetation with 30% open water areas to support integrated fish, shrimp, and crab farming. The ongoing projects include 80 km² of mangrove restoration in Sumatra, 53 km² in Java, and 250 km² in North Sumatra and Aceh, while protecting 23 mangrove species and 41 fish species. Yagasu collaborates with institutions such as World Agroforestry (ICRAF) and the Center for International Forestry Research (CIFOR) to support project implementation (CIFOR-ICRAF 2024).

The project is registered under Verra's Verified Carbon Standard (VCS), project 1493..

Carbon Credit Financing and Revenue

- The project receives investment from 12 carbon investors through pre-financing (US$3,000/ha) and carbon credit offtake agreements (South Pole 2022).
- Upfront carbon finance supports initial mangrove restoration costs until carbon credits are generated.
- Additional income is generated from mangrove by-products, including seafood, coffee, fruit, batik, and honey, increasing farmers' livelihoods.

Case Study 4: Mangrove Restoration Project – Delta Carbon

Indus River Delta, Sindh, Pakistan

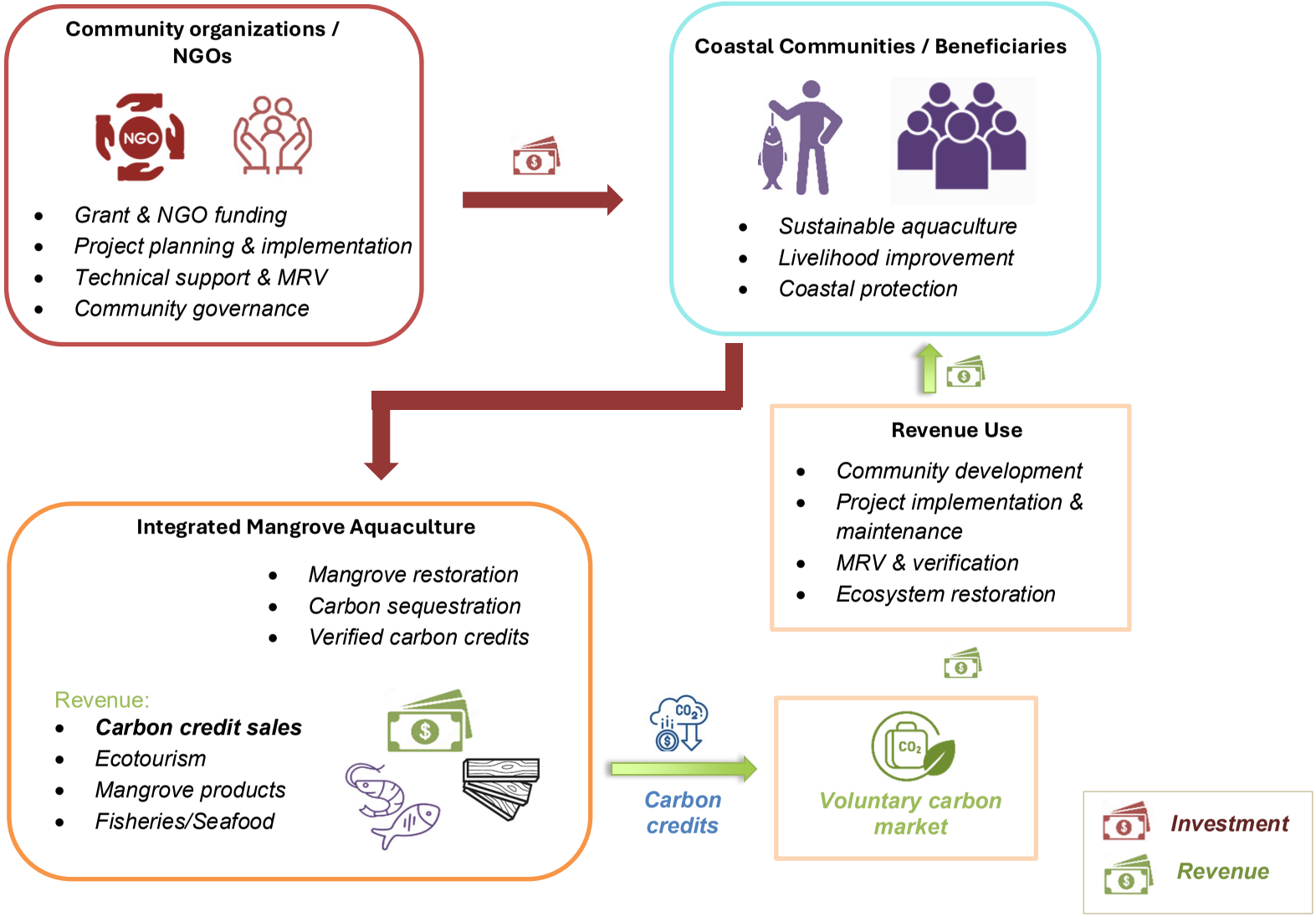
This is one of the world's largest blue carbon initiatives, covering about 350,000 ha of degraded tidal land in the Indus Delta under a 60-year public–private partnership between Indus Delta Capital and the Government of Sindh. Residents of 60 villages take part in restoration, and the restored mangroves support biodiversity, fisheries, livelihoods and protection against flooding and erosion (Carbon Market Institute 2026; Verra 2026).

The project is registered under Verra's Verified Carbon Standard (VCS; VM0033) and validated under the CCB Standards.

Carbon Credit Financing and Revenue

- The first issuance, in 2022, was about 3.1 million credits, sold to corporate buyers. The developer targets over 250 million credits over the 60-year project life; Verra estimates about 142 million tonnes of removals for the first phase (Carbon Market Institute 2026; Verra 2026).
- Credits are issued only after third-party verification of the carbon actually stored (ex post), so forward buyers bear the risk of under-delivery, as in a forward-offtake agreement.
- Carbon finance supports local employment and investments in community health, water and education (Carbon Market Institute 2026).

Model 2: Community-Led Carbon Financing Model (Ex-Post Verification)



Community-led carbon financing follows an ex-post financing model in which carbon credits are issued only after emission reductions or carbon sequestration have been independently verified. Unlike forward-funded approaches, these projects are typically initiated and managed by local communities, farmer cooperatives, community-based organizations, or NGOs, with technical support from specialized carbon developers and certification bodies. The model emphasizes local ownership, community participation, and direct reinvestment of carbon revenues into ecosystem conservation and rural development.

Integrated Mangrove Aquaculture (IMA) projects under this model combine mangrove conservation and restoration with sustainable aquaculture and fisheries management. Communities establish protected mangrove areas alongside sustainable fishing and aquaculture zones, restoring critical nursery habitats that support shrimp, mud crabs, finfish, and other commercially important coastal species. Community members actively participate in mangrove restoration, forest patrols, monitoring activities, and alternative livelihood programmes that reduce pressure on natural mangrove resources while strengthening food security and household resilience.

Since carbon credits are generated only after verified climate benefits have been achieved, initial project development is commonly supported through grants, NGO funding, or philanthropic finance. Once carbon sequestration has been independently verified, carbon credits such as Plan Vivo Certificates or Verified Carbon Standard (VCS) credits are issued and sold through voluntary carbon markets. Revenue is distributed according to community-approved benefit-sharing mechanisms, with a substantial proportion typically reinvested in local priorities, including ecosystem management, community infrastructure, education, healthcare, and livelihood improvement programmes. Smaller allocations are used to support project administration, monitoring, verification, and governance, creating a sustainable source of long-term financing for community-led conservation.

Carbon accounting generally follows standards designed for community-based projects, particularly Plan Vivo and Verra's Verified Carbon Standard (VCS). Monitoring, Reporting and Verification (MRV) combines participatory community monitoring with scientific oversight from technical experts and research institutions. Local community members are trained to collect field data on biomass growth, mangrove condition, and ecosystem health, while independent third-party verification confirms carbon sequestration and compliance with certification requirements. This participatory approach not only reduces monitoring costs but also strengthens local capacity, transparency, and long-term stewardship of mangrove ecosystems.

Lessons for the Indian Sundarbans. Projects in Kenya, Madagascar and Myanmar (Case Studies 5–8) show that community-led projects can succeed with modest revenues when governance and benefit-sharing are transparent. The Myanmar project (Case Study 8) is particularly relevant: an NGO paid the upfront costs, village mangrove conservation committees hold the land rights, and credit sales are expected to repay the investment (WIF 2018), an arrangement that could be adapted to Joint Forest Management Committees or farmer groups in the Sundarbans. The Sundarbans has strong community organizations and NGOs that could act as aggregators. NEWS's SAIME pilot has already organized 42 IMA farmers into two groups linked to a farmer producer company (NEWS 2023), but the small creditable area per farm (Section 4.6) means that grants or CSR funds would be needed to cover development costs.

Case Study 5: Mikoko Pamoja Mangrove Conservation

The project is in **Gazi Bay**, on the southern coast of **Kenya**

The project protects 117 ha of state-owned mangroves and is implemented over a 20-year period**,** with activities scheduled to continue until 2033**.**The Gazi Community Organization manages the project with technical support from KMFRI **(**Kenya Marine and Fisheries Research Institute), while ACES (The Association for Coastal Ecosystem Services) ensure transparent financial transfers. (World Bank 2025; Wylie et al. 2016).

The project is certified under the Plan Vivo Standard (PVCs)

Carbon Credit Financing and Revenue

- Carbon credits are independently verified and sold through the Markit Environmental Registry to corporations, institutions, and individuals.
- The project verifies at least 3,000 tCO_2e annually, with more than 18,000 Plan Vivo Certificates issued to date.
- Between 2014 and 2023, carbon credit sales generated US$176,081**,** averaging about US$17,000 per year**.**
- Revenue is used to support community development, staff wages, and mangrove conservation (World Bank 2025).

Case Study 6: Vanga Blue Forest Project Kenya (VBF)

The project is in the **Vanga Bay, Kawale County, Southern Kenya.**

Started in 2019, the project covers 460 ha of mangroves, 450 ha conserved and 10 ha restored (ACES 2019; Chimbi 2022). Local fishers harvest Silverfish (Rastrineobola argentea), locally known as Dagaa, along with other fish, squid, shrimp, and octopus as key sources of food and livelihoods. Around 30% of employment in Vanga is linked to fisheries, and the communities in Vanga, Jimbo, Jasini, and Kiwegu established two protected areas in Vanga Bay to support sustainable fisheries (Kairo 2025).

The project is certified under the Plan Vivo Standard**.**

Carbon Credit Financing and Revenue

- Before expansion, the project managed 4.6km^2 under Payments for Ecosystem Services (PES) agreements, generating 5,500 tCO_2 in removals and emission reductions.
- Following expansion, the project increased its PES-managed area to 800 ha (8 km^2), achieving 8,700 tCO_2 in removals and emission reductions.
- Annual carbon revenue increased from US$47,000 to US$81,000, with community development funds increasing from US$14,000 to US$28,000 annually (Kairo 2025).

Case Study 7: Community-Led Mangrove Conservation and Restoration

The project is in **Tahiry Honko**, the **southwest of Madagascar.**

The Tahiry Honko project (meaning “preserving mangroves” in the language of the local Vezo community) is located in the Velondriake Locally Managed Marine Area (LMMA) and involves the conservation and restoration of over 1,200 hectares of mangroves. The Vezo, traditional fishers living in coastal villages, are highly dependent on marine and coastal resources for their livelihoods. Since 2014, around 200 consultations and workshops have been conducted across 10 villages, leading to the first certification of carbon emission reduction(Blue Ventures 2019).

These credits are verified according to the Plan Vivo Standard.

Carbon Credit Financing and Revenue

- Carbon credits are used as a sustainable financing mechanism for the long-term management of the Velondriake Protected Area and its natural resources, with 1,371 tCO_2 certified in June 2021.
- Annual revenue from credit sales is allocated 80% to activities on the ground, such as forest patrols, mangrove reforestation, fuelwood plantations and school fees, and 20% to the Government of Madagascar for REDD+ governance (Vanderklift et al. 2022)
- The Velondriake Association manages carbon credit revenues with financial oversight from Blue Ventures, which receives 7% of total funds to cover external verification and auditing costs.
- A total of 1,371 Plan Vivo Certificates were sold to My Climate and Only One, generating $24,845 in revenue at prices ranging between $15 and $25 per certificate

Case Study 8: Mangrove Restoration Ayeyarwady Myanmar (VCS 1764)

The project is in the **Shwe Thuang Yan Township, Ayeyarwady, Myanmar,** .

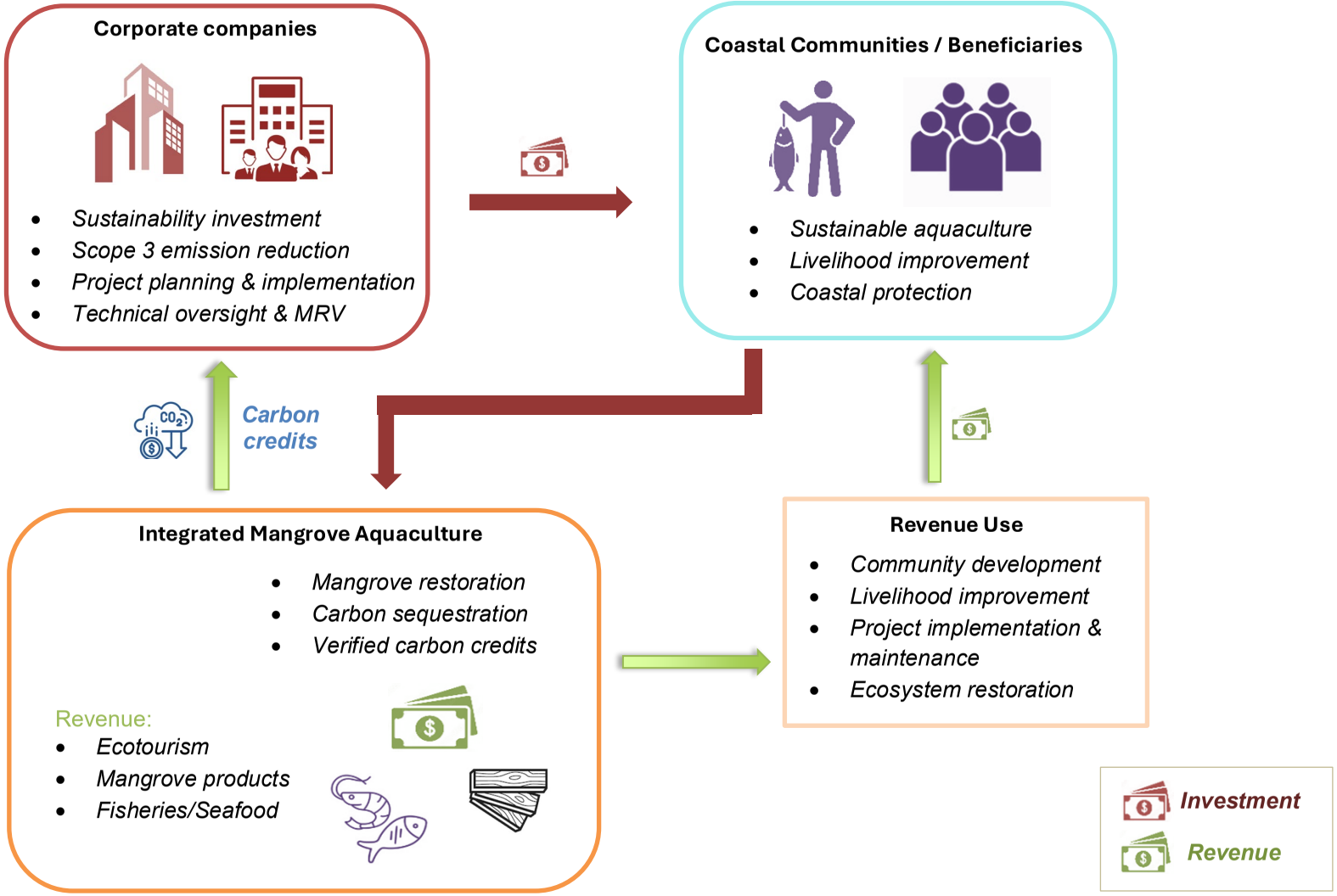
Worldview International Foundation (WIF), an NGO, has planted about 9.1 million mangroves of six species on about 2,146 ha of degraded land since 2015. Pathein University and village mangrove conservation committees hold the land rights and provide the labour; the regional government owns the land. The project also aims to reduce erosion and salt intrusion and increase fish catch (WIF 2018).

The project is registered in Verra’s Verified Carbon Standard (VCS) Program, 1764.

Carbon Credit Financing and Revenue

- WIF financed the start-up costs and expects to recover them from the sale of Verified Carbon Units issued after verification.
- 30% of the project budget goes to education, livelihoods, microloans, aquaculture, scholarships, solar lamps and fuel-saving stoves; new livelihoods include oyster culture, mangrove dyes, nipa sap and seaweed.
- The project expects to sequester about 3.68 million tCO_2e over its 20-year crediting period (2015–2035), about 184,000 tCO_2e per year (WIF 2018).

Model 3: Corporate Supply Chain Insetting Model



The corporate supply chain insetting model integrates carbon finance directly into a company's own supply chain rather than purchasing offsets from unrelated projects. Under this approach, corporate companies invest in integrated mangrove aquaculture (IMA) systems located within their sourcing landscapes or areas that influence their operations. The model creates long-term partnerships between corporate investors, project developers, implementation partners, and coastal farming communities, allowing companies to reduce Scope 3 emissions while strengthening supply chain resilience and supporting sustainable livelihoods. IMA projects funded through insetting combine mangrove restoration with sustainable aquaculture to improve both environmental and production outcomes. Restored mangrove ecosystems protect coastlines from erosion and storm surges, improve water quality, provide nursery habitats for fish and crustaceans, and enhance the productivity and resilience of aquaculture systems. These ecosystem services help secure raw material supplies while generating measurable carbon sequestration and biodiversity benefits.

Financing is primarily provided through corporate sustainability funds, impact investment vehicles, or dedicated carbon funds that supply upfront capital for project implementation, including mangrove nurseries, restoration activities, aquaculture improvements, community engagement, and long-term monitoring. Corporate partners frequently work alongside project developers during project planning and implementation, providing technical expertise, sustainability standards, and long-term oversight to ensure successful delivery and verification of project outcomes. In return, companies receive the verified carbon credits generated by the project and use them to support internal climate commitments, supply chain decarbonization strategies, or corporate net-zero goals. Alongside carbon benefits, projects create local employment through nursery management, tree planting, ecosystem maintenance, sustainable aquaculture, and alternative livelihood activities, ensuring that financial benefits are shared with participating communities. Projects are typically certified under internationally recognized standards such as Verra's Verified Carbon Standard (VCS), with robust Monitoring, Reporting and Verification (MRV) systems combining field measurements, remote sensing, carbon stock assessments, and independent third-party verification. Carbon accounting covers above-ground and below-ground biomass, dead organic matter, soil organic carbon, and, where applicable, greenhouse gas emissions associated with aquaculture systems. This integrated approach provides corporations with high-quality, traceable carbon credits while simultaneously improving ecosystem health, strengthening climate resilience, and enhancing the sustainability of coastal production landscapes.

Lessons for the Indian Sundarbans. Case Study 9 is itself an example of corporate-funded restoration in the Sundarbans. Insetting is a natural fit because the Sundarbans supplies shrimp to Indian seafood exporters, who face growing sustainability requirements in export markets.

Case Study 9: India Sundarbans Mangrove Restoration

The project is in **West Bengal, India**.

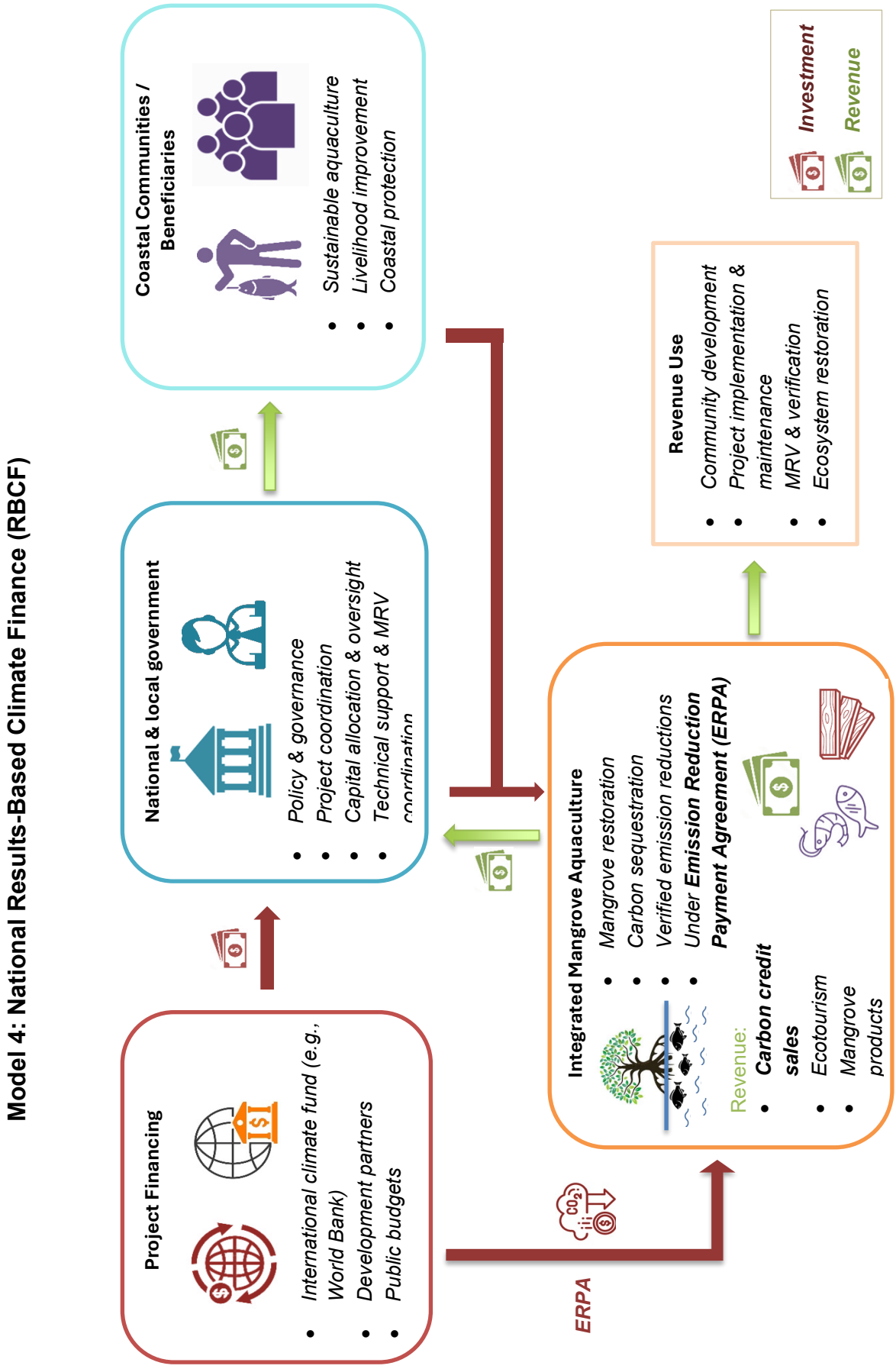
The project, covering 4,403 hectares, was funded by the Livelihoods Carbon Fund (formerly the Danone Fund for Nature), supported by companies including Danone, Schneider Electric, Crédit Agricole S.A., Michelin, Hermès, SAP, CDC Climate, La Poste, Firmenich, and Voyageurs du Monde. It aims to restore degraded mangrove areas through community-based planting of over 16 million mangroves. The project enhances coastal protection by reducing tidal flooding and erosion, while restored mangrove ecosystems provide nursery and feeding habitats for fish, mollusks, and crustaceans, supporting local livelihoods and food security (Livelihoods Funds 2020; Livelihoods Venture 2020).

The project is certified under Verra's Verified Carbon Standard (VCS)

Carbon Credit Financing and Revenue

- The Livelihoods Fund finances the project and owns the carbon credits, while the Nature Environment and Wildlife Society (NEWS) serves as the implementing partner, and UNIQUE Forestry and Land Use GmbH provides carbon consultancy. Investors include Danone, Mars, Firmenich and Veolia.
- The project has a crediting period from 2010 to 2030, with a total of 1,024,976 carbon credits expected to be generated (Wylie et al. 2016; ID-RECCO 2022).

5.2. Section B: Public and Sovereign Model



The National Results-Based Climate Finance (RBCF) Model operates at a jurisdictional or national scale, where governments receive climate finance after achieving and independently verifying pre-agreed emission reduction targets. Unlike project-based voluntary carbon market approaches, RBCF supports landscape-scale climate action by linking verified environmental outcomes to performance-based payments from multilateral organizations or climate funds. The model involves partnerships among national and local governments, international financial institutions, technical agencies, implementation partners, and coastal communities to deliver integrated climate, environmental, and development objectives.

For integrated mangrove aquaculture (IMA), RBCF can support the restoration and sustainable management of extensive coastal landscapes by integrating mangrove conservation, sustainable aquaculture, fisheries management, and climate-resilient land-use planning. Governments coordinate restoration activities, strengthen environmental governance, promote sustainable aquaculture practices, and implement policies that reduce mangrove degradation while improving coastal livelihoods. This landscape approach enhances carbon sequestration, protects biodiversity, improves coastal resilience, and supports long-term food security and income generation for coastal communities.

Project implementation is generally financed through public budgets, development partners, and international climate finance during the initial stages. Financial returns are generated only after verified emission reductions have been achieved. These verified outcomes are commonly transferred through Emission Reduction Payment Agreements (ERPAs), under which buyers agree to purchase verified emission reductions once predefined performance targets have been met. Unlike conventional carbon credit transactions, ERPAs provide results-based payments linked to independently verified climate outcomes, creating strong incentives for effective implementation, transparent governance, and long-term environmental performance.

Monitoring, Reporting and Verification (MRV) is conducted using nationally coordinated systems that integrate satellite remote sensing, field inventories, carbon accounting methodologies, and independent third-party verification. These systems support national greenhouse gas inventories, Nationally Determined Contributions (NDCs), and Biennial Transparency Reports (BTRs) under the Paris Agreement while ensuring that reported emission reductions are credible and measurable. Once payments are received, funds are distributed through established benefit-sharing mechanisms to support mangrove conservation, sustainable aquaculture, local infrastructure, community development, institutional capacity building, and continued monitoring. By linking financial incentives directly to verified climate outcomes, the RBCF model enables governments to scale integrated mangrove aquaculture systems while delivering long-term climate, environmental, and socio-economic benefits.

Lessons for the Indian Sundarbans. Case Study 10 (Indonesia) shows how results-based payments can operate at landscape scale, and the government role in Case Study 4 (Pakistan) shows that state agencies can also anchor market-financed projects. In West Bengal, the Forest Department and national schemes could play this role. One example is MISHTI (Mangrove Initiative for Shoreline Habitats & Tangible Incomes), announced in the 2023–24 Union Budget, which aims to restore about 540 km² of mangroves in coastal states and union territories over five years (MoEFCC 2023; see Section 5.3).

Case Study 10: East Kalimantan Jurisdictional Emissions Reduction Indonesia

The project is in **East Kalimantan Province, Indonesia**.

The project covers seven districts, three cities, 103 sub-districts, and 1,038 villages across 12.7 million hectares of tropical forest and coastal landscape. With 6.5 million hectares (54%) of remaining tropical rainforest, the program mainly addresses reforestation and forest degradation; mangrove and coastal areas form part of the province's landscape that illustrate results-based payments operating at jurisdictional level FCPF 2019)

Verified emission reductions from the project are sold under the World Bank's Emission Reduction Payment Agreement

Carbon Credit Financing and Revenue

- Primarily funded by government sources (74.5%), with remaining contributions from the private sector (21.7%) and development partners (3.8%).
- Performance-based payments (results-based finance) where verified Emission Reductions (ERs) are sold/transferred to the FCPF Carbon Fund (valued at up to $110 million USD for reducing 22 million tCO_2 over the 2019–2024 period) (FCPF 2019).

5.3 Applying the business models in Indian Sundarbans under the context of CCTS

Each of the four business models can, in principle, be implemented either through India's CCTS Offset Mechanism, generating Carbon Credit Certificates (CCCs) for domestic buyers, or through an international voluntary standard. The choice affects who can buy the credits, which methodology applies, and whether host-country authorization is needed. Under both routes, the eligibility constraints described in Section 4.2 apply to the area that can be credited. Table 8 summarizes how each model could be applied in the Indian Sundarbans.

Table 8. Business models under the CCTS and voluntary-market pathways in the Indian Sundarbans

Model	CCTS Offset Mechanism pathway	Voluntary carbon market pathway	Likely Sundarbans actors	Main constraints
1. Forward-funded private investment	Developer registers as a non-obligated entity; Indian obligated entities or corporates sign forward offtake agreements for CCCs.	International investors or buyers pre-purchase VCS or Gold Standard credits (as in Case Studies 1–4).	Carbon developers (e.g., EKI, VNV), corporate buyers, NEWS as implementer.	CCC prices not yet discovered; CCCs trade on power exchanges in monthly sessions, and bilateral or forward arrangements need CERC approval (CERC 2026); export of credits requires authorization.
2. Community-led (ex-post)	NGO or farmer producer organization registers as a non-obligated entity and bundles many farms in one project; CCCs sold after verification.	Plan Vivo or VCS grouped project (as in Case Studies 5–8).	NEWS and other local NGOs, farmer producer organizations, panchayats.	Small creditable area per farm; pre-finance needed for PDD and validation (CSR funds are a possible source: under Section 135 of the Companies Act, 2013, qualifying companies must spend 2% of average net profits on CSR, and environmental sustainability is an eligible activity under Schedule VII (Government of India 2013)).
3. Corporate supply-chain insetting	Seafood exporters or processors finance IMA in their sourcing areas; CCCs either retired for the company's own claims or sold.	Insetting claims under the company's climate targets, with or without VCS credits (as in Case Study 9).	Shrimp exporters and processors sourcing from West Bengal; retailers in export markets.	Risk of double claiming between insetting claims and credit sales; traceability to the farm.
4. National / state results-	State agency (e.g., West Bengal Forest Department)	Results-based payments from climate funds, or	West Bengal Forest Department, MoEFCC,	Corresponding adjustments if outcomes are transferred

based finance	implements restoration on state land; CCCs issued to the state, or results-based payments linked to verified outcomes.	Article 6.2 cooperation under decision 2/CMA.3 (as in Case Study 10).	MISHTI programme (MoEFCC 2023), multilateral funds.	internationally (UNFCCC 2022); international transfer is possible only for activities on India's notified Article 6 list (PIB 2023), and the current list includes no forestry or mangrove activities, its only removal activity being carbon capture, utilization and storage (MoEFCC 2025); benefit-sharing with communities on state land.

Source: Authors' creation

India's list of activities eligible for international transfer under Article 6.2 and 6.4, revised after the national authority's notification was amended on 22 August 2025, includes 13 activities and none that are nature-based (MoEFCC 2025). Mangrove credits from the Sundarbans therefore cannot currently be authorized for international transfer with corresponding adjustments, although they can be issued as CCCs for domestic use. Trading of CCCs is governed by regulations notified by the Central Electricity Regulatory Commission in February 2026 (CERC 2026).

6. Major Challenges and Implementation Barriers

Despite its considerable potential, implementing carbon financing for integrated mangrove aquaculture (IMA) systems faces several financial, institutional, technical, and governance challenges. A diversified financing approach is required to support large-scale mangrove restoration and conservation, yet significant funding gaps remain. Financial barriers include high upfront investment requirements, costly project development and verification processes, delayed carbon revenue, and limited access to pre-financing for smallholder farmers and community-based organizations. These challenges are further compounded by limited public financial resources and institutional capacity to support project implementation.

Policy and legal barriers also remain significant. Unclear land tenure and carbon ownership, particularly in coastal areas where public, private, and customary rights overlap, create uncertainty regarding project eligibility, benefit-sharing arrangements, and legal responsibilities. Lengthy and complex permitting procedures can substantially increase project costs and implementation time, discouraging investment. In many countries, weak institutional coordination, limited technical capacity, evolving carbon regulations, and the complexity of international carbon market requirements further constrain project development.

Technical and environmental challenges also affect project feasibility. Establishing robust Monitoring, Reporting and Verification (MRV) systems require specialized expertise, reliable field measurements, remote sensing capabilities, and long-term monitoring, all of which can be costly and technically demanding. In addition, IMA projects must manage environmental risks such as coastal erosion, flooding, changing hydrological conditions, and potential leakage, while ensuring the permanence and environmental integrity of carbon benefits over the project lifetime (Global Mangrove Alliance 2024; World Bank 2025).

Challenges specific to the Indian Sundarbans: For the Indian Sundarbans, ***four*** different challenges stand out. Firstly, the CCTS methodology proposed credits only new planting on degraded habitats without disturbing soil and entails that only a part of the IMA farm can be credited (as described in section 4.2). Second, the demand and prices for the CCCs from the Offset Mechanisms are yet to be established, which make the process of forward finance and revenue earnings uncertain for communities to adapt. Third, tenure is split between government managed reserve forest and private or leased land in the inhabited zone, making carbon-credits and benefit sharing requiring different negotiations in different zones, and areas in intertidal zones entail CRZ clearances (MOEFCC 2019). Fourth, erosion, island loss create a high permanent risks, which will affect buffer requirements and investor appetite (World Bank 2014; Bera and Maity 2019). Anthropogenic activities add pressure to this. For example, in Satjelia island, plantations guarded by the communities through the Forest Protection Committee (FPC) sustained better. However, illegal cutting and grazing resumed as funds for the FPC ended (Choudhury et al 2018).

7. Recommendations and Conclusion

Scaling carbon financing for IMA requires coordinated action across policy, finance, and local governance. National policies should promote integrated coastal management by aligning environmental, fisheries, aquaculture, and land-use planning while ensuring the meaningful participation of local communities throughout project design, implementation, and benefit sharing. Establishing clear land tenure, carbon ownership, and transparent governance frameworks will improve investor confidence and facilitate project development. Flexible pre-financing mechanisms, including grants, concessional finance, and blended finance, can help overcome early-stage investment barriers by supporting feasibility studies, baseline assessments, MRV system development, and institutional capacity building before carbon revenues are generated. As projects mature and risks decline, private investment and commercial finance can play an increasingly important role in scaling implementation. Innovative financing approaches, including policy-based carbon crediting, sustainable supply chain partnerships, risk-sharing instruments, and results-based climate finance, can further strengthen the financial viability of IMA projects.

Recommendations for Indian Sundarbans – the key ***two*** steps that would help to test and scale carbon finance for IMA farms in Indian Sundarbans are as follows –

(i) Pilot an aggregated CCTS project in which an NGO or a Farmer Producer Organization (FPO) registers as a non-obligated entity covering many farms, with planting parcels designed from the outset to meet BM FR05.001 conditions.

(ii) Use CSR funds (Government of India 2013), the MISTHI program (MOEFCC 2023), and the grant finance to cover feasibility, Project Design Document preparation, validation and the transition period before issuance of CCC.

Since the CCTS is evolving, and periodically accepting technical feedback from practitioners, project developers, researchers, and academics, it is imperative that project developers could also consider the following recommendations regarding *proactive regulatory engagement*, *tenure-based benefit sharing*, and *empirical baseline gathering* to strengthen the regulatory framework.

(i) **Engage CCTS authorities on mixed-landscape methodologies:** Invite the Bureau of Energy Efficiency (BEE)—as the Administrator for the Indian Carbon Market (ICM)—and the relevant technical committees to develop specific guidance or a modular addition under draft methodology BMFR05.001 for mixed mangrove–aquaculture landscapes. This should clarify spatial boundary rules for planted parcels within active farms and define additionality criteria for existing mangroves retained in IMA systems.

(ii) **Establish Sundarbans-specific tenure and benefit-sharing protocols:** Develop clear benefit-sharing guidance tailored to the Sundarbans that distinguishes between state-owned forest/revenue land and privately held aquaculture ponds, ensuring that farmers who forego production area to integrate mangroves receive direct, equitable compensation.

(iii) **Conduct cluster-level techno-economic feasibility studies:** Commission site-level feasibility and cost-benefit assessments across two to three representative IMA clusters to replace the illustrative financial assumptions in Section 4.6 with empirical local data on capital expenditure, maintenance, and yield impacts.

Overall, carbon financing offers a promising mechanism to support the long-term sustainability of integrated mangrove aquaculture systems by generating incentives for ecosystem restoration, climate mitigation, biodiversity conservation, and sustainable livelihoods. Although financial, technical, and governance challenges remain, strengthening enabling policies, institutional capacity, high-integrity carbon standards, and community participation will be essential for scaling IMA projects and realizing their full climate and socio-economic potential.

8. References

ACES (Association for Coastal Ecosystem Services). 2019. Vanga Blue Forest Project: Project Design Document (PDD), for Validation Using Plan Vivo Standards. With Vanga Blue Forest, KMFRI, Edinburgh Napier University and Kenya Forest Service. 27 December 2019. https://sustainabletravel.org/wp-content/uploads/Vanga-Blue-Forest-PDD_27dec19_PlanVivo.pdf.

Africa Renewal. 2023. “How Kenyan Coastal Villagers Are Cashing In on Carbon Credits.” Africa Renewal, January 2023. United Nations. https://www.un.org/africarenewal/magazine/january-2023/how-kenyan-coastal-villagers-are-cashing-carbon-credits.

Ahmed, Nesar, and James S. Diana. 2015. “Threatening ‘White Gold’: Impacts of Climate Change on Shrimp Farming in Coastal Bangladesh.” *Ocean & Coastal Management* 114: 42–52. https://doi.org/10.1016/j.ocecoaman.2015.06.008.

Ahmed, Nesar, Shirley Thompson, and Marion Glaser. 2018. “Integrated Mangrove-Shrimp Cultivation: Potential for Blue Carbon Sequestration.” *Ambio* 47 (4): 441–52. https://doi.org/10.1007/s13280-017-0946-2.

Ahmed, Nesar, and Max Troell. 2010. “Fishing for Prawn Larvae in Bangladesh: An Important Coastal Livelihood Causing Negative Effects on the Environment.” *Ambio* 39 (1): 20–29. https://doi.org/10.1007/s13280-009-0002-y.

Bera, Rakesh, and Ramkrishna Maiti. 2019. “Quantitative Analysis of Erosion and Accretion (1975-2017) Using DSAS: A Study on Indian Sundarbans.” Regional Studies in Marine Science 28:100583. https://doi.org/10.1016/j.rsma.2019.100583.

Bhattacharya, Snigdhendu, and Subhrajit Sen. 2022. “The Reality of Saving Young Mangroves in Sundarbans.” Mongabay India. Republished by EastMojo. 11 September 2022. https://eastmojo.com/environment/2022/09/11/the-reality-of-saving-young-mangroves-in-the-sundarbans/.

BioCarbon Fund. 2026. “Results-Based Payments.” World Bank Group. Accessed October 23, 2026. https://www.biocarbonfund-isfl.org/results-based-climate-finance.

BLS (US Bureau of Labor Statistics). 2026. Consumer Price Index for All Urban Consumers (CPI-U), U.S. City Average, All Items (1982–84 = 100): Annual Averages 2010 (218.056) and 2025 (321.943; October 2025 not collected). Washington, DC: BLS. https://www.bls.gov/cpi/data.htm. Blue Ventures. 2019. *Tahiry Honko: Community Mangrove Project, Southwest Madagascar*. Plan Vivo Project Design Document, revised version, August 2019. https://www.clevel.co.uk/wp-content/uploads/2022/05/tahiry_honko_pdd.pdf.

Breithaupt, Joshua L., Havalend E. Steinmuller, Andre S. Rovai, et al. 2023. “An Improved Framework for Estimating Organic Carbon Content of Mangrove Soils Using Loss-on-Ignition and Coastal Environmental Setting.” *Wetlands* 43 (6): 57. https://doi.org/10.1007/s13157-023-01698-z.

Bureau of Energy Efficiency (BEE). 2025a. BM FR05.001: Afforestation and Reforestation of Degraded Mangrove Habitats. Version 1.0, 27 March 2025. Offset Mechanism under the Carbon Credit Trading Scheme. New Delhi: Ministry of Power. https://beeindia.gov.in/sites/default/files/BM%20FR05.001.pdf.

Bureau of Energy Efficiency (BEE). 2025b. *Detailed Procedure for Offset Mechanism under CCTS*. https://beeindia.gov.in/sites/default/files/Detailed%20Procedure%20for%20Offset%20Mechanism_CCTS.pdf

Bureau of Energy Efficiency (BEE). 2026. “List of Accredited Carbon Verification Agency Empanelled under CCTS.” Accessed October 23, 2026. https://beeindia.gov.in/view_content.php?lid=568&lang=1.

CERC (Central Electricity Regulatory Commission). 2026. Central Electricity Regulatory Commission (Terms and Conditions for Purchase and Sale of Carbon Credit Certificates) Regulations, 2026. Notified 27 February 2026. New Delhi: CERC. https://climate-laws.org/document/central-electricity-regulatory-commission-terms-and-conditions-for-purchase-and-sale-of-carbon-credit-certificates-regulations-2026_eb77

Chimbi, Joyce. 2022. “Community Project Helps Kenya Aim for Climate Goals One Mangrove Tree at a Time.” Mongabay, January 10, 2022. https://news.mongabay.com/2022/01/community-project-helps-kenya-aim-for-climate-goals-one-mangrove-tree-at-a-time/ .

Chopin, Thierry, Jonathan A. Cooper, Gregor Reid, Stephen Cross, and Christine Moore. 2012. “Open-Water Integrated Multi-Trophic Aquaculture: Environmental Biomitigation and Economic Diversification of Fed Aquaculture by Extractive Aquaculture.” *Reviews in Aquaculture* 4 (4): 209–20. https://doi.org/10.1111/j.1753-5131.2012.01074.x.

CIFOR-ICRAF. 2024. “547-Mangrove Restoration and Coastal Greenbelt Protection in the East Coast of Aceh and North Sumatra Province, Indonesia.” ID-RECCO Database. Accessed October 23, 2026. https://www.reddprojectsdatabase.org/547-mangrove-restoration-and-coastal-greenbelt-protection-in-the-east-coast-of-aceh-and-north-sumatra-province-indonesia/.

DMCR (Department of Marine and Coastal Resources). 2022. Regulation of the Department of Marine and Coastal Resources on Carbon Credit Trading and Benefit Sharing Obtained from Planting and Maintaining the Mangrove Forest for Community B.E. 2565 (2022). Announced 19 July 2022; Royal Thai Government Gazette. Unofficial translation by Knowledge for Development Foundation. https://data.opendevelopmentmekong.net/dataset/8122c2f1-c287-4128-8216-2c87ebbc12e8

ECB (European Central Bank). 2011. Euro foreign exchange reference rates: US dollar, annual average 2010 (USD 1.3257 per euro). ECB Data Portal, series EXR.A.USD.EUR.SP00.A. https://data.ecb.europa.eu/data/datasets/EXR/EXR.A.USD.EUR.SP00.A .

EKI. 2026. “Move towards a Net Zero Future.” Accessed October 23, 2026. https://enkingint.org/.

FAO (Food and Agriculture Organization of the United Nations). 2010. Carbon Finance Possibilities for Agriculture, Forestry and Other Land Use Projects in a Smallholder Context. Rome: FAO. Chapter 4, Table 2. https://www.fao.org/4/i1632e/i1632e04.pdf .

Farzanmanesh, Raheleh, Kourosh Khoshelham, and Sebastian Thomas. 2021. “Technological Opportunities for Measuring and Monitoring Blue Carbon Initiatives in Mangrove Ecosystems.” *Remote Sensing Applications: Society and Environment* 24: 100612. https://doi.org/10.1016/j.rsase.2021.100612.

Forest Carbon Partnership Facility (FCPF). 2019. *East Kalimantan Jurisdictional Emission Reductions Program, Indonesia*. Emission Reductions Program Document (ER-PD), May 2019. https://www.forestcarbonpartnership.org/system/files/documents/Revised%20ERPD.pdf.

FSI (Forest Survey of India). 2024. India State of Forest Report 2023. 18th ed. Dehradun: Forest Survey of India, Ministry of Environment, Forest and Climate Change, Government of India. https://fsi.nic.in/forest-report-2023

Giri, Sandip, Sourav Samanta, Partho Protim Mondal, Oindrila Basu, Samiran Khorat, Abhra Chanda, and Sugata Hazra. 2021. “A Geospatial Assessment of Growth Pattern of Aquaculture in the Indian Sundarbans Biosphere Reserve.” Environment, Development and Sustainability 24 (3): 4203–25 (published online 28 June 2021; print issue 2022). https://doi.org/10.1007/s10668-021-01612-9

Giri, Sandip, Tim M. Daw, Sugata Hazra, Max Troell, Sourav Samanta, Oindrila Basu, Charlotte L. J. Marcinko, and Abhra Chanda. 2022. “Economic Incentives Drive the Conversion of Agriculture to Aquaculture in the Indian Sundarbans: Livelihood and Environmental Implications of Different Aquaculture Types.” Ambio 51 (9): 1963–77. https://doi.org/10.1007/s13280-022-01720-4

GoI (Government of India). 2008. Government of India Submission to UNFCCC to Revise Country Forest Definition for CDM A/R Projects. Designated National Authority, India, 7 July 2008. https://cdm.unfccc.int/DNA/cdf/files/2008/0707_india.pdf

Gold Standard. 2026. *A Practitioner's Guide: Aligning the Voluntary Carbon Market with the Paris Agreement*. https://www.goldstandard.org/publications/a-practitioners-guide-aligning-the-voluntary-carbon.

Goto, Garrett M., Candela Sofia Goñi, Rod Braun, Miguel Cifuentes-Jara, Daniel A. Friess, Jennifer Howard, Dane H. Klinger, Solina Teav, Thomas A. Worthington, and Jonah Busch. 2025. "Implementation Costs of Restoring Global Mangrove Forests." One Earth 8 (7): 101342. https://doi.org/10.1016/j.oneear.2025.101342

Government of India. 2013. The Companies Act, 2013 (Act No. 18 of 2013), Section 135 and Schedule VII. New Delhi: Ministry of Law and Justice. https://www.indiacode.nic.in/handle/123456789/2114.

ID-RECCO. 2022. "India Sunderbans Mangrove Restoration" (Mangrove Afforestation in Sunderbans with Community Approach for Reducing GHG Emissions), project 603. International Database on REDD+ Projects and Programmes Linking Economic, Carbon and Communities Data. https://www.reddprojectsdatabase.org/603-india-sunderbans-mangrove-restoration/.

IFC (International Finance Corporation). 2023. Deep Blue: Opportunities for Blue Carbon Finance in Coastal Ecosystems. Washington, DC: IFC, in collaboration with Silvestrum and Climate Focus. https://www.ifc.org/content/dam/ifc/doc/2023-delta/deep-blue-opportunities-for-blue-carbon-finance-in-coastal-ecosystems-optimized.pdf.

IPCC (Intergovernmental Panel on Climate Change). 2014. 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands. Edited by Takahiko Hiraishi, Thelma Krug, Kiyoto Tanabe, Nalin Srivastava, Jamsranjav Baasansuren, Maya Fukuda, and Tiffany G. Troxler. Switzerland: IPCC. https://www.ipcc-nggip.iges.or.jp/public/wetlands/.

Kairo, James G. 2025. "Blue Carbon Case Studies." Presentation, Green Finance Kenya 2025 Round Table, Nairobi, September 3–4, 2025. https://www.fsdkenya.org/wp-content/uploads/2025/09/Blue-Carbon-Case-Studies.pdf.

Leal, Maricé, and Mark D. Spalding, eds. 2024. *The State of the World's Mangroves 2024*. Global Mangrove Alliance. https://doi.org/10.5479/10088/119867.

Livelihoods Funds. 2019. "Senegal: The Largest Mangrove Restoration Programme in the World." Accessed October 23, 2026. https://livelihoods.eu/?p=74.

Livelihoods Funds. 2020. "India (Sundarbans): 16 Million Mangrove Trees to Protect Local Communities." Accessed October 23, 2026. https://livelihoods.eu/projects/news-india/.

Livelihoods Venture. 2020. "An Interview with Ajanta Dey, India." Accessed October 23, 2026. https://livelihoods.eu/?p=11473.MoEFCC (Ministry of Environment, Forest and Climate Change). 2019. Coastal Regulation Zone Notification, 2019. G.S.R. 37(E), Gazette of India, Extraordinary, 18 January 2019. New Delhi: Government of India.

MoEFCC (Ministry of Environment, Forest and Climate Change). 2023. Operational Guidelines: MISHTI Programme (Mangrove Initiative for Shoreline Habitats & Tangible Incomes). New Delhi: Government of India. https://nationalcampa.nic.in/dashboard/GuidelinesPDF/665052fa8dd59.pdf.

MoEFCC (Ministry of Environment, Forest and Climate Change). 2025. India's Engagement in Article 6 of Paris Agreement. Presentation, 23 September 2025 (slide: List of activities finalised by Govt. of India under Article 6.2 and Article 6.4). https://ca1-aip.edcdn.com/S1-2_MOEFCC-Engagement_in_Article_6_of_Paris_Agreement_v3.pdf.

Murray, Brian C., Linwood Pendleton, W. Aaron Jenkins, and Samantha Sifleet. 2011. *Green Payments for Blue Carbon: Economic Incentives for Protecting Threatened Coastal Habitats*. NI R 11-04. Nicholas Institute for Environmental Policy Solutions, Duke University. https://nicholasinstitute.duke.edu/sites/default/files/publications/blue-carbon-report-paper.pdf.

Nature Environment and Wildlife Society (NEWS). 2023. Sustainable Aquaculture in Mangrove Ecosystem (SAIME). Brochure, July 2023. Kolkata: NEWS. https://naturewildlife.org/wp-content/uploads/2024/11/SUSTAINABLE-AQUACULTURE-IN-MANGROVE-ECOSYSTEM.pdf.

Nature Environment and Wildlife Society (NEWS). 2026. "Nature Environment and Wildlife Society." Accessed October 23, 2026. https://naturewildlife.org/eventnew/.

ProClime. 2026. "Accelerating Climate Action, Together." Accessed October 23, 2026. https://www.proclime.world/.

Procton, Alex. 2024. *State of the Voluntary Carbon Market 2024*. Ecosystem Marketplace, Forest Trends Association. https://www.forest-trends.org/publications/state-of-the-voluntary-carbon-market-2024/.

Rainforest Rescue et al. 2026. Letter from 72 organisations calling for an end to carbon-credit trading from mangroves in Aceh and North Sumatra (Livelihoods Fund–Yagasu project). June 2026. https://www.rainforest-rescue.org/files/en/Letter%20Stop%20Carbon%20Credit%20Trading%20by%20Danone.pdf.

Reclimatize. 2026. "India's CCTS Voluntary Offset Mechanism: The 8 Approved Methodologies, Who Can Participate, and the Commercial Case for Early Registration." Accessed October 23, 2026. https://reclimatize.in/ccts-voluntary-offset-mechanism-methodologies/.

Sahana, Mehebub, Gopala Areendran, and Haroon Sajjad. 2022. "Assessment of Suitable Habitat of Mangrove Species for Prioritizing Restoration in Coastal Ecosystem of Sundarban Biosphere Reserve, India." Scientific Reports 12: 20997. https://doi.org/10.1038/s41598-022-24953-5.

Satyukt. 2026. "Satellite-Based MRV Solution for Carbon Credits (Measurement, Reporting, and Verification)." Accessed October 23, 2026. https://satyukt.com/MRV_carbon.html.

Sinha, Milon, Nimai Bera, R. C. Bhatta, Thies Geertz, Sabyasachi Chakraborty, Ajanta Dey, Prasanna Surathkal, and Natasha Majumder. 2024. "Coastal Aquaculture in the Indian Sundarban: Evaluating Production Economics and Farmers Perception of Mangrove Ecosystem Benefits." International Journal for Research in Applied Science and Engineering Technology 12 (2): 1257–68. https://doi.org/10.22214/ijraset.2024.58535.

South Pole. 2022. Case Study: Mangrove Restoration and Coastal Greenbelt Protection (Livelihoods Fund–Yagasu, Aceh and North Sumatra, Indonesia). March 2022. Zurich: South Pole. Hosted by WWF-UK. https://www.wwf.org.uk/sites/default/files/2022-07/case_study_livelihoods_yagasu_mangrove_restoration.pdf.

TraceX. 2026. "DMRV for Carbon Project Developers." Accessed October 23, 2026. https://tracextech.com/dmrv-for-carbon-project-developers/.

United Nations Framework Convention on Climate Change (UNFCCC). 2015. Paris Agreement. https://unfccc.int/sites/default/files/english_paris_agreement.pdf.

United Nations Framework Convention on Climate Change (UNFCCC). 2022. Report of the Conference of the Parties Serving as the Meeting of the Parties to the Paris Agreement on Its Third Session, Held in Glasgow from 31 October to 13 November 2021. Addendum. Part Two: Action Taken. FCCC/PA/CMA/2021/10/Add.1 (decisions 2/CMA.3 and 3/CMA.3). https://unfccc.int/documents/460950.

Vanderklift, Mat, Andy Steven, Dominique Benzaken, Torsten Thiele, Chip Cunliffe, Lalao Aigrette Ravaoarinorotsihoarana, Amy Schmid, and Jacqueline Wharton. 2022. Blue Forest Finance: Financing the Protection and Restoration of Blue Forests and Meadows. Australia: CSIRO, for the IORA Indian

Ocean Blue Carbon Hub. https://research.csiro.au/iora-blue-carbon-hub/wp-content/uploads/sites/321/2022/11/Blue-forest-finance-guide-FINAL.pdf.

Vanderklift, Mathew A., Raymundo Marcos-Martinez, James R. A. Butler, Michael Coleman, Anissa Lawrence, Heidi Prislan, Andrew D. L. Steven, and Sebastian Thomas. 2019. "Constraints and Opportunities for Market-Based Finance for the Restoration and Protection of Blue Carbon Ecosystems." Marine Policy 107: 103429. https://doi.org/10.1016/j.marpol.2019.02.001.

Verra. 2023a. VM0033 Methodology for Tidal Wetland and Seagrass Restoration, v2.1, 4 September 2023. Washington, DC: Verra. https://verra.org/methodologies/vm0033-methodology-for-tidal-wetland-and-seagrass-restoration-v2-1/.

Verra. 2023b. VMD0051 Methods for Monitoring Carbon Stock Changes in Tidal Wetland Restoration and Conservation Activities (M-TW), v1.1, 18 December 2023. Washington, DC: Verra. https://verra.org/documents/vmd0051-methods-for-monitoring-carbon-stock-changes-in-tidal-wetland-restoration-and-conservation-activities-m-tw-v1-1.

Verra. 2024. VM0007 REDD+ Methodology Framework (REDD+MF), v1.8. Washington, DC: Verra. https://verra.org/documents/vm0007-redd-methodology-framework-v1-8-clean.

Verra. 2026. "Restoring Pakistan's Mangroves to Protect Climate, Communities, and Coastlines" (Delta Blue Carbon case study). Last updated 23 September 2026. Washington, DC: Verra. https://verra.org/case-studies/delta-blue-carbon/.

VNV. 2026. "Impact Areas: Nature Based Solutions." Accessed October 23, 2026. https://vnv.earth/.

Wachpanich, Nicha. 2024. "Thailand Turns to Mangrove Carbon Credits despite Scepticism." *Dialogue Earth*, September 30, 2024. https://dialogue.earth/en/nature/thailand-turns-to-mangrove-carbon-credits-despite-scepticism/.

WEF (World Economic Forum). 2025. Investing in Mangroves: The Corporate Playbook. White Paper, April 2025. Geneva: World Economic Forum. https://reports.weforum.org/docs/WEF_Investing_in_Mangroves_2025.pdf.

WIF (Worldview International Foundation). 2018. Reforestation and Restoration of Degraded Mangrove Lands, Sustainable Livelihood and Community Development in Myanmar. VCS Project Description, Version 3.0, VCS Project 1764, 19 February 2018. Yangon: WIF. https://www.cooleffect.org/lib/content/wp-content/uploads/2021/01/Myanmar_PROJ_DESC_1764_19FEB2018.pdf.

World Bank. 2014. Building Resilience for Sustainable Development of the Sundarbans: Strategy Report. Washington, DC: World Bank. http://hdl.handle.net/10986/20116.

World Bank. 2025. *Carbon Crediting: A Results-Based Approach to Mobilizing Additional Climate Financing*. https://openknowledge.worldbank.org/server/api/core/bitstreams/ae205ad4-e801-4ddf-9c64-34d0091092e8/content.

World Bank Group. 2026. "What You Need to Know about Results-Based Climate Finance." Accessed October 23, 2026. https://www.worldbank.org/en/news/feature/2022/08/17/what-you-need-to-know-about-results-based-climate-finance.

World Economic Forum. 2026. *Turning the Tide: A Financier's Guide to Investing in Blue Carbon Ecosystems*. https://reports.weforum.org/docs/WEF_Turning_the_Tide_A_Financier's_Guide_to_Investing_in_Blue_Carbon_Ecosystems_2026.pdf.

WWF-India. 2017. Sundarban in a Global Perspective: Long Term Adaptation and Development. Discussion Paper. New Delhi: WWF-India.

https://documents1.worldbank.org/curated/en/183661546838959347/pdf/Sundarban-in-a-Global-Perspective-Long-Term-Adaptation-and-Development-Discussion-Paper.pdf.

Wylie, Lindsay, Ariana E. Sutton-Grier, and Amber Moore. 2016. “Keys to Successful Blue Carbon Projects: Lessons Learned from Global Case Studies.” *Marine Policy* 65: 76–84. https://doi.org/10.1016/j.marpol.2015.12.020.



CGIAR is a global research partnership for a food-secure future. CGIAR science is dedicated to transforming food, land, and water systems in a climate crisis. Its research is carried out by 13 CGIAR Centers/Alliances in close collaboration with hundreds of partners, including national and regional research institutes, civil society organizations, academia, development organizations and the private sector. www.cgiar.org

To learn more about the CGIAR Research Portfolio, please visit www.cgiar.org/cgiar-research-portfolio-2025-2030/

Contact

Avinandan Taron, Researcher - Environmental and Resource Economist, IWMI, Colombo, Sri Lanka (a.taron@cgiar.org)

CGIAR CLIMATE ACTION