

**Data Collection Survey on
Formulating Partnership Initiative for
the Conservation and Sustainable Use of
Mangrove
(QCBS)**

Final Report

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**JIN Corporation
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Data Collection Survey on Formulating Partnership Initiative
for the Conservation and Sustainable Use of Mangrove (QCBS)

Final Report

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Acronyms

ABS	Access and Benefit-Sharing
AF	Adaptation Fund
AFOLU	Agriculture, Forestry and Other Land Use
ASC	Aquaculture Stewardship Council
ASEAN	Association of South-East Asian Nations
ASIC	Asian Seafood Improvement Collaborative
BAPPENAS	National Development Planning Agency (Badan Perencanaan Pembangunan Nasional)
BR	Biosphere Reserve
BRG	Peatland Restoration Agency (Badan Restorasi Gambut)
BRGM	Peatland and Mangrove Restoration Agency (Badan Restorasi Gambut dan Mangrove)
BRIN	Badan Riset dan Inovasi Nasional
CBD	Convention of Biological Diversity
CBEMR	Community-Based Ecological Mangrove Restoration
CDM	Clean Development Mechanism
CDP	Carbon Disclosure Project
CDSB	Climate Disclosure Standards Board
CFU	Colony Forming Unit
COP	Conference of the Parties
CSR	Corporate Social Responsibility
CTI	Coral Triangle Initiative
CTS	Center for Technology Services
DNA	Deoxyribonucleic Acid
DO	Dissolved Oxygen
DSI	Digital Sequence Information
EDINET	Electronic Disclosure for Investors NETwork
EIRR	Economic Internal Rate of Return
ESG	Environment, Social, Governance
EU	European Union
FAO	Food and Agriculture Organization
FCPF	Forest Carbon Partnership Facility
FIRR	Financial Internal Rate of Return
FLRM	Forest and Landscape Restoration Mechanism
FMO	Nederlandse Financierings-Maatschappij voor Ontwilleelingslagen
FRA	The Global Forest Resources Assessment
FSB	Financial Stability Board

GBFF	Global Biodiversity Framework Fund
GCF	Green Climate Fund
GEF	Global Environment Facility
GHG	Green House Gases
GMA	Global Mangrove Alliance
GRI	Global Reporting Initiative
GSIA	Global Sustainable Investment Alliance
ICMA	International Capital Market Association
IFRS	International Financial Reporting Standard
IIRC	International Integrated Reporting Council
IOC	Intergovernmental Oceanographic Commission
IPCC	Intergovernmental Panel on Climate Change
IR	Investor Relations
ISME	International Society for Mangrove Ecosystem
ISO	International Organization for Standardization
ISSB	International Sustainability Standards Board
ITMOs	Internationally Transferred Mitigation Outcomes
IUCN	International Union for Conservation of Nature
JBIB	Japan Business Initiative for Biodiversity
JCM	Joint Crediting Mechanism
JFGE	Japan Fund for Global Environment
JICA	Japan International Cooperation Agency
KM4B	Knowledge Management for Biodiversity
KM-GBF	Kunming-Montreal Global Biodiversity Framework
KNCF	Keidanren Nature Conservation Fund
KOIN	Conservation Indonesia (Konservasi Indonesia)
KPI	Key Performance Indicator
LUCF	Land Use Change and Forestry
LULUCF	Land Use, Land Use Change and Forestry
M4CR	Mangrove for Coastal Resilience
MAP	Mangrove Action Project
MDGs	Millenium Development Goals
MFF	Mangrove for the Future
MIC	Mangrove Information Center
MMAF	Ministry of Marine Affairs and Fisheries
MOEF	Ministry of Environment and Forestry

mRNA	Messenger Ribonucleic Acid
MSC	Marine Stewardship Council
NAMRIA	National Mapping and Resource Information Authority
NDC	Nationally Determined Contribution
NGO	Non-Governmental Organization
NPO	Non-Profit Organization
NTFP	Non-Timber Forest Products
NUG	National Unity Government
ODA	Official Development Assistance
PCR	Polymerase Chain Reaction
ProPO	Prophenoloxidase
RCF	Research Center for Fishery
REDD+	Reducing Emissions from Deforestation and Forest Degradation and the Role of Conservation, Sustainable Management of Forests and Enhancement of Forest Carbon Stocks in Developing Countries
RICA	(A product of probiotics developed by RICAFE)
RICAFE	Research Institute for Coastal Aquaculture and Fishery Extension
RNA	Ribonucleic Acid
SAC	State Administration Council
SASB	Sustainability Accounting Standards Board
SDGs	Sustainable Development Goals
SICA	Central American Integration System (Sistema de la Integración Centroamericana)
SOD	Superoxide Dismutase
SSB	Sustainability Standards Board
STREAM	Sustainable Tourism through Energy Efficiency with Adaptation and Mitigation Measures
TCFD	Task Force on Climate-related Financial Disclosures
TEEB	The Economics of Ecosystems and Biodiversity
TNC	The Nature Conservancy
TNFD	Taskforce on Nature-related Financial Disclosures
ToR	Terms of Reference
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNEP-FI	UNEP Finance Initiative
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change

UN-REDD	United Nations Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries
UNWTO	United Nations World Tourism Organization
USAID	United States Agency for International Development
VCS	Verified Carbon Standard
VRP	Value Reporting Foundation
WI	Wetland International
WIF	Worldview International Foundation
WSSV	White Spot Syndrome Virus
WWF	World Wide Fund for Nature

Summary

1. Overview of the Study

1.1) Background and Context of the Study

Mangroves provide a wide range of ecosystem services, delivering multiple benefits to people living in vulnerable coastal environments. However, the global mangrove area decreased by approximately 22% between 1980 and 2020. If this trend continues, coastal communities will no longer be able to benefit from such diverse ecosystem services, and their livelihoods will be threatened by the depletion of fishery resources and by disaster risks associated with sea-level rise and severe typhoons driven by climate change.

At the 13th Conference of the Parties to the Convention on Biological Diversity in 2016 (Cancun), the Cancun Declaration was adopted to promote the mainstreaming of biodiversity into agriculture, forestry, fisheries, and tourism. In realizing this commitment, the transition to a green economy plays a key role. To effectively and sustainably promote such a transition, it is indispensable to improve the quality and value addition of ecosystem-based products, develop markets, and strengthen collaboration with the private sector.

Some private companies with a high awareness of the sustainable use of ecosystem services have engaged in mangrove reforestation under Corporate Social Responsibility (CSR) initiatives. Furthermore, the growing influence of Environment, Social, and Governance (ESG) investment is increasing corporate awareness of biodiversity conservation and sustainable use within the supply chains of raw material-producing countries.

For private companies to implement such initiatives at the field level, it is essential to have collaboration with a wide range of stakeholders. However, an effective information network to support this remains underdeveloped. In addition, compared to Western countries, Japan still lags behind in establishing an enabling environment for ESG investment. Therefore, it is important to share and disseminate information to promote such an enabling environment.

For Japanese private companies to engage in biodiversity conservation, including mangroves, in a sustainable manner through ESG investment, it is necessary to establish a platform for information sharing and dissemination among diverse stakeholders. Such a platform should organize and communicate information on corporate collaboration, local needs and activities, methods for evaluating ecosystem services, and concrete financing mechanisms. This study aims to collect and organize the information to be shared and disseminated through the platform, and to examine proposals for its functions and organizational framework.

1.2) Purpose of the Study

This study aims to collect the necessary information for establishing a platform that facilitates effective information sharing and dissemination among stakeholders, and to promote partnership projects between local organizations engaged in mangrove conservation and sustainable use and the companies supporting them. Furthermore, it proposes a structure and activity plan for such a platform. Through pilot activities conducted in the field, the study verifies and consolidates the various benefits derived from mangrove

conservation. By sharing and disseminating these results through the proposed platform, the study intends to enhance corporate interest in supporting mangrove conservation initiatives.

2. Status, Conservation Challenges, and Policies on Mangroves

2.1) Global Status of Mangroves

The regions with the largest mangrove areas are South and Southeast Asia followed by West and Central Africa, South America, the Caribbean and Central America, and Oceania. However, significant declines in mangrove areas have been observed in South and Southeast Asia, Oceania, and West and Central Africa. Southeast Asia, which accounts for approximately 30 percent of the world's mangrove area, has experienced the most substantial loss. This region has significant relevance to Japan because it hosts the largest number of Japanese companies.

2.2) Current Mangrove Conservation Policies and Initiatives in Southeast Asian Countries

Indonesia, which accounts for 19.1 percent of the world's mangrove area, is considered to be a main mangrove country. However, large-scale conversion to aquaculture ponds, as well as logging for timber, paper, and wood chips, has led to significant mangrove loss. Local communities, domestic and international NGOs, and some government-related and private companies are actively engaged in conservation and reforestation efforts. In addition, in recognition of the role of mangroves in climate change mitigation, the government has formulated a national plan to restore 600,000 hectares.

Thailand has extensive and biodiversity-rich mangrove forests along the Andaman Sea, while nearly 50 percent of the mangroves along the Gulf of Thailand have been lost due to charcoal production, conversion to aquaculture, urbanization, and industrial development. The government now classifies mangrove forests nationwide into conservation and development zones, with a particular focus on restoring areas illegally converted.

In the Philippines, the large-scale conversion of mangroves into aquaculture ponds in the past caused a substantial reduction in mangrove area. Consequently, new aquaculture pond development is now restricted, and laws mandate the establishment of greenbelts around existing ponds. Although mangrove forests have been designated as protected areas, enforcement remains weak.

Vietnam experienced severe mangrove destruction during the Vietnam War due to defoliant spraying. After the war, the government led reforestation efforts, but conversion to aquaculture also occurred at the same time. In recent years, conservation and replanting have been focused, supported by local communities and NGOs.

In Malaysia, some mangrove forests on the Peninsular side are managed through sustainable use, with a 30-year cycle of planting and harvesting. On the contrary, on the Bornean side, large areas were previously clear-cut for woodchip production without sustainable activities. Such practices are now prohibited, and clear

management processes have been developed, such as the classification of mangroves into four management zones under formal management plans.

Myanmar has faced extensive mangrove loss due to conversion for settlements, farmland, aquaculture ponds, and logging for timber and fuelwood. Conservation efforts have included the establishment of protected areas, reforestation, and partnerships with local communities, the private sector, and international organizations. However, since the 2021 coup, concerns have arisen about the stagnation of these initiatives.

2.3) Donor and NGO Initiatives for Mangrove Conservation

Numerous NGOs are engaged in mangrove-related activities. Representative organizations include Wetlands International, Mangroves for the Future, The Nature Conservancy, Worldview International Foundation, myclimate, and the Mangrove Action Project. In addition, international initiatives such as the Global Mangrove Alliance and its sub-initiative, the Mangrove Breakthrough, have been established under the leadership of these NGOs. These initiatives promote mangrove protection and restoration in collaboration with international organizations, national governments, research institutions, civil society groups, and private companies. Furthermore, various international agencies are implementing programs related to both mangrove ecosystems and aquaculture, with many of them adopting an integrated approach that recognizes the interconnection between the two sectors.

2.4) Initiatives for Mangrove Conservation in Each Country by Japanese Companies

In relation to the production, processing, and distribution of extensive shrimp aquaculture, five Japanese companies are currently engaged in activities in Indonesia and two in Vietnam. On the other hand, no such extensive shrimp aquaculture activities by Japanese companies have been identified in Thailand, the Philippines, Malaysia, or Myanmar. As for mangrove conservation, the number of publicly listed Japanese companies undertaking mangrove reforestation projects has been increasing in recent years. The main areas of activity are in Southeast Asian countries such as Indonesia, Thailand, Philippines, and Vietnam. These initiatives tend to be carried out continuously in the same countries over multiple years. A similar trend is also observed among non-listed companies implementing mangrove planting activities in connection to their Corporate Social Responsibility (CSR) initiatives.

3. International Initiatives and Financial Mechanisms for Nature Conservation

3.1) International Initiatives for Natural Environment Conservation

In recent years, many international agreements have been established to promote corporate investment in the conservation and restoration of ecosystems and biodiversity, including mangroves. These include the Kunming-Montreal Global Biodiversity Framework under the Convention on Biological Diversity (CBD), the Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC), and the Sustainable Development Goals (SDGs). These international goals are mutually complementary and have

given rise to numerous initiatives led by governments, NGOs, and private enterprises that aim to contribute to their achievement. The outcomes of these derivative initiatives are reported and consolidated through forums such as the Conferences of the Parties (COPs).

3.2) Financial Mechanisms for Natural Environment Conservation

The main mechanisms for mobilizing financial resources can broadly be categorized into the introduction of public funding and private financing. Since 2015, the utilization of private capital has gained increasing importance, with ESG investment rapidly expanding among companies practicing ESG management. Going forward, it is imperative to further promote ESG investment by private enterprises while also establishing frameworks for the appropriate assessment and verification of such initiatives.

In the forestry conservation sector, the major types of ESG-oriented business activities are (1) activities that promote conservation through funds and other financial instruments, and (2) conservation project planning and implementing led by the corporations themselves. The former includes CSR initiatives and carbon credit purchases derived from investment in forest conservation, while the latter typically involves investments aimed at building ESG-conscious supply chains. Funds that invest in profit-oriented businesses related to environmental conservation remain underdeveloped. In particular, those targeting the forestry or agricultural sectors are limited, and investment funds specifically focused on mangrove restoration and conservation are even more scarce.

3.3) Effective Corporate Information Disclosure and Communication for ESG Investment

In recent years, frameworks for ESG information disclosure have been developed by governments, international organizations, stock exchanges, and NGOs. Although such efforts have been led mainly by overseas actors, Japan's Ministry of Economy, Trade and Industry (METI) has also issued guidance. These frameworks serve as conceptual frameworks rather than mandatory standards, and since they are complementary to each other, companies are encouraged to utilize them effectively according to their specific needs to achieve better ESG disclosure.

Ideally, corporate Investor Relations (IR) includes comprehensive ESG disclosure that meets diverse information needs. However, when corporate resources are limited, focusing on common indicators shared across multiple frameworks is an effective strategy. On top of that, it is important for companies to recognize the diversity of ESG investment strategies and to expand disclosure efforts with an awareness of information users. Currently, the coexistence of numerous overlapping frameworks has resulted in a lack of coherence, prompting ongoing efforts to improve harmonization and complementation. Nevertheless, attention must be paid to the fact that multiple initiatives for harmonization are evolving in parallel. Furthermore, disclosure and investment related to biodiversity remain insufficient, and there is a growing recognition that the sustainable use of natural capital and the conservation of biodiversity are indispensable for the continuity of economic activity.

ESG-related information is disclosed through various media such as integrated reports, CSR reports, data books, and corporate websites, and companies are expected to select appropriate disclosure media and target audiences according to the nature of the information and stakeholder needs.

4. Corporate Interests Related to Nature Conservation

4.1) Background and Overview of the Corporate Survey

To promote corporate engagement in addressing environmental issues through collaboration with private companies pursuing ESG management, a questionnaire survey targeting private corporations was conducted.

The survey questions were broadly structured into four categories: 1) Overall trends in corporate initiatives for forest and natural environment conservation; 2) Motivations behind such initiatives; 3) Challenges and constraints hindering these efforts; and 4) Types of information and mechanisms considered effective for promoting corporate actions.

4.2) Results of the Corporate Survey

A total of 22 companies responded to the questionnaire, which was distributed through the Japan Business Federation (Keidanren) Committee on Nature Conservation. Many respondents expressed strong interest in forest and natural environment conservation, and in mangrove conservation efforts in developing countries. These initiatives were often pursued as part of corporate philosophy or to foster environmental awareness among employees, indicating that environmental conservation is being recognized as an important component of corporate behavior. However, when it comes to implementing projects in developing countries, the key challenges cited by many companies were insufficient information on the practical aspects of local operations and the technical know-how required for measuring the outcomes of their initiatives. Accordingly, the survey results revealed that many companies seek reliable and practical information to overcome these challenges.

4.3) Interviews with Private Companies

To ensure that the content of information collected, shared, and disseminated through the proposed information platform would be useful and attractive to potential users, interviews were conducted with seven private companies that are currently involved in or interested in tropical and subtropical forest conservation.

The interviews identified several main areas of corporate interest concerning mangroves: carbon credits, ecosystem valuation, and mangrove reforestation activities.

4.4) Workshop on Promoting Mangrove Conservation through Corporate Participation

Based on the specific interests identified through the corporate survey and interviews, a workshop was organized with participation from five private companies to further deepen discussions and exchange views. The study team provided an overview of the project and explained the purpose and structure of the proposed

information platform, followed by a presentation by JICA who outlined Indonesia's relevant policies, international mangrove conservation efforts, and the latest global trends in this field. During the discussion session with participating companies, the key topics included corporate interests related to mangrove conservation, cross-sectoral issues, and sector-specific challenges including generation of carbon credits, contributions to the natural environment and local communities (CSR), and the development of sustainable resource procurement and management systems.

5. Structure, Functions, and Content of the Information Platform

5.1) Structure and Functions of the Information Platform

The specific functions of the proposed information platform are as follows:

- The collection of information on the status of mangroves and conservation policies in countries where mangroves grow.
- The compilation of scientific knowledge on the functions and ecosystem services provided by mangrove ecosystems.
- The collection of information on NGOs and private companies engaged in mangrove conservation activities and projects at the field level.
- The collection of information on grants, investment funds, carbon credit schemes, and other mechanisms related to biodiversity conservation including mangroves.
- The collection of information on private companies supporting mangrove conservation and their success stories.
- The organization and dissemination of collected information to relevant stakeholders through websites, seminars, and other channels.

The implementation framework of the information platform is envisioned as follows:

- Form of the platform: The platform will be web-based, providing easy access to stakeholders both in Japan and overseas.
- Secretariat structure and functions: The secretariat will be responsible for updating and maintaining information shared through the platform, and facilitating collaboration among private companies, research institutions, local NGOs, and government entities engaged in mangrove conservation. The secretariat will be hosted within JICA, and its operation will be linked with existing JICA-managed websites, such as the "Forest for the World Platform".

5.2) Content to be Shared and Disseminated through the Information Platform

The information platform is designed to serve as a hub for collecting, sharing, and disseminating information related to mangroves, with the aim of facilitating the formation of collaborative projects among stakeholders.

The platform content will be broadly structured into three main categories: 1) information on mangroves, 2) policies and international frameworks that contribute to mangrove conservation, and 3) initiatives related to mangrove conservation.

6. Collection of Information and Development of a Protocol for Ecosystem Service Evaluation

6.1) Ecosystem Services and Functions of Mangroves

Ecosystem services refer to the benefits that people obtain from ecosystems, which are categorized into four types in the Millennium Ecosystem Assessment: provisioning services, regulating services, supporting services, and cultural services.

Mangroves provide diverse ecosystem services and deliver multiple benefits to people, particularly to communities residing in coastal areas. The ecosystem services expected in the silvo-aquaculture pilot sites under this study can be summarized as follows:

- Provisioning services: Provision of food and raw materials
- Regulating services: Climate regulation, mitigation of local disasters, and pollination
- Supporting services: Provision of habitats for flora and fauna
- Cultural services: Conservation of natural landscapes, opportunities for recreation and tourism, and provision of knowledge for science and education

To evaluate the ecosystem services of a specific project, a With-action scenario and a Without-action scenario were established, and the difference in economic value between these scenarios is used as the basis for evaluation. In this study, the evaluation was conducted in Bontomanai, South Sulawesi Province, where two scenarios were set, which are a With-action scenario (implementation of silvo-aquaculture) and a Without-action scenario (current extensive aquaculture).

6.2) Evaluation Method of Ecosystem Services

This study developed a protocol for evaluating ecosystem services of silvo-aquaculture, with reference to the TEEB Synthesis Report (2010). The protocol summarizes the methods for estimating the annual economic value per unit area of ecosystem services that are expected to change or improve through mangrove planting and aquaculture under silvo-aquaculture systems. The evaluation process consists of 1) scenario setting, 2) identification of target objects and phenomena for evaluation, 3) selection of appropriate evaluation methods, 4) collection and analysis of relevant information, and 5) calculation of economic value.

6.3) Results of Ecosystem Service Valuation in the Pilot Activity

In the pilot activity conducted in Bontomanai, South Sulawesi, the With-action scenario showed an increase in the economic value of ecosystem services related to climate regulation, mitigation of local disasters, and

provision of habitats. On the other hand, the economic value of food and raw material provision was significantly lower in the With-action scenario. This was attributed to the employment of full-time workers and the limited productivity due to underdeveloped aquaculture techniques. In the With-action scenario, full-time workers were assumed to be employed for the designated ponds. However, in actual practice, workers usually manage multiple ponds, suggesting potential for improving economic value through reduced labor costs. Furthermore, while native species were used in this study, the use of exotic and more easily cultivable species such as Tilapia or Vannamei shrimp could enhance the provisioning services related to food and raw material supply.

7. Implementation of the Pilot Activity

7.1) Selection of Target Country and Site

The target country for the pilot activity was considered based on information related to mangroves in Southeast Asian countries and seven selection criteria. As a consequent, Indonesia was selected as the pilot country due to its high consistency and relevance with this study, both in terms of project implementation and potential for future expansion. Indonesia was considered to have favorable conditions for smooth implementation and further development. Within Indonesia, the pilot site was selected in South Sulawesi Province based on literature review, stakeholder interviews, and field survey results.

7.2) Overview of the Pilot Activity

The pilot activity aimed to examine whether silvo-aquaculture, a system integrating mangrove planting and shrimp aquaculture, could serve as a potential business model for ESG investment from Japan, and to identify related challenges and opportunities. The activity was implemented from April 2023 to June 2025.

7.3) Basic Concept of the Pilot Activity: Verification of the silvo-aquaculture business model

Based on preliminary field surveys, a silvo-aquaculture business model was formulated that integrates mangrove planting and shrimp aquaculture, which is the target for ESG investment from Japan and benefits local livelihoods. On top of that, technical and socio-economic verification items were defined, and the results were organized through comparison between the Without-action scenario (continuing conventional extensive aquaculture) and the With-action scenario (introducing silvo-aquaculture).

The three components in the pilot activity were (1) shrimp aquaculture verification, (2) mangrove planting verification, and (3) a socio-economic survey. In the technical and managerial verification of the business model, two water management systems, concurrent and separate systems, were compared to collect and provide baseline data.

7.4) Silvo-aquaculture (Shrimp Aquaculture) in the Pilot Activity

Black tiger shrimp was selected as the main cultured species, with seaweed and milkfish co-cultured to maintain ecological balance. Monitoring focused on water quality and changes in organisms serving as shrimp feed.

Water quality management was difficult in the technical verification ponds, resulting in the high mortality of shrimp. In the social verification ponds, water management was also challenging. However, during the third production cycle, which coincided with the rainy season, growth conditions improved, and a certain amount of data were obtained. Analysis showed that shrimp in the pond with mangroves (S3) exhibited faster growth and larger body weight, suggesting that mangroves might have increased food availability and promoted growth. White spot syndrome virus (WSSV) infection was detected at the beginning of this cycle.

The results for seaweed showed favorable growth within salinity of 5 to 40 ppt and temperatures of 27 to 35°C, while growth ceased at salinity above 45 ppt.

The greatest challenge in shrimp aquaculture was disease, including bacterial, fungal, and viral infections. WSSV is fatal to shrimp and affects crustaceans in general, making eradication difficult. Mass production of disease-resistant broodstock derived from surviving individuals has been proposed as a countermeasure. It was also confirmed that adding probiotics (RICA) to the nursery tanks during the intermediate culture stage improved shrimp immunity and survival rates against *Vibrio* infection.

To recover investment costs, it is necessary to minimize risks and losses through diversification. Silvo-aquaculture should therefore introduce polyculture systems involving multiple species, such as black tiger, Vannamei shrimp, mud crabs, seaweed, milkfish, and tilapia to enhance resilience against disease and water quality fluctuations while promoting macro benthic organism growth and water purification.

In parallel, an inventory survey of aquatic fauna inside and outside the ponds was conducted, identifying 91 taxa. This result highlighted the importance of mangrove ecosystems for coastal biodiversity conservation and fisheries resource maintenance.

7.5) Silvo-aquaculture (Mangrove Planting) in the Pilot Activity

In the technical verification ponds, two mound levels were constructed: low mounds that remained submerged and high mounds exposed during water exchange. In the concurrent ponds, only *Rhizophora mucronata* was planted, while in the separate ponds, both *Rhizophora mucronata* and *Bruguiera gymnorrhiza* were planted. Survival and growth were monitored, and replanting was conducted when seedlings died.

Monitoring results showed that *Rhizophora* had the highest survival and growth rates on high mounds under the separate system, whereas the concurrent system showed poorer performance, indicating that the separate system is more suitable for *Rhizophora*. Conversely, *Bruguiera* seedlings completely died on low mounds, and survival on high mounds was also low.

In the social verification ponds, no height difference was applied to the mounds, but two water management systems (concurrent and separate) were compared, with both *Rhizophora mucronata* and *Bruguiera*

gymnorhiza planted. The results showed higher *Rhizophora* survival in the separate system, while *Bruguiera* survival remained low overall.

Vegetation surveys were also conducted using the belt transect method at three sites: 1) planted mangrove stands in the RICAFE compound, 2) natural mangrove forests adjacent to the social verification ponds, and 3) naturally regenerated mangroves in abandoned ponds. Results showed that in artificial plantations, high-density planting led to competition-induced mortality and methane emissions, providing no conclusive evidence of contribution to climate change mitigation. Natural mangrove forests had dense canopy layers, high litter accumulation, and active aerobic decomposition through good tidal exchange, with no methane emission observed. In naturally regenerated areas dominated by *Avicennia*, biomass accumulation was much lower than in plantation sites.

7.6) Socio-economic Survey in the Pilot Activity

The survey targeted all aquaculture ponds in the Bontomanai area. Fifty-five ponds were randomly sampled, and structured interviews were conducted with 55 households associated with those ponds as owners, tenants, or workers. Key informant interviews were also carried out to collect information on the value chains of shrimp and carbon credits.

The results revealed a shortage of labor due to aging and out-migration of young workers, leading to increased pond leasing and contract-based production. Specialized aquaculture management businesses were emerging, with ponds being consolidated through leasing or management contracts, potentially serving as local partners for future collaboration. Although extensive aquaculture continues amid deteriorating water quality and aging infrastructure, the introduction of advanced technologies could stimulate reinvestment and refurbishment of ponds, presenting significant potential demand for ESG investment. Furthermore, residents recognized the disaster prevention benefits of mangroves, indicating strong social incentives for participation in mangrove conservation through silvo-aquaculture.

7.7) Verification of the Silvo-aquaculture Business Model Based on the Pilot Activity

To verify the potential of silvo-aquaculture as an ESG investment target, a management unit of 20 ha was assumed. The Without-action scenario (conventional aquaculture) was compared with two With-action scenarios (silvo-aquaculture) that incorporated the results from the pilot activity.

For the With-action scenarios, technical specifications were set for four elements (culture density, mangrove interaction, eco-feed, and species selection) with the aim of optimization from environmental and economic perspectives. Based on the challenges identified in the pilot activity, semi-intensive milkfish aquaculture was considered as an alternative that offers both sustainability and higher market value for shrimp aquaculture. Technical specifications for mangrove planting were developed based on species composition, ground elevation, water management method, biodiversity, and carbon sequestration potential. The results suggested the need for optimal species arrangement per pond, multi-layered forest structure through thinning, improved water management facilities, and regular carbon stock monitoring. From a management perspective,

incorporating the findings from the socio-economic survey, the model should include ecosystem service valuation, pond leasing for scaling up, local partner development, and promotion of ESG investment to achieve clustering and sustainable expansion of silvo-aquaculture. At the same time, due consideration should be given to pond owners who prefer not to lease or outsource aquaculture operations.

Financial and economic analysis based on the With-action scenario showed that both semi-intensive black tiger shrimp and semi-intensive milkfish models generated higher annual profits than the Without-action scenario. In particular, the semi-intensive milkfish model demonstrated high profitability and can be regarded as a promising ESG investment target. From the viewpoint of initial investment and management costs, the payback period was estimated at 7 years for the milkfish model and 9 years for the shrimp model, indicating that both can be viable and sustainable in the long term.

8. Recommendations

8.1) Recommendations on Ecosystem Service Valuation for Silvo-aquaculture

Ecosystem service valuation can vary significantly depending on the assumptions and parameters set in each scenario. Therefore, validating the appropriateness of such settings is of critical importance. However, since assumptions often involve elements that have not yet been implemented, certain estimations are unavoidable, making full validation inherently limited. This limitation should be noted when conducting or interpreting ecosystem service valuation.

In the With-action scenario, activities that have not yet been implemented must be assumed. Since knowledge about such activities is accumulated over time, it will become easier to assess the appropriateness of these assumptions. Therefore, the continuous technical accumulation related to the With-action scenario will be essential for the effective application of ecosystem service valuation in future initiatives.

8.2) Recommendations from the Perspective of Shrimp Aquaculture in Silvo-aquaculture

The pilot activity confirmed that mangroves can provide certain benefits to shrimp aquaculture. At the same time, it revealed the technical and operational challenges currently facing shrimp aquaculture, as well as the potential disadvantages that mangroves may impose on aquaculture. The extent of the labor, cost, and ecological impacts required to mitigate these disadvantages remains unclear.

Furthermore, the optimal water management method for silvo-aquaculture has yet to be identified. Although several promising approaches were proposed, further development and accumulation of both technical and managerial know-how are necessary to determine the most effective system.

While many valuable insights have been obtained, considerable uncertainties remain. One possible reason is that aquaculture stakeholders have not been sufficiently engaged in silvo-aquaculture initiatives, resulting in limited efforts from their perspective. Moving forward, closer collaboration between forestry and aquaculture stakeholders will be essential.

8.3) Recommendations from the Perspective of Mangrove Planting in Silvo-aquaculture

To advance mangrove planting through silvo-aquaculture, it is necessary to develop appropriate water management approaches that can create favorable conditions for mangrove growth. Moreover, thinning at appropriate stages should be considered to ensure healthy mangrove development. At the same time, further discussion is needed on long-term mangrove management strategies aimed at maintaining sufficient biomass and achieving sustainable stand development.

8.4) Recommendations for the Introduction of the Silvo-aquaculture Business Model

The verification of the silvo-aquaculture business model has shown that feasibility depends more on market recognition of ecosystem service valuation and benefits from biodiversity than profitability alone. To promote the widespread adoption of silvo-aquaculture, it must first be established as a viable business. This requires not only technical advancement but also market mechanisms that acknowledge positive ecosystem service outcomes and translate them into price premiums. Currently, such market conditions are not yet in place, and thus the creation of a social and market environment in which ecosystem service valuation is recognized by businesses and consumers is an urgent priority.

Semi-intensive milkfish aquaculture shows high potential for successful integration with silvo-aquaculture, but further empirical verification is required, particularly to assess whether mangrove planting under such systems provides tangible ecological benefits.

The verification process has produced limited yet highly valuable findings, further technical validation, and closer collaboration between aquaculture and forestry stakeholders. The establishment of a social environment that enhances the awareness of ecosystem service valuation, and the effective use of information through dedicated platforms will be essential for scaling up and sustaining silvo-aquaculture across different regions.

1. Overview of the Study

1.1 Background and Context of the Study

Ecosystem services are categorized into four types: provisioning, regulating, supporting, and cultural services. Among them, mangroves offer a wide range of ecosystem services and provide various benefits, especially to communities in vulnerable coastal environments. For instance, provisioning services include the supply of fishery resources, while regulating services serve the prevention of coastal erosion and the reduction of disaster risks such as tsunamis and storm surges. In addition, regarding carbon storage, one of the regulating services, it is revealed that mangroves make a significant contribution to climate change mitigation because the amount of carbon stored in the soil is much higher than that of terrestrial forests¹.

Meanwhile, mangrove areas are rapidly declining worldwide. The global mangrove area, which was 18.8 million hectares in 1980, had decreased to 14.7 million hectares² by 2020, representing a reduction of approximately 22% over four decades. If this trend persists, coastal residents will be unable to benefit from the diverse ecosystem services, and their livelihoods will be threatened by the depletion of fishery resources and disaster risks associated with sea level rise and intense storms driven by climate change.

At the 13th Conference of the Parties to the Convention on Biological Diversity in 2016 (Cancun), the Cancun Declaration was adopted to promote the mainstreaming of biodiversity into agriculture, forestry, fisheries, and tourism. Achieving this objective requires the advancement of a green economy. To effectively and sustainably promote a green economy, it is essential to enhance the quality and value addition of products derived from ecosystems and to develop markets in collaboration with companies.

Private companies with a strong awareness of the sustainable use of ecosystem services have shown interest in mangrove conservation, which serves various ecosystem services. Some companies have already undertaken mangrove plantation initiatives in connection to Corporate Social Responsibility (CSR). Furthermore, with the growing recognition of Environmental, Social, and Governance (ESG) investment, emphasizing that socially and environmentally responsible investment contributes to long-term company growth, companies are increasing their awareness of biodiversity conservation and sustainable use in the supply chains in countries where raw materials are sourced.

For private companies to implement such initiatives on the ground, they need effective collaboration with a wide range of stakeholders, including other companies for sharing information, research institutions possessing scientific and technical expertise to properly evaluate ecosystem services, Non-Governmental Organizations (NGOs) involved in on-the-ground activities, and local governments. However, an effective information network to support such collaboration remains underdeveloped. Furthermore, since Japan still

¹ https://adaptation-platform.nies.go.jp/climate_change_adapt/qa/09.html, <https://www.ffpri.affrc.go.jp/research/saizensen/2021/20211224-03.html>, http://mangrove.or.jp/subpage/about_mangroves.html
(Data referenced as of May 13, 2025)

² FAO (2007) *The World's Mangroves 1980-2005*, FAO (2023) *The World's Mangroves 2000-2020*
(Data referenced as of July 4, 2025)

lags behind in establishing an enabling environment for ESG investment compared to western countries, it is critically important to share and disseminate information to promote such an environment.

To promote engagement in biodiversity conservation, including mangroves, through ESG investment among private Japanese companies, it is essential to build a platform for sharing and disseminating information among diverse stakeholders. This platform should organize and provide information concerning inter-company collaboration, local needs and activities, methods for evaluating ecosystem services, and tangible financing mechanisms. This study aims to collect and organize such information to be shared and disseminated through the platform, and to examine proposals for its functions and organizational framework.

1.2 Purpose of the Study

To promote the formation of collaborative projects between local organizations engaged in mangrove conservation and sustainable use and the companies that support them, this study aims to collect information on financing mechanisms, project schemes, and the needs of companies with regard to collaborative projects, which are necessary for building a platform that effectively shares and disseminates information among stakeholders. Furthermore, the study proposes the structure and activity plan of the platform. The objectives of this study also include enhancing company interest in supporting mangrove conservation initiatives by verifying and compiling the various benefits generated by mangrove conservation efforts through pilot activities in the field, and sharing and disseminating the results through the proposed platform. It must be noted that the purposes of this study were revised through a contract amendment, reflecting updates to the concept and content of the platform (details provided later).

2. Current Status of Mangroves, Challenges in Conservation, and Policies

2.1 Current Status of Mangroves by Country

2.1.1 Global Mangrove Status

According to the Food and Agriculture Organization (FAO) (2020)³, among the 223 countries and regions worldwide for which information was available, 113 countries and regions possess mangroves. The global mangrove area in 2020 was estimated at 14.72 million hectares. By region, South and Southeast Asia holds the largest share at 36.2%, followed by West and Central Africa (15.7%), South America (14.4%), the Caribbean and Central America (9.2%), and Oceania (8.5%) (Table 1). Global mangrove area decreased by 1.04 million ha over the 30-year period from 1990 to 2020. The most significant declines occurred in South and Southeast Asia (790,000 ha), Oceania (190,000 ha), and West and Central Africa (130,000 ha). On the other hand, increases were observed in the Caribbean and Central America (80,000 ha) and North America (40,000 ha) (Figure 1).

Table 1: Mangrove Area by Region (Estimates for 1990, 2000, 2010, 2020)

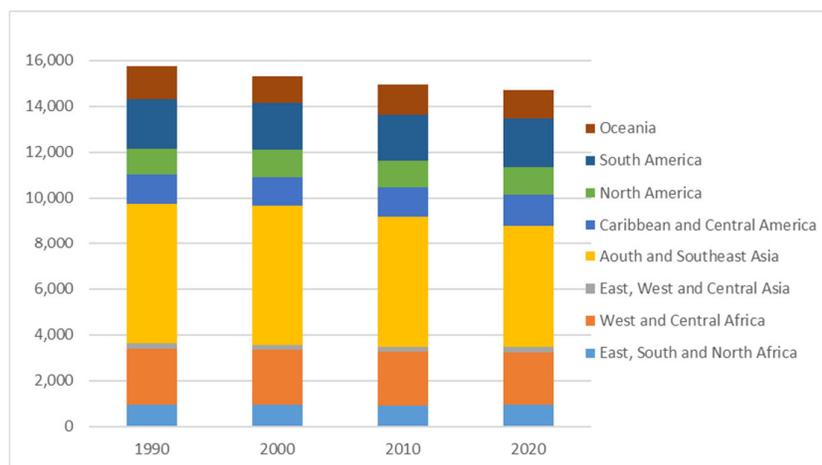
Region	Mangrove Area (thousand ha)				Change 1990-2020 (thousand ha)	Share in global mangrove area in 2020
	1990	2000	2010	2020		
South and Southeast Asia	6,117	6,108	5,713	5,330	-787	36.2%
East, West and Central Asia	214	212	215	216	2	1.5%
East, South and North Africa	963	933	915	936	-27	6.4%
West and Central Africa	2,436	2,400	2,349	2,304	-132	15.7%
Caribbean and Central America	1,279	1,271	1,257	1,357	78	9.2%
North America	1,152	1,167	1,190	1,195	43	8.1%
South America	2,152	2,050	1,976	2,124	-28	14.4%
Oceania	1,447	1,150	1,314	1,255	-192	8.5%
Worldwide	15,759	15,292	14,928	14,717	-1,042	100.0%

(Compiled by the study team based on Table 31 from FAO (2020))

The rate of global mangrove area loss has been declining from 46,700 ha/year (1990-2000) to 36,400 ha/year (2000-2010), and to 21,100 ha/year (2010-2020) (Table 2). The rate of decline in South and Southeast Asia accelerated sharply after 2000, reaching 900 ha/year (1990-2000), 39,500 ha/year (2000-2010), and 38,300 ha/year (2010-2020), and this rate of decline has been maintained. The increase in mangrove area in Oceania

³ The figures in Table 30 and Table 31 of FAO (2020) do not match, nor do they correspond to the aggregated figures from the individual Country Reports. The reason for this discrepancy is unclear; however, the Table is based on the figures presented in Table 31.

(16,400 ha/year) during 2000-2010, coupled with increases in the Caribbean and Central America (10,000 ha/year) and South America (14,800 ha/year) during 2010-2020, likely offset the decline in South and Southeast Asia, resulting in a slower overall global decline.



(Compiled by the study team based on FAO (2020))

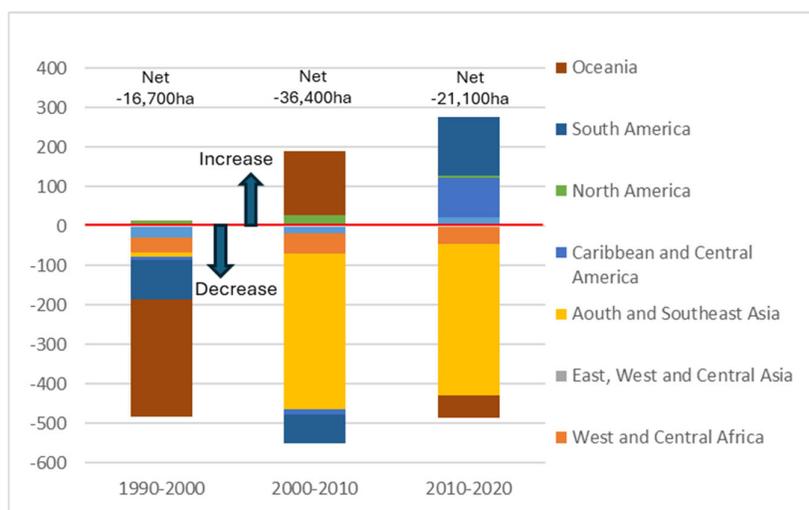
Figure 1: Changes in Mangrove Area by Region

Table 2: Rate of Change in Mangrove Area by Region

Region	Change in Mangrove Area over 10 Years (thousand ha)			Annual Change in Mangrove Area (thousand ha/year)			Change from 1990 to 2020 (thousand ha)
	1990-2000	2000-2010	2010-2020	1990-2000	2000-2010	2010-2020	
South and Southeast Asia	-30	-18	21	-3.0	-1.8	2.1	-27
East, West and Central Asia	-36	-51	-45	-3.6	-5.1	-4.5	-132
East, South and North Africa	-2	3	1	-0.2	0.3	0.1	2
West and Central Africa	-9	-395	-383	-0.9	-39.5	-38.3	-787
Caribbean and Central America	-8	-14	100	-0.8	-1.4	10.0	78
North America	15	23	5	1.5	2.3	0.5	43
South America	-102	-74	148	-10.2	-7.4	14.8	-28
Oceania	-297	164	-59	-29.7	16.4	-5.9	-192
Worldwide	-467	-364	-211	-46.7	-36.4	-21.1	-1,042

(Compiled by the study team based on FAO (2020))

Over the 30-year period from 1990 to 2020, mangrove areas have consistently declined in South and Southeast Asia and West and Central Africa. Furthermore, the area lost during this 30-year period was significantly greater in South and Southeast Asia. Focusing specifically on the 30-year period from 1990 to 2020, South and Southeast Asia shows a persistent declining trend and the largest area loss, making it the region with the most severe mangrove area reduction globally. Following this in severity is West and Central Africa, which also exhibits a persistent declining trend and a large area loss. Figure 2 shows the 10-year increase and decrease in area for each region, revealing that the area reduction in South and Southeast Asia significantly impacts the global decline in mangrove areas.



(Compiled by the study team based on FAO (2020))

Figure 2: Rate of Change in Mangrove Area by Region

By country, Indonesia has the largest estimated mangrove area in 2020 (2.8 million ha), accounting for 19.1% of the global total. Next are Brazil (1.31 million ha, 8.9%), Nigeria (980,000 ha, 6.6%), and Mexico (940,000 ha, 6.4%). These four countries together cover 41% of the global area. These countries are major players in Southeast Asia, South America, West and Central Africa, and North America, respectively. Focusing on these nations, the change in mangrove area in each region is mentioned below. Note that South and Southeast Asia are divided into Southeast Asia and South Asia for the purpose of analysis, as the mangrove area within a single region is disproportionately large compared to other regions, which creates an imbalance.

2.1.2 Southeast Asia

The following 10 countries possess mangrove forests, with Indonesia, Malaysia, Myanmar, the Philippines, and Thailand accounting for 97% of the total area in the region (2020). The overall mangrove area in the region peaked in 2000 and has been declining since. Countries showing a continuous decline include Indonesia, Malaysia, Vietnam, and Cambodia. The Philippines experienced a decline from 2010 to 2020, but overall has shown an increasing trend since 1990. Thailand increased its area until 2000 and has maintained it since then. Myanmar has fluctuated every decade, but over the 30-year period from 1990 to 2020, it has lost 114,000 hectares, indicating an undeniable overall downward trend.

Table 3: Trends in Mangrove Area by Country in Southeast Asia (thousand ha)

	1990	2000	2010	2020
Brunei Darussalam	18.42	18.42	18.42	18.42
Cambodia	79.63	66.74	58.81	55.47
Indonesia	3,554.00	3,486.00	3,018.00	2,807.00
Malaysia	467.76	438.02	429.77	409.29

Myanmar	517	486	539.59	402.89
Philippines	130.05	220.29	310.53	296.27
Singapore	0.85	0.85	0.83	0.84
Thailand	177.00	245.00	244.00	244.00
Timor-Leste				1.40
Vietnam		70.21	69.02	57.20
Total	4,944.71	5,031.53	4,688.97	4,292.78

(Compiled by the study team based on FAO (2020))

2.1.3 South Asia

The following five countries possess mangrove forests, with India and Bangladesh accounting for the largest share. Data from 2010 is available for all five countries, and it shows that India (463,000 ha) and Bangladesh (447,000 ha) together account for 89% of the region's total. While India and Sri Lanka have increased their mangrove areas, Pakistan has consistently seen a decline. Bangladesh lacks data for 1990 and 2020. Referring to FAO (2003) as reference data, the areas were 596,000 ha in 1980, 610,000 ha in 1990, and 623,000 ha in 2000, suggesting an increasing trend until 2000. However, the 2000 area reported by FAO (2020) is 459,000 ha, which significantly diverges from the FAO (2003) data, making it difficult to draw conclusions at present.

Table 4: Trends in Mangrove Area by Country in South Asia (thousand ha)

	1990	2000	2010	2020
Bangladesh		459.49	446.85	
India	426.00	448.00	463.00	521.00
Maldives	0.04	0.04	0.04	0.04
Pakistan	207.00	158.00	98.00	40.00
Sri Lanka	9.10	11.21	15.69	20.15
Total	642.14	1,076.74	1,023.58	581.19

(Compiled by the study team based on FAO (2020))

2.1.4 East, West and Central Asia

The following eight countries have provided data on mangroves. Saudi Arabia (158,000 ha) accounts for 73% of the region's total, its size being markedly larger than other West Asian countries. However, Saudi Arabia's mangrove area has shown no significant increase or decrease over the past 30 years. Similarly, other West Asian countries except Iraq have also shown little change in mangrove area, suggesting their data may not have been updated. Iraq showed no change until 2010, but its area decreased by 2020. China has increased its area since reaching a low point in 2000.

Table 5: Trends in Mangrove Area by Country in East, West and Central Asian (thousand ha)

	1990	2000	2010	2020
Bahrain (Desk study)	0.09	0.09	0.09	0.09
China	24.47	22.3	24.93	31.78
Iran (Islamic Republic of)	25.76	25.76	25.76	19.23
Kuwait (Desk study)	0.01	0.01	0.01	0.01
Oman	1.00	1.00	1.00	1.00
Saudi Arabia (Desk study)	158.00	158.00	158.00	158.00

United Arab Emirates (Desk study)	3.80	4.00	4.30	4.30
Yemen	0.95	0.90	0.90	0.90
Total	214.08	212.06	214.99	215.31

(Compiled by the study team based on FAO (2020))

2.1.5 East, South and North Africa

The following 12 countries are included in this region, encompassing not only nations on the African continent but also island nations in the Indian Ocean such as the Comoros, Mauritius, and Seychelles. Data for Somalia is unavailable and is not included in the table below. As of 2020, the four countries facing the Indian Ocean—Mozambique (359,000 ha), Madagascar (283,000 ha), Tanzania (158,000 ha), and Kenya (61,000 ha)—accounted for 95% of the regional total. For the region as a whole, the trend was declining until 2010 but recovered by 2020. By country, Mozambique showed little change, while Madagascar continued to decline. Tanzania declined until 2010 but then increased sharply. Kenya showed little change. Other countries also showed little change, suggesting their data may not have been updated.

Table 6: Trends in Mangrove Area by Country in East, South and North Africa (thousand ha)

	1990	2000	2010	2020
Comoros	0.14	0.14	0.14	0.14
Djibouti	0.00	0.00	0.00	0.10
Egypt	0.39	0.39	0.39	0.50
Eritrea	6.40	6.40	6.40	6.40
Kenya	61.00	60.00	60.50	61.00
Madagascar	330.00	315.00	298.00	283.00
Mauritius	0.07	0.09	0.20	0.20
Mozambique	354.33	355.90	357.47	359.04
Seychelles	3.23	3.23	3.23	3.23
South Africa	2.00	2.00	2.00	2.00
Sudan	33.00	30.00	31.00	30.00
United Republic of Tanzania	140.00	127.00	123.00	158.10
total	930.56	900.15	882.33	903.71

(Compiled by the study team based on FAO (2020))

2.1.6 West and Central Africa

Comparing data available for all 18 countries in 2010, Nigeria (997,000 ha) leads the list, followed by Guinea-Bissau (285,000 ha), Cameroon (275,000 ha), Guinea (237,000 ha), Senegal (198,000 ha), and Gabon (156,000 ha), which possess substantial areas. These six countries account for 90% of the regional total. Overall, the region's mangrove area is declining. By country, Nigeria stabilized its area after 2000 and has maintained it since. Guinea-Bissau peaked in 2000 and has declined since. Guinea may be declining, and Gabon is also showing a decreasing trend. Senegal stands out with its mangrove area continuing to increase. Many countries, including Cameroon, show no change in data, suggesting data may not have been updated.

Table 7: Trends in Mangrove Area by Country in West and Central Africa (thousand ha)

	1990	2000	2010	2020
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Angola	31.17	31.17	31.17	31.17
Benin	7.71	3.34	1.28	0.16
Cameroon	275.00	275.00	275.00	275.00
Democratic Republic of the Congo	30.80	19.50	19.50	19.50
Equatorial Guinea	26.06	25.34	24.98	24.25
Gabon	175.90	165.81	155.72	145.62
Gambia	36.00	36.00	36.00	36.00
Ghana	16.80	13.80	11.00	11.00
Guinea	250.00	250.00	237.00	
Guinea-Bissau (Desk study)	254.42	300.17	284.67	265.29
Liberia	10.90	10.90	10.90	10.90
Mauritania	0.30	0.20	0.20	0.22
Nigeria	1,012.00	997.00	997.00	976.40
Saint Helena (Desk study)	2.00	2.00	2.00	2.00
Sao Tome and Principe	0.10	0.10	0.10	0.10
Senegal	191.69	194.89	198.06	221.59
Sierra Leone	145.00	105.00	95.00	85.00
Togo		1.30	1.00	
Total	2,465.85	2,431.52	2,380.58	2,104.20

(Compiled by the study team based on FAO (2020))

2.1.7 Caribbean and Central America

Many Caribbean countries are small island nations, and the mangrove areas they possess are often not extensive. However, this also means they have long coastlines, and some countries do possess significant mangrove areas. In 2020, Cuba (650,000 ha) led the region, followed by Panama (165,000 ha), the Bahamas (142,000 ha), and Nicaragua (103,000 ha). These four countries accounted for 78% of the total mangrove area in the region. Overall, the regional mangrove area shows an increasing trend, with Cuba experiencing a sharp increase from 2010 to 2020. Panama shows a slight decrease, while the Bahamas shows no change. Nicaragua may be declining since peaking in 2010. Most other countries maintain their current status, but Belize, Haiti, and Puerto Rico show a decreasing trend similar to Panama.

Table 8: Trends in Mangrove Area by Country in the Caribbean and Central America (thousand ha)

	1990	2000	2010	2020
Anguilla (Desk study)	0.09	0.09	0.09	0.09
Antigua and Barbuda (Desk study)	1.21	0.85	0.67	0.67
Aruba (Desk study)	0.42	0.42	0.42	0.42
Bahamas	141.96	141.96	141.96	141.96
Belize	75.56	74.54	72.67	71.96
Bermuda (Desk study)	0.01	0.01	0.01	0.01
Bonaire, Sint Eustatius and Saba (Desk study)	0.35	0.35	0.35	0.35
British Virgin Islands (Desk study)	0.63	0.59	0.59	0.59
Cayman Islands (Desk study)	7.49	7.19	6.89	6.59
Costa Rica	36.25	36.25	36.25	36.25
Cuba	535.00	539.00	530.00	650.00
Curaçao (Desk study)	0.07	0.07	0.07	0.07
Dominican Republic	29.40	29.40	29.32	29.32
El Salvador	39.80	39.80	39.80	39.80
Grenada	0.18	0.18	0.18	0.18
Guadeloupe	3.59	3.50	3.47	3.45

Haiti	15.00	14.30	13.10	12.50
Honduras		49.48	50.79	49.25
Jamaica	9.75	9.73	9.73	9.73
Martinique	2.14	2.14	2.17	2.21
Montserrat (Desk study)	0.01	0.01	0.01	0.01
Nicaragua		107.45	114.16	103.43
Panama	183.61	174.44	169.64	164.84
Puerto Rico		10.46	5.71	4.10
Saint Kitts and Nevis (Desk study)		0.01	0.01	0.01
Saint Lucia			0.18	0.18
Saint Vincent and the Grenadines	0.04	0.04	0.04	0.04
Saint-Martin (French Part) (Desk study)	0.03	0.03	0.03	0.01
Sint Maarten (Dutch part) (Desk study)	0.04	0.04	0.04	0.04
Trinidad and Tobago	5.37	5.37	5.37	5.37
Turks and Caicos Islands (Desk study)	23.60	23.60	23.60	23.60

(Compiled by the study team based on FAO (2020))

2.1.8 North America

Only the United States and Mexico possess mangrove forests, and while there are some fluctuations, overall, the area of mangroves can be said to be increasing.

Table 9: Trends in Mangrove Area by Country in North America (thousand ha)

	1990	2000	2010	2020
Mexico	912.21	931.45	947.08	944.06
United States of America	240.00	236.00	243.00	251.00
Total	1,152.21	1,167.45	1,190.08	1,195.06

(Compiled by the study team based on FAO (2020))

2.1.9 South America

The following eight countries possess mangrove forests, with Brazil (1,315,000 ha), Guyana (276,000 ha), Venezuela (203,000 ha), and Ecuador (154,000 ha) accounting for 91% of the region's total area in 2020. For the region as a whole, the trend was declining until 2010, but there was a sharp increase in 2020. Brazil continues to decline, while Guyana showed no significant change until 2010 but experienced a sharp increase in 2020. Venezuela also continues to decline, while Ecuador has maintained its current status since stabilizing in 2000. Colombia and French Guiana declined until 2000, stabilized, and then began increasing.

Table 10: Trends in Mangrove Area by Country in South America (thousand ha)

	1990	2000	2010	2020
Brazil	1,423.89	1,413.92	1,323.58	1,314.58
Colombia	42.60	30.40	37.00	51.70
Ecuador	163.00	150.00	154.81	154.31
French Guyana	58.60	54.50	59.20	64.70
Guyana	81.00	81.00	81.00	275.88
Peru				6.43
Suriname	60.00	60.00	60.00	60.00
Venezuela (Bolivarian Republic of)	323.00	260.00	260.00	202.84

Total	2,152.09	2,049.82	1,975.59	2,130.44
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(Compiled by the study team based on FAO (2020))

2.1.10 Oceania

The following 16 countries possess mangrove forests. Looking at the data available for 2010, just two countries—Australia (913,000 ha) and Papua New Guinea (281,000 ha)—account for 91% of the regional total. Mangrove areas in all countries except Australia have remained largely unchanged, indicating that Australia's trends largely determine the region's overall increase or decrease. In Australia, there was a sharp decline from 1990 to 2000, but by 2010, the trend reversed and the area recovered to some extent.

Table 11: Trends in Mangrove Area by Country in Oceania (thousand ha)

	1990	2000	2010	2020
American Samoa	0.06	0.05	0.04	0.04
Australia	1,045.00	749.00	913.00	
Fiji	48.15	48.15	48.15	48.15
French Polynesia (Desk study)	0.01	0.01	0.01	0.01
Kiribati (Desk study)	1.18	1.18	1.18	1.18
Marshall Islands	0.12	0.12	0.12	0.12
Micronesia (Federated States of)	9.94	10.01	10.08	10.11
New Caledonia (Desk study)	25.88	25.88	25.88	25.88
New Zealand	28.00	28.00	28.00	28.00
Niue	3.00	3.00	3.00	3.00
Papua New Guinea		281.00	281.00	281.00
Samoa	0.36	0.35	0.35	0.35
Tonga	1.00	1.00	1.00	1.00
Tuvalu	0.05	0.04	0.03	0.02
Vanuatu	2.70	2.50	2.50	2.50
Wallis and Futuna Islands (Desk study)	0.09	0.04	0.02	0.02
Total	1,165.54	1,150.33	1,314.36	401.38

(Compiled by the study team based on FAO (2020))

2.1.11 Summary

As seen above, the three regions experiencing the most significant decline in mangrove area worldwide were South and Southeast Asia, West and Central Africa, and Oceania. The situation can be summarized as follows.

Table 12: Trends in Southeast Asia, South Asia, West and Central Africa, and Oceania

	Regional trend	Trend by country
Southeast Asia	Declining trend since peaking in 2000.	Indonesia, Malaysia, Myanmar, the Philippines, and Thailand account for 97% of the region, with Indonesia and Malaysia showing a declining trend.
South Asia	Due to data gaps in Bangladesh, it is difficult to make an analysis.	India and Bangladesh account for 89% of the region, with India showing an increasing trend, and Bangladesh being difficult to assess due to data gaps.
West and Central Africa	The trend continues to decline. Data may not have been updated for some countries.	Nigeria, Guinea-Bissau, Cameroon, Guinea, Senegal, and Gabon account for 90% of the region. Nigeria's area has remained stable since bottoming out in 2000. Cameroon's area has shown no significant change, while Guinea-Bissau, Guinea, and Gabon have seen a declining trend, and Senegal has shown an increasing trend.

Oceania	There are no increases or decreases in countries other than Australia; it depends on Australia's movements.	Australia and Papua New Guinea account for 91% of the region. Australia's decline halted in 2000 and has since recovered. Papua New Guinea has seen no change in area.
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As previously stated, Southeast Asia accounts for approximately 30% of the world's mangrove area. However, in the 30-year period from 1990 to 2020, the region has experienced a continuous decline in mangroves, with the largest reduction in area. It can be said that Southeast Asia is one of the regions globally facing the most severe loss of mangrove area. Given this context, Southeast Asia is a critically important region for mangrove conservation. Furthermore, as it is the region with the highest concentration of Japanese corporate investment and strong ties to Japan, we will now provide a more detailed description of the current state of mangroves in this area. In the next section, the implementation of the pilot activities will be discussed based on information from the six countries, namely, Indonesia, Malaysia, Myanmar, the Philippines, Thailand, and Vietnam. Vietnam is included due to its unique mangrove habitats along its elongated territory and the significant expansion of Japanese companies there.

2.1.12 Current Status of Mangroves in Southeast Asian Countries

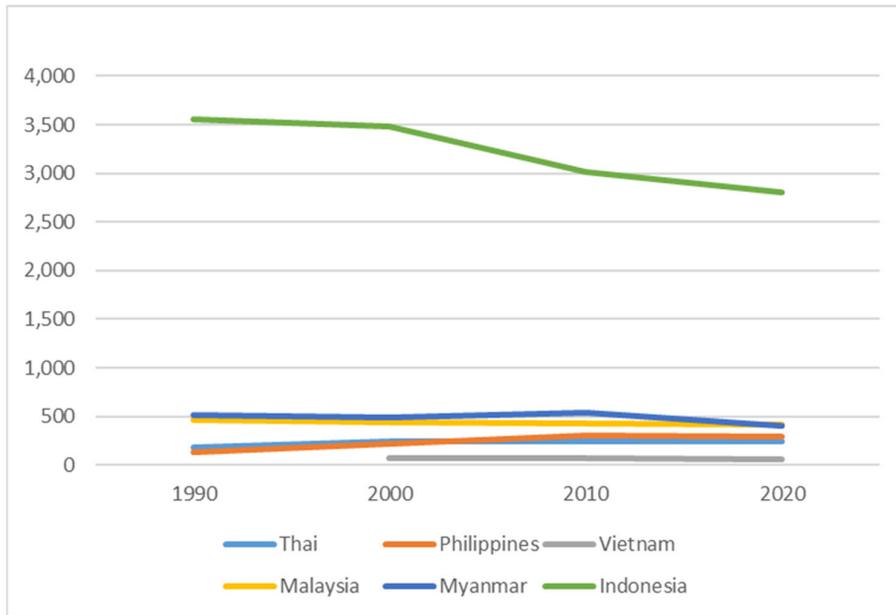
The changes in mangrove forest area from 1990 to 2020 are as follows.

Table 13: Changes in Mangrove Forest Area in Six Southeast Asian Countries

	Year	Indonesia	Thailand	Philippines	Vietnam	Malaysia	Myanmar
Mangrove forest area (thousand ha)	1990	3,554	177	130		468	517
	2000	3,486	245	220	70	438	486
	2010	3,018	244	311	69	430	540
	2020	2,807	244	296	57	409	403
Annual Average Change in mangrove Area (ha)		-24,900	+2,233	+5,541	-651	-1,949	-3,804
Percentage of change from 2000		-19.5%	-0.4%	+34.5%	-18.5%	-6.6%	-17.1%

(Compiled by the study team based on FAO (2020))

The changes in mangrove forest area for these six countries are shown in the figure below.

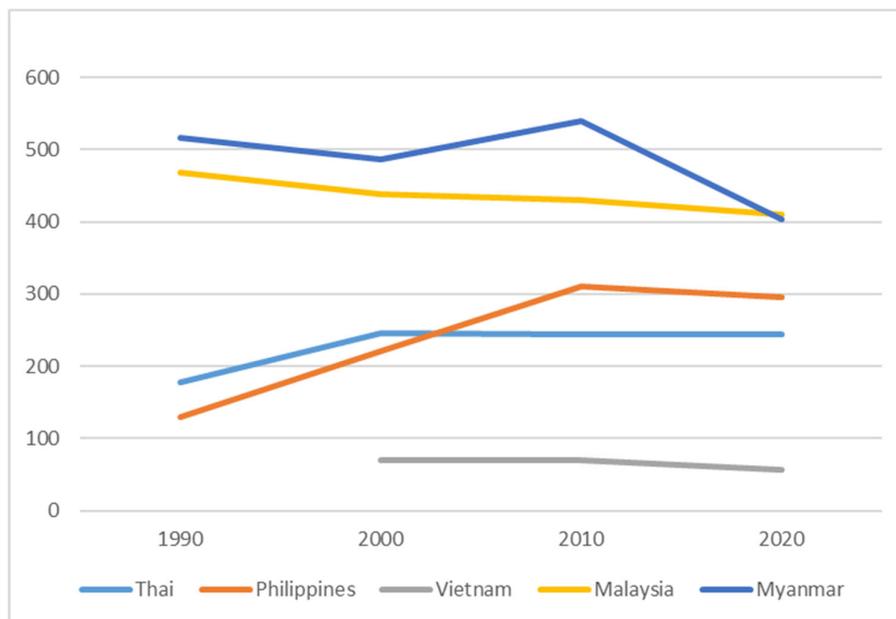


(Compiled by the study team based on FAO (2020))

Figure 3: Changes in Mangrove Forest Area

In Indonesia, mangrove forest area decreased by 747,000 hectares over the 30-year period from 1990 to 2020, at a rate of 24,900 hectares per year, the highest among the six countries.

The changes in mangrove forest area for the five countries excluding Indonesia are shown in the figure below.



(Compiled by the study team based on FAO (2020))

Figure 4: Change in Mangrove Forest Area (Excluding Indonesia)

The three countries showing a decreasing trend are Myanmar, Malaysia, and Vietnam, with reduction rates of 3,804 ha/year, 1,949 ha/year, and 651 ha/year, respectively. Thailand and the Philippines show increasing trends, but these may be due to the change of estimation methodology. The increase in Thailand's area in 2000 is thought to be due to changes in forest inventory methods. However, even after the forest inventory change, the area decreased by only 1,000 ha between 2000 and 2020, which can be considered essentially unchanged. In the Philippines, the 2010 area may have been overestimated due to changes in satellite image analysis methods, raising questions about the apparent decline observed from 2010 to 2020. However, even if the 2010 data is questionable, the overall trend from 1990 to 2020 shows an increase.

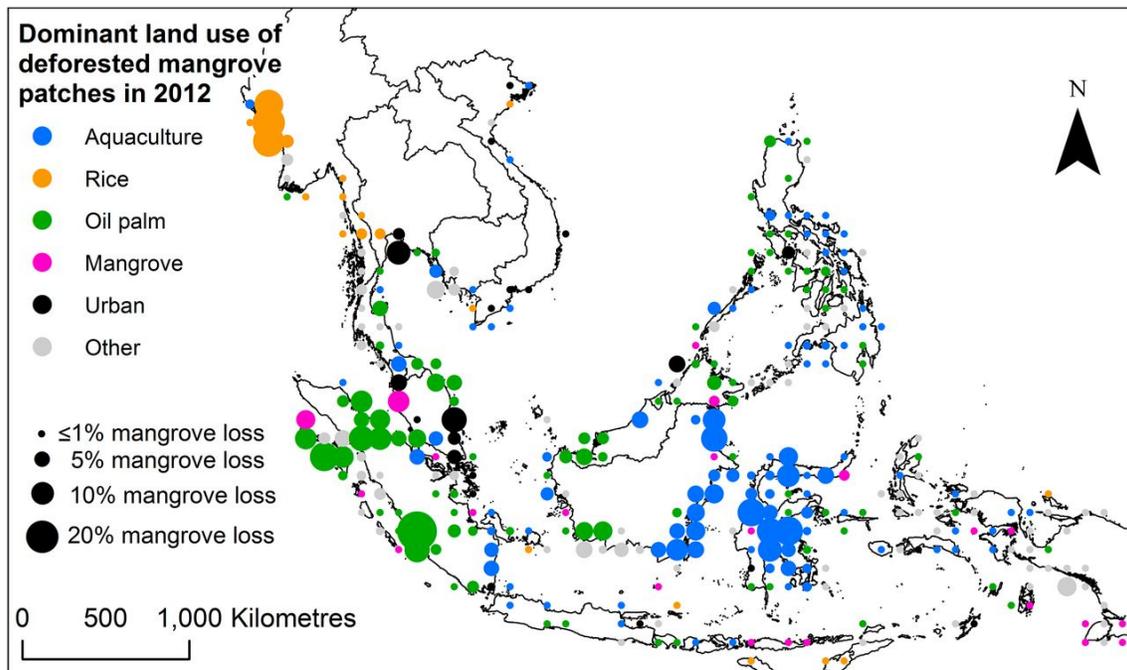
Comparing the rates of decline since 2000, when forest area data became available for all four countries showing a decline, Indonesia experienced a 19.5% decrease, Vietnam 18.5%, Myanmar 17.1%, and Malaysia 6.6%. Indonesia thus had the largest decrease in area and also the highest rate of decline.

The primary factors contributing to mangrove forest loss in Southeast Asia over the past 30 years include conversion to aquaculture ponds, conversion to agricultural land, non-mangrove afforestation, and urban development. In recent years, rice cultivation has also been identified as a contributing factor in some regions. According to Richards and Friess (2016), the most notable mangrove forest area declines between 2000 and 2012 occurred in Myanmar's Rakhine State, Indonesia's Sumatra and Kalimantan islands, and Malaysia. Thailand, Vietnam, and the Philippines maintained lower rates of decline. Table 14 and Figure 5 below analyze and summarize the subsequent land use of mangrove forests that disappeared based on satellite imagery.

Table 14: Land Use (%) after Mangrove Loss in Six Southeast Asian Countries (2000–2012)

	Indonesia	Thailand	Philippines	Vietnam	Malaysia	Myanmar
Fishponds	48.6	10.8	36.7	21.0	14.7	1.6
Rice production	0.1	5.6	0.9	10.4	0.1	87.6
Oil palm	15.7	40.0	11.1	0.5	38.2	1.1
Mangrove forest restoration	22.6	5.1	7.3	0.6	17.6	0.5
Urban development	1.9	14.4	2.7	62.5	12.8	1.6
Other	11.2	24.1	41.3	4.9	16.7	7.6
Area lost during the same period	60,906ha	3,504ha	1,423ha	531ha	18,836ha	27,957ha

(Compiled by the study team based on Richards and Friess (2016))



(Quoted from Richards and Friess (2016))

Figure 5: Primary Land Use after Mangrove Loss in 2012

On this basis, the primary land uses following mangrove forest loss include conversion to aquaculture ponds on Sulawesi and eastern Kalimantan in Indonesia, oil palm plantations on Sumatra, rice cultivation in Myanmar, and oil palm plantations and urban development in Malaysia. It can be inferred that mangrove forests were often cleared specifically for these land uses.

2.2 Current Status of Mangrove Conservation Policies and Initiatives in Southeast Asian Countries

The current status of mangroves and conservation policy directions in respective Southeast Asian countries are summarized as below.

2.2.1 Indonesia

In Indonesia, the following government agencies are involved in mangrove management.

Table 15: Government agency responsible for mangroves in Indonesia

Governmental organization	Roles and responsibilities
Ministry of Environment and Forestry (MOEF)	Areas designated as “mangrove forests” under the Forestry Act are conserved and managed by the Ministry of Environment and Forestry. In practice, the Ministry of Environment and Forestry is the primary governing body. The Ministry was divided into the Ministry of Forestry and the Ministry of Environment in 2024, and the Directorate of Mangrove Restoration, Directorate General of Watershed Management and Forest Restoration, the Ministry of Forestry is in charge of mangrove restoration.

Ministry of Marine Affairs and Fisheries (MMAF)	Responsible for managing mangrove forests in coastal and island areas. However, since many mangrove forests are designated protected areas, the Ministry of Fisheries and Oceans is responsible for only a limited area.
Ministry of Agrarian and Spatial Planning Affairs/National Land Agency	Responsible for matters concerning land ownership in mangrove forests and matters designated as “conservation” or “production” in spatial planning.
National Development Planning Agency (BAPPENAS)	The mangrove forest utilization plan is a part of the national development plan.
Local Governments Province: Provinsi District: Kecamatan Village: Desa/Kelurahan	Local governments at the provincial, district, and village levels are also involved. Management responsibility is shared among local governments; the province for community-based coastal management, the district for commercial use, and the village for managing natural resources, confusion is observed at the field level regarding jurisdictional responsibilities.

Compiled by the study team based on Banjade et al. (2017)

Regarding research related to mangroves and aquaculture, the Research Institute for Coastal Aquaculture and Fishery Extension (RICAFE), under the Ministry of Marine Affairs and Fisheries, had played a key role. However, due to recent organizational reforms by the Indonesian government, RICAFE has been restructured into an institution specialized in education and extension related to coastal aquaculture, and research responsibilities have now been transferred to BRIN, which oversees Indonesia's public research institutions.

The National Strategy of Mangrove Ecosystem Management, formulated in 2012, states that the utilization of mangrove forests must balance conservation and reforestation, promote coordination and cooperation among stakeholders, reaffirm the roles and responsibilities of communities and local governments, and emphasize sustainable management based on research, science, and technology. It also calls for the establishment of a National Coordination Team and National Working Group to facilitate coordination across sectors. Amidst the ongoing decline of mangrove forests—driven by factors such as the rapid expansion of aquaculture ponds and logging for pulp and charcoal production, regardless of legality—local residents, domestic and international NGOs, government-affiliated and some private companies are working to conserve and reforest mangrove forests. However, local governments have few incentives to engage in mangrove conservation and reforestation, and they do not necessarily possess the necessary personnel or technology. Low levels of interest in conservation have been a significant obstacle. Furthermore, while various mangrove management authorities were delegated to local governments in 2014 legal revisions, which raised hopes for more community-based initiatives, confusion persists at the field level due to the complexity of the work and misconduct by administrative staff.

In recent years, the Indonesian government has positioned mangrove conservation and restoration as a key issue in its climate change mitigation efforts. In December 2020, a Presidential Decree was issued to extend the mandate and expand the authority of the existing Peatland Restoration Agency (Badan Restorasi Gambut: BRG), leading to the establishment of the Peatland and Mangrove Restoration Agency (BRGM), which incorporates mangrove restoration functions. Under this Presidential Decree, the Ministry of Environment and Forestry and BRGM formulated a Mangrove Restoration Roadmap (2021–2030) in 2021, and as part of this process, the government aims to restore 600,000 ha of mangrove forest over the four-year period from 2020 to 2024, among other efforts to strengthen related policies and initiatives. As part of these initiatives, the Indonesian government, with support from the World Bank (419 million USD), is implementing the

“Mangroves for Coastal Resilience” (M4CR) program, a national-level strategic mangrove restoration initiative. M4CR aims to restore and conserve mangrove ecosystems while enhancing the resilience of coastal communities. It is being carried out through four key activities: policy and institutional strengthening, restoration and sustainable landscape management, improvement of community livelihoods, and project management and monitoring. The program targets the restoration of 75,000 ha of mangroves across nine Provinces including Riau, North Sumatra, East Kalimantan, North Kalimantan, West Papua, and Papua.

Indonesia's coastline stretches extensively along both the Pacific and Indian Oceans, making it the world's largest mangrove nation, accounting for 19.1% of the global mangrove area. However, there is significant impact from human disturbance including conversion of mangrove areas near settlements to aquaculture ponds, and logging of mangroves for timber, paper, wood chips, and other processed products in remote areas.

Sumatra and Java feature steep mountains. River sedimentation is increasing due to factors like the loss of natural forests from these mountains and changes in land use by people. While mangroves still cover large areas along Sumatra's east coast, they are found only in limited regions on the west coast. Traditional methods utilizing natural mangroves for aquaculture of milkfish, tilapia, shrimp, and shellfish have been practiced for centuries. However, the recent conversion of mangrove forests into shrimp ponds is incomparably larger in scale. Consequently, mangrove forests along Sumatra's west coast now survive only in patchy remnants. On the island of Java, significant mangrove forests remain only along parts of the southern coast, though small natural mangrove forests persist at the western and eastern extremities of the island. Originally, mangrove forests were widely distributed across the island of Java, but since the 1980s, 90% have been converted into farmland or aquaculture ponds. These large-scale land use changes have severely impacted fisheries, raised concerns about pesticide contamination and oil pollution from nearby refineries, and accelerated sedimentation in estuaries. Furthermore, this region experiences active seismic activity. The 2004 Indian Ocean earthquake off Sumatra generated a tsunami reaching heights of 30 meters that directly struck the area. While the original mangrove sites had been converted into residential areas and shrimp ponds, it is said that even if mangroves had remained, their protective function would have been largely ineffective against such a massive tsunami. Conversely, anecdotal evidence exists showing that mangroves provided effective protection in some areas of southern Sumatra⁴. Regarding conservation and sustainable use trends, mangrove reforestation and sustainable forestry are being implemented on Sumatra Island. Logging for charcoal, timber, and wood chip production is conducted on a 30-year rotation cycle. Conservation efforts through protected area designation and reforestation initiatives also continue.

Kalimantan occupies about two-thirds of Borneo Island, encompassing the island's southern and eastern coasts, as well as part of the western coast. The island was originally covered in forest, but much of its coastal area has been converted to farmland and oil palm plantations. Significant mangrove forests remain, primarily along the eastern and western coasts. Approximately 90% of Kalimantan's mangrove forests are located within timber concessions and are being logged for wood chips and pulp. It is estimated that over 65% of

⁴ Spalding et al (2010) World Atlas of Mangroves. 319p. Earthscan. London.

Kalimantan's mangrove forests may have already been lost, largely due to conversion into traditional and conventional aquaculture ponds, as well as urban and rural development and oil and gas industry development. Few mangrove forests are designated as protected areas.

Sulawesi Island and the Nusa Tenggara (Lesser Sunda Islands) region are located in central to eastern Indonesia, including the Maluku Islands. The Nusa Tenggara region is mountainous and somewhat arid, limiting the extent of mangrove forests. However, the mangroves found on its numerous islands play a significant role. In these areas, mangroves are important as timber and fuel, and also as habitats for fisheries resources. Mangrove forests degradation and loss has occurred on relatively developed islands due to logging for timber and firewood on Lombok Island, tourism on the southern coast of Bali Island, and coastal development on Sulawesi Island. Since 2000, numerous community-based initiatives to restore mangrove forests have been undertaken, though their success varies. While many protected areas include mangrove forests, the proportion of total protected area is not large.

Papua Province occupies the western half of New Guinea Island. Due to active tectonic movements, the northern coast is uplifting while the southern coast is subsiding, causing mangrove forests to migrate inland. Extensive natural mangrove forests cover the area and are particularly prominent along the southern and western coasts. Biogeographically, it incorporates elements of both the Australian and Indo-Malayan regions, with some plant species found only on the north coast or only on the south coast. The vastness and near-pristine state of the mangrove forests, combined with their straddling of two biogeographic regions, result in a rich fauna, including marsupials such as wallabies and possums. Human impact has been relatively minor, but outside designated protected areas, logging for timber and timber extraction continue, and this impact is beginning to grow significantly. Timber concessions cover two-thirds of the island. Ongoing logging has led to deteriorating local security and the depletion of natural resources from the forest, affecting water supply and fish populations. The impact of mining development is also significant, causing environmental pollution such as inland water contamination reaching coastal areas and copper accumulation rates reaching 40 times the normal level. Mangrove forests are being cleared for infrastructure development.

2.2.2 Thailand

In Thailand, mangrove forests exist along the Gulf of Thailand coast and the western coast facing the Andaman Sea, with 80% of Thailand's mangrove forests located on the Andaman Sea side. While the mangrove forests on the Andaman Sea side are vast and rich in biodiversity, the mangrove forests on the Gulf of Thailand side, which were once widely distributed, lost nearly 50% of their area between the 1970s and 1990s. This loss was due to commercial logging for charcoal production, conversion to shrimp ponds, and urban and industrial development. Simultaneously, the income of many fishermen declined sharply. Furthermore, the remaining mangrove forests on the Gulf of Thailand side, particularly in the northern part of the Gulf, have been significantly degraded by logging for firewood and construction materials.

In Thailand, which frequently suffers typhoon damage, mangrove forests protect the coastline. It has been reported that they contributed to mitigating the impact of the tsunami caused by the 2004 Indian Ocean

earthquake off Sumatra (Bhandari et al., 2004). Furthermore, traditional uses of mangroves extend beyond direct consumption for charcoal production, firewood, building materials, fishing gear, and medicinal purposes. They also serve as habitats for diverse aquatic resources, and aquaculture has been practiced by clearing only small sections of mangroves.

In Thailand, mangrove administration falls under the jurisdiction of the Department of Marine and Coastal Resources in the Ministry of Natural Resources and Environment. The Forestry Research and Development Bureau, Royal Forest Department, Ministry of Natural Resources and Environment serves as the relevant research institution.

Recognizing the importance of sustainable mangrove use, the Thai government classified all mangrove forests nationwide into two categories: Conservation Zones and Development Zones. In Conservation Zones, mangrove use is strictly regulated; existing permits for activities like logging and aquaculture are not renewed, and government agencies are responsible for mangrove restoration efforts. Development zones refer to areas converted from former mangrove forests, with illegal conversions specifically mandated for regeneration. For mangrove restoration, the government and NGOs are conducting reforestation activities involving local communities, alongside educational and research initiatives. Furthermore, mangrove forests in the Andaman Sea are being conserved through measures such as designation as protected areas.

2.2.3 Philippines

In the Philippines, large-scale conversion from mangrove forests to aquaculture ponds occurred in the 1960s, resulting in a significant reduction in mangrove forest area. While estimates vary, data from the National Agency for Land Resources Investigation and Management (NAMRIA) cited by Spalding (1990) indicates that the area was approximately 375,000 ha around 1950, but had decreased to 161,000 ha by 1987. Since the 1980s, efforts by the government of the Philippines to reforest lost mangrove forests have intensified. Since 1995, community-based forest management has been the primary strategy for forest regeneration. Whether due to these efforts or data inaccuracies is unclear, but NAMRIA data indicates recovery to 247,000 ha by 2003. However, many of these planting programs involved planting *Rhizophora* seedlings without considering the condition of the planting sites, resulting in low survival rates. In contrast to these government planting programs, small-scale community planting initiatives have shown success, providing benefits such as timber and firewood supply, improved fishery resources, and enhanced coastal protection functions.

In the Philippines, mangrove administration is overseen by the Forest Management Bureau (FMB) of the Department of Environment and Natural Resources (DENR). The Forest Products Research and Development Institute (FPRDI), under the Department of Science and Technology (DOST), serves as the relevant research institution.

The conversion of mangrove forests into aquaculture ponds, a major cause of mangrove loss in the Philippines, resulted from a national policy promoting aquaculture development through financing. This

conversion proceeded largely without planning, leading to the abandonment of many ponds by the 2000s. Small-scale silvo-fisheries were experimentally implemented but had not reached commercialization by 2000. Furthermore, the remaining mangrove forests show signs of degradation in intensively used areas. This degradation affects not only structural aspects—such as reduced tree height and open canopy—but also ecological functions, including a decrease in both the number and diversity of resident crabs. Currently, legal frameworks are being strengthened, including restrictions on new aquaculture pond development and mandatory planting of buffer zones around existing ponds. Furthermore, mangrove forests have been designated as protected areas, advancing conservation in name, but their effectiveness remains limited.

2.2.4 Vietnam

Vietnam's coastline is extensive, and the country itself stretches north to south. Consequently, differences exist, such as the northern subtropical region having fewer mangrove species compared to the tropical southern region. It is well known that mangroves in Vietnam contribute to the conservation of aquatic resources. Furthermore, mangroves are deeply and widely rooted in the lives of residents, who traditionally use them for building materials and firewood, and plant them to protect coastal areas from natural disasters.

Mangrove forest loss began before the Vietnam War, but it is estimated that approximately 100,000 hectares of mangrove forests were destroyed by defoliant spraying during the war. While natural regeneration was severely hindered, the government spearheaded reforestation efforts after the war. However, alongside this reforestation, the conversion of mangrove forests into shrimp ponds progressed, and unsustainable economic development significantly degraded the mangroves. While the expansion of shrimp ponds was promoted as national policy, in recent years the government has focused on protecting and reforesting mangroves, with support from residents and NGOs.

The Administration of Forestry, Ministry of Agriculture and Rural Development oversees mangrove-related administration. Relevant research institutions include the Silviculture Research Institute, Forest Industry Research Institute, Forestry Economics Research Centre, Forest Ecology and Environment Research Institute, Forest Protection Research Centre, and Non-Timber Forest Products Research Centre.

2.2.5 Malaysia

Malaysia consists of the peninsula and the northwestern part of Borneo Island, which includes the states of Sabah and Sarawak. The peninsula holds 18% of the country's mangroves, with approximately 90% located along its west coast. In Matang, on the northern west coast, sustainable mangrove management involving 30-year cycles of planting and harvesting has been practiced for over 100 years, and charcoal production is also thriving. Sabah State, located in northern Borneo, holds 59% of the nation's mangroves, while Sarawak State, situated to its west, holds 23%. Mangrove utilization on the Borneo side has not been sustainable; large areas were logged for chip production, but such clear-cutting has been prohibited since the late 1980s. On the other

hand, according to the analysis by Richards & Friess (2016), one of the major land-use conversions driving mangrove loss in Southeast Asia between 2000 and 2012 was the expansion of oil palm plantations. It is estimated that approximately 16% of the total mangrove loss during this period was attributable to conversion to oil palm cultivation. In Malaysia, this trend has been accelerated by government policies promoting oil palm production and the growing market demand.

In Malaysia, the Forestry Department Peninsular Malaysia (Ministry of Natural Resources and Environment) administers mangrove-related affairs, while the Forest Research Institute Malaysia handles mangrove research.

As tourism grows in importance in Malaysia, environmentally conscious ecotourism—such as boat tours to observe proboscis monkeys and fireflies—is promoted to avoid the risk of inappropriate coastal development. Conversely, between 1973 and 2000, 16% of the nation's mangrove forests, particularly in Peninsular Malaysia and Sarawak, were converted for other uses such as agriculture (rice, coconut, cocoa, and oil palm), aquaculture, and urban development. This conversion significantly impacted fisheries and forestry. Coastal erosion due to mangrove loss and subsequent seawater intrusion into farmland have also occurred.

Malaysia clearly defines its management process by classifying mangrove forests into four zones: production forests, restricted production forests, protected forests, and non-production forests, and by formulating management plans (MECS, 2012). Furthermore, having experienced the tsunami caused by the 2004 Sumatra earthquake, Malaysia is also undertaking mangrove reforestation aimed at mitigating tsunami impacts. While these efforts pursue sustainable mangrove forest management, pressure to increase timber production amid the rapid decline of inland forests poses a threat. Efforts to designate areas containing mangroves as protected zones are also progressing. 10% of the mangrove forests on the peninsula, 9.5% of those in Sarawak, and 1.2% in Sabah are designated as protected zones of some kind. Through these various approaches, we are engaging local communities in the sustainable use, conservation, and reforestation of mangrove forests, while also actively pursuing research to address the challenges that arise in the process.

2.2.6 Myanmar

Myanmar possesses a long and complex coastline that includes numerous islands and deltas. Mangrove forests are particularly abundant in Rakhine State facing the Bay of Bengal, the Ayeyarwady region, and the Tanintharyi region in the south facing the Andaman Sea. Within these areas, wetlands, farmland, and human settlements are intricately intertwined. Myanmar's flora spans both the Southeast Asian and Indian subcontinental biogeographic realms, giving it the unique feature of hosting mangrove species from both regions within its borders. Mangrove forests in Myanmar are disappearing at a faster rate than in neighboring countries. The causes include conversion to human settlements, farmland, and salt fields. Since the late 1990s, conversion to shrimp and fish ponds has increased, and since the 2000s, conversion to rice fields has also progressed. Furthermore, even in the remaining mangrove forests, degradation is advancing due to logging for timber and firewood. Reports of declining fish catches and coastal erosion have increased alongside

mangrove loss.

In Myanmar, the Forest Department of the Ministry of Natural Resources and Environmental Conservation and the government-affiliated Forest Research Institute oversee mangrove-related administration and research. Within this context, initiatives for community-led mangrove planting, supported by the Forest Department, are increasing. Community groups can hold ownership rights to mangrove areas for up to 30 years and retain rights to the trees they plant. Since 1990, they have been experimentally attempting mangrove reforestation.

Myanmar lacks policies on land use and land-use conversion (MECS, 2012). To advance mangrove conservation under these circumstances, efforts include establishing protected areas, planting trees, engaging local communities and the private sector, and collaborating with international organizations. However, following the February 2021 coup, the Ministry of Natural Resources and Environmental Conservation submitted a Nationally Determined Contribution (NDC) to the UNFCCC in 2021. This NDC states objectives such as “planting 4,634 hectares of mangroves by 2027,” “Prioritize the conservation of important mangrove areas,” and “Strengthen the resilience of mangroves and coastal communities at risk of flooding.” However, the current status and progress of these initiatives remain unclear. Following the coup, the State Administration Council (SAC), established by the military regime, and the National Unity Government (NUG), formed in opposition to the military regime, are in a state of contention. The SAC delegation that attempted to participate in UNFCCC COP26 was denied entry, and the international community does not recognize the SAC. It is difficult to determine how the SAC and NUG will approach these goals, and policy implementation is expected to stall (UN-REDD, 2022)⁵.

2.3 Initiatives by Donors and NGOs for Mangrove Conservation in Southeast Asian Countries

Numerous NGOs engage in mangrove-related initiatives, and some of the most prominent ones are listed below. The following information is based on each organization's website.

Table 16: Major NGOs engaged in mangrove-related initiatives

Organization	Activity summary
International Society for Mangrove Ecosystem (ISME)	<ul style="list-style-type: none"> • An international NPO established in 1990. In addition to mangrove restoration and conservation activities around the world, it also conducts research, public awareness campaigns, training programs, and dissemination of related information. • Since 2022, it has been implementing a project in Mauritius titled “Human resource development and scientific support for conservation/restoration and sustainable utilization of mangrove ecosystems in Mauritius.” Through joint mangrove survey activities with local NGOs, the organization has been fostering human resource development for the conservation, restoration, and sustainable use of mangrove ecosystems. • In collaboration with the Sabah Forestry Department in Malaysia, it has been conducting a mangrove reforestation project since 2011, aiming to restore mangrove forests. To date, 13 species of mangroves have been planted across approximately 360 ha of degraded land and mudflats. • In Gujarat, India, the organization has been working with the Indian Mangrove Society and local NGOs

⁵ UN-REDD Programme (2022) Options for Analysing Mangrove Ecosystem Services and Biodiversity in Myanmar.

	<p>to implement reforestation activities since 2009. The project aims to improve local livelihoods by mitigating storm surge damage to farmland, conserving biodiversity, and providing low-cost livestock feed.</p> <ul style="list-style-type: none"> • Website: (https://mangrove.or.jp/)
Wetland International (WI)	<ul style="list-style-type: none"> • A global nonprofit organization dedicated to wetland conservation and restoration. With offices in 19 countries, it implements numerous projects across three strategic areas: coastal and delta regions, rivers and lakes, and peatlands. • Regarding mangroves, for five years starting in 2015, it implemented Building with Nature in Central Java, Indonesia. This project aims to protect approximately 70,000 coastal residents from erosion, tsunamis, and storm surges while simultaneously achieving natural mangrove regeneration and sustainable aquaculture. • By installing permeable structures made of branches to trap sediment, the project sufficiently raises the coastal seabed. This facilitates natural mangrove regeneration and the formation of natural flood barriers while supporting sustainable aquaculture by local residents. • Website: (https://www.wetlands.org/)
Mangrove for the Future (MFF)	<ul style="list-style-type: none"> • An international NGO working on coastal ecosystem conservation and sustainable development in Southeast Asia and South Asia. Mangroves symbolize its activities, but the organization does not specialize solely in mangrove conservation. • Operates in India, Indonesia, the Maldives, Seychelles, Sri Lanka, Thailand, Bangladesh, Cambodia, Myanmar, Pakistan, Vietnam, Malaysia, Kenya, and Tanzania. • Supports coastal management activities through small-scale (- 25,000USD), medium-scale (50,000USD - 100,000USD), and large-scale (100,000USD - 300,000USD) funding. Prioritize long-term sustainable coastal ecosystem management, particularly focusing on climate change mitigation and adaptation, disaster prevention and mitigation, promoting healthy ecosystems, sustainable livelihoods, and actively engaging the private sector in sustainable business development. • Website: (http://www.mangrovesforthefuture.org/)
The Nature Conservancy (TNC)	<ul style="list-style-type: none"> • An international environmental NGO established in the United States in 1951. Its mission is to “conserve the lands and waters on which all life depends.” It implements 38 directly managed projects and projects through 34 partners across 72 countries and regions. • Regarding mangroves, it formed the Blue Carbon Initiative with partners in Indonesia, working to improve policy frameworks for mangrove conservation and develop sustainable management plans. Through socio-economic research on local communities' livelihoods, it explores new livelihood opportunities that do not harm mangroves. • It focuses on women's roles in conservation, and established the Women Leaders' Forum within the Coral Triangle Initiative (CTI), including Indonesia and the Philippines, aiming to achieve the following: <ul style="list-style-type: none"> • In Indonesia and Malaysia, it is working to introduce reduced-impact logging (RIL-C) techniques. This involves improving tree harvesting methods and forest road construction, harvesting only high-quality standing trees, minimizing ecological impact, and creating sustainable forestry. In Indonesia, it secured a 15-year concession to promote the implementation of this technique. • Website: (https://www.nature.org/en-us/)
Worldview International Foundation (WIF)	<ul style="list-style-type: none"> • WIF is based in Yangon, Myanmar, and focuses on mitigating the impacts of climate change through blue carbon. Its activities center on mangrove planting, which it considers the most cost-effective tool for climate change adaptation, as mangroves serve as a buffer between land and sea and conserve coastal ecosystems. • By utilizing the Verified Carbon Standards (VCS), a voluntary program where third parties certify carbon emission reductions, WIF generates tangible financial value for its initiatives. The project aims to secure funding by selling VCS-certified CO2 reductions to private companies and public institutions. Simultaneously, mangrove planting protects residents from extreme weather events like sea level rise, while increased aquatic resources contribute to food security for local communities. • WIF focuses on mangrove conservation and reforestation. It has developed an astonishing planting method, achieving a 96% survival rate for mangrove seedlings and plans to launch on-site mangrove conservation projects starting in 2021. • Website: (https://www.worldview.foundation/)
myclimate	<ul style="list-style-type: none"> • An international NGO based in Switzerland. It focuses on providing information and services that companies seek—such as calculating corporate carbon footprints and conducting life cycle assessments (quantifying environmental impacts throughout a product's entire life cycle, from raw material sourcing and production to distribution, disposal, and recycling)—to help these companies more easily engage

	<p>in climate change mitigation efforts.</p> <ul style="list-style-type: none"> • It implements over 125 projects across 37 countries, working to transition from fossil fuels to renewable energy and planting forests with smallholder farmers using energy-efficient techniques. • In Myanmar, it collaborates with universities on a project empowering women and restoring mangroves, addressing carbon sequestration, biodiversity conservation, disaster prevention and mitigation, poverty reduction, and education. It empowers local women through training in dyeing, sewing, and other skills, and provides scholarships to girls from impoverished families. Payments for carbon credits generated through these projects fund activities protecting local livelihoods, scholarships, and solar panel installations in schools. • Mangrove-related activities are conducted only in Myanmar. In Indonesia, Thailand, and Vietnam, the company focuses on stable supply of recycled fuels and renewable energy using animal waste, waste oil, sewage, etc. • Website: (https://www.myclimate.org/)
Mangrove Action Project (MAP)	<ul style="list-style-type: none"> • An international NGO based in the United States. It works at the grassroots level to conserve and restore mangroves through a bottom-up approach, focusing on field activities, advocacy, educational activities, and networking with other organizations. • MAP advocates for Community-Based Ecological Mangrove Restoration (CBEMR), a method that promotes natural mangrove regeneration by mimicking the natural growth processes derived from mangrove ecology and biology. This approach not only fosters diverse mangrove growth to enhance resilience against climate change but also reduces costs by eliminating the need for nurseries and planting expenses. • CBEMR involves discussions with local residents, local NGOs, relevant government agencies, and other stakeholders from the initial stages. It aims to build consensus on sharing survey results, the objectives of mangrove restoration, division of labor for the work, and distribution of benefits. • In Thailand, 13 abandoned shrimp ponds along the Andaman Sea were selected as demonstration sites. Over a decade, CBEMR was implemented, successfully restoring mangrove forests. Building on this success, demonstrations have been conducted in Indonesia and Myanmar, and other institutions are beginning to adopt CBEMR, enabling scaling up. MAP supports these developments by conducting training on CBEMR implementation. • Website: (https://mangroveactionproject.org/)

In addition, there are international initiatives spearheaded by these international NGOs. The main ones include the Global Mangrove Alliance and Mangrove Breakthrough, which are summarized as follows.

Table 17: International initiatives led by international NGOs

Initiative	Summary
Global Mangrove Alliance (GMA)	<ul style="list-style-type: none"> • It was established in 2017 and led by core members including Conservation International, IUCN, The Nature Conservancy, WWF, and Wetlands International, with the goal of promoting mangrove conservation and restoration. • The Alliance forms a global network with participation and collaboration from over 30 organizations and entities across more than 100 countries, including NGOs, academic and research institutions, private companies, government agencies, local communities, and funding bodies. • It has set three concrete targets to be achieved by 2030, namely, Halt Loss (Reduce human-driven mangrove loss to near zero), Restore Half (Restore half of the approximately 11,700 km² of mangroves lost since 1996), and Double Protection (Increase the proportion of mangroves under protection from the current 42% to 80% by adding approximately 61,000 km² to protected areas). • To achieve these targets, the GMA engages in a range of activities, including supporting alternative livelihoods to minimize mangrove loss, mobilizing finance, improving policy frameworks, building stakeholder capacity, and sharing knowledge with communities and decision-makers. • Website: (https://www.mangrovealliance.org/)
Mangrove Breakthrough	<ul style="list-style-type: none"> • It was launched at the 27th Conference of the Parties to the UN Framework Convention on Climate Change (UNFCCC COP27) in 2022, as part of a Global Mangrove Alliance (GMA) activity. It was initiated by the GMA and the UN Climate Change High-Level Champions, in response to the growing need for a unified global approach to the conservation and restoration of mangrove ecosystems. The initiative now includes participation from GMA members, 31 countries, international organizations,

	<p>and NGOs.</p> <ul style="list-style-type: none"> • With a foundation of USD 4 billion in sustainable finance, it provides a framework for both state and non-state actors to collaborate toward achieving a science-based global target of protecting more than 15 million hectares of mangrove ecosystems worldwide by 2030. • The initiative focuses on four key commitments, namely, halting further loss of mangroves, restoring half of the recently lost mangroves, doubling global protection of mangroves, and securing sustainable, long-term financing for all existing mangroves. • Website: (https://www.mangrovebreakthrough.com/)
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Various international organizations are undertaking initiatives related to mangroves and aquaculture, with many initiatives viewing mangroves and aquaculture as interconnected. Among these, focusing primarily on those relevant to the six countries mentioned above and considering the trends of each international organization, the situation is summarized as follows.

Table 18: Initiatives by International Organizations Related to Mangroves and Aquaculture

Organization	Country	Duration	Project name	Activity contents
FAO ⁶	Myanmar	Pending approval (4 years)	My-Coast: Ecosystem-Based Conservation of Myanmar's Southern Coastal Zone	Strengthen the capacity of organizations at both the national and regional levels to improve coastal management practices, thereby contributing to marine biodiversity conservation, climate change mitigation, and increased food production.
	Myanmar	2016-2019	FishAdapt: Strengthening the Adaptive Capacity and Resilience of Fisheries and Aquaculture-dependent Livelihoods in Myanmar	Inland and coastal fishermen and aquaculture producers enhanced their capacity to adapt to climate change by understanding their own vulnerabilities, implementing measures to reduce them, embracing new technologies, and sharing knowledge.
	Global		<ul style="list-style-type: none"> • The Global Forest Resources Assessment (FRA): This assessment compiles and publishes data on the status, management, and use of global forest resources every five years, with mangroves included as a specific category. • The Forest and Landscape Restoration Mechanism (FLRM): Launched in 2014, the FLRM promotes forest and landscape restoration activities and provides technical support, including monitoring and reporting. It currently supports 19 countries, including mangrove restoration projects. • The United Nations Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (UN-REDD Programme): Launched in 2008, this is a joint program with the United Nations Development Programme (UNDP) and the United Nations Environment Programme (UNEP). It provides technical support for REDD⁺-related activities in various countries, including mangrove conservation. In Vietnam, it has launched a UN-REDD project to address the problem of illegal conversion of mangrove forests into shrimp ponds, which was causing degradation. 	
World Bank ⁸	Philippines	Under preparation	Fishing Communities Seek Security in Aquaculture and Mangrove Restoration	Plant mangroves in abandoned aquaculture ponds, support crab aquaculture and establish value chains for boosting residents' income, and enhance the capacity of fishing villages to adapt to climate change.
	Philippines	2014-2018	Capturing Coral Reef and Related Ecosystem Services	It developed an innovative model to evaluate the ecosystem services provided by mangroves, seagrass, and coral reefs, and implemented activities to

⁶ <http://www.fao.org/forestry/mangrove/3651/en/> (accessed May 10, 2021)

⁷ Reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries

⁸ <https://www.worldbank.org/en/home> (accessed May 10, 2021)

				enhance the sustainability of marine businesses and marine management plans.
	Philippines	2016-2022	Mekong Delta Integrated Climate Resilience and Sustainable Livelihoods Project	In the Mekong Delta, initiatives are being implemented to strengthen climate resilience through climate change adaptation planning and land and water management.
	Myanmar	2020	Investment Analysis for Mangrove Ecosystems in the Ayeyarwady Region	Myanmar launched the Myanmar Reforestation and Rehabilitation Program (2017-2026) in 2016, aiming to improve residents' incomes through forest restoration. This survey conducted detailed investigations into the condition of mangroves and residents' livelihoods in the relevant areas.
	Indonesia	2022-2027	Mangroves for Coastal Resilience (M4CR)	Projects are underway in four provinces—North Sumatra, Riau, North Kalimantan, and East Kalimantan—for mangrove management, conservation, and restoration (targets: 75,000 ha restoration, 700,000 ha conservation), along with income diversification and livelihood improvement in coastal areas.
UNEP ⁹	Indonesia	2014-2018	Standardized Methodologies for Carbon Accounting and Ecosystem Services Valuation of Blue Forests	Implemented in five countries: Indonesia, Ecuador, Madagascar, Mozambique, and the United Arab Emirates. By appropriately utilizing the value of coastal carbon and ecosystem services that contribute to climate change mitigation and adaptation, the project provided knowledge, experience, and tools to increase income, leading to better coastal ecosystem management, and enabling global expansion.
UNESCO ¹⁰	Global			<ul style="list-style-type: none"> • July 26 is “World Mangrove Ecosystem Conservation Day”: Designated at the 2015 UNESCO General Conference. • Biosphere Reserve (BR): Of the 669 BRs worldwide, 86 include mangrove ecosystems. • World Heritage Sites: As of 2010, 21 designated sites worldwide include mangrove ecosystems, with the following in Southeast Asia: <ul style="list-style-type: none"> ➤ Ujung Kulon National Park, Indonesia ➤ Komodo National Park, Indonesia ➤ Puerto-Princesa Subterranean River National Park, Philippines ➤ Tubbataha Reefs Natural Park, Philippines • Blue Carbon Initiative: The Intergovernmental Oceanographic Commission (IOC) within UNESCO operates the Blue Carbon Initiative program, aiming to mitigate climate change through the conservation of coastal marine ecosystems.
UNWTO ¹¹	Indonesia	2011-2014		In collaboration with the Indonesian Ministry of Tourism and Creative Economy, it implemented the Sustainable Tourism through Energy Efficiency with Adaptation and Mitigation Measures (STREAM) project. It promoted energy efficiency and the use of renewable energy in all hotels and restaurants in Pangandaran, West Java, and launched a regeneration program with local residents to protect and restore coral reefs and mangroves. More than 2,000 residents participated and planted 38,000 mangrove trees. Various activities were prepared to encourage visiting tourists to participate in green tourism, such as providing opportunities to use bamboo bicycles, solar-powered boats, and participate in mangrove planting. As a result, tourists were encouraged to take climate-friendly actions, such as offering them vouchers for mangrove planting in exchange for reusing towels.

⁹ <https://gefblueforests.org/> (accessed May 10, 2021)

¹⁰ <https://en.unesco.org/commemorations/mangroveday> (accessed May 10, 2021)

¹¹ <http://sdg.iisd.org/news/unwto-project-delivers-climate-adaptation-mangrove-protection-in-indonesia/> (accessed May 10, 2021)

Meanwhile, JICA has implemented numerous mangrove-related initiatives as follows.

Table 19: JICA's Mangrove-Related Initiatives

Country	Project name	Modality	Duration
Indonesia	Feasibility Study for Mangrove Forest Resource Conservation and Development*	Development study (DS)	1992-1999
	Mangrove Information Center Project	Technical cooperation (TC)	2001-2006
	Support for Local Mangrove Conservation Process*	TC	2007-2010
	Project on Mangrove Ecosystem Conservation and Sustainable Use in the ASEAN Region	TC	2011-2014
	Project on Capacity Building for Restoration of Ecosystems in Conservation Areas (mangrove restoration and management are included)	TC	
	The Project for Comprehensive Assessment and Conservation of Blue Carbon Ecosystems and Their Services in the Coral Triangle (Blue CARES) (mangrove ecosystem is included)	TC	2017-2022
Philippines	Forestry Sector Project (mangrove planting is included)	Grant aid (GA)	1993-2003
	Fisheries Resource Management Project (mangrove planting is included)	Loan assistance (LA)	1998-2008
	Improving Quality of Life through Mangrove Forest Restoration in Negros Island*	Technical Cooperation for Grassroots Projects (TCGP)	2007-2010
	The Project for Comprehensive Assessment and Conservation of Blue Carbon Ecosystems and Their Services in the Coral Triangle (Blue CARES) (mangrove ecosystem is included)	TC	2017-2022
Vietnam	Natural Mangrove Forest Conservation and Environmental Human Resource Development Project in Can Gio, Ho Chi Minh City*	TCGP	2004-2007
	The Project for Afforestation on the Coastal Sandy Area in Southern Central Viet Nam (Phase 2) (mangrove planting is included)	GA	2009-
	The Project for Environmental Protection in Halong Bay (mangrove planting is included)	TC	2010-2013
	Sustainable Natural Resource Management Project (mangrove management is included)	TC	2015-2021
Malaysia	Technical Cooperation Programme for Bornean Biodiversity and Ecosystems Conservation in Sabah, Malaysia (mangrove ecosystem management is included)	TC	2002-2007
	Technical Cooperation Programme for Bornean Biodiversity and Ecosystems Conservation in Sabah, Malaysia Phase 2 (mangrove ecosystem management is included)	TC	2007-2012
	Project on Sustainable Development for Biodiversity and Ecosystems Conservation in Sabah (mangrove ecosystem management is included)	TC	2013-2017
	The Project on development of management systems for multiple utilization of biodiversity in the tropical rainforests at the protected areas in Sarawak (mangrove management is included)	TC	2021-2026
Myanmar	Development Study on the Participatory Integrated Mangrove Management Plan in the Ayeyarwady Delta*	DS	2002-2005
	Integrated Mangrove Rehabilitation and Management through Community Participation in the Ayeyawady Delta	TC	2007-2013
	The Project for Mangrove Rehabilitation Plan for Enhancement of Disaster Prevention in Ayeyawady Delta	GA	2012-
India	Project for Ecosystem Restoration in Gujarat (mangrove planting is included)	LA	2020-
	Tamil Nadu Biodiversity Conservation and Greening Project for Climate Change Response (mangrove planting is included)	LA	2022-
Palau	Project for Enhancement of Integrated Management of Coastal Ecosystems in Palau for Strengthening their Resilience to Climate Change (mangrove monitoring and management are included)	TC	2022-2025
Iran	The Project for Community-Based Sustainable Development Master Plan of Qeshm Island toward "Eco-Island" (mangrove management is included)	TC	2015-2018
	The Project on "Development and Implementation of a Master Plan for Environmental Conservation and Management of Southern Coastal Areas of the I. R. Iran (Case Study Hormozgan Province)" (mangrove management	TC	2017-2020

	is included)		
Oman	Study on Mangrove Forest Restoration, Conservation, and Management Planning*	DS	2002-2004
	Qurm (Mangrove) Environment Information Center (QEIC) Development	TC	2012-2013
Regional Organization for the Protection of the Marine Environment (ROPME)	The ROPME-JICA partnership program, aiming marine environment protection including mangroves in Persian Gulf		2015-2019
Senegal	The study on sustainable management of the mangrove in the Petit-Cote and Saloum Delta in the Republic of Senegal: Sustainable management plan for mangrove forests	DS	2001-2005
	The Project Aimed at the Enhancement of Sustainability in the Mangrove Forest Management of Saloum Delta in the Republic of Senegal	TC	2005-2008
Mauritius	Project for the Development of Integrated Coastal Ecosystem Management System (mangrove monitoring and management are included)	TC	2022-2027
Brazil	Restoration of Degraded Mangrove Ecosystems on the Northern Brazilian Coast. Project	TCGP	2005-2008
Mexico	Coastal Wetland Conservation in Yucatan Peninsula (mangrove management is included)	TC	2003-2010
Sistema de la Integracion Centroamericana (SICA)	Project for Capacity Development on Integrated Management and Conservation of Biodiversity at regional level in SICA Region (mangrove management is included)	TC	2019-2024
Global	Data Collection survey on Formulating Partnership Initiative for the Conservation and Sustainable Use of Mangrove	Data collection survey	2021-2025

*The projects with asterisk are old and the official English titles are not available; therefore these titles are not official.

2.4 Initiatives by Japanese Companies for Mangrove Conservation in Southeast Asian Countries

2.4.1 Examples of Companies Engaged in Extensive Shrimp Aquaculture Production, Processing, and Distribution

Silvo-aquaculture, which combines mangrove planting with shrimp aquaculture, can serve as one aspect of private companies' ESG management initiatives, appealing to investors focused on ESG investments from perspectives such as mangrove planting and conservation, and environmentally conscious raw material procurement. Therefore, we focused our information gathering specifically on silvo-aquaculture and the extensive aquaculture that forms its basis.

Japanese companies involved in the production, processing, and distribution of extensive shrimp aquaculture are summarized in Table 20, below. Five Japanese companies and others are engaged in this activity in Indonesia, while two are active in Vietnam. No extensive shrimp aquaculture activities by Japanese companies were confirmed in Thailand, the Philippines, Malaysia, or Myanmar.

Table 20: Examples of Japanese companies/organization involved in shrimp production, processing, and distribution through extensive aquaculture

	Company/organization	Activities
Indonesia	ALTER TRADE JAPAN, Inc.	It established Alter Trade Indonesia (PT ATINA) in Indonesia. PT ATINA is implementing shrimp aquaculture improvement projects at the following two locations: <ul style="list-style-type: none"> • Sidoarjo, East Java (supported by the Sidoarjo Fisheries Office and the Asian Seafood Improvement Collaborative (ASIC)) • Pinrang, South Sulawesi Province (supported by the Green Co-operative General

		Incorporated Association, the Pinrang District Fisheries Office and the NGO Konservasi Indonesia: KOIN)
	Japanese Consumers' Co-operative Union (JCCU)	The Shrimp Aquaculture Improvement Project is being implemented in Sulawesi from July 2018 and in Java from 2021 by the following organizations: [Japan] Japanese Consumers' Co-operative Union, World Wide Fund for Nature (WWF) Japan [Indonesia] WWF Indonesia, PT. Bogatama Marinusa/PT. BOMAR (in Sulawesi), PT. MISAJA MITRA (in Java)
	Nichirei Fresh Inc.	The Aquaculture Improvement Project is implemented by the following organizations: [Japan] WWF Japan, Nichirei Fresh [Indonesia] WWF Indonesia, PT. Mustika Minanusa Aurora (PT. MMA)
	YL Forest Co., Ltd.	<ul style="list-style-type: none"> • Conducting joint research with the Sidarjo Institute of Marine and Fisheries Technology on extensive shrimp aquaculture using silvo-fishery methods. An experimental farm is located in Pasuruan Regency, East Java Province. • Implementing the “Megumi-no-mori-zukuri Project” involving mangrove afforestation in Banyuasin Regency, South Sumatra Province. The total area is 3,000 hectares, utilizing former aquaculture ponds and fallow land. The silvo-fishery pond development cost (from land preparation to completion of planting) is approximately 1.8 million JPY per plot (2ha), with about 90% of this being land preparation costs.
	Japan International Forestry Promotion and Cooperation Center (JIFPRO)	In Banyuasin Regency, South Sumatra Province, a study was conducted to develop a business model for extensive shrimp aquaculture, commissioned by YL Forest Co., Ltd.
Thai	Unable to confirm	Unable to confirm
Philippines	Unable to confirm	Unable to confirm
Vietnam	Seikatsu Club Consumers' Co-operative Union	Extensive black tiger shrimp aquaculture is implemented in Can Tho City by the following organizations: [Japan] West Japan Farmers Union Co., Ltd., Seikatsu Club Consumers' Co-operative Union [Vietnam] Farmers Union Venture Co., Ltd., Seaprimexco Co., Ltd.
	Japanese Consumers' Co-operative Union (JCCU)	Shrimp aquaculture is being implemented in Soc Trang Province by the following organizations. The project obtained Aquaculture Stewardship Council (ASC) certification. [Japan] Japan Consumers' Co-operative Union [Vietnam] Vietnam Clean Seafood Corporation (Vina Cleanfood)
Malaysia	Unable to confirm	Unable to confirm
Myanmar	Unable to confirm	Unable to confirm

2.4.2 Examples of Companies Engaged in Mangrove Conservation

Companies that conducted mangrove planting activities as part of their CSR initiatives for biodiversity conservation from fiscal year 2016 to fiscal year 2019 are shown in Table 21. The number of listed companies undertaking mangrove planting activities has increased annually, rising from 6 companies in fiscal 2016 to 16 companies in fiscal 2019. Most activities are concentrated in Southeast Asian countries: Indonesia, Thailand, the Philippines, and Vietnam. Due to the characteristic that mangrove cultivation requires many years, activities tend to be conducted continuously within the same country. It is presumed that CSR mangrove planting activities by non-listed companies follow a similar trend.

This table is based on “Case Studies on Activities for Biodiversity” published by the Keidanren Committee on Nature Conservation (KCNC), which was compiled from survey results. While the case studies up to 2019

provided detailed and comprehensive information, those from fiscal 2022 onward, which were resumed after the COVID-19 pandemic, include only selected examples. As it is difficult to compile comparable data for the later years, only information up to 2019 is organized in this table.

Table 21: Japanese companies engaged in mangrove reforestation initiatives and their country of operation

Company	2016	2017	2018	2019
ORIX Corporation		Philippines	Philippines	
T.RAD Co., Ltd.				Indonesia
Nabtesco Corporation	Thai	Thai		
Nichirei Corporation	Indonesia	Indonesia		Indonesia
Pioneer Corporation			Thai	
Brother Industries, Ltd.	Thai	Thai	Thai	Thai
Ricoh Company, Ltd.			Mexico	
Ando Hazama Corporation		Myanmar		
Kyowa Kirin Co., Ltd.		Thai		
Mitsui Chemicals, Inc.	Thai		Thai	
Sumitomo Rubber Industries, Ltd.			Indonesia	Indonesia
Sumitomo Bakelite Co., Ltd.				Indonesia
Sumitomo Chemical Co., Ltd.		Thai	Indonesia	Indonesia
Chubu Electric Power Co., Inc.				Vietnam
Tsubakimoto Chain Co.			Thai	Thai
Tokio Marine & Nichido Fire Insurance Co., Ltd.	Indonesia	Indonesia	Indonesia	Indonesia
Nisshin Seifun Group Inc.				Thai
Nippon Light Metal Holdings Co., Ltd.				Thai
Nippon Shokubai Co., Ltd.			Indonesia	Thai
NSK Ltd.		Thai	Thai	Thai
Ryoden Corporation			Thai	Thai
FUJIFILM Holdings Corporation				Vietnam
Fuji Electric Co., Ltd.	Thai			
Meidensha Corporation			Thai	Thai
Total	6	9	13	16
Indonesia	2	2	4	6
Thai	4	5	7	8
Philippines	0	1	1	0
Vietnam	0	0	0	2
Myanmar	0	1	0	0
Others	0	0	1	0

Source: Keidanren Committee on Nature Conservation (KCNC) Case Studies on Activities for Biodiversity FY2016, 2017, 2018 and 2019.

3. International Initiatives and Financial Mechanisms for Nature Conservation

3.1 International Initiatives and Financial Mechanisms for Nature Conservation

This section highlights three international agreements, namely, Kunming-Montreal Global Biodiversity Framework (GBF) in the Convention on Biological Diversity (CBD), Paris Agreement in the United Nations Framework Convention on Climate Change (UNFCCC), and the Sustainable Development Goals (SDGs), as central international agreements for promoting corporate investment in biodiversity. These international initiatives complement each other in achieving their objectives while also spawning numerous derivative initiatives aimed at contributing to their goals. The outcomes of these derivative initiatives are reported and consolidated at the Conferences of the Parties (COP). This section outlines the three agreements and explains their achievements to date and future directions relevant to the objectives of this study. The funding mechanisms for advancing these agreements are discussed in Section 4.2 below.

3.1.1 Convention on Biological Diversity

(1) Background

The Convention on Biological Diversity (CBD) was adopted in 1992 with the objectives of (1) the conservation of biological diversity, (2) the sustainable use of its components, and (3) the fair and equitable sharing of benefits arising from the utilization of genetic resources. Currently, 196 countries and regions are parties to the Convention. The Global Environment Facility (GEF) has been established as the official financial mechanism to support the implementation of the CBD. The Conference of the Parties (COP) is held every two years. At the 15th COP held in 2022, the Kunming-Montreal Global Biodiversity Framework (KM-GBF) was adopted. This framework succeeds the previous Aichi Biodiversity Targets and sets out concrete goals to be achieved by 2030. Notably, it includes the “30x30” target of protecting 30% of terrestrial and marine areas by 2030, mobilizing \$200 billion annually by 2030 (including support for developing countries), reforming subsidies, and strengthening the sharing of benefits from genetic resources. In total, 23 specific targets are outlined. The KM-GBF is expected to address shortcomings in the achievement of the Aichi Targets by providing a more measurable, action-oriented framework, with strengthened mechanisms for financing and implementation. At COP16 held in October 2024, an agreement on financing and implementation plans was not reached. However, at a resumed meeting in Rome, Italy, in February 2025, parties reached consensus on the establishment of a new mechanism for benefit-sharing of genetic resources and a roadmap toward the provision of 200 billion USD annually to developing countries.

(2) Achievements in Promoting Biodiversity Conservation by Companies

Marine and coastal biodiversity

Particularly for companies involved in fisheries, tourism, and energy sectors, there is an increasing demand for business to be operated with consideration for the conservation and sustainable use of coastal and marine ecosystems. Participation in sustainable fisheries certification schemes such as the Marine Stewardship

Council (MSC) and blue carbon projects is progressing. Specifically, based on Decision X/29 adopted at COP10, guidelines and institutional frameworks have been strengthened to require fisheries, tourism, and development companies to conduct appropriate environmental impact assessments and consult with local communities regarding marine protected areas and coastal ecosystem conservation. As a result, an increasing number of countries have incorporated obligations into government regulations that require companies to consider the conservation value of shorelines, mangroves, coral reefs, and other ecosystems when undertaking development activities. Furthermore, the KM-GBF sets targets of conserving 30% of biodiversity key areas (Target 3) and of restoring 30% of degraded ecosystems (Target 2) in coastal and marine ecosystems by 2030. Companies can contribute to achieving this goal through mangrove conservation efforts.

Equitable sharing of benefits arising from the utilization of genetic resources (Access and Benefit-Sharing: ABS)

Access and Benefit-Sharing (ABS) is the third objective of the CBD. Regarding this, the Nagoya Protocol, which establishes procedures for implementing ABS, was adopted at COP10 held in Nagoya in 2010. The Protocol entered into force in 2014, and the first meeting of the Parties to the Nagoya Protocol was held alongside COP12. The Japanese government ratified the Nagoya Protocol in 2017 and concurrently issued the “Guidelines on Access to Genetic Resources and Fair and Equitable Sharing of Benefits Arising from their Utilization (ABS Guidelines)” (Ministry of the Environment, 2021). These guidelines legally incorporate access and benefit-sharing procedures into corporate research and development activities. Specifically, they clarify the necessity of formal procedures and benefit-sharing agreements when acquiring genetic resources in sectors such as pharmaceuticals, cosmetics, and agriculture, thereby promoting risk management and legal compliance. Through this mechanism, company activities create incentives for resource providers such as countries and local communities to continue conserving biodiversity. Additionally, the value of cultural and traditional knowledge has gained international recognition, prompting companies to emphasize respecting such knowledge. Furthermore, the guidelines clarify the ethical responsibilities of companies in raw material procurement and R&D, and it is contributing to what is called “responsible innovation.” Within the KM-GBF, Goal C and Target 13 address the “fair and equitable sharing of benefits arising from the utilization of genetic resources, associated traditional knowledge, and digital sequence information (DSI) on genetic resources.” To achieve this, Parties are obligated to establish legal frameworks, policies, and capacity-building measures for the fair sharing of benefits from genetic resource utilization by 2030. Moreover, decisions have been adopted to strengthen the ABS Guidelines within the context of the KM-GBF. The Conference of the Parties has also requested that the full scope of the Nagoya Protocol be addressed in the implementation of the KM-GBF.

Sustainable use

Resolution VIII/17 adopted at COP8 officially called for business engagement, encouraging companies to integrate the Strategic Plan of the CBD and its targets, including the Aichi Targets, into their business

strategies. This has served as a catalyst for companies to advance sustainable business models and improve production practices. The KM-GBF includes goals aimed at ensuring the sustainable conservation of biodiversity. Its package of supplementary decisions includes frameworks such as “Capacity-building and Technical Cooperation for Sustainable Use” (Decision 15/8), which call upon countries to establish sector-specific foundations for the sustainable use of biological resources. Moreover, the Global Biodiversity Framework Fund (GBFF), a financial mechanism supporting the KM-GBF, identifies “Action Area Five: Strengthening Sustainable Use” as one of its programming priorities.

Scientific assessment

Private companies are contributing to advancing scientific assessments by developing and implementing ecosystem impact assessments and biodiversity monitoring technologies. Internationally, there is a growing trend to incorporate Biodiversity Impact Assessments into corporate strategies. Specifically, at COP6, the Akwé: Kon Voluntary Guidelines were established to evaluate the impacts of projects involving traditional lands and local communities on biodiversity, culture, environment, and society. These guidelines encourage companies to conduct environmental and social impact assessments when operating on sacred sites, indigenous territories, and similar areas, serving as a framework for more comprehensive impact evaluations. In addition, efforts to strengthen Knowledge Management for Biodiversity (KM4B) have been undertaken. Through knowledge sharing, data organization, and capacity building, KM4B supports decision-making based on scientific evidence. Effective monitoring and decision-making in the 15-year plan of the KM-GBF require integration and sharing of diverse data and knowledge, and KM4B is playing a key supporting role.

Strategic plan from the Convention

The KM-GBF, adopted at COP15 in 2022 as a new strategic plan, is also referred to as the "Post-2020 Framework." It serves as the successor to the Aichi Targets (2011–2020), taking into account both their achievements and challenges. Covering the period from 2022 to 2030, the framework aims to halt and reverse biodiversity loss (nature positive) by 2030, with a long-term vision toward 2050 of "Living in Harmony with Nature." Specifically, the framework sets out 23 global targets. Among them, one of the most prominent is the “30 by 30” target of effectively conserving and managing at least 30% of terrestrial, inland water, marine, and coastal areas by 2030. Other goals include ecosystem restoration, enhanced financial support for biodiversity, elimination of harmful subsidies, fair and equitable benefit-sharing of genetic resources, and ensuring good governance. Reflecting lessons learned from the previous framework, the KM-GBF places a strong emphasis on the implementation capability and measurability of its targets. Each Party is required to develop or update its national strategies and action plans in alignment with the framework, considering national circumstances, and to report regularly on their implementation status.

Climate change, biodiversity, and the Sustainable Development Goals (SDGs)

The KM-GBF goes beyond the traditional scope of nature conservation alone, and places strong emphasis on integration with other sectors such as climate change mitigation and adaptation, land degradation,

development policies, and reform of economic incentives. It is designed to be complementary to the broader Sustainable Development Goals (SDGs), particularly those related to poverty, hunger, climate, and the conservation of terrestrial, marine, and freshwater ecosystems. At COP16, a decision titled “Biodiversity and Climate Change” was adopted to strengthen the linkages between biodiversity and climate change. This decision has opened the door for formal discussions on enhanced policy coherence and potential joint programs between related conventions such as the CBD and the UNFCCC. The decision urges Parties to maximize the synergies between biodiversity action and climate change measures while avoiding unintended negative impacts of climate action on biodiversity when implementing targets. It also highlights the need to address the nexus between climate, biodiversity, and oceans, and promotes cooperation with the UNFCCC. Work in these areas is expected to progress further. Additionally, Parties, observers, and stakeholders have been invited to submit views on enhanced policy coherence by May 2025. Discussions are also underway on the possibility of developing a joint work program among the CBD, UNFCCC, and the United Nations Convention to Combat Desertification (UNCCD). The decision further includes encouraging the integration of nature-based solutions and ecosystem-based approaches for climate mitigation and adaptation into national strategies. This reflects a direction toward aligning climate policies with the conservation and restoration of ecosystems that have carbon sequestration and climate stabilization functions—such as forests, wetlands, and coastal areas. Regarding the relationship between the KM-GBF and the SDGs, it has been reaffirmed that the KM-GBF contributes to the implementation of the 2030 Agenda for Sustainable Development. It was also confirmed that progress toward the SDGs and the realization of sustainable development across its three dimensions (environmental, social, and economic) is essential for achieving the goals and targets of the KM-GBF. Moreover, the important link between biodiversity and cultural diversity was acknowledged, reaffirming the need to place biodiversity, its conservation, the sustainable use of its components, and the fair and equitable sharing of benefits arising from the use of genetic resources at the heart of the sustainable development agenda.

Business and biodiversity

The objectives of the Convention on Biological Diversity can only be achieved with private sector participation. Regarding private sector involvement, the first resolution on private sector participation was adopted at COP8 (2006). At COP10 (2010), resolutions for recommending the establishment of a platform for private sector participation, the Business and Biodiversity Initiative, and international cooperation with business were passed. At COP9 (2008), the German government spearheaded the launch of the Business and Biodiversity Initiative with participation from nine Japanese companies. Within Japan, the Japan Business Initiative for Biodiversity (JBIB) was established in 2008 to conduct joint research, share information, engage in dialogue with citizens and NGOs, and make policy recommendations.

The Ministry of the Environment recognizes businesses as key players in biodiversity conservation and has budgetary measures to support collaboration with them. These include the Guidelines for Private Sector Participation in Biodiversity Conservation (Revised 2017), the Environmental Reporting Guidelines (2018), the International Standard for Biodiversity (ISO 14001, revised 2015), the Case Studies of Private Sector

Participation for Businesses (2020), and the Good Practices for Corporate Information Disclosure (2020) with the aim of promoting private sector participation.

Furthermore, the Ministry of the Environment collaborates with the Keidanren Nature Conservation Council (141 companies), the Private Sector Participation Partnership for Biodiversity, JBIB, the Biodiversity Measures Committee of the Japan Association of Industries and Environment (JAIE), the Eco-First Promotion Council, and other business associations. These collaborations contribute inputs for the Convention on Biological Diversity's Strategic Plan 2011-2020 and the Aichi Targets, promote the dissemination and implementation of the SDGs, foster ESG investment, and provide input for the Post-2020 Global Biodiversity Framework. In November 2020, the Ministry of Environment and Keidanren launched the “Biodiversity Business Contribution Project” to explore business opportunities through technologies, products, and services that contribute to achieving the goals of the Post-2020 Global Biodiversity Framework (Ministry of the Environment, 2010 and 2021; Mitsui Sumitomo Insurance, 2021). This study examines and proposes the structure and operational methods for an information platform to enhance private-sector collaboration for mangrove conservation, drawing on examples of such government-business partnerships.

3.1.2 United Nations Framework Convention on Climate Change

(1) Background

In May 1992, the United Nations adopted the United Nations Framework Convention on Climate Change (UNFCCC), which aims to stabilize greenhouse gas (GHG) concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. The Convention entered into force in March 1994 and, as of 2021, has 197 parties comprising countries and regional organizations. The Convention addresses the treatment of developed and developing countries as “common but differentiated responsibilities and respective capabilities,” categorizing them as (1) Annex I countries (countries with GHG reduction targets (developed countries and countries with economies in transition)), (2) Non-Annex I countries (developing countries not subject to GHG reduction targets), and (3) Annex II countries (developed nations) obligated to provide financial cooperation to enable Non-Annex I countries to fulfill their treaty obligations). Financial mechanisms established for implementing the Convention include the Green Climate Fund (GCF), the Adaptation Fund (AF), and the Global Environmental Facility (GEF). Subsequently, at COP3 held in Kyoto (1997), the Kyoto Protocol was agreed upon, clearly stipulating binding reduction targets for developed countries. Furthermore, at COP21 held in Paris (2015), the Paris Agreement was adopted as the new international framework for addressing climate change after 2020.

(2) Achievements in Promoting Biodiversity Conservation by Companies

From the Kyoto Protocol to the Paris Agreement

The period from 1997, when the Kyoto Protocol was adopted, to 2015, when the Paris Agreement was adopted, saw a clear pattern of confrontation between developed and developing countries in international

negotiations. Within this framework, only countries like Japan and Europe, which account for just under 30% of global emissions, were assigned reduction obligations. Furthermore, countries like the United States, which refused to ratify the Protocol, and China, which was considered a developing country at the time of its signing, were not subject to any obligations. This led Japanese industry to express dissatisfaction, stating that “the Kyoto Protocol is unfair in terms of international competition.” Against this backdrop, the industry is said to have supported the Japanese government's decision not to participate in the extension of the Protocol (Japan Research Institute website, CSR-related Movements: COP17: Withdrawal from the Kyoto Protocol and Japanese Companies, 2012). This perceived unfairness surrounding the Kyoto Protocol is thought to have been one factor constraining proactive corporate decarbonization efforts. Furthermore, there was a tendency to assume that public fund transfers would be central to countermeasures, meaning it was a period where responses based on the critical role of corporate action in decarbonization were insufficient. On the other hand, this period can be viewed as a preparatory phase preceding the full-scale emergence of ESG investing. During this time, efforts began to establish and disseminate various corporate reporting and disclosure standards to regulate ESG investing. Since the 2015 Paris Agreement, climate change has been recognized as a tangible investment and business risk and opportunity. Consequently, market value standards have shifted, and ESG investment has expanded rapidly. The development of market rules enabling this expansion progressed throughout this period.

The Kyoto Protocol (1997) clearly stipulated binding reduction targets for developed countries (emissions for the five-year period from 2008 to 2012 compared to 1990 levels: Japan -6%, US -7%, EU -8%, other developed countries -5%). While the Kyoto Protocol did not impose reduction obligations on developing countries, the establishment of these targets represented a crucial step in the international community's cooperative effort to address global warming. Concurrent with the adoption of the Kyoto Protocol, the “Kyoto Mechanisms” were introduced, allowing forests and agricultural land to be counted as “sinks,” with the carbon they absorb being credited toward reduction targets (Ministry of Environment, 2021).

The Kyoto Protocol stipulated that consideration of reduction targets for developed countries (Annex I countries) for the period after 2013 should begin no later than 2005. Therefore, at COP13 (2007), recognizing the need to develop a comprehensive next framework, the Bali Action Plan was adopted. It established an Ad Hoc Working Group to complete deliberations on this framework by COP15 (2009). However, at COP15 (2009), conflicts between developed and developing countries became pronounced, preventing consensus. The Copenhagen Accord was agreed upon as a voluntary commitment open only to participating Parties¹².

At COP16 (2010), the Cancun Agreements were adopted, establishing a vision for achieving significant global emissions reductions by 2050 to limit temperature rise to below 2°C above pre-industrial levels. Developing countries such as India and Brazil showed willingness to contribute to emissions reductions, and the agreements incorporated reduction targets and actions for both developed and developing countries. The agreement included provisions related to support for developing countries, such as the establishment of the

¹² Its official status will be as a document outside the UNFCCC framework.

Green Climate Fund (GCF), the creation of a technology mechanism, the development of climate adaptation plans for developing countries, and measures to address deforestation and forest degradation in developing countries (REDD+). However, no agreement was reached on the so-called new post-Kyoto framework, which had been the original objective (Ministry of the Environment, 2021; Environmental Innovation Information Organization, 2011). At COP17 (2011), the “Ad Hoc Working Group on the Durban Platform” was established. It was agreed that this working group would complete its tasks by the end of 2015 at the latest, aiming to bring a new post-Kyoto Protocol framework into effect by 2020. Meanwhile, Japan stated it would not participate in the second commitment period of the Kyoto Protocol, arguing that a Kyoto Protocol without the participation of all countries raises issues of fairness and effectiveness.

The Paris Agreement and Afterwards

At COP21 (2015), the Paris Agreement was adopted as the successor to the Kyoto Protocol and the international framework for climate change issues after 2020. The Paris Agreement's goal is to keep the global average temperature rise well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C. To achieve this, global GHG emissions must peak as soon as possible, and by the latter half of the 21st century, GHG emissions and absorption (e.g., through forests) must be balanced. The Paris Agreement is groundbreaking because it applies to all major emitters, including developing countries. Furthermore, unlike the top-down approach of the Kyoto Protocol, the Paris Agreement adopts a bottom-up approach, which is another reason it is considered a revolutionary framework.

Under the agreement, each country is allowed to voluntarily formulate its own greenhouse gas (GHG) emission reduction or limitation targets, which is known as Nationally Determined Contributions (NDCs), taking into account its national circumstances, including socioeconomic conditions and private sector initiatives. These NDCs are expected to reflect each country's unique context, incorporating efforts from both the public and private sectors. Within this framework, companies are not only striving to reduce emissions through their own initiatives but also are actively engaging in the use of offset and credit mechanisms, such as the Joint Crediting Mechanism (JCM) and voluntary carbon credits. As a result, corporate efforts to reduce GHG emissions are expected to further accelerate and expand. This has resulted in alleviating the sense of unfairness felt by Japanese companies regarding the Kyoto Protocol.

Another distinctive feature of the Paris Agreement is the positioning of market mechanism utilization under Article 6. To expand carbon offset credit trading through promoting carbon markets, the private sector is designated as a key player in emissions reduction, anticipating extensive engagement from this sector. Specifically, Article 6.2 stipulates the use of systems like Japan's JCM and other mechanisms where countries can trade Internationally Transferred Mitigation Outcomes (ITMOs)—emission reductions transferred internationally—with other nations. Furthermore, Article 6.4, as a successor to the Kyoto Protocol's Clean Development Mechanism (CDM), established a mechanism under UN leadership to issue credits (emission reductions) to countries and companies undertaking greenhouse gas reduction projects. These credits can be purchased by other countries and companies to offset their emissions. Furthermore, the agreement

underscores the importance of conserving and enhancing sinks like forests, expresses expectations for mechanisms to curb emissions from deforestation and forest degradation in developing countries, and mandates efforts by developing countries themselves. These provisions support a market-based valuation of investment in sinks within developing countries.

At COP29 held in November 2024, all requirements concerning Article 6 of the Paris Agreement were agreed upon for the first time, completing the rulebook. This enables the full operationalization of Article 6. It signifies the launch of the “international carbon market,” where countries and companies can participate in other nations' emission reductions through credits.

3.1.3 Sustainable Development Goals

(1) Background

The SDGs are international goals to be achieved by 2030, outlined in the “2030 Agenda for Sustainable Development” adopted unanimously by UN member states at the September 2015 UN Summit. They succeed the Millennium Development Goals of 2001. Comprising 17 goals and 169 targets, they pledge to “leave no one behind” on Earth. Unlike the MDGs, which set eight development goals specifically for developing countries, the SDGs were established as universal development goals for both developing and developed countries. The High-Level Political Forum (HLPF) serves as the review mechanism for the SDGs. It comprises two types of meetings: the SDG Summit, a leader-level meeting held every four years during the UN General Assembly, and the annual ministerial-level meeting hosted by the Economic and Social Council (ECOSOC) in July. The SDG Summit has been held in 2015, 2019 and 2023.

Japan's implementation framework includes the SDGs Promotion Headquarters, headed by the Prime Minister, and the SDGs Promotion Roundtable Conference, established under this headquarters to facilitate discussions among a broad range of experts (Ministry of Foreign Affairs, 2021). Additionally, extensive support activities are underway to assist businesses in integrating SDGs into their management practices. These include the launch of the “SDGs Management/ESG Investment Study Group” by the Ministry of Economy, Trade and Industry (METI), the revision of the Keidanren Corporate Action Charter to reflect SDG principles, and initiatives by local chambers of commerce and industry and Junior Chambers International (JCI) chapters nationwide.

(2) Approaches Related to Promoting Corporate Investment in Biodiversity Conservation

SDGs with comprehensive goals encompassing the agendas of the Convention on Biological Diversity and the United Nations Framework Convention on Climate Change

Recognizing that various development challenges are interconnected, the number of goals and targets in the SDGs increased compared to the MDGs. This reflects the view that it is more desirable to address interconnected development challenges in an integrated manner (Ministry of Foreign Affairs, 2015).

Consequently, the agendas of the Convention on Biological Diversity and the United Nations Framework Convention on Climate Change have been integrated as part of these goals, broadening the range of approaches available to companies investing in biodiversity conservation. Of the 17 goals in total, those directly related to biodiversity conservation include Goal 12 (Sustainable Consumption and Production), Goal 13 (Climate Action), Goal 14 (Life Below Water), Goal 15 (Life on Land), and Goal 17 (Strengthening the Means of Implementation and Revitalizing the Global Partnership for Sustainable Development). Therefore, the SDGs can be considered an initiative that ensures the validity of corporate investment in biodiversity conservation.

The private sector, including businesses, is the key player in achieving the SDGs

The most significant feature of the adopted 2030 Agenda for Sustainable Development is its universality, which commits all countries, including developed nations, to achieving sustainable environments and societies. Furthermore, recognizing the growing international consensus that businesses and civil society are key actors in development, it emphasizes the importance of a “global partnership” where all stakeholders play their part (Ministry of Foreign Affairs, 2015). Given this nature of the SDGs, it is expected that businesses will integrate the SDGs into their management practices and lead sustainable development to achieve them. Here, ESG investment is positioned as a necessary means of financing for integrating the SDGs (Ministry of Economy, Trade and Industry, 2019; Ministry of the Environment, 2020). In this context too, the SDGs serve as an initiative that ensures the legitimacy of promoting corporate biodiversity investment.

3.2 Funding Mechanisms for Nature Conservation

3.2.1 Outline of the Funding Mechanisms

- (1) A funding mobilization mechanism aimed at promoting biodiversity conservation, climate change mitigation, and the SDGs

The mechanisms for mobilizing funds aimed at biodiversity conservation, climate change mitigation, and promoting the SDGs are broadly categorized into (A) mobilizing public funds, and (B) mobilizing private funds.

Table 22: Funding mechanisms aiming at promoting biodiversity conservation, climate change and the SDGs

Category	Funding mechanism	Example
A: Public funds	(1) Treaty	GEF, GCF, FCPF ¹³ etc.
	(2) National public budgets	National budgets/funds, ODA ¹⁴ , etc.
	(3) Others	NGO activities, philanthropic initiatives, etc.
	(4) Funds from public development bank	International and national development bank funds
B: Private funds	(5) Funds from private commercial bank	Fundraising from capital markets (investment specifically targeting environmental solutions is limited)
	(6) CSR activity funds	CSR funds contributed by individual companies

¹³ FCPF: Forest Carbon Partnership Facility

¹⁴ ODA: Official Development Assistance

	(7) Carbon markets	CDM, JCM, REDD+ etc.
	(8) Innovative capital markets and consumer markets (including biodiversity)	(Capital markets) Green bonds, blue bonds, etc. (Consumer markets) Payments for ecosystem services

Since 2015, it has become widely understood that addressing global challenges such as environmental issues and worldwide development problems cannot be achieved solely through conventional funding sources like those mentioned in A above. To bridge this gap, promoting the utilization of private capital is crucial. Consequently, ESG investment by companies practicing ESG management, as outlined in (6), (7), and (8) above, has grown rapidly. The purpose of this survey is also to gather information to promote the mobilization of private funds for mangrove conservation. On the other hand, regarding the status of ESG investment in companies practicing ESG management as described above, according to a report released by the Global Sustainable Investment Alliance (GSIA) on November 29, 2023, global ESG investment in 2022 amounted to 30.3 trillion USD (approximately 4,460 trillion JPY), marking the first negative growth since the GSIA began its survey. This was influenced by a halving of investment in the United States, which accounted for more than half of global ESG investment. In the United States, ESG investment that does not reflect the reality is increasingly being harshly criticized as “greenwashing.” The GSIA report mentioned above also excludes ESG funds with greenwashing concerns from its calculations. This trend is expected to spread to Europe and beyond, making it urgent to establish a framework for more appropriately evaluating ESG investment initiatives by private companies, along with efforts to promote ESG investment by private companies.

(2) Project Types Utilizing Funding Mechanisms by ESG Management Companies Involved in Forest Conservation

Activity types by ESG management companies engaged in forest conservation can be broadly categorized into (1) activity types where ESG companies promote forest conservation through financial support or donations rather than conducting activities as the primary business entity themselves, and (2) activity types where ESG companies themselves act as the main planning and operational entities for forest conservation projects.

Examples of type (1) include donations to funds as part of CSR or social contribution activities, direct donations to forest conservation organizations, NPOs, or public interest foundations, and support or investment in venture/startup companies conducting forest monitoring using satellites/drones or developing new materials utilizing forest resources. Additionally, this category includes: crowdfunding-style support for specific projects (such as afforestation or biodiversity conservation), purchasing carbon credits through investments in forest conservation projects to offset corporate carbon emissions, and managing funds through the establishment of proprietary funds or grant programs focused on forest conservation, or through consortium-type funds formed by multiple companies.

Activities in type (2) include: conducting company-led afforestation and forest creation projects on company-owned or leased land, forest management and conservation activities such as biodiversity conservation,

thinning, pest control, and *satoyama* maintenance, environmental education and awareness initiatives like experiential learning programs and internal/external training sessions centered on forest environments, and linking company products with forest conservation, such as selling products where a portion of sales is allocated to forest conservation. Additionally, there are collaborative projects involving partnerships with NPOs, local governments, and community residents, such as community-wide Satoyama conservation and forest tourism development.

Table 23: Types of Forest Conservation Initiatives by Companies Practicing ESG management

Activity type	Overview	Example Activities
Indirect Implementation via Funding/Investment	Support and promote forest conservation not by the company itself becoming the project implementer but through financial support, donations, investments in or support for other organizations/companies, carbon credit purchases, etc.	<ul style="list-style-type: none"> • Donations/financial support to foundations, NPOs, public interest foundations, etc. • Investments in startups or forest conservation projects • Establishment and operation of company-owned funds • Purchasing carbon credits or offsetting carbon emissions through investment in forest projects
Direct Implementation	Conducting forest conservation projects and education/awareness initiatives in-house	<ul style="list-style-type: none"> • Company-owned afforestation and forest management projects • Environmental education and tourism development • Sales of products utilizing forest resources • Joint projects in collaboration with NPOs, local governments, and community residents

(3) Projects Supported by a Fund, which is Utilized by Companies Practicing ESG Management and Being Involved in Forest Conservation

In section (2) above, the types of forest conservation projects undertaken by companies practicing ESG management is classified. However, a key aspect of both types is funding. Here, the project types utilizing funds are categorized as follows. Specifically, the project types are categorized into three categories: CSR projects, purchase of carbon credits through investment in forest conservation, and investment in building ESG-conscious supply chains.

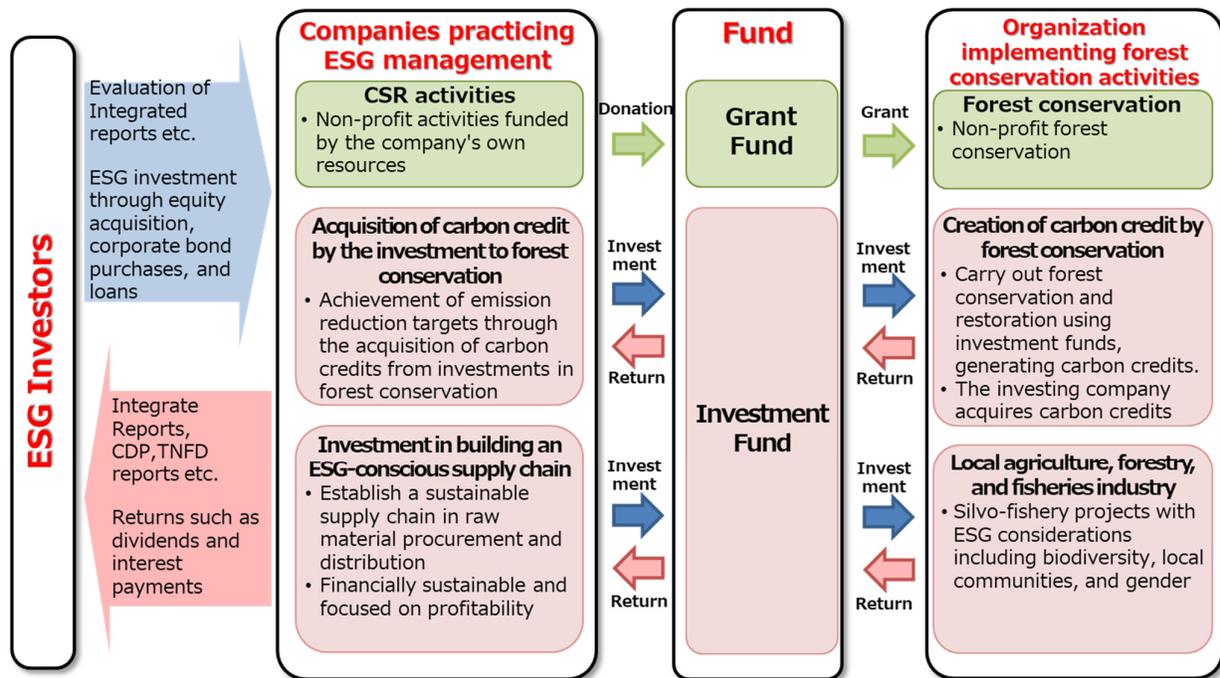


Figure 6: Projects supported by a fund, which is utilized by companies practicing ESG management and involved in forest conservation

CSR projects are non-profit projects funded by the internal resources of companies practicing ESG management. When such projects are implemented through funds, companies practicing ESG management donate to funds supporting forest conservation projects in Japan and developing countries. Each fund uses these donations to support forest conservation projects in Japan or developing countries. Companies and organizations implementing forest conservation projects apply for support from these funds along with their project plans. The management committees established for each fund select the projects to be supported. Companies practicing ESG management that donate to these funds disclose information about these initiatives in their integrated reports, etc. Institutional investors engaged in ESG investment evaluate this information and invest in companies practicing ESG management through stock acquisitions, corporate bond purchases, and loans, etc. A certain number of such funds supporting natural environment conservation already exist, and many Japanese companies make donations to them as part of their CSR activities.

On the other hand, some companies pursue ESG management through investment rather than CSR. This primarily include aiming to achieve emission reduction targets by acquiring carbon credits through investments in forest conservation, or building sustainable supply chains that consider ESG in raw material procurement and distribution. When such investment takes place through funds, companies practicing ESG management invest in investment funds that fund these projects. These investment funds leverage advanced expertise to select forest conservation-related projects and invest in them. Profits and carbon credits generated through these projects are returned to the investing companies. The companies practicing ESG management investing in these funds disclose information through integrated reports and frameworks like the CDP

(Carbon Disclosure Project, an NGO operating an environmental information disclosure system) which are collecting, analyzing, and disclosing corporate sustainability data. They also disclose information through frameworks such as the Taskforce on Nature-related Financial Disclosure (TNFD) and the Task Force on Climate-related Financial Disclosures (TCFD). Institutional investors engaged in ESG investment then evaluate this information and invest in companies practicing ESG management through equity acquisitions, corporate bond purchases, loans, and other means.

Currently, investment in for-profit ventures related to natural environment conservation is still developing. They are particularly limited in the forest conservation and agriculture sectors, and even more so in the mangrove restoration and conservation field.

3.2.2 Examples of Funding Mechanisms

(1) CSR Projects

As mentioned above, grant funds to support organizations engaged in environmental conservation initiatives in Japan and overseas already exist. Many Japanese companies contribute to these grant funds as part of their CSR activities. Some specific examples of these funds are described below.

Keidanren Nature Conservation Fund

1) Background and Objectives

The Keidanren Nature Conservation Fund (KNCF), a public trust, was established in April 2000. It was recognized by the Environmental Agency (now the Ministry of the Environment) and the Ministry of Foreign Affairs. The Keidanren Nature Conservation Council, as the settlor, contributed 110 million JPY. Sumitomo Trust Bank (now Sumitomo Mitsui Trust Bank) served as the trustee. Since then, it has received donations from numerous private companies, including Keidanren member firms, and individuals. It has continuously implemented grant programs with an annual project scale totaling approximately 150 million JPY.

2) Activities

Activities are conducted in the following two areas:

- Grants for projects undertaken by private organizations (including foreign organizations) concerning the conservation of the natural environment in developing regions, primarily in the Asia-Pacific region.
- Grants for outstanding conservation activities and projects related to the sustainable utilization of Japan's natural environment.

An overview of the fund's grant programs is described below.

Table 24: Overview of Grant Program Application Categories for Fiscal 2023 and Beyond

Grant Program		First-time Grants	Grants for NGOs in Least Developed Countries	Standard Project Grants	Collaborative Project Grants
Purpose & Features		Grants primarily aimed at broadening the base of stakeholders engaged in biodiversity conservation efforts. Application and reporting forms are simplified as much as possible to reduce the burden on applicant organizations.		Grants following the established format and scale. Supports projects in their initial stages and new initiatives.	Provides large-scale grants over three years. Prioritizes support for projects that serve as models for other organizations through collaboration with government, local communities, businesses, etc.
Eligible Organization		Organizations with no prior KNCF grant history	Grassroots organizations in “Least Developed Countries”	<ul style="list-style-type: none"> ■ Organizations capable of providing appropriate reports on project implementation status, budget, financial statements, and other fiscal matters as requested by the Foundation ■ Organizations with legal status or voluntary groups possessing equivalent social credibility ■ Organizations with at least three years of proven experience in nature conservation activities 	<ul style="list-style-type: none"> ■ Projects must be collaborative efforts involving multiple organizations (two or more) ■ Organizations capable of providing appropriate reports on project implementation status, budget, financial statements, and other fiscal matters as requested by the Foundation ■ Organizations with legal status or voluntary groups possessing equivalent social credibility ■ Organizations with at least three years of proven experience in nature conservation activities
		The requirements for Standard Project Grants are not applied	The requirements for Standard Project Grants are not applied		
Activity Areas	Japan	◎	—	◎	—
	Overseas	◎	◎	◎	◎
Eligible Activities		Activities contributing to the realization of the KM-GBF			
		① Initiatives related to biodiversity conservation			
		② Initiatives contributing to solving social issues or achieving the SDGs for this purpose ③ Human resource development (environmental education) initiatives			
Annual Grant Amount		Up to 1 million JPY		Up to 10 million JPY	Up to 20 million JPY

3) Fund Structure

The Keidanren Nature Conservation Fund operates under the following structure.

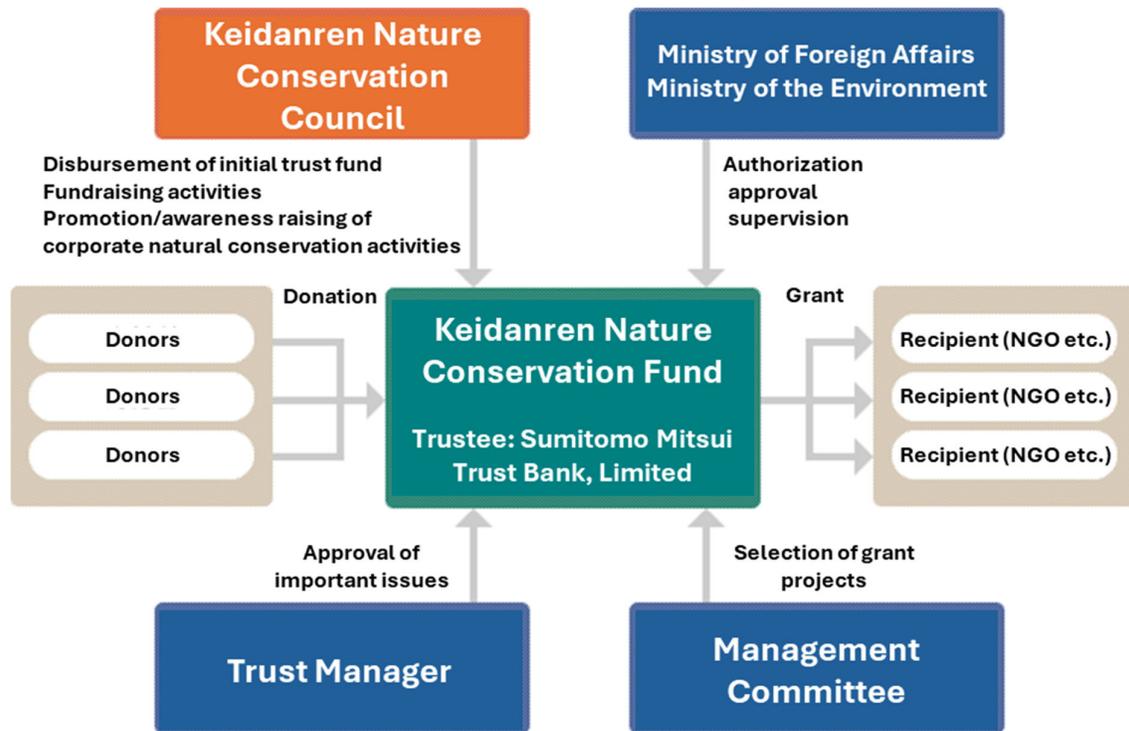


Figure 7: Keidanren Nature Conservation Fund Management Structure¹⁵

4) Current Status and Achievements

From April 2022 to December 2022, donations were received from 202 corporations and 8 groups, along with 126 individuals. Since its establishment in 1992, the fund has supported a cumulative total of 1,736 projects over 30 years starting from fiscal 1993, with total support amounting to approximately 5 billion JPY. Supported activities vary from natural resource management related to biodiversity conservation, protection of rare flora and fauna, as well as afforestation and environmental education.

Following the adoption of the Kunming-Montreal Global Biodiversity Framework (GBF) as the new global biodiversity targets at the 15th Conference of the Parties (COP15) at the Convention on Biological Diversity in December 2022, the Fund's new grant policy includes supporting projects contributing to achieving the GBF's 23 targets, creating new grant programs, and contributions to programs implemented by UNDP.

The breakdown of the fund's supported projects by type and the regional distribution of supported projects are as follows (as of July 2019).

¹⁵ <https://www.keidanren.net/kncf/fund/about> (accessed on 26th April 2024)

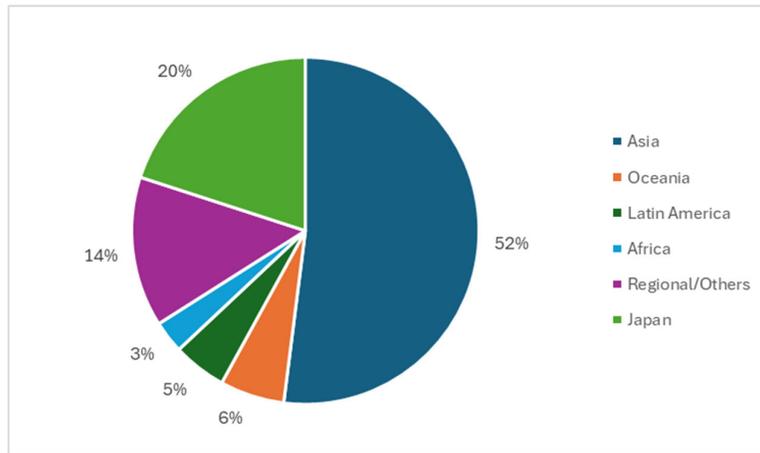


Figure 8: Number of projects by region

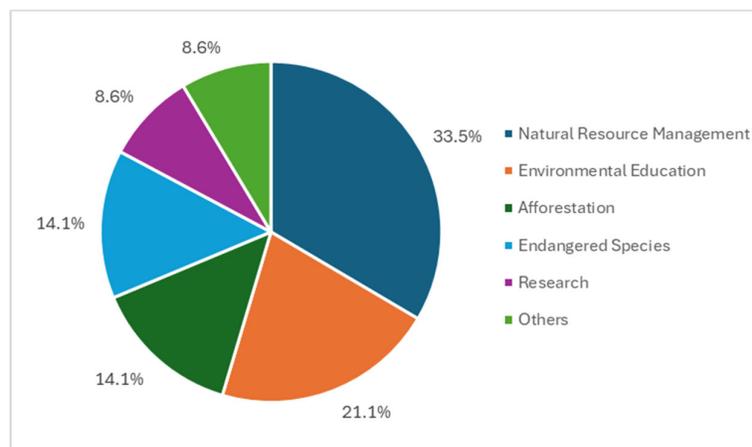


Figure 9: Number of projects by type

Japan Fund for Global Environment (JFGE)

1) Background and objectives

It was established in May 1993 by the then-Environment Agency (now the Ministry of the Environment), which took the lead in response to the recognition of the importance of initiatives by private non-profit organizations (NGOs/NPOs) at the United Nations Conference on Environment and Development (Earth Summit) in June 1992. Its purpose is to support environmental conservation activities by NGOs/NPOs and to promote a national movement for environmental conservation.

2) Activities

The Fund's activities consist of grant programs and promotion programs. Eligible organizations for grant programs are legally defined as “corporations and other organizations operating based on private initiatives.” This includes foundations, incorporated associations, specified non-profit organizations (NPOs), as well as organizations without legal personality. Eligible activities are as follows:

- (A) Activities by domestic private organizations for environmental conservation in developing regions
 (B) Activities by overseas private organizations for environmental conservation in developing regions
 (C) Activities by domestic private organizations for environmental conservation within Japan

Table 25: Overview of Grant Programs

	Continuous-Project Grant	General Grant	Front-Runner Grant	Platform Grant	Special Grant (Regional Circular and Ecological Spheres)
Outline	Support for activities with the aim of taking root in the community to develop continually and become established as sustainable activities	Support for organizations to improve their problem solving skills, develop more effective activities, and further develop as an organization	Support for Japanese environmental NGOs and NPOs to take the lead in creating new models and institutions for civil society	Support for organizations to improve their problem solving skills, develop more effective activities, and further develop as an organization	Support for Japanese environmental NGOs and NPOs to take the lead in creating new models and institutions for civil society
Activities Targeted by the Grant	<ul style="list-style-type: none"> • Activities that contribute to environmental conservation • Activities that aim to sustain the above environmental conservation activities • Activities that aim for development in collaboration with various other actors 	<ul style="list-style-type: none"> • Activities that contribute to environmental conservation • Activities that tackle emergent issues or topics, or utilize new methodologies 	Environmental conservation activities that seek to create new values and institutions	Activities for environmental conservation that are aimed at establishing a foundation for collaboration among various organizations to engage in and solve environmental issues through cooperation and collaboration	Activities for the preparation and establishment of a foundation for activities that aim to solve integrated environmental, social and economic issues in collaboration with local governments, corporations, and various stakeholders, and that will play a central role in the creation of a regional circular and ecological sphere
Grant Period	Up to 3 years	Up to 3 years	In principle 3 years	Up to 3 years	Up to 2 years
Annual Grant Amount	500,000 - 3,000,000 JPY	2,000,000 - 8,000,000 JPY (Category A) 2,000,000 - 6,000,000 JPY (Category B, C)	6,000,000 - 12,000,000 JPY	2,000,000 - 8,000,000 JPY	500,000 - 2,000,000 JPY

3) The Mechanism of the Fund

The JFGE was established based on funding contributions from both the government and the private sector. The proceeds from its operations are used to provide grants and other support for environmental conservation activities carried out by domestic and international private organizations (NGOs/NPOs). The fundamental mechanism is illustrated in the diagram below. Given the nature of the JFGE system, which

involves both government funding and private contributions, it is essential for the government to bear responsibility for proper management and to streamline administration and ensure efficient operation of the system. In this context, the fund was placed under the Japan Environment Cooperation, a corporation specializing in environmental conservation projects. Subsequently, in April 2004, the operations were transferred to the Environmental Restoration and Conservation Agency, an independent administrative agency.

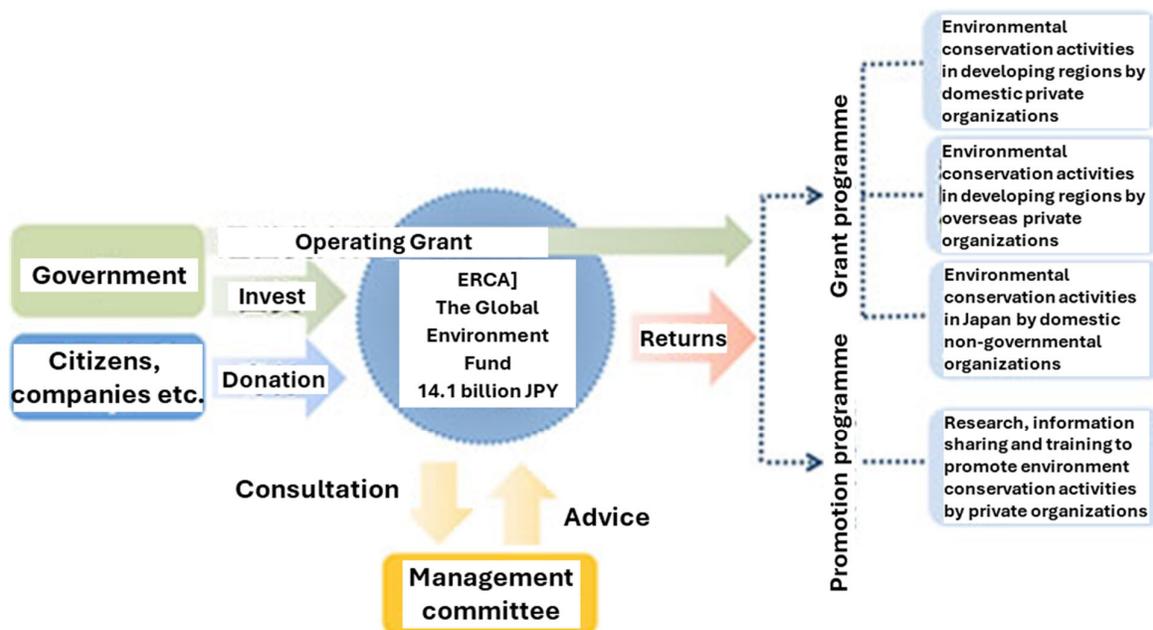


Figure 10: Structure of the JFGE¹⁶

4) Current Status and Achievements

From April 2023 to February 2024, contributions were made by 106 companies, 274 individuals, 14 national and local governments, and 22 other organizations. The fund's accumulation status has remained around 14 billion JPY since 2000. Of this amount, approximately 9.4 billion JPY comes from government contributions, with the remaining 4 billion-plus JPY coming from private donations (individuals, companies, and organizations). The trends in the number of grants and grant amounts for the fund over the past 10 years are as follows.

¹⁶ <https://www.erca.go.jp/jfge/about/outline/outline02.html> (accessed on 26th April 2024)

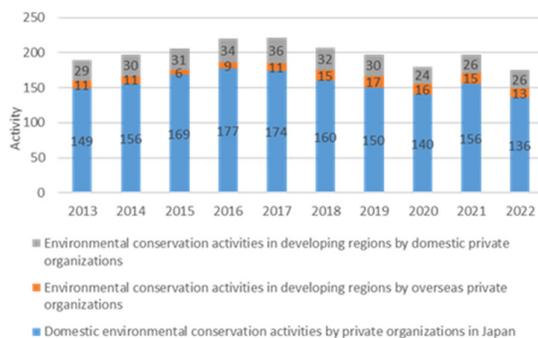


Figure 11: Number of grants

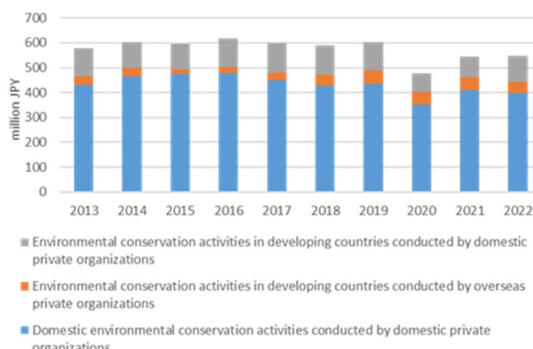


Figure 12: Amount of grants

Pro Natura Foundation Japan

1) Background and Objectives

Pro Natura Foundation Japan was established in April 1993 and subsequently transitioned to a public interest incorporated foundation in December 2011. Its purpose is to contribute to the conservation of the global environment and biodiversity by providing grants and other support necessary to promote activities that contribute to the conservation of natural environments in Japan and overseas, and to advance the research and studies that form the basis for these activities.

2) Activities

Grant programs consist of the following four categories.

Table 26: Outlines of the Grant Program

Grant Program		Grant Amount and Period	
Pro Natura Fund Grant	This grant program provides support to organizations involved in foundational research grounded in fieldwork for nature conservation, community based environmental protection efforts, and initiatives aligned with specific annual themes established by the foundation.	Grant for domestic research	1 million JPY/Project/1-2 years
		Grant for domestic activities	1 million JPY/Project/1 year
		Grant for domestic activities (for local NPOs)	1.5 million JPY/Project/1 year
		Grant for overseas activities	1 million JPY/Project/1 year 2 million JPY/Project/2 years
National Trust Activity Grant	A grant program jointly implemented by the Japan National Trust Association (a Public Interest Incorporated Association) and our foundation to help secure ecologically or culturally important local land.	8 million JPY/organization	
Emergency Grant	A grant program that supports high-priority and time-sensitive projects related to research, studies, and public awareness or educational activities for nature conservation both in Japan and abroad.	1 million JPY/Project/1 year	
Collaborative Grant	A grant program that aims to achieve project goals in collaboration with selected organizations, leveraging unique perspectives and networks, while also considering ongoing partnerships.	Grant for International NGO	1 million JPY/Project/1 year
		Grant for academic associations	
		Grant for international program	

3) Mechanism of the Fund

Detailed information regarding the foundation's operational structure and mechanisms could not be confirmed. However, for each grant program, projects are selected by a review committee composed of experts knowledgeable in environmental studies, regional sociology, and related fields, and are subsequently finalized following a resolution by the foundation's Board of Directors.

4) Current Status and Achievements

The number of projects and funding amounts for each grant program are as follows.

Table 27: Number of Projects and Amount by Grant Program (Unit: Thousand Yen)

Grant Program		FY2021		FY2022		FY2023	
		No. of Projects	Amount	No. of Projects	Amount	No. of Projects	Amount
Pro Natura Fund Grant	Grant for domestic research	11	10,200	10	9,950	15	14,990
	Grant for domestic activities	5	4,050	4	3,480	5	4,330
	Grant for domestic activities (for local NPOs)	5	4,350	3	2,860	3	3,000
	Grant for overseas activities	0	0	3	3,000	2	1,980
	Grant for specific theme 1	2	3,460	3	2,970	3	5,820
	Grant for specific theme 2	0	0	2	3,870	3	5,870
	Sub-total	23	22,060	25	26,130	31	35,990
National Trust Activity Grant		1	1,800	1	1,700	0	0
Emergency Grant		1	2,000	1	1,000	0	0
Collaborative Grant	Grant for international NGOs	1	940	2	1,750	2	1,740
	Grant for academic associations	0	0	2	1,408	1	900
	Grant for international programs	2	2,096	0	0	1	470
	Sub-total	3	3,036	4	3,158	4	3,110
Total		28	28,896	31	31,988	35	39,100

(2) Acquisition of Carbon Credits through Investment in Forest Conservation

As mentioned above, the funding mechanisms for acquiring carbon credits through investments in forest conservation remain limited. While several examples exist in the United States, where forest management is well-established, it is hard to identify any funding mechanisms for acquiring carbon credits through mangrove conservation initiatives in developing countries. The details of one such mechanism, the Livelihoods Carbon Fund, are provided below.

Livelihoods Carbon Fund¹⁷

The Livelihoods Carbon Fund was established in Paris, France, in 2011. This investment fund aims to contribute to improving the social status and food security of rural communities in developing countries

¹⁷ <https://livelihoods.eu/lcf/> (accessed on 26th April 2024)

through ecosystem restoration, while also providing investors with access to carbon credits. In return for their contributions, investors receive high-social-value carbon credits, which they can use to offset a portion of their own emissions.

The three areas of focus for fund activities are (1) rural energy, (2) agroforestry, and (3) mangrove restoration.

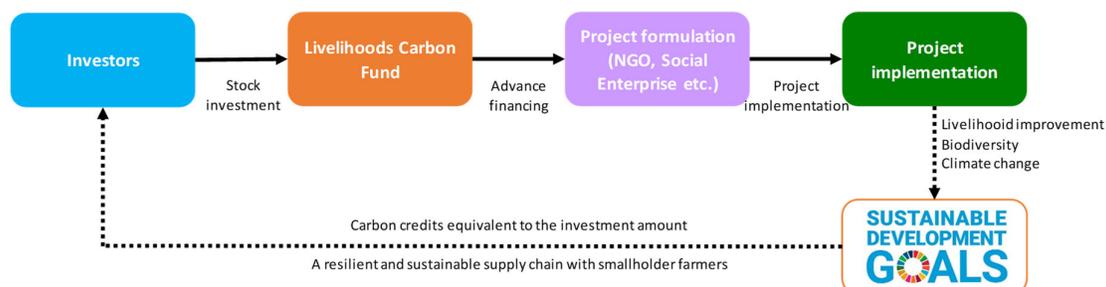


Figure 13: Basic mechanisms of the Livelihoods Carbon Fund

The first phase of the fund was established in 2011 with investments from ten companies: Danone, Schneider Electric, Crédit Agricole, Michelin, Hermès, SAP, Caisse des Dépôts Group, La Poste, Firmenich, and Voyager du Monde. The second phase of the fund was funded in 2017 by Crédit Agricole, Danone, Firmenich, Hermès, Michelin, SAP, Schneider Electric, Voyager du Monde, and further joined by Eurofins in 2019.

In 2021, Livelihoods Carbon Fund 3 was launched with investments from 14 companies: Bel Group, Chanel, Danone, DEG Invest, Eurofins, Hermès, L'Occitane, Mars, Mauritius Commercial Bank, McCain Foods, Orange, SAP, Schneider Electric, and Voyager du Monde.

The results of the first phase (2011-2016) of this investment fund, the second phase (completed but with no available results data), and the investment plan for the currently ongoing third phase are shown in the table below.

Table 28: Achievements from Carbon Investment Fund Phase 1 and Targets for Phases 2 and 3

Achievement item	Phase 1 (2011–2016)	Phase 2 (2017–) targets (results not yet published)	Phase 3 (2021–) targets
Number of beneficiaries	1 million	2 million	2 million
Number of trees planted	130 million	(TBD)	(TBD)
Improved stoves installed	120,000 households	(TBD)	(TBD)
CO2 absorption over 20 years	10 million tons	12 million tons	30 million tons
Number of projects	9 projects (Africa, Asia, South America)	(TBD)	(TBD)
Investment amount	45 million EUR	65 million EUR	159 million EUR

Looking at the results of Phase 1, if we assume a carbon credit return of 500 yen per ton over 20 years for a 40 million EUR (approximately 5.3 billion JPY) investment, 10 million tons of CO2 credits would be worth about 5 billion JPY, roughly balancing the budget. Although it depends on the price per ton of CO2, the fund would purchase CO2 credits with its capital and consume that capital over 20 years. By contributing funds

to this fund and investing in projects that reduce CO2 emissions and create social value, companies can add the CO2 equivalent of the acquired credits to their own emission reductions. This enhances their corporate value and attracts investment from ESG investors.

(3) Investment in Building an ESG-conscious Supply Chain

Similar to the limited funding mechanisms for acquiring carbon credits through investments in forest conservation, funding mechanisms for investments in building ESG-conscious supply chains are also extremely limited. Particularly for mangrove-related initiatives, only the Meloy Fund, introduced below, has been identified to date.

Meloy Fund¹⁸

The Meloy Fund was established in the United States as an impact investment fund to promote the recovery and revitalization of coastal fisheries in Indonesia and the Philippines. It aims to foster sustainable fisheries by purchasing debt and investing in equity in small and micro-sized fisheries-related enterprises. The fund is a wholly-owned subsidiary of Rare, an international environmental organization operating in over 50 countries worldwide.

The fund is managed by Deliberate Capital, LLC, in partnership with Rare. Investors and partners entrusting the fund with their capital include the Global Environment Facility (GEF), the Netherlands Development Finance Company (Nederlandse Financierings-Maatschappij voor Ontwikkelingslanden: FMO), Jeremy & Haneroa Gransham Environmental Trust, the United States Agency for International Development (USAID), and JPMorgan Chase & Co. These include financial institutions, aid agencies, philanthropic organizations, and conservation entities. Ensuring appropriate financial returns and maintaining financial soundness are key objectives in the fund's operations.

The fund aims to improve the livelihoods of 100,000 fishing households and enhance the resource management of 1.2 million hectares of coastal habitats over a 10-year period. Additionally, alongside financing, technical assistance is provided by specialized institutions with expertise in financial management, corporate governance, project implementation, marketing, and sustainable fisheries. These institutions act as partners to local investee companies, supporting business growth.

ESG investors provide capital to the fund. The fund then invests this capital in debt purchases or equity investments in small and micro enterprises practicing ESG management in fisheries. It generates interest, profits, and dividends, and returns these gains to the ESG investors.

¹⁸ <https://www.meloyfund.com/> (accessed on 26th April 2024)

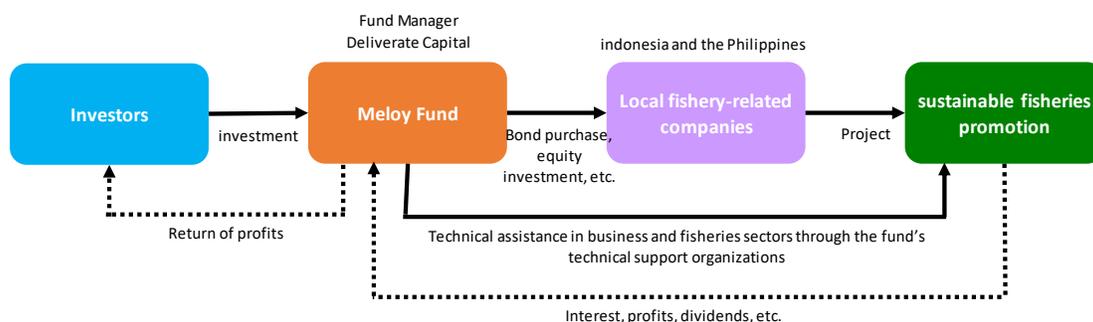


Figure 14: Mechanism for Fund Management and Project Implementation of the Meloy Fund

The fund invests in initiatives related to mangrove conservation and improvements in shrimp aquaculture, but no instances were identified where it supported silvo-aquaculture operations through loans or debt purchases. However, given the nature of the fund, it is conceivable that silvo-aquaculture could become an investment target should profitability be assured.

(4) Other Nature Conservation-Related Investment Funds

As mentioned above, while investment funds specializing in forest management, primarily in the United States, exist for nature conservation-related investments, initiatives focused on mangroves are scarce. However, funds supporting initiatives in developing countries such as South America, or those supporting coastal protection and sustainable fisheries, have been identified. It is conceivable that these funds may invest in mangrove-related initiatives in developing countries in the future. Moreover, they can serve as references in terms of operational frameworks for funding mechanisms. Therefore, for reference, funds promoting private capital mobilization for natural capital, including the above-mentioned Livelihood Carbon Fund and Meloy Fund, are listed below.

Table 29: Investment Funds to Promote Mobilization of Private Capital for Nature Conservation

Fund	Fund manager	Project activities	Funding scale	Japanese companies that invest in the fund
Athelia Sustainable Ocean Fund ¹⁹	Mirova	A fixed-capital fund by 2027 to promote sustainable fishery resource management, circular economy, and marine conservation including mangrove conservation. It also aims to generate carbon credits.	132 million USD	Not confirmed
Land Degradation Neutrality Fund ²⁰	Mirova	A fixed-capital fund by 2030 for restoring degraded land, mitigating climate change, protecting biodiversity and critical ecosystems, creating jobs and strengthening	200 million USD	Not confirmed

¹⁹ <https://www.mirova.com/sites/default/files/2022-06/SOF%20Report%202021-Final.pdf> (accessed on 18th April 2024)
<https://www.greenfinanceinstitute.com/gfihive/case-studies/sustainable-ocean-fund/> (accessed on 18th April 2024)

²⁰ <https://www.greenfinanceinstitute.com/gfihive/case-studies/land-degradation-fund/> (accessed on 18th April 2024)

		sustainable businesses, and improving rural development and gender equality. It will also generate carbon credits.		
Livelihood Carbon Fund #1 ²¹	Livelihoods Funds	Contribute to improving the social status and food security of rural communities in developing countries through ecosystem restoration while also providing investors with access to carbon credits.	40 million EUR	Not confirmed
Livelihood Carbon Fund #2 ²²	Livelihoods Funds		100 million EUR	
Livelihood Carbon Fund #3 ²³	Livelihoods Funds		150 million EUR	
Imprint Nature-Based Opportunities ²⁴	Goldman Sachs Asset Management	It aims to achieve financial returns through investments in forestry projects primarily in the Americas, Asia, Africa, and Europe while also targeting the receipt of carbon credits.	Not confirmed	Mitsubishi UFJ Financial Group, Inc.
Manulife Forest Climate Fund ²⁵	Manulife Investment Management Timberland and Agriculture Inc.	It aims to achieve financial returns through investments in forestry projects primarily in the United States, while also targeting the receipt of carbon credits.	500 million USD	Mitsubishi UFJ Financial Group, Inc. JA Mitsui Leasing Co., Ltd. Tokio Marine & Nichido Fire Insurance Co., Ltd. Idemitsu Kosan Co., Ltd. Sumitomo Mitsui Trust Bank, Limited
Meloy Fund	Deliberate Capital	Sustainable fisheries and aquaculture in Indonesia and the Philippines, improvement of marine ecosystems, enhancement of coastal community livelihoods, and revitalization of coastal economies.	20 million USD	None

3.3 Effective Information Disclosure and Communication Methods for Companies Aimed at ESG Investment

3.3.1 Existing Evaluation and Measurement Methods and Frameworks

As previously stated, in recent years, many investors have come to recognize the importance of considering the sustainability of business activities, including non-financial ESG factors, when evaluating corporate value from a medium to long-term perspective. Investment and financing practices incorporating this consideration are increasingly prevalent. Private companies are facing demands from investors to address a wide range of issues, and companies whose response is insufficient are viewed in an increasingly critical light. In response to these developments, private companies are also accelerating their ESG initiatives and enhancing their information disclosure to ensure accountability to stakeholders, including investors.

²¹ <https://livelihoods.eu/lcf/> (accessed on 18th April 2024)

²² <https://livelihoods.eu/lcf/> (accessed on 18th April 2024)

²³ <https://livelihoods.eu/lcf/> (accessed on 18th April 2024)

²⁴ https://www.bk.mufg.jp/news/news2023/pdf/news0630_1.pdf (accessed on 18th April 2024)

²⁵ <https://www.smtb.jp/-/media/tb/about/corporate/release/pdf/240419.pdf> (accessed on 18th April 2024)

<https://www.idemitsu.com/jp/news/2024/240417.pdf> (accessed on 18th April 2024)

<https://www.smtb.jp/-/media/tb/about/corporate/release/pdf/240419.pdf> (accessed on 18th April 2024)

<https://kyodonewsprwire.jp/release/202404089124> (accessed on 18th April 2024)

https://www.tokiomarine-nichido.co.jp/company/release/pdf/230629_01.pdf (accessed on 18th April 2024)

Given this situation, frameworks such as standards, benchmarks, frameworks, and guidance for disclosing ESG information are being provided by governments, international organizations, stock exchanges, NGOs, and others. While these efforts are primarily from overseas, within Japan, some ministries and agencies have also released disclosure frameworks, such as TCFD by the Ministry of Economy, Trade and Industry and TNFD by the Ministry of the Environment.

This section outlines the objectives, characteristics, and key considerations for understanding the major domestic and international frameworks for ESG information disclosure. It then identifies common elements across these frameworks deemed useful for disclosure and discusses the media for ESG information disclosure. Framework-related matters concerning biodiversity are addressed later in Section 3.3.2(2).

(1) Purpose and Characteristics of Major ESG Disclosure Frameworks

Since the early 2000s, various organizations have developed diverse ESG disclosure frameworks. While these frameworks are not mandatory, they significantly influence many companies' disclosure practices. An overview of the major domestic and international ESG disclosure frameworks is provided below.

Major Overseas ESG Disclosure Frameworks

① GRI Standards

GRI (Global Reporting Initiative) is a non-profit organization established in the United States in 1997 led by environmental NGOs with the aim of enhancing transparency regarding corporate environmental actions (later expanded to include social and economic issues). In 2000, GRI created the first edition of the GRI Guidelines, a corporate reporting standard and one of the world's longest-standing ESG disclosure standards. The name was changed from “GRI Guidelines” to “GRI Standards” in 2016. The GRI Standards aim to promote sustainable development by encouraging companies to disclose their impacts on the economy, environment, and society beyond the scope of climate change in a “Sustainability Report” directed not only at investors but also at a broader range of stakeholders (including employees, suppliers, socially vulnerable groups, and local communities, etc.). They have a strong tendency toward rule-based approach and are setting specific disclosure items and metrics for economic, environmental, and social topics.

② International Integrated Reporting Framework

The International Integrated Reporting Council (IIRC) was established in 2010 by organizations including the Global Reporting Initiative (GRI) to promote disclosure on corporate value creation and enhance dialogue with investors. In 2013, it established the International Integrated Reporting Framework, a new reporting format that combines financial and non-financial information. It encourages companies to prepare “Integrated Reports” to communicate to investors how they are creating sustainable long-term value through their business activities, utilizing various forms of capital including natural capital. It does not prescribe specific disclosure items or metrics since it uses a principles-based approach.

③ SASB Standard

The Sustainability Accounting Standards Board (SASB) is a nonprofit organization established in the United States in 2011 to meet investor demand for evaluating and comparing companies' non-financial information. In 2018, it published specific SASB Standards for 77 industries using a rules-based approach. While initially aimed at disclosure standards for U.S. companies during the development phase, its positioning was ultimately changed to disclosure standards for companies worldwide. SASB Standards require companies to disclose sustainability-related information, such as environmental and social data, that is financially material to investors in line with industry-specific items.

④ Final Report: Recommendations of the TCFD

TCFD was established in 2015 by the Financial Stability Board (FSB) to help investors assess companies' climate risks and opportunities. In 2017, it published the TCFD Recommendations, including its final report, urging companies to communicate information on climate-related risks and opportunities, along with scenario analysis, to the financial sector, including investors, using a consistent framework. It recommends disclosing climate-related financial information in key annual reports and similar documents. While strongly principle-based, it explicitly requires the disclosure of GHG emissions.

⑤ Final Recommendations of the TNFD

TNFD is an international framework established in 2021 aiming to enable companies and financial institutions to assess and disclose risks and opportunities related to natural capital and biodiversity. In September 2023, its final recommendations (TNFD Framework v1.0) were published. It is gaining attention as an international standard for disclosing information on natural elements beyond climate change (such as land use, water resources, and biodiversity), and is expected to exert significant global influence going forward. Disclosure is intended to be integrated into existing reports (such as annual reports and integrated reports). While adopting a principles-based approach, it strongly recommends disclosing dependencies and impacts.

Table 30: Overview of Major Global ESG Disclosure Frameworks

	GRI Standards	IIRC	SASB Standards	TCFD (Recommendations)	TNFD (Recommendations)
Purpose	Identifying the impacts that a company has on the economy, environment, and society, and disclosing them in a sustainability report.	Explaining sustainable value creation through integrated reporting.	Disclosing financially material sustainability-related information to investors.	Disclosing climate-related risks and opportunities to financial market participants under a consistent framework.	Appropriately assessing and managing nature-related risks and opportunities related to business activities, and communicating them using a standardized framework.
Disclosure items / Target areas	ESG in general	Finance and ESG in general	ESG in general (depends on the industry)	Climate change (including GHG emissions, water usage, energy usage etc.)	Broadly covers natural capital and biodiversity

Difference by industry	Developing industry-specific standards for some sectors	No special provisions	Different requirements set by industry classification	Guidance created for certain industries (e.g., financial and energy sectors)	Guidance created for 14 industries
Approach	Rule-based approach	Principle-based approach	Rule-based approach	Principle-based approach	Principle-based approach
Target stakeholders for disclosure	Stakeholders include employees, suppliers, socially vulnerable groups, local communities, and others.	Investors and other	Investors and other	Investors and other	Investors and other
Materiality	Double	Single	Single	Single	Not limited to any specific group (applicable to companies adopting any of the frameworks)
Method of Compliance with Standards	Self-declaration Notification to GRI of the use of the Standard	Self-declaration	Self-declaration Attachment of disclosure tables is recommended	Self-declaration	Self-declaration
Anticipated disclosure reports	Sustainability report (with references to disclosures in other media)	Integrated reports	Disclosure through various reports and websites	The original annual financial report (including integrated reports, etc.)	Existing major reports (such as annual reports and integrated reports)
Adoption status by companies (Worldwide)	4,198 organizations reported compliance or reference (for 2017 reports)	More than 1,700 organizations (from 72 countries) have issued reports	341 companies (from January to August 2020)	470 supporters (excluding financial and public institutions)	
Adoption status by companies (Japan)	152 organizations (for 2017 reports)	513 organizations have issued reports	No data available	191 supporters (excluding financial and public institutions)	

Compiled by the study team based on information from the Daiwa Institute of Research Ltd. (2021)

With the recent increase in ESG investment, there has been a growing demand for companies to disclose non-financial information. In response, as previously mentioned, a variety of disclosure frameworks and standards have been developed internationally. However, particularly in the early stages, there was significant overlap and inconsistency among these frameworks, resulting in confusion for both companies and investors. To resolve these issues and promote the international standardization of consistent ESG disclosures, the 2020s have seen significant efforts to integrate and reorganize major frameworks.

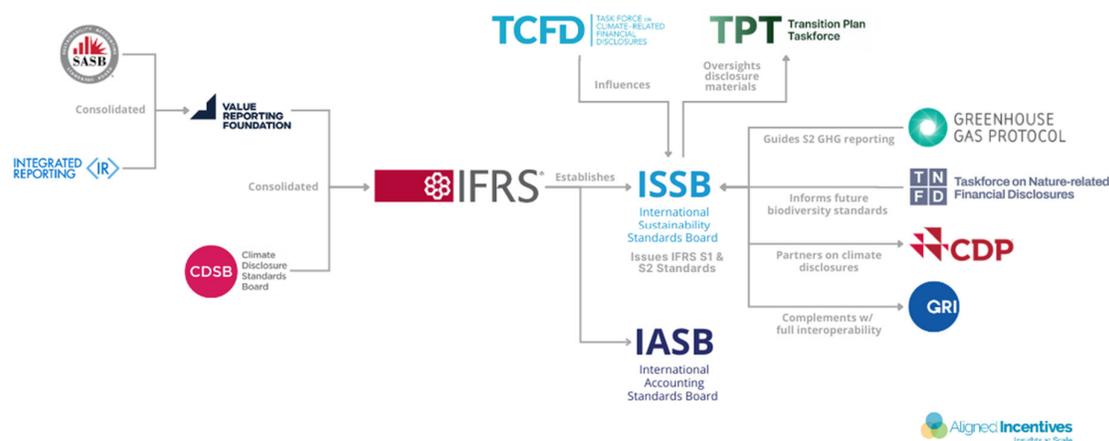
Amid increasing demand for consistency, comparability, and efficiency in ESG disclosures, SASB and IIRC announced their merger in 2021, resulting in the formation of the Value Reporting Foundation (VRF), a new organization that unified their activities. Subsequently, the VRF was integrated into the IFRS Foundation in 2022, leading to the establishment of the International Sustainability Standards Board (ISSB). This integration created a comprehensive platform for sustainability and integrated reporting frameworks, enabling more consistent reporting for both companies and investors.

In line with this movement, the Climate Disclosure Standards Board (CDSB), which had led climate-focused disclosure initiatives, was also integrated into the ISSB.

In June 2023, the ISSB published two international sustainability disclosure standards: “IFRS S1: General Requirements for Disclosure of Sustainability-related Financial Information” and “IFRS S2: Climate-related Disclosures.” Through this development, the framework of the TCFD was effectively absorbed into IFRS S2, clearly positioning ISSB standards as the central global framework for ESG investment-related disclosures going forward.

Meanwhile, the GRI remains an independent framework. However, collaboration is progressing to ensure alignment and enhance interoperability with the ISSB.

These integrations have created an environment in which companies can effectively disclose the necessary information while clearly distinguishing between the two disclosure perspectives of financial materiality (for investors) and double materiality (for broader stakeholders). Looking ahead, further developments are expected, including the advancement of frameworks such as the TNFD and new standards related to human rights and human capital. ESG disclosure is thus expected to evolve into a more integrated and effective framework.



Source: Compiled by the study team based on the Aligned Incentives (2024)

Figure 15: Alignment of Global ESG Disclosure Frameworks

Major ESG Disclosure Frameworks in Japan

The major ESG disclosure frameworks in Japan are summarized as follows.

Table 31: Overview of major ESG disclosure framework in Japan

Framework	Disclosure item	Background and main features
Guidance for Collaborative Value Creation	Finance and ESG-related matters	Developed under the leadership of the Ministry of Economy, Trade and Industry (METI) as a guide to systematically and integrally organizing information that should be communicated to investors, such as corporate philosophy, business model, strategy, and governance, in order to enhance the quality of disclosures and dialogue with investors. Using a principle-based approach, it does not set specific disclosure items or metrics.
Environmental Reporting Guidelines 2018	Environment	Since the establishment of the “Guidelines for Preparing Environmental Reports: How to Create Understandable Environmental Reports” in 1997, the content has been regularly revised. The 2018 edition specifies concrete indicators for disclosing environmental impacts resulting from corporate activities.
Annual Securities Report	Finance and ESG-related matters	Disclosures stipulated under the Financial Instruments and Exchange Act to ensure investors have sufficient information to make informed investment decisions. In November 2023, a new section titled “Concepts and Initiatives on Sustainability” was introduced, strengthening disclosure requirements related to sustainability. Using a principle-based approach, the setting of specific disclosure items or metrics is limited.
Corporate Governance Report	Governance	Information disclosure required by securities exchanges for listed companies to communicate the status of corporate governance to investors. Using a rule-based approach, specific disclosure items and metrics regarding corporate governance are set out in the “Disclosure Guidelines.”
Guidelines for Human Capital Visualization	Finance and ESG-related matters	Guidelines formulated by METI in 2022 to promote disclosure of information recognizing human capital as an asset, aiming to enhance corporate value and ensure accountability to investors and society. Primarily supports listed companies in practicing human capital management, comprehensively disclosing both financial and non-financial information. It was developed with a principle-based approach, encouraging the selection and disclosure of key items.
TCFD Guidance	Climate change	Practical guidance developed by METI in 2018 to strategically understand climate-related risks and opportunities in line with TCFD recommendations and systematically disclose them to investors. The latest version, “Guidance 3.0,” was published in October 2022 in collaboration with the TCFD Consortium.

Source: Compiled by the study team based on GPIF (2019)

(2) Points of Comparison Between the ESG Disclosure Frameworks

The frameworks mentioned above are conceptual in nature and are not mandatory standards that companies must strictly adhere to. Moreover, these frameworks are not in competition with one another; rather, they are complementary. This view has been emphasized by the International Integrated Reporting Framework, GRI, and SASB (Daiwa Institute of Research, 2021), and, as noted earlier, efforts toward integration and alignment among these frameworks are progressing. Therefore, companies are expected to effectively utilize the disclosure items and indicators established by each framework in accordance with their individual needs, while striving to achieve better and more meaningful information disclosure. To do so, it is essential for companies to have a solid understanding of the various ESG disclosure frameworks. The following section outlines key points for comparing different ESG disclosure frameworks.

① Disclosure Items/Target Areas, and Target Industries

The disclosure items and subject areas covered vary depending on the framework. Some, like the TCFD, focus exclusively on climate change (the “E” in ESG), while others, such as the GRI Standards, cover a much

broader range of topics. These include not only environmental issues but also social matters such as human rights and diversity, as well as economic issues like anti-competitive behavior. In addition, while some frameworks are designed to be applicable across all industries, others provide industry-specific disclosure items or guidance tailored to the unique characteristics of each sector.

② Principle-based Approach and Rule-based Approach

Another important distinction among the various frameworks is whether their standards follow a principle-based approach, which primarily relies on narrative disclosures of qualitative information and general indicators, or a rule-based approach, in which specific disclosure items and metrics are clearly defined. A rule-based approach can enhance comparability for investors by standardizing the information disclosed. However, it often leaves little room for companies to reflect their unique characteristics or context in the disclosure. On the other hand, a principle-based approach allows companies to communicate organization-specific information in greater depth. Yet, it may make cross-company comparisons more difficult and can present challenges for companies in determining what and how to disclose in the absence of detailed guidance.

③ Target Users

The intended users, or stakeholders, differ depending on the standards set by each framework. Some frameworks are designed primarily for investors, while others target a broader range of users, including not only investors but also suppliers, socially vulnerable populations, local communities, and other stakeholders. However, even in cases where investors are identified as the primary audience, many frameworks are considered to provide information that can be meaningfully utilized by a wider range of stakeholders.

④ Materiality

Materiality refers to the concept of importance, and serves as a benchmark for determining which information should be considered significant when a company discloses information. Materiality has two dimensions: one is the impact that environmental and social issues have on a company's business activities and financial performance, and the other is the impact that a company's business activities have on the environment and society. The approach that focuses solely on the former is referred to as single materiality, while the approach that considers both perspectives is known as double materiality. Materiality is closely linked to the intended users of a given disclosure standard. Standards that primarily target investors typically adopt a single materiality approach, as their main objective is to convey how environmental and social issues may financially affect the company (e.g., the International Integrated Reporting Framework). On the other hand, when a standard is designed for a broader range of stakeholders, it generally adopts a double materiality approach, since it also emphasizes the need to disclose how a company's activities impact the environment and society.

⑤ Adoption of the Frameworks

ESG disclosure frameworks generally serve as guidelines or standards that encourage voluntary disclosure. In most cases, it is sufficient for companies to disclose information in accordance with the framework's

requirements and indicate both the framework used and the fact that they have aligned with it. However, in some cases, such as with the GRI Standards, companies are required to formally notify the organization (GRI) when they claim compliance with the standards.

⑥ Expected Disclosure Reports

The method of disclosure also differs depending on the purpose of each framework. For example, the GRI Standards are intended for the preparation of sustainability reports, while the International Integrated Reporting Framework is designed for the creation of integrated reports. If ESG information is disclosed through statutory filings such as the Annual Securities Report (*Yūka Shōken Hōkokusho*), it becomes subject to review during audit procedures and is also made publicly available via EDINET, the electronic disclosure system operated by Japan’s Financial Services Agency. On the other hand, if the disclosure is made through documents such as integrated reports, the primary channel is the company’s website, and the information is only conveyed to individuals who access and read it there. Therefore, it is important to consider not only the framework itself but also which reporting medium is expected or appropriate for each framework when planning ESG disclosures.

3.3.2 Methods of Information Disclosure and Communication

(1) Disclosure Items and Commonalities Across Frameworks

In corporate investor relations (IR), ESG disclosure that addresses a wide range of information needs is ideal. However, in situations where resources are limited, it is effective to first focus on the common elements shared across ESG disclosure frameworks, as this can contribute to more efficient and impactful IR practices. After that, it is essential to recognize the diversity of ESG investment strategies and gradually expand disclosures with the intended users in mind.

A comparison of the disclosure items across major global and domestic ESG disclosure frameworks is presented below.

Table 32: Commonalities Among Major Global and Domestic ESG Disclosure Frameworks

	International Integrated Reporting Framework	GRI Standard	SASB Standard	TCFD	TNFD	Guidance for Collaborative Value Creation	Environmental Reporting Guidelines	Annual Securities Report	Corporate Governance Report	Guidelines for Human Capital Visualization	TCFD Guidance
Organizational/Business Overview	○	○	—	○	○	—	○ Only environment	○	○	○	○
Business Model (Overview)	○	—	—	○	○	○	○ Only environment	○	—	—	○

Message from the Board and Executive Management	–	○	–	–	–	–	○ Only environment	○	–	○	–
Communication with Stakeholders	–	○	–	–	–	○	○ Only environment	○ Specific matters concerning labor unions	○	○	–
Governance (Structure, Policies, and Mechanisms)	○	○	○	○ Only climate change	○	○	○ Only environment	○	○	○	○
Identification of Materiality (Topics to be Disclosed)	○	○	○	○ Only climate change	○	○	○ Only environment	○	–	○	○
Recognition of ESG Risks and Opportunities (Including Financial Impacts and Outlooks)	○	○	○	○ Only climate change	○	○	○ Only environment	○	–	○	○
Use of Scenario Analysis on Climate Change	–	–	○	○	○ Nature-related risks	–	– Not Officially Required, but Referenced	–	–	–	○
Strategy and Initiatives (on Material Topics)	○	○	○	○ Only climate change	○	○	○ Only environment	○	–	○	○
Performance (KPIs etc.) on Material Topics	○ Unspecified	○	○	○ Only climate change	○	○ Unspecified	○ Only environment	○ Unspecified	○ Only governance	○	○

Compiled by the study team based on the Daiwa Research Institute (2021) and GPIF (2019)

Global and domestic ESG disclosure frameworks generally share common disclosure items such as Governance, Identification of Materiality, Recognition of ESG Risks and Opportunities, Strategies and Initiatives, and Key Performance Indicators (KPIs). When disclosing ESG-related information, companies are encouraged to consider the interconnectedness of these elements. By supplementing disclosures with information on how these components relate to one another, companies can help users gain a deeper and more coherent understanding of their ESG performance and outlook.

While companies often rely on existing disclosure frameworks when reporting ESG information, it is important to understand the characteristics and commonalities of each framework. They should also carefully

consider who the intended users of the information are and choose the most appropriate framework accordingly. It contributes to more effective and efficient ESG disclosures.

As discussed above, ESG disclosure frameworks are increasingly being harmonized and integrated to ensure greater consistency and interoperability. This trend is expected to improve usability for both companies and investors, and thus should continue to be closely monitored.

(3) Selection of Disclosure Medium

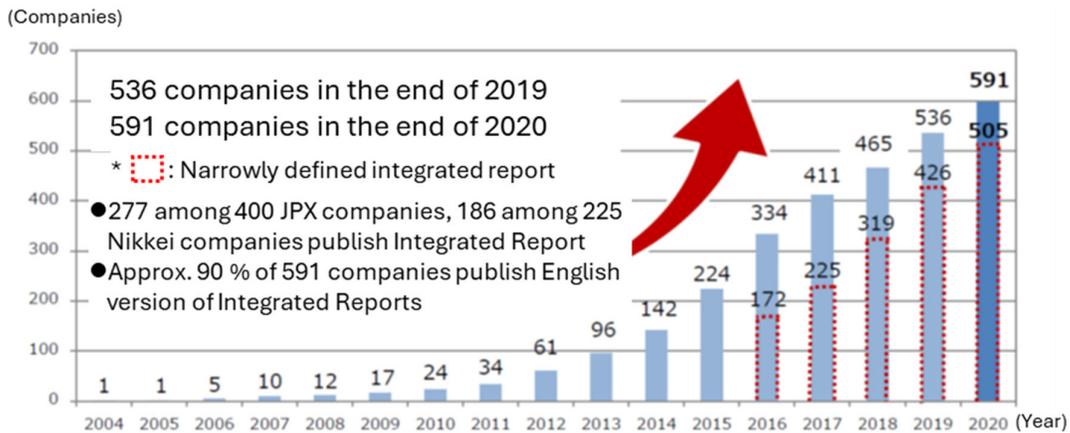
There are various media available for ESG disclosure, including Integrated Reports, Sustainability (CSR) Reports, Data Books, and Corporate Websites. Each medium tends to target different types of users, as outlined below.

Table 33: Main ESG Disclosure Media and Their Intended Users

Disclosure media	Intended users	Remarks
Integrated report	Investors	
Sustainability (CSR) report	Employees, customers etc.	
Data book focused on the evaluation items	ESG rating agencies	Aiming to improve ESG ratings by responding to detailed data requests from ESG rating agencies
Website	Stakeholders Seeking Additional Information	

Source: compiled by the study team based on the various documents

The number of companies voluntarily preparing integrated reports, primarily targeting investors, has been increasing year by year. According to a survey, 591 companies issued integrated reports between January and December 2020, as shown in Figure 16, indicating a continuous upward trend.



Source: Disclosure & IR Research Institute, Inc. (2021)

Figure 16: Number of companies issuing integrated reports

In cases where information is intended for a broader range of stakeholders, companies may issue reports such as Sustainability Reports, CSR Reports, Annual Reports, or Environmental Reports, which include more extensive ESG-related information. Among the 591 companies mentioned above that published integrated reports, many also issued additional materials targeting multiple stakeholders, such as sustainability reports or data books. The number of such companies is shown in Table 34.

Table 34: Status of Publication of Additional Reports (Multiple Selections Allowed, Unit: Number of Companies)

Medium	2019	2020
Sustainability Reports (including CSR reports, data books, etc.)	107	122
Full versions or summary versions	28	41
ESG Data Books (including ESG booklets and similar materials)	25	34
Environment reports and related publications	16	12
Others (materials intended to facilitate dialogue with investors and other stakeholders)	22	29
Total	182	217

Source: Disclosure & IR Research Institute, Inc. (2021)

In recent years, the number of required disclosure items has increased, and since space in these reports can be insufficient, more companies are creating dedicated ESG information pages on their websites to promote disclosure. Some companies have posted executive message videos on their websites to emphasize their commitment to ESG initiatives. Others design their websites with ESG rating agencies in mind, providing indexes aligned with the key evaluation criteria of major ESG rating agencies. Additionally, to respond to detailed data disclosure requests from ESG rating agencies, some companies prepare separate data books or similar publications to disclose a large amount of quantitative information.

While some disclosures are made through institutional information disclosure media such as Corporate Governance Reports and Securities Reports, the Financial Services Agency's Disclosure Working Group recently reported that further promotion of non-financial information disclosure in Securities Reports should be encouraged. Consequently, disclosures through Securities Reports may become more active in the future (Mizuho Research & Technologies, 2018).

Choosing which media to use for disclosure and whether to primarily target investors or also include other stakeholders requires considering investors' and other stakeholders' information needs, as well as the content and materiality of the information. Moreover, regardless of the medium used, it is expected that the various elements of disclosure will be presented coherently and with a clear narrative. To enhance the accessibility of information for overseas investors, it is also desirable to disseminate ESG information not only in the company's native language but also in widely used global languages.

4. Company Interest in Natural Environment Conservation

4.1 Background and Overview of the Company Survey

In recent years, alongside the growing awareness of the serious impact of environmental issues on socio-economic systems, there is an increasing recognition of the importance of private sector engagement in addressing environmental challenges, such as climate change and natural environment conservation, as an essential step toward achieving the Sustainable Development Goals (SDGs). In view of this background, in this study, a company survey was conducted to promote environmental initiatives through partnerships with the private sector pursuing ESG management according to the following objectives:

- 1) To collect and analyze information regarding the status, interests, barriers, and challenges of company initiatives in forest and natural environment conservation as well as mangrove conservation in Japan and abroad, and the types of information and mechanisms that could effectively promote such efforts.
- 2) To examine the types of information to be shared and disseminated with companies and organizations interested in forest and natural environment conservation initiatives domestically and internationally based on the collected data and its analysis.

This survey targeted persons in charge of ESG, sustainability, or CSR within each company. The content of the questionnaire was finalized through consultation with the Climate Change Global Environment Department of JICA and the Keidanren Nature Conservation Fund. The questionnaire was structured as follows:

- 1) Questions on general trends in forest and natural environment conservation initiatives
- 2) Questions on the motivation for engaging in forest and natural environment conservation
- 3) Questions on barriers and challenges to forest and natural environment conservation initiatives
- 4) Questions on effective information and mechanisms to promote forest and natural environment conservation

The questionnaire was designed to collect opinions on corporate initiatives for forest and natural environment conservation as part of their ESG management, efforts to conserve forest and natural environment in developing countries, and activities related to mangrove conservation. It was also structured to identify the challenges companies face when implementing such initiatives in developing countries and the types of information valuable for overcoming those challenges.

4.2 Survey Results

Through the Keidanren Nature Conservation Fund, a request for cooperation in responding to a corporate survey was sent to approximately 130 member companies of the Fund. The survey was conducted by Google Form with a response period of two months from November 2023 to January 2024. As a result, responses were obtained from a total of 22 companies (response rate: 16.9%). Based on these responses, the results of the questionnaire for each question item are as follows.

1) General trends in forest and natural environment conservation initiatives

At the time of the response, 86% (19 companies) of the responding companies were actively engaged in forest and natural environment conservation activities within Japan as part of their CSR or ESG management strategies. Additionally, 59% (13 companies) reported implementing such activities in developing countries, and 14% (3 companies) indicated they were in the planning stage for future implementation. Furthermore, 50% (11 companies) reported initiatives related to mangrove plantation, restoration, or conservation either domestically or in developing countries. These results show proactive efforts among companies toward forest and natural environment conservation both in Japan and abroad.

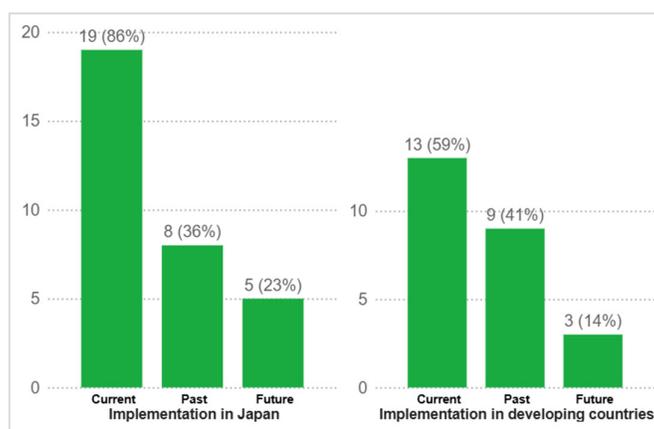


Figure 17: Number of companies engaged in forest and natural environment conservation from the perspective of CSR and ESG management

In addition to actual initiatives and plans for forest and natural environment conservation, 82% (18 companies) of respondents expressed interest in conservation efforts in developing countries, and 73% (16 companies) showed interest in mangrove plantation, restoration, and conservation in those countries.

2) Motivation for engaging in forest and natural environment conservation

Many responding companies cited contribution to climate change mitigation and biodiversity conservation (82%, 18 companies), corporate philosophy (64%, 14 companies), and fostering environmental awareness among employees (64%, 14 companies) as key motivations behind the engagement in forest and natural environment conservation. On the other hand, fewer responding companies were motivated by carbon credit generation (36%, 8 companies) or attracting ESG investment (32%, 7 companies). Only 18% (4 companies) expected added value to their products or services through forest and natural environment conservation efforts.

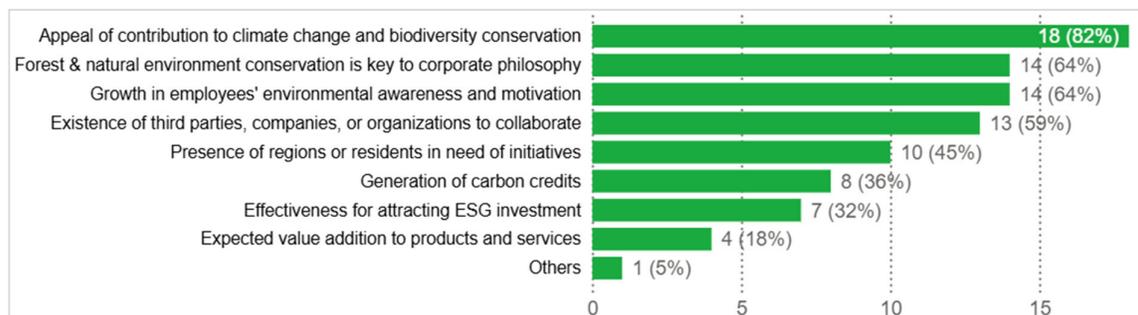


Figure 18: Motivation for forest and natural environment conservation (multiple responses possible)

Similarly, in mangrove restoration and conservation efforts in developing countries, 55% of responding companies (12 companies) cited employees' environmental awareness and motivation as key drivers. Only 36% (8 companies) expected to attract ESG investment, and just 5% (1 company) anticipated added value to forestry or fishery products and related services. This suggests that generating direct business benefits does not serve as a strong motivation for companies to engage in mangrove restoration and conservation.

On the other hand, many respondents recognized ecosystem service enhancement (73%, 16 companies) and carbon credit generation (59%, 13 companies) as benefits of mangrove plantation restoration and conservation, which indicates their expectations for tangible environmental contributions through the efforts in this field.

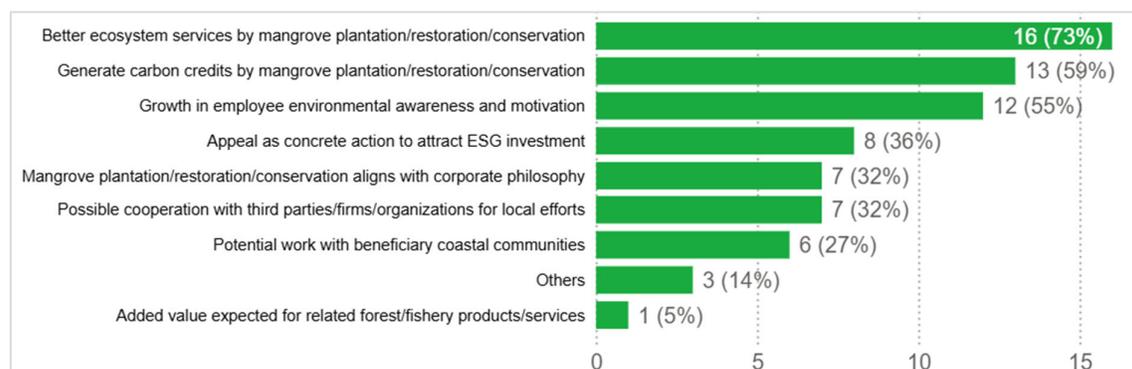


Figure 19: Expected benefits of mangrove restoration and conservation in developing countries (multiple responses possible)

3) Barriers and challenges to forest and natural environment conservation

In developing countries, 59% (13 companies) noted that short-term results are difficult to achieve and medium-term efforts are necessary. Other challenges included difficulty in identifying reliable local partners (59%, 13 companies), lack of expertise in evaluating conservation and biodiversity (50%, 11 companies), and uncertainty regarding carbon credit generation (36%, 8 companies).

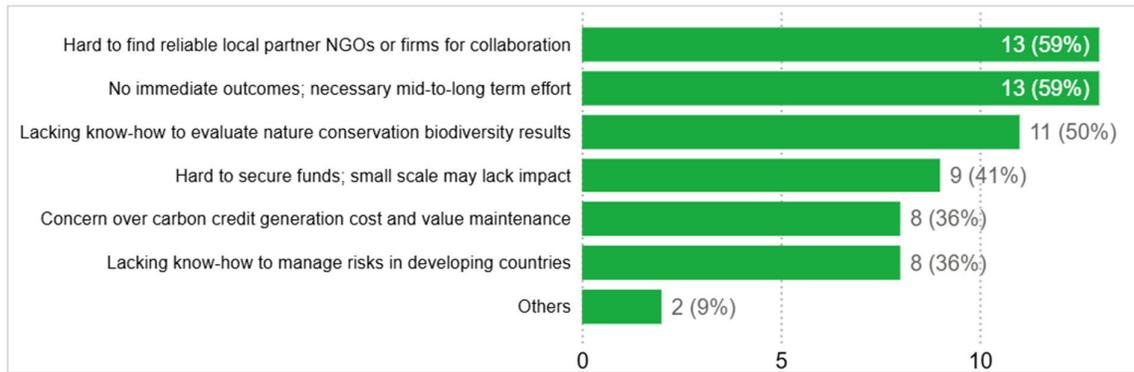


Figure 20: Barriers and challenges to forest and natural environment conservation in developing countries (multiple responses possible)

For mangrove restoration and conservation, many responding companies cited difficulty in identifying local partners (64%, 14 companies), lack of knowledge in managing specific project risks (59%, 13 companies), and insufficient expertise in ecosystem and biodiversity evaluation (64%, 14 companies).

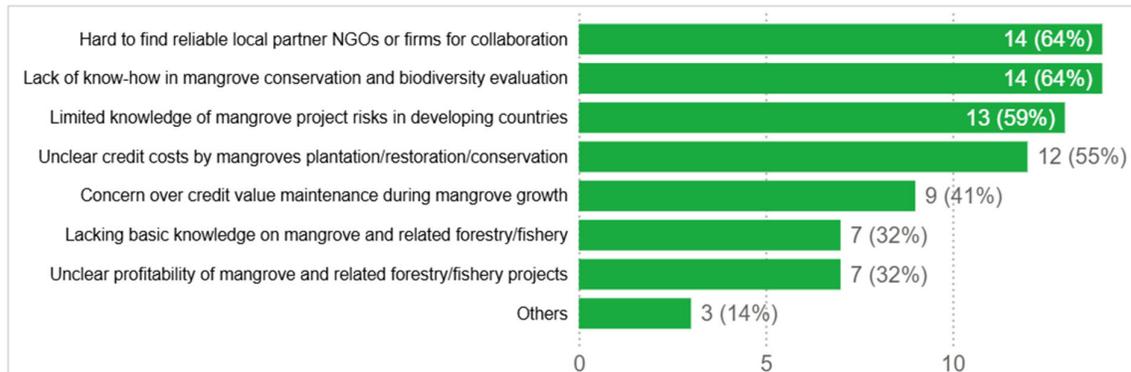


Figure 21: Barriers and challenges to mangrove restoration and conservation in developing countries (multiple responses possible)

4) Information and mechanisms effective for promoting forest and natural environment conservation initiatives

To promote forest and natural environment conservation in developing countries, many responding companies sought information that could address the identified barriers. The most requested was information on reliable local partners (82%, 18 companies), followed by carbon credit generation and acquisition (77%, 17 companies), cost and scale of required inputs (77%, 17 companies), evaluation of restored ecosystem services (77%, 17 companies), and know-how on risk management (73%, 16 companies).

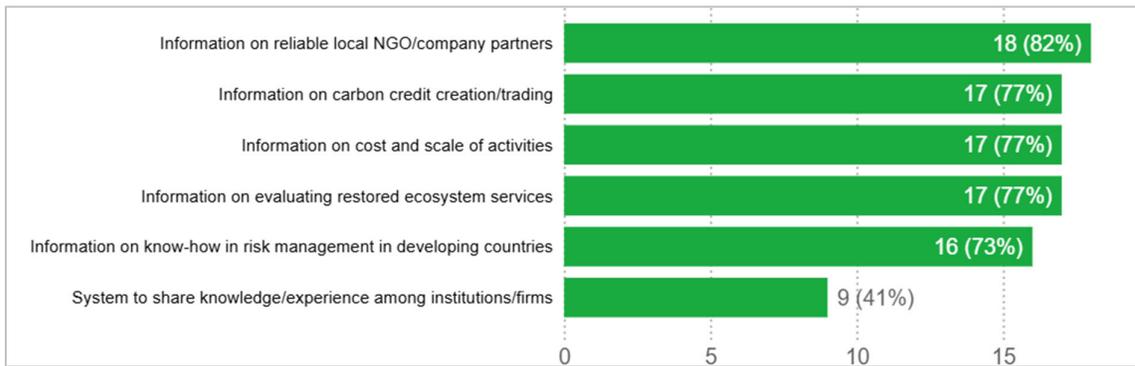


Figure 22: Effective information and mechanisms for promoting forest and natural environment conservation in developing countries (multiple responses possible)

Furthermore, in addressing challenges related to mangrove plantation, conservation, and restoration, there is a broad demand for information that can help solve issues faced by many responding companies, such as know-how on ecosystem and biodiversity assessment (86%, 19 companies), generation and acquisition of carbon credits (73%, 16 companies), identification of reliable local partners (64%, 14 companies), and project risk management in developing countries (64%, 14 companies).

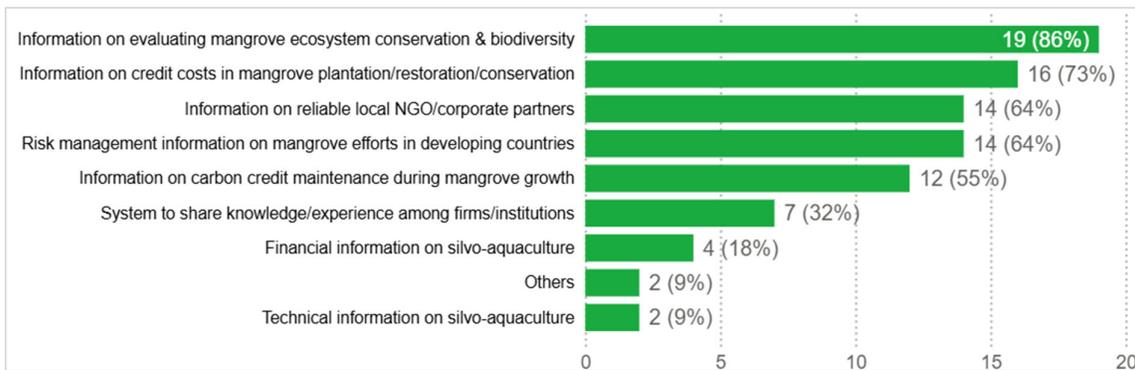


Figure 23: Effective information and mechanisms for promoting mangrove restoration and conservation in developing countries (multiple responses possible)

Many of the responding companies demonstrated a strong interest in forest and natural environment conservation, as well as mangrove conservation in developing countries. It was observed that many of these companies engage in these activities from the perspective of alignment with their corporate philosophy and fostering environmental awareness among employees, and they regard such efforts as important components of company action. On the other hand, when it comes to implementing initiatives in developing countries, many companies face challenges due to a lack of information essential for implementation and management in the field, such as identifying reliable local partners and managing project risks as well as technical know-

how for measuring the outcomes of their initiatives, such as methods for biodiversity assessment and information on carbon credit generation. Therefore, the survey results show that many responding companies are seeking information that could help address these challenges.

It should be noted that only 22 companies responded to the survey out of approximately 130 member companies of the Keidanren Nature Conservation Fund. Given that member companies are expected to have a certain degree of interest in natural environment conservation, the limited number of responses may indicate that themes such as “mangroves” and initiatives “in developing countries” are not necessarily recognized as urgent priorities for them. On the other hand, there was a moderate level of interest in these topics among the 22 responding companies, which is by no means an insignificant number. In conducting company interviews and a workshop (described later), the selection of target companies was based on several factors, including whether they had responded to this company survey and whether they appeared to have some connection to mangrove conservation or shrimp aquaculture.

4.3 Company Interviews

To ensure that the content of the information collected, shared, and disseminated via the information platform (described later) is useful and appealing to its users, we contacted 17 private companies identified through publicly available web information as being either engaged in or likely to be interested in forest conservation in tropical and subtropical regions. We requested their cooperation in a survey regarding their information needs. From the responding companies, we conducted interviews with a total of 7 companies either in person or online between October 2024 and January 2025. These interviews gathered details on each company's specific initiatives, areas of interest and expectations, and the challenges they face.

As the interviews with each company contain non-public information, this report generalizes the content to some extent without identifying specific company names. The following were cited as the main areas of interest regarding mangroves.

Table 35: Key Issues Concerning Mangroves

Category	Specific Areas of Interest
Carbon Credits	<ul style="list-style-type: none"> • Creation of carbon credits • Accurate and reliable measurement methods for carbon stored through mangrove afforestation • Information on soil carbon measurement methods (e.g., absorption coefficients) • Process for crediting carbon credits • Information on credible international events related to carbon credits
Ecosystem Assessment	<ul style="list-style-type: none"> • Various assessment methods related to ecosystem conservation • Quantitative and reliable measurement methods for biodiversity • Effective ways to communicate the “value” of mangrove ecosystems • How to incorporate ecosystem service assessments into corporate activities
Mangrove Afforestation	<ul style="list-style-type: none"> • Information on identifying suitable sites for mangrove planting and local regulations • Information on local partners and consultants for mangrove planting • Mangrove planting methods and techniques to improve survival rates • Impacts of mangrove planting on local ecosystems

	<ul style="list-style-type: none"> • Benefits to local communities from mangrove planting and private sector interest • Methods for assessing the environmental value of actual mangrove planting
Other	<ul style="list-style-type: none"> • Exit Strategy for CSR Initiatives

Based on these specific concerns regarding mangrove conservation by private companies, a workshop titled “Workshop to Promote Mangrove Conservation through Private Sector Participation” was held to further explore these issues and exchange opinions. Details of this workshop are reported in the next section.

4.4 Workshop on Promoting Mangrove Conservation through Private Sector Participation

This workshop was held at JICA Headquarters on February 24, 2025. The objectives of this workshop were as follows.

- Introduction to the purpose and content of information sharing and the information platform for this survey project
- Sharing information and exchanging opinions on international initiatives, private sector trends, and growth environments related to mangrove conservation
- Sharing information and exchanging opinions on specific areas of interest and challenges for private companies undertaking mangrove conservation
- Surveying this information and reflecting it on the information platform

Five private companies with seven participants took part in this workshop.

First, the study team explained the overall scope of this survey project and the purpose and concept of the information platform. Subsequently, JICA outlined international mangrove initiatives, including relevant policies in Indonesia, international initiatives for mangrove conservation (Global Mangrove Alliance, Mangrove Breakthrough, Mangrove Alliance for Climate, High-Quality Blue Carbon Principle and Guidance, etc.), mangrove-related events at CBD-COP16, and other recent international developments. Subsequently, during the session for exchanging views with private companies, discussions covered (1) confirmation of corporate interest in mangrove conservation (Figure 24), (2) cross-disciplinary issues (Figure 25), and (3) sector-specific issues ((a) challenges related to carbon credit generation (Figure 26), (b) contributions to the natural environment and local communities (CSR) (Figure 27), and (c) sustainable resource procurement/management system development (Figure 28)). The results are as follows.

Session 2 (1) Confirming Key Considerations for Mangrove Conservation		
Carbon Credits	Japanese mangroves (mostly state-owned forests)	
Blue carbon credits (Currently focused on seagrass beds in Japan)	Domestic mangroves (environmental conservation, nurturing the next generation, regional contribution)	Finding local partners
Interest from companies interested in credits (Why choose mangroves when other ecosystems exist?)	Ecosystem Scale (Aiming to conserve not only mangroves but the entire connected ecosystem)	Biodiversity Conservation → Environmental DNA
Linking conservation activities to credits ensures sustainability → How to connect them?	A portion of sales goes toward conservation activities. Implemented for a sustainable supply chain	Benefits to Local Communities (Utilizing data on population, fishery resources, etc.) → Generating Added Value
Treatment of mangrove absorption capacity remains unregulated	Technical and organizational capacity for medium-to-long-term monitoring is a challenge	
Emissions targets: Mangroves are not classified as terrestrial forests → Positioned as not contributing to emissions reduction	Conservation Projects / Restoration Projects	Funding Methods
Can be credited but not counted toward national or SBTi emission reductions	Restoration of former aquaculture ponds	
Seagrass is included in VCS, but seaweed is not	TCFD/TNFD (risks were identified, but mangroves were excluded due to project scale)	

Figure24: Identifying Key Concerns for Corporate Participation in Mangrove Conservation (Results)

Session 2 (2) Identifying Issues by Theme

① Cross-Sectoral Issues

Selection of Local Implementing Organizations	Unclear land ownership → High barriers to carbon (asset) trading	Afforestation and monitoring → Creates local employment
Explore through local universities and NGOs → Difficult to achieve expected progress on the ground?	Land ownership is a minimum requirement even for ASC certification	Leverage local pride (endangered species) to strengthen community ties
Regardless of scale, the effort required for crediting remains the same	How to identify mangrove conservation sites and potential? (Analyze prior land use, suitable tree species, etc., via satellite imagery)	Adding value to resources nurtured by mangroves
	For crediting, other factors besides land ownership are also challenges (lack of historical data)	Silvofishery: Unclear how to monetize. Will this pilot project identify successful conditions?
	Securing large tracts of land for project implementation is difficult	Indonesia: Carbon projects require mandatory registration

Figure25: Cross-disciplinary Issues (Results)

Session 2 (2) Identifying Challenges by Theme

② Sector-Specific Issues 1) Carbon Credit Generation

How much will corporate offsets be recognized? → The system is underdeveloped (it could serve as an incentive for companies but has not been established)	Regarding blue carbon, the Cabinet Secretariat excluded it from consideration, yet it is recognized under the GX-ETS emissions trading system, causing confusion	Biodiversity assessment → Broad concept; data collected through individual tree surveys, etc. (Basic data can be used)
Difficult to collaborate with mangrove specialists	Only limited methodologies can be used depending on the country	Animal species monitoring surveys (spot checks) Surveys conducted by local staff (regularly) + experts (as needed)
Difficulty creating carbon credits through "conservation" → "removal" is preferred (insufficient incentives for conservation)	Limited credit methodologies, while different methodologies vary in credit acquisition difficulty → No established methodology	Environmental DNA
Methods for acquiring blue carbon credits remain unclear. → Without coefficients, actual measurement is required, but this is costly.	Unclear which methodology is appropriate under what conditions and which to use → Need a flowchart to organize methodologies	Risk management related to credit creation (illegal logging, inadequate monitoring pose risks)
Struggling to procure seeds domestically		

Figure26: Sector-Specific Issue (1) Carbon Credit Generation (Results)

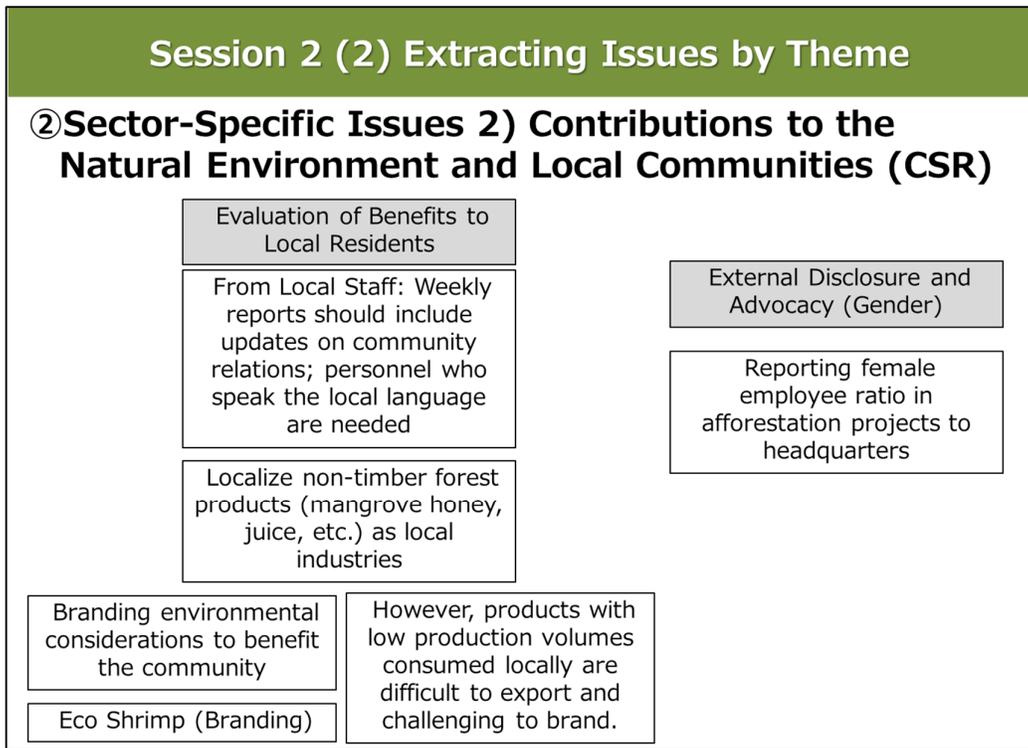


Figure27: Sector-Specific Issue (2) Contributions to the Natural Environment and Local Communities (CSR) (Results)

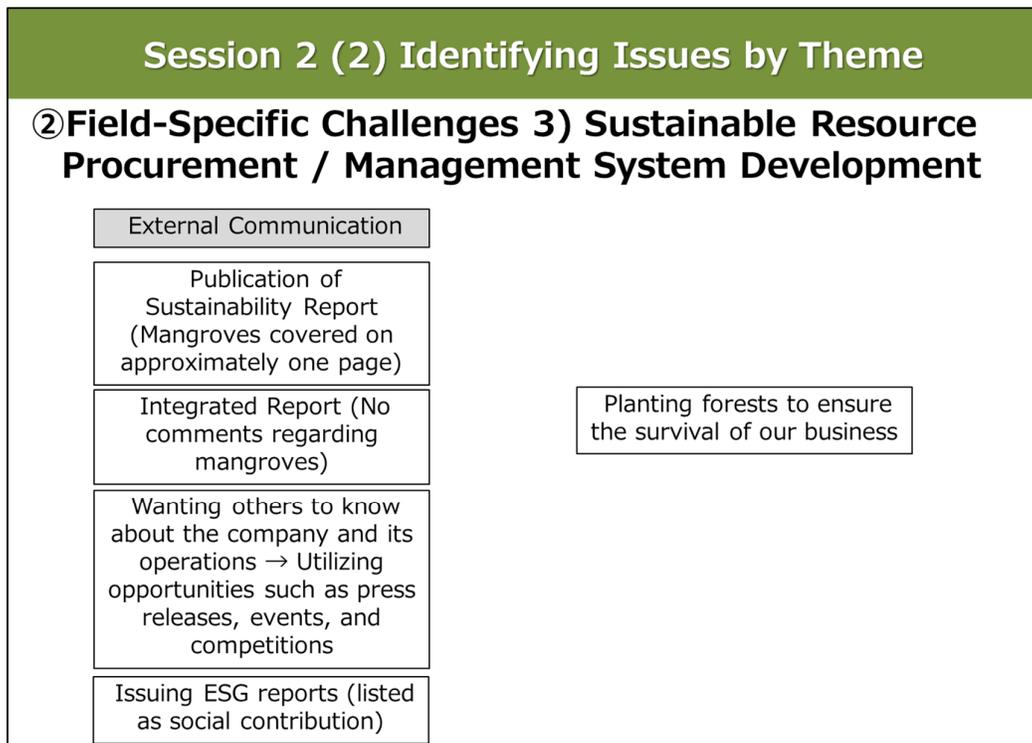


Figure28: Sector-Specific Issue (3) Sustainable Resource Procurement / Management System Development (Results)

While it is important to note that the limited number of participants—seven individuals from five companies—may have skewed the focus toward certain areas of interest, the discussion highlighted diverse perspectives and challenges aligned with each company's specific initiatives. For example, even companies interested in mangrove planting for carbon credit generation face challenges: how to justify choosing mangroves over other tree species (from an accountability perspective to stakeholders), how to link conservation activities to carbon credit generation to ensure sustainability (positioning mangrove planting as a tool for sustainable conservation), and methodological uncertainties, such as how to calculate carbon sequestration by mangroves (focusing on mechanisms to make credits tradable). Furthermore, while diverse specific opinions and perspectives were exchanged regarding carbon credit generation, contributions to the natural environment and local communities (CSR) and sustainable resource procurement/management system development saw fewer opinions. However, these included unique views likely based on the companies' own initiatives, suggesting diverse interests even among the 7 participants from 5 companies.

Taking into account the opinions and concerns regarding mangrove conservation expressed by these private companies, we reviewed the content for the information platform and made efforts to establish it. The information platform will be explained in the next chapter.

5. Structure, Functions, and Content of the Information Platform

5.1 Structure and Functions of the Information Platform

To advance mangrove conservation through collaboration between private companies and organizations engaged in conservation activities, it is essential to promote the sharing of information related to conservation projects, provide various forms of support for these projects, and encourage investment. To achieve this, the development of a supporting framework, namely, a public-private partnership framework, is necessary. Against this background, the purpose of this survey was to propose a platform to facilitate collaboration. As part of this effort, we have engaged in the collection of information on corporate needs and funding mechanisms, and conducted pilot activities to verify potential business models. Based on these activities, a conceptual image of the proposed platform has been developed, as shown in the figure below. The platform is envisioned as an information hub dedicated to the collection, sharing, and dissemination of mangrove-related information, and aimed at facilitating the formation of collaborative projects.

The specific functions of the platform are as follows:

- Collecting information on the current status of mangroves and related conservation policies in mangrove-growing countries
- Gathering scientific knowledge on the value of mangrove ecosystem functions and services
- Collecting information on NGOs and companies involved in on-the-ground mangrove conservation activities and projects
- Compiling information on schemes and mechanisms for biodiversity conservation including mangroves such as grants, investment funds, and carbon credit systems
- Gathering information on companies supporting mangrove conservation and related successful case studies
- Organizing the collected information and disseminating it to stakeholders via a website, seminars, and other channels

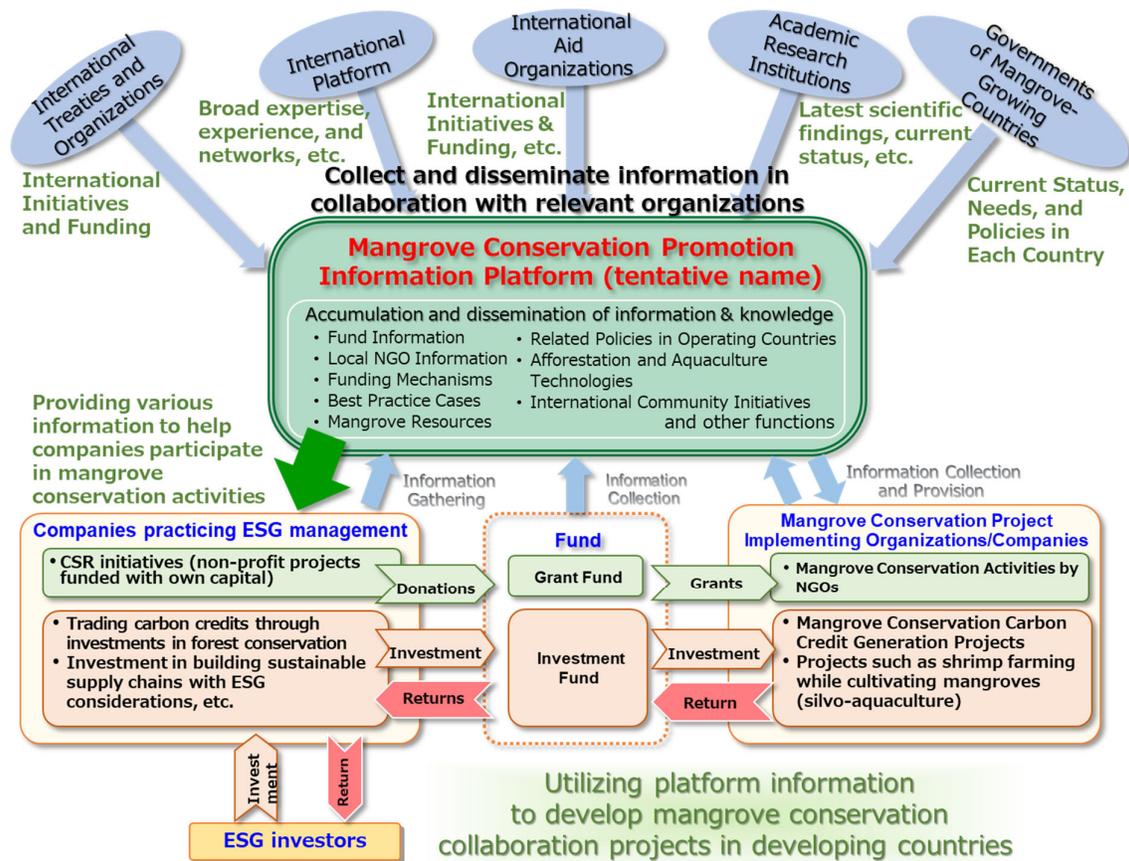


Figure 29: Conceptual Image of the Platform as an Information Hub to Facilitate the Development of Collaborative Projects

The implementation structure of the information platform is as follows.

- Form of the Information Platform: The platform will take the form of a web-based information platform.
- Structure and Functions of the Secretariat: The secretariat will be responsible for regularly updating the shared and disseminated information, and facilitating collaboration among private companies, research institutions, local NGOs engaged in on-the-ground activities, and local governments. The secretariat will be established within JICA, with the potential to collaborate with existing JICA-operated websites, such as the “Japan Public-Private Platform for Forest-based Solutions”

5.2 Information to Be Shared and Disseminated via the Platform

As described in Section 5.1, the information platform proposed in this survey is expected to function as an information hub dedicated to collecting, sharing, and disseminating mangrove-related information with the aim of facilitating the development of collaborative projects.

The composition and content of the information to be disseminated through the platform are as follows. In addition to the information contained in this report, the platform will continuously organize and share the most up-to-date information.

Table 36: Composition and content of the information platform

Top Page	1st Layer	2nd Layer	3rd Layer	
	What the Information Platform Aims to Achieve			
	About Mangroves			
		What Are Mangroves?		
		Characteristics of Mangroves		
		Types of Mangroves		
		Adaptation of Mangroves to the Intertidal Zone		
		Multiple Benefits Provided by Mangroves (Ecosystem Services)		
		What Are Ecosystem Services?		
		Reliable International Frameworks and Methodologies for Ecosystem Service Evaluation		
		Overview of the Ecosystem Service Evaluation Protocol for Silvo-Aquaculture Businesses		
		Current Status of Mangroves		
		Global Distribution of Mangroves		
		Changes in Mangrove Area		
		Causes of Mangrove Area Decline		
		JICA Efforts in Mangrove Conservation		
		JICA Initiatives		
		Policies and International Frameworks Supporting Mangrove Conservation		
		National Policies Related to Mangrove Conservation		
		Mangrove Conservation Policies in Major Mangrove-Growing Countries		
		International Initiatives to Promote Investment Contributing to Mangrove Conservation		
		Global Investment Promotion Initiatives (e.g., Global Alliance, Mangrove Alliance for Climate Change)		
		Evaluation, Measurement, and Disclosure Frameworks Related to ESG Initiatives		
		ESG Evaluation, Measurement, and Disclosure Frameworks		
		Reliable International Frameworks and Methodologies for Ecosystem Service Evaluation		
		Guidelines for ESG Initiatives		
		International Initiatives for Promoting Investment (e.g., ICMA)		
		Mangrove Conservation Initiatives		
		Conservation through CSR		
		Company-Led Projects (Case Studies: Japanese Companies and Local Organizations)		
		Commissioned Projects (Case Studies: Companies and Local Organizations)		
		Projects via Grant Funds (Case Studies: Companies and Local Organizations)		
		Conservation through ESG Investment: Building Sustainable Supply Chains		
		Building Sustainable Supply Chains (Projects by Investment Funds, Case Studies: Companies and Local Organizations)		
		Case Studies of Business Model Validation for ESG-Based Conservation		
		About Silvo-Aquaculture		
		Conservation through ESG Investment: Carbon Credit Acquisition		
		Carbon Credit Acquisition (Projects by Investment Funds, Case Studies: Companies and Local Organizations)		

6. Information Gathering and Protocol Development for Ecosystem Services Valuation

6.1 Ecosystem Services and Benefits Provided by Mangroves

6.1.1 What are ecosystem services?

The term “ecosystem services” became widely recognized through the Millennium Ecosystem Assessment, a comprehensive scientific assessment of global biodiversity and ecosystem conservation and sustainable use led by the United Nations from 2001 to 2005. Ecosystem services refer to the benefits that people obtain from ecosystems. The Millennium Ecosystem Assessment classified ecosystem services into four categories: provisioning services, regulating services, supporting services, and cultural services.

Mangroves provide a variety of ecosystem services and give multifaceted benefits to people, including coastal communities. Mangrove ecosystem services include the following.

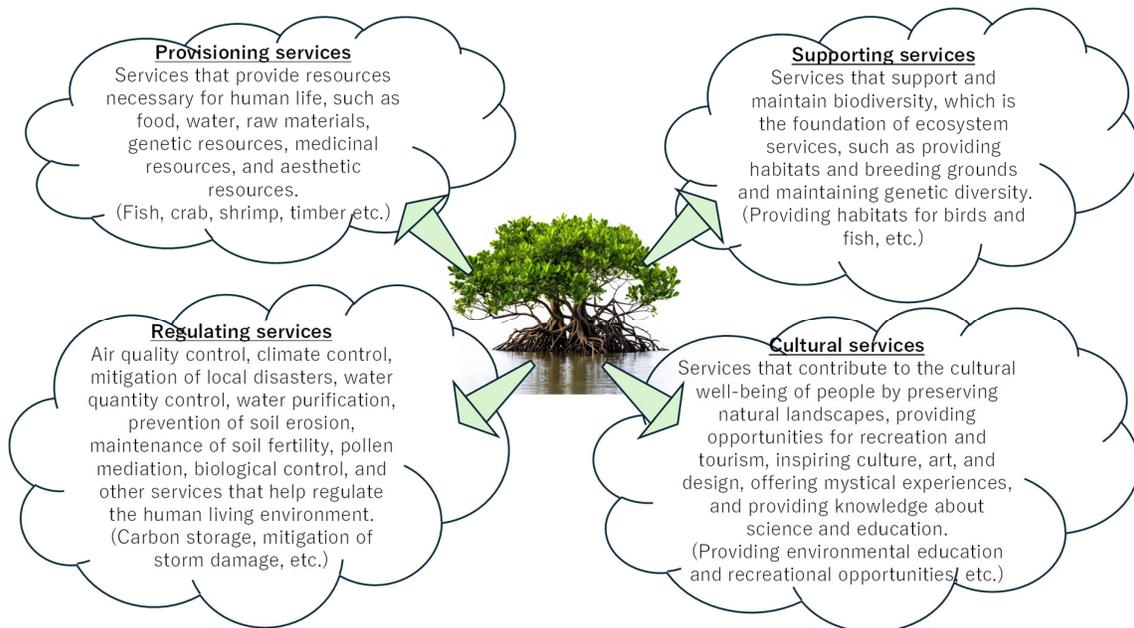


Figure30: Classification of ecosystem services (examples of mangroves are shown in parentheses)

6.1.2 What are the ecosystem services provided by silvo-aquaculture?

Silvo-aquaculture is a combination of mangrove planting and aquaculture. The ecosystem services presented at silvo-aquaculture sites are organized in the table below.

Table37: Ecosystem services expected from silvo-aquaculture

Ecosystem services	Ecosystem service occurrences
(A) Provisioning services	
Food	<ul style="list-style-type: none"> • Aquaculture products such as fish, shrimp, and crab produced for consumption. • Honey, fruits, starch, etc. harvested from mangrove.
Raw material	<ul style="list-style-type: none"> • Industrial raw materials such as seaweed produced by aquaculture. • Wood materials such as lumber, charcoal, and handicrafts obtained from mature mangrove forests.
(B) Regulating services	
Climate regulation	<ul style="list-style-type: none"> • In aquaculture, greenhouse gases such as nitrous oxide are produced from the feces and urine of farmed aquatic organisms. • During the growth of mangroves, carbon is stored in biomass such as roots, stems, and leaves, and also in the soil through dead branches and fallen leaves. On the other hand, carbon is released into the atmosphere through the decomposition of these materials. In addition, methane is produced during the decomposition of organic matter.
Mitigation of local disasters	<ul style="list-style-type: none"> • Aquaculture ponds temporarily store water during floods to mitigate their effects. • Mangrove planting is expected to mitigate damage caused by strong winds, flooding, and landslides.
Pollination	<ul style="list-style-type: none"> • Insect pollination services may occur in mangrove planting.
(C) Supporting services	
Habitat	<ul style="list-style-type: none"> • Mangrove planting will be carried out in a manner that maximizes biodiversity. To this end, supporting services will be provided to the growth and habitat of plants, birds, fish, shrimp, crabs, and other organisms.
(D) Cultural services	
Conservation of the natural environment	<ul style="list-style-type: none"> • Mangrove reforestation restores the natural landscape.
Opportunities (recreation and tourism)	<ul style="list-style-type: none"> • It is possible to organize paid tours offering experiences such as shrimp aquaculture and harvesting, mangrove planting, and observation. Furthermore, there is potential for setting up a fishing pond and restaurant.
Education	<ul style="list-style-type: none"> • Silvo-aquaculture is recognized as a concrete and rational approach to regional development and environmental issues, and has the potential to become a subject of research, education, technological development, observation, and training.

6.1.3 Ecosystem services evaluated through pilot activities

As described later, in order to evaluate the ecosystem services of a business, first, a scenario with action and a scenario without action are established. Next, the economic value of each scenario is evaluated and the difference between the two is calculated as the value of the ecosystem services provided by the business.

Silvo-aquaculture was implemented as a pilot activity in Bontomanai, South Sulawesi Province, Indonesia, where low-input aquaculture is practiced. Two scenarios were set: With-action scenario (implementing silvo-aquaculture) and Without-action scenario (continuing with the current low-input aquaculture). The ecosystem services evaluated in the pilot activity are summarized in Table 38.

Table38: Ecosystem services evaluated in pilot activities in South Sulawesi Province, Indonesia

	Ecosystem services	Without-action scenario (current low-input aquaculture)	With-action scenario (silvo-aquaculture)
1	Food	- Shrimp (<i>Penaeus vannamei</i>) - Fish (<i>Chanos chanos</i>)	- Shrimp (<i>P. monodon</i>) - Fish (<i>C. chanos</i>)
2	Raw material	- Seaweed (<i>Gracilaria vermiculophylla</i>) - Salt	- Seaweed (<i>G. vermiculophylla</i>)
3	Climate regulation	- In aquaculture, greenhouse gases such as nitrous oxide are produced from the feces and urine of farmed aquatic organisms.	- In aquaculture, greenhouse gases such as nitrous oxide are produced from the feces and urine of farmed aquatic organisms. - During the growth of mangroves, carbon is stored in biomass
4	Mitigation of local disasters	- Aquaculture ponds temporarily store water during floods to mitigate their effects. - No service	- Aquaculture ponds temporarily store water during floods to mitigate their effects. - Mangrove planting is expected to mitigate damage caused by strong winds, flooding, and landslides.
5	Habitat	- No service	- Mangroves provide habitat for birds

6.2 Methods for Evaluating Ecosystem Services

6.2.1 Methods for evaluating ecosystem services

Ecosystem service evaluation involves making ecosystem services visible by converting their value into economic terms. The international project “The Economics of Ecosystems and Biodiversity (TEEB)” published its integrated report (TEEB 2010) in 2010. The report discusses the effectiveness of visualizing the value of ecosystem services with the aim of creating a society that recognizes the value of ecosystem services and reflects it in its decision-making and actions. It is frequently cited when evaluating ecosystem services. TEEB uses the term “habitat services group” instead of “foundation services group.” This report will also use the term “habitat services group” throughout. This study also referenced the TEEB Integrated Report (2010) to develop an ecosystem services evaluation protocol for silvo-aquaculture.

TEEB considers ecosystem services as total economic value. Total economic value can be classified into use value and non-use value. Use value is the value generated by humans directly or indirectly using services.

Use value can be divided into direct use value, indirect use value, and option use value. Direct use value is mainly traded in markets. TEEB divides direct use value into consumptive value and non-consumptive value. For example, fishery products and agricultural products are classified as consumptive value. Consumptive value primarily includes supply services. On the other hand, value used for recreation, research, and education is classified as non-consumptive value. Non-consumptive value primarily includes cultural services. Indirect use value is primarily centered on regulatory services and includes items that are not traded in the market economy. Option use value is the value people feel for retaining the option to use something in the future.

Non-use value is the value that people feel for the maintenance of something, regardless of its direct or indirect use. For example, it is the value that humans derive from the satisfaction of knowing that a particular species of animal or plant or an ecosystem remains intact.

TEEB takes a step-by-step approach to converting ecosystem services into economic value, first recognizing the value and then proving it. As described below, the protocol developed in this study outlines the step-by-step approach as a set of work procedures.

6.2.2 Protocol for evaluating ecosystem services in pilot activities

Until now, there has been no protocol for evaluating ecosystem services specific to silvo-aquaculture. Therefore, based on literature survey and field surveys in South Sulawesi, Indonesia, this study created a protocol for evaluating ecosystem services specific to silvo-aquaculture. The history of the creation of this protocol is shown in Table 39.

Table 39: The history of the creation of the protocol

Year and month	Contents
October 2023	The study team created a draft protocol for evaluating the ecosystem services of silvo-aquaculture.
March 2024	The study team visited Graduate School of Agriculture, Kyoto University, to consult with Prof. Kuriyama, a leading authority on ecosystem service valuation, about the draft protocol and obtain his advice.
April 2024	The study team revised the draft protocol based on advice from Prof. Kuriyama.
May 2024	The study team evaluated the economic value of ecosystem services in pilot activities using the draft protocol.
From January to April 2025	JICA and the study team finalized the draft protocol.

The protocol developed in this study outlines a method for evaluating the annual economic value of ecosystem services per hectare (ha) provided by silvo-aquaculture businesses. The TEEB Synthesis Report (TEEB 2010) focuses on global-scale ecosystem services, whereas this protocol is designed for the village-level scale. Furthermore, the TEEB Synthesis Report (2010) addresses not only the production and enhancement of the economic value of ecosystem services, but also the loss and depletion of that value. This protocol also addresses not only the production and enhancement of the economic value of ecosystem services in silvo-aquaculture but also the loss and depletion of that value.

6.2.3 Methods used to evaluate ecosystem services for pilot activities

The protocol developed in this study summarizes the method for evaluating the annual economic value of ecosystem services per hectare that changes and improves through mangrove planting and aquaculture using silvo-aquaculture. The workflow is shown in Figure 31, and a summary is given below.

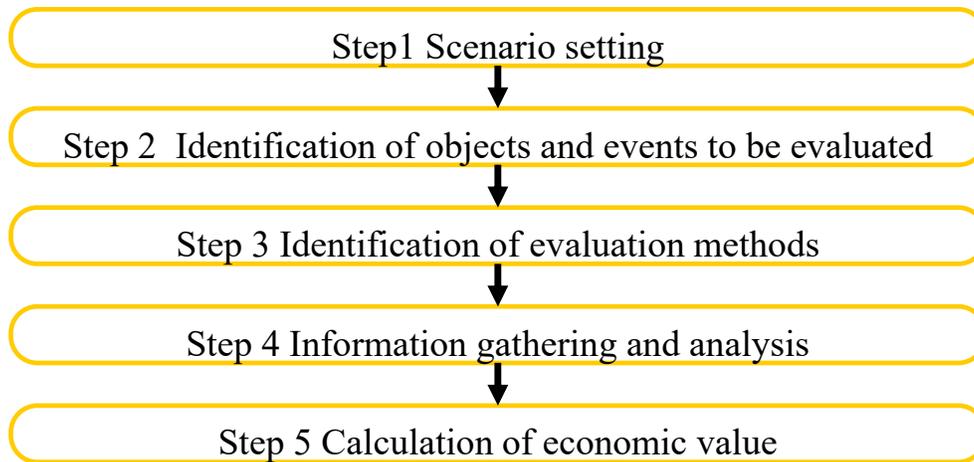


Figure 31: The workflow for ecosystem service evaluation for silvo-aquaculture

Step 1: Scenario setting

In Bontomanai, South Sulawesi Province, Indonesia, where pilot activities were conducted, mangrove forests were cut down about 50 years ago to develop aquaculture ponds, and currently vanamei shrimp (*Penaeus vannamei*) and black tiger shrimp (*P. monodon*), seaweed (*Gracilaria vermiculophylla*), and milkfish (*Chanos chanos*) are being cultured in an extensive manner. To evaluate the ecosystem services that are changing and improving due to silvo-aquaculture in Bontomanai, we set up a With-action scenario (implementing silvo-aquaculture) and a Without-action scenario (continuing with the current extensive aquaculture).

The economic value of ecosystem services provided by each scenario was calculated, and the difference between the economic values of the two scenarios was considered to be the value of ecosystem services provided by silvo-aquaculture.

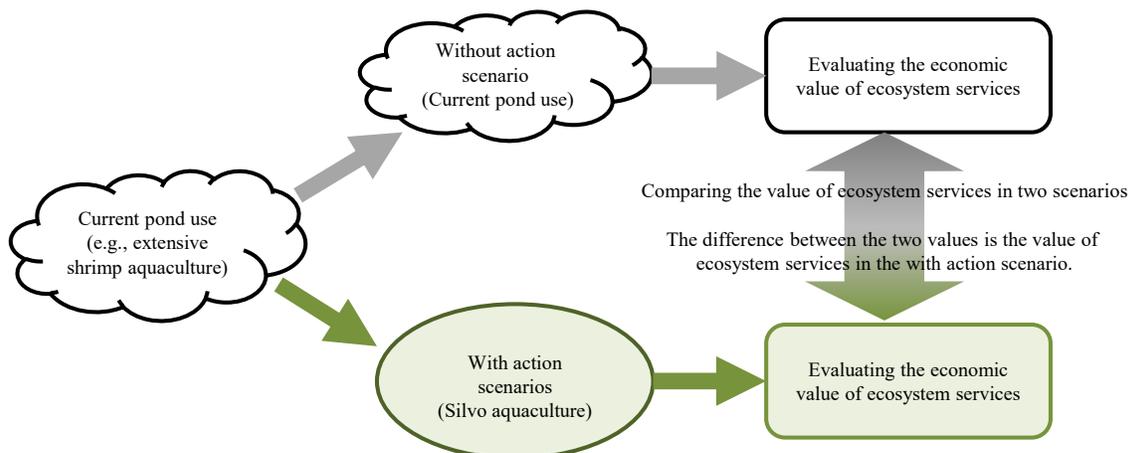


Figure 32: Setting up without-action and with-action scenarios for calculating changes in ecosystem service values provided by silvo-aquaculture

Step 2: Identification of objects and events to be evaluated

Ecosystem services to be evaluated were identified based on observations and interviews conducted in the target area. The identified evaluation targets are shown in Table 38.

Step 3: Identification of evaluation methods

Evaluation methods have been identified for each ecosystem service. (For details on each evaluation method, refer to the attached protocol and evaluation report.)

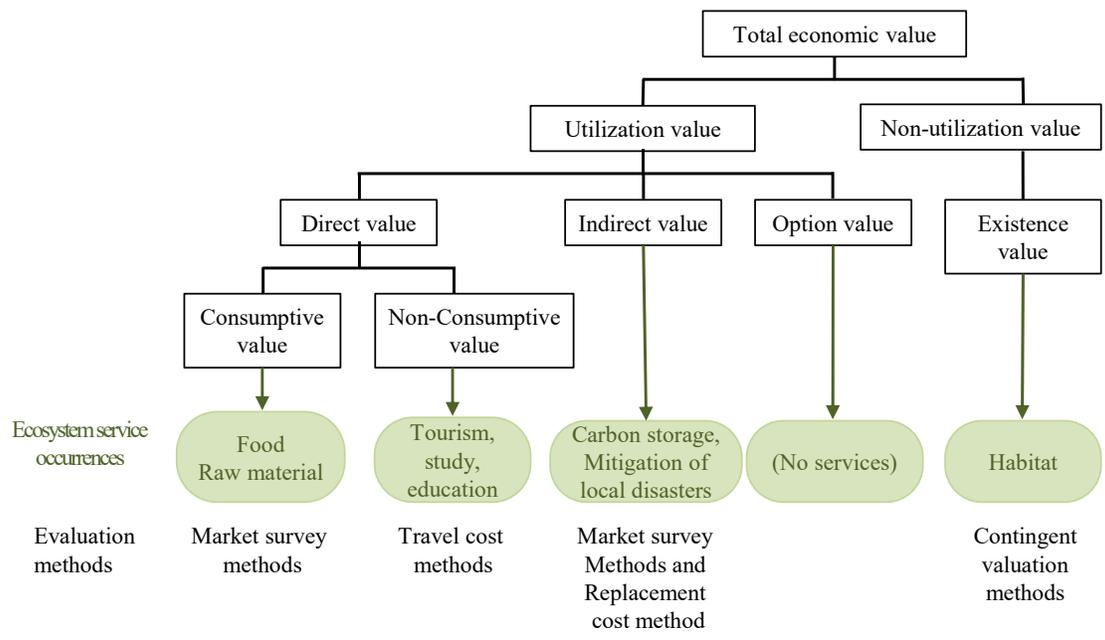


Figure 33: Classification of total economic evaluation and ecosystem services evaluated by silvo-aquaculture and their evaluation methods

Step 4: Information gathering and analysis

Information was collected and evaluated for each ecosystem service. (For details on the methods used to collect and evaluate information for each ecosystem services, refer to the attached protocol and evaluation report.)

Step 5: Calculation of economic value

The economic value of each ecosystem service calculated in Step 4 was added together to determine the annual economic value of ecosystem services per hectare of silvo-aquaculture.

6.3 Results of Valuation of Ecosystem Service in Pilot Activities

The results of the ecosystem service evaluation of the pilot activity in Bontomanai, South Sulawesi Province, Indonesia, are shown below. (For details of the results, refer to the attached protocol and evaluation report.)

The target areas are shown in Figure 34.

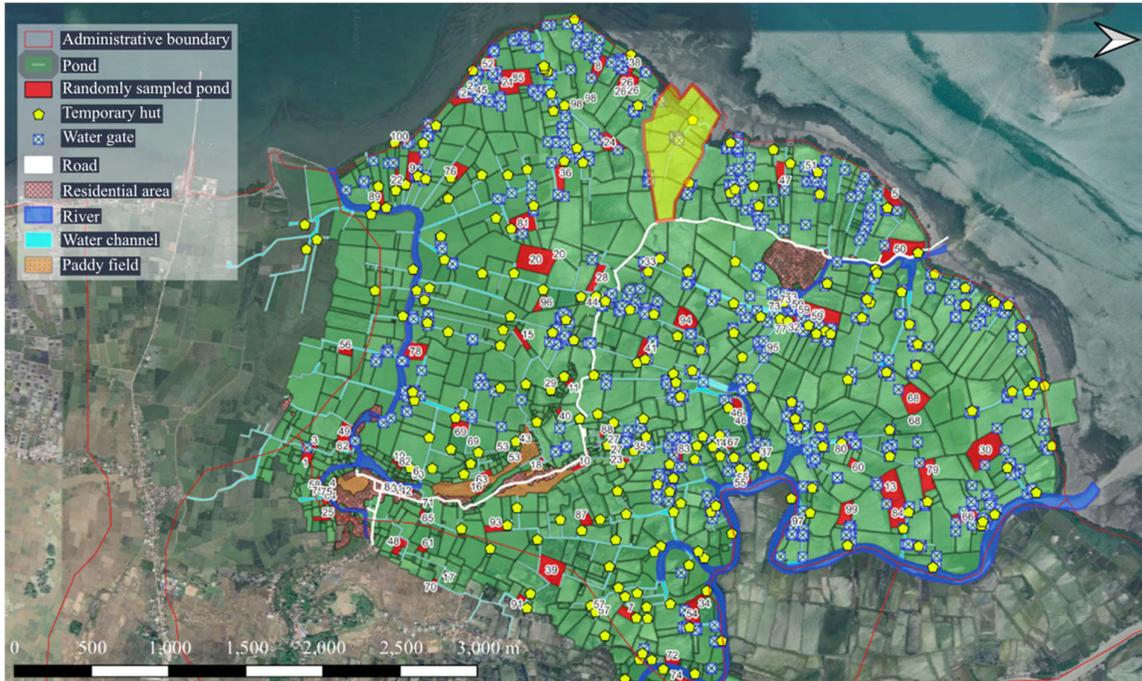


Figure 34: Target area for evaluation: Bontomanai, South Sulawesi Province, Indonesia

Table 40 shows the ecosystem services evaluated in both scenarios and the evaluation methods used.

Table 40: Ecosystem services evaluated in both scenarios and the evaluation methods

	Ecosystem service	Without-action scenario (current low-input aquaculture)	With-action scenario (silvo-aquaculture)	Evaluation methods
1	Food	- Vanamei shrimp (<i>P. vannamei</i>) - Milkfish (<i>C. chanos</i>)	- Black tiger shrimp (<i>P. monodon</i>) - Milkfish (<i>C. chanos</i>)	Market research methods
2	Raw material	- Gracilaria (seaweed) - Salt	- Gracilaria (seaweed)	Market research methods
3	Climate regulation	- In aquaculture, greenhouse gases such as nitrous oxide are produced from the feces and urine of farmed aquatic organisms.	- In aquaculture, greenhouse gases such as nitrous oxide are produced from the feces and urine of farmed aquatic organisms. - During the growth of mangroves, carbon is stored in biomass	Market research methods
4	Mitigation of local disasters	- Aquaculture ponds temporarily store water during floods to mitigate their effects.	- Aquaculture ponds temporarily store water during floods to mitigate their effects.	Replacement cost method
		- No service	- Mangrove planting is expected to mitigate damage caused by strong winds, flooding, and landslides.	Replacement cost method
5	Habitat	- No service	- Mangroves provide habitat for birds	Contingent valuation method

(1) Ecosystem service valuation of the Without-action scenario

Economic value of food and raw material

In Bontomanai, ponds are used for aquaculture of various species and salt production. Information on aquaculture costs and sales was investigated. The profit obtained by subtracting costs from sales was used as the economic value of ecosystem services of food and raw material.

Economic value of climate regulation

In the without-action scenario, nitrous oxide is emitted from the feces and urine of aquaculture shrimp and fish. The economic value of this emission was calculated using the protocol created in this survey, which incorporates the GHG guidelines of the Intergovernmental Panel on Climate Change (IPCC).

Economic value of mitigation of local disasters

Flood mitigation (water storage capacity of 1 ha pond)

In aquaculture ponds, the difference in height between the water surface and the dike is 80 cm. In the event of a flood, a 1-hectare pond can store water with a volume of 80 cm x 100 m x 100 m. This economic value of flood mitigation was calculated based on the cost of constructing a pond with this storage capacity.

(2) Ecosystem service valuation of the With-action scenario

In the pilot phase of this survey, black tiger shrimp and milkfish aquaculture was conducted from April to June 2025.

Figure 35 shows an image of pond utilization in the pilot activities. The economic value of the separate silvo-aquaculture system was calculated for Pond S1 (mangrove planting) and Pond S2 (aquaculture) as a pair. Additionally, the economic value of the concurrent silvo-aquaculture system was calculated for Pond S3 (mangrove planting and aquaculture within a single pond).



Figure 35: Image of pond use in pilot activities

(2-1) Separate system silvo-aquaculture

Economic value of food and raw material

Pond S1 (approx. 0.085 ha) was planted with 160 mangrove trees. Pond S2 (approx. 0.2 ha) was stocked with milkfish, black tiger shrimp, and Gracilaria. The costs and revenues associated with the use of these ponds were investigated.

Economic value of climate regulation

As in the Without-action scenario, nitrous oxide is also emitted from the feces and urine of aquaculture shrimp and fish in the With-action scenario. The economic value of this emission was calculated using the protocol created in this survey, which incorporates the GHG guidelines of the Intergovernmental Panel on Climate Change (IPCC).

Economic value of mitigation of local disasters

Flood mitigation (water storage capacity of 1 ha pond)

In aquaculture ponds, the difference in height between the water surface and the dike is 80 cm. In the event of a flood, a 1-hectare pond can store water with a volume of 80 cm x 100 m x 100 m. The economic value of flood mitigation was calculated based on the cost of constructing a pond with this storage capacity.

Calming storm

The mangroves planted mitigate strong winds blowing to temporary huts around fish ponds. The economic value of calming storm was calculated based on the construction costs of windbreak fences for these temporary huts. The size of the windbreak fences was determined to be 4 m in height and 5 m in length based on the size of the temporary huts. The cost of the windbreak fences was calculated separately for bamboo

and wooden materials used in Bontomanai. An illustration of the windbreak fences is shown in Figure 36.

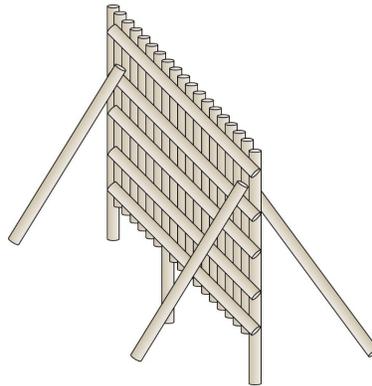


Figure 36: Image of windbreak fences in Bontomanai, South Sulawesi, Indonesia

There are 228 temporary huts in Bontomanai (1,300 ha). This means that the density of temporary huts in Bontomanai is 0.175 huts/ha.

Economic value of habitat

The mangroves planted provide a habitat for wild birds such as heron. The value of mangroves as a habitat is irreplaceable, as there are no suitable alternatives. Therefore, the economic value of the habitat provided by mangroves was evaluated using a contingent valuation method.

From May to June 2024, a survey using a contingent valuation method was conducted in Bontomanai. First, a preliminary survey was conducted to confirm that the questions were understood and to set the range of willingness to pay. Willingness to pay was collected using a double-bounded approach.

Subsequently, the survey conducted interviews with 54 people selected at random. The survey results were statistically processed to calculate the amount respondents were willing to pay.

The calculated willingness to pay amount was multiplied by the number of households in Bontomanai, and then divided by the area of Bontomanai (1,300 ha) to determine the economic value of the habitat per hectare.

(2-2) Concurrent system silvo-aquaculture

Economic value of food and raw material

Pond S3 (approx. 0.25 ha) has 196 mangroves planted in an area of approx. 0.045 ha within Pond S3. Milkfish, black tiger shrimp, and Gracilaria were stocked in Pond S3. The cost and sales of the food and raw materials provided by these ponds were investigated.

Economic value of climate regulation

The method for calculating economic value is the same as the separate system, but since the areas of aquaculture ponds and land under reforestation differ between the separate and concurrent systems, the areas used in the concurrent system were applied in the calculation.

Economic value of mitigation of local disasters

Flood mitigation (water storage capacity of 1 ha pond)

Description omitted as it has the same economic value as the separate system.

Calming storm

Description omitted as it has the same economic value as the separate system.

Economic value of habitat

Description omitted as it has the same economic value as the separate system.

The economic values of each ecosystem service calculated using these methods are shown in Table 41 for the Without-action scenario. The results for the With-action scenario (separate system) and With-action scenario (concurrent system) are shown in Table 42.

Table 41: Economic value of ecosystem services in the Without-action scenario (IDR/ha/year)

	Ecosystem services	Shrimp: 3 cycles/year	Shrimp: 2 cycles/year Salt: 1 cycle/year	Milkfish and Gracilaria: 3 cycles/year
1	Food Raw material	16,140,000 IDR	17,260,000 IDR	25,500,000 IDR
2	Climate regulation	-17,455 IDR	-11,637 IDR	-6,309 IDR
3	Mitigation of local disasters	Flood mitigation	34,000,000 IDR	34,000,000 IDR
		Calming storm	0 IDR	0 IDR
4	Habitat	0 IDR	0 IDR	0 IDR
	Total	50,122,545 IDR	51,248,363 IDR	59,493,691 IDR

Table 42: Economic value of ecosystem services in the With-action (separate style and concurrent style) scenario (IDR/ha/year)

	Ecosystem services	Separate system	Concurrent system
1	Food Raw material	-110,812,500 IDR	-87,030,000 IDR
2	Climate regulation	391,330 IDR	216,073 IDR
3	Mitigation of local disasters	Flood mitigation	34,000,000 IDR
		Calming storm	From 822,500 IDR to 1,564,500 IDR
4	Habitat	35,228 IDR	35,228 IDR
	Total	From -75,563,442 IDR to -74,821,442 IDR	From -51,956,199 IDR to -51,214,199 IDR

Based on the above, it can be concluded that the with-action scenario resulted in an increase in the economic value of ecosystem services related to “climate regulation,” “mitigation of local disasters,” and “habitats.”

On the other hand, the economic value of ecosystem services related to “food and raw materials” is significantly more negative in the with-action scenario. This is because, in the pilot activities, full-time aquaculture workers were hired to collect data related to aquaculture, such as water quality. In reality, aquaculture workers can work alone in multiple ponds, making it possible to reduce labor costs for aquaculture workers. Additionally, the current lack of established aquaculture technologies for shrimp, fish, and seaweed using silvo-aquaculture is likely contributing to the low estimated profitability.

In this pilot activity, silvo-aquaculture was conducted using indigenous species, but if easily farmed exotic species such as tilapia (*Oreochromis mossambicus*) and vanamei shrimp are used, improvements in food supply services and raw material supply services can be expected.

This time, silvo-aquaculture was conducted using native species. However, when using easily farmed non-native species such as tilapia or banana shrimp, improvements in food supply services and raw material supply services can be expected.

7. Implementation of Pilot Activities

7.1 Selection of the Country and Area for Pilot Activities

7.1.1 Selection Criteria for the Target Country for Pilot Activities and Current Status of Each Country

Based on the information related to mangroves in Southeast Asian countries described in Chapter 2, a selection process was undertaken to identify target countries for the implementation of pilot activities. The following selection criteria for the target countries were set:

(1) Current Status of Mangroves

This criterion involved reviewing the total mangrove forest area and its trends, as well as government initiatives related to mangrove restoration. Countries with higher rates of mangrove deforestation have a greater urgency for conservation and sustainable use efforts, while project implementation in countries with large mangrove forest areas offers a greater potential impact. Understanding the status of government efforts in conservation, restoration, and sustainable utilization is also valuable in assessing the feasibility and future scalability of public-private partnership initiatives.

(2) Current Status of Greenhouse Gas (GHG) Emission Reduction

The direction and actions taken by candidate countries toward GHG emissions reduction are critical for evaluating the feasibility and long-term sustainability of public-private partnership initiatives. For this reason, the GHG emission volumes of each candidate country and their NDCs under the Paris Agreement were reviewed to assess the alignment of private sector initiatives with national efforts, particularly in sectors like agriculture and forestry where mangroves are relevant.

(3) Current Status of Carbon Offset Initiatives

Carbon offset initiatives are considered one of the core activities expected to motivate private companies' mangrove planting efforts. This criterion involved assessing the implementation status of market-based mechanisms such as the JCM, REDD+, and other carbon offset schemes in each candidate country to examine the potential for expanding carbon offset projects through private sector collaboration.

(4) Current Status of Shrimp Aquaculture

Since the planned pilot activity involves silvo-aquaculture²⁶ integrated with mangrove reforestation and shrimp aquaculture, it is essential that there is an existing foundation in shrimp aquaculture in order to facilitate smooth implementation and future scalability of the activity. Thus, the shrimp production volume and trends in each candidate country, as well as the types of shrimp aquaculture practices, were reviewed to assess the feasibility of introducing and expanding silvo-aquaculture projects.

²⁶ In this report, the term "silvo-aquaculture" will be used to refer to the business model being developed in this survey, while the term "silvo-fishery" will be used to refer to general silvo-fishery practices.

(5) Past Cooperation with JICA

Ensuring consistency with JICA's ongoing and planned projects in target countries is crucial for the institutionalization and expansion of public-private partnership initiatives. Accordingly, JICA's sectoral positioning and past efforts in relevant fields were examined to verify the relevance of proposed activities in each country.

(6) Potential for Collaboration with Japanese Companies

For the sustainable development of this initiative, it is vital to ensure supply chain integration through collaboration with companies engaged in mangrove conservation, restoration, and sustainable use, as well as those involved in extensive shrimp aquaculture, processing, and distribution. Therefore, the potential for future collaboration with relevant Japanese companies was assessed.

(7) Potential for Collaboration with International Organizations, Development Partners, and NGOs

While knowledge and experiences from individual projects implemented by international organizations, development partners, and NGOs can be leveraged for this study, it is currently difficult to assess the feasibility of direct field-level collaboration. However, future opportunities for on-the-ground partnerships were considered by identifying organizations actively involved in mangrove and ecosystem-related initiatives and assessing their regional networks and presence.

Since the content of the information platform proposed through the survey and future activities will be examined based on the implementation and validation of pilot activities, the pilot activities themselves are of critical importance. Among the selection criteria, those deemed most essential for smooth and effective implementation of the pilot activities are (4) Current Status of Shrimp Aquaculture (directly related to pilot activities), (6) Potential for Collaboration with Japanese Companies (important for supply chain development), and (3) Carbon Offset Initiatives (closely linked to private sector involvement). On the other hand, criteria crucial for assessing future expansion potential are (1) Current Status of Mangroves, (2) Current Status of GHG Emission Reduction (to understand national efforts), and (7) Collaboration with International Organizations, Donors, and NGOs (to explore future partnership potential).

In line with the above selection criteria, an assessment was made of six candidate countries, and their priority levels are summarized in Table 43. Countries that demonstrate strengths in each criterion are shaded in gray for clarity.

Table 43: Summary of the evaluation based on the selection criteria

	Indonesia	Thailand	Philippines	Vietnam	Malaysia	Myanmar
Current Status of Mangroves	<ul style="list-style-type: none"> Area: 2.8 million ha (ranked 1st) Largest decrease in area (750,000 ha over 30 years), highest rate of decrease (19.5% over 20 years) High reforestation rate in deforested areas (22.6%) 	<ul style="list-style-type: none"> Area: 240,000 ha (ranked 5th) Area has remained almost unchanged over the past 30 years Low reforestation rate in deforested areas (5.1%) 	<ul style="list-style-type: none"> Area: 300,000 ha (ranked 4th) Data reliability is questionable, but area has increased by 34.5% over 30 years Low reforestation rate in deforested areas (7.3%) 	<ul style="list-style-type: none"> Area: 60,000 ha (ranked 6th) Decreased by approx. 13,000 ha over 20 years (18.5% decrease) Very low reforestation rate in deforested areas (0.6%) 	<ul style="list-style-type: none"> Area: 410,000 ha (ranked 2nd) Decreased by approx. 59,000 ha over 30 years (6.6% decrease) Relatively high reforestation rate in deforested areas (17.6%) 	<ul style="list-style-type: none"> Area: 400,000 ha (ranked 3rd) Decreased by 114,000 ha over 30 years (17.1% decrease) Very low reforestation rate in deforested areas (0.5%)
Current Status of GHG Emission Reduction	<ul style="list-style-type: none"> AFOLU²⁷ accounts for the highest share (43.6%) of total emissions; urgent action needed NDC sets an ambitious reduction target for the forestry sector (CM2: 91%) 	<ul style="list-style-type: none"> LULUCF²⁸ considered a GHG sink; increased by 47% over 16 years since 2000, contributing 25% to total emission reductions No specific action plan for LULUCF outlined in NDC 	<ul style="list-style-type: none"> LUCF²⁹ positioned as a GHG sink; large increase over 6 years prior to 2000, but data reliability is low Although climate change awareness is high due to frequent disasters, focus remains mainly on the energy sector 	<ul style="list-style-type: none"> AFOLU emissions reduced by 36% over 6 years from 2010; currently 14% of total emissions NDC includes a target to increase forest cover to 45% by 2030, but overall interest in forestry sector emission reduction is low 	<ul style="list-style-type: none"> LULUCF plays a critical role as a GHG sink; increased by 33% over 6 years from 2010, contributing to 75% of total GHG reductions Forest cover is consistently maintained at over 50% 	<ul style="list-style-type: none"> LULUCF sink function declined by 6% over 5 years from 2000 due to forest loss and slash-and-burn farming No numerical GHG reduction target in NDC, but targets related to protected areas exist
Current Status of Carbon Offset Initiatives	<ul style="list-style-type: none"> 160 JCM projects. Most active among the countries; strong movement towards market-based mechanisms 	<ul style="list-style-type: none"> 79 JCM projects. Relatively active in market-based initiatives 	<ul style="list-style-type: none"> Only 18 JCM projects. Limited activity in market mechanisms 	<ul style="list-style-type: none"> 105 JCM project. Active engagement in market-based approaches Formulated an implementation plan for the Paris Agreement, including the development of a domestic carbon market. 	<ul style="list-style-type: none"> Only 17 JCM projects; but 143 CDM and 12 VCS projects registered by 2018 (active market-based initiatives) 	<ul style="list-style-type: none"> Only 33 JCM projects. Not very active in market-based approaches
Past Cooperation with JICA	<ul style="list-style-type: none"> Project development plan: Climate change and 	<ul style="list-style-type: none"> Project development plan: Environment and 	<ul style="list-style-type: none"> Not a priority area, but relevant thematic training 	<ul style="list-style-type: none"> Project development plan: Addressing climate 	<ul style="list-style-type: none"> Project development plan: Focus on economic 	<ul style="list-style-type: none"> Project development plan not confirmed

²⁷ AFOLU: Agriculture, Forestry and Other Land Use

²⁸ LULUCF: Land Use, Land Use Change, and Forestry

²⁹ LUCF: Land Use Change and Forestry

* (M) refers to mangrove-related projects. (E) refers to ecosystem services-related projects.	nature conservation are key sub-target areas <ul style="list-style-type: none"> (M) Ongoing cooperation since the 1990s (E) 5 projects related to provisioning and cultural ecosystem services 	climate change are minor target areas <ul style="list-style-type: none"> (M) Technical cooperation for GHG reduction (2010–2012) (E) 3 projects related to provisioning services 	provided under "Disaster Risk Reduction and Management Program" <ul style="list-style-type: none"> (M) Related cooperation from 1990s to 2010s (E) Only one project related to habitat and species 	change, disaster, and environmental degradation is a minor priority area <ul style="list-style-type: none"> (M) Ongoing cooperation since early 2000s (E) 10 projects mainly focused on provisioning services 	advancement and quality of life <ul style="list-style-type: none"> (M) Biodiversity and ecosystem conservation projects implemented for 10 years from early 2000s (E) Only 2 projects, mainly for provisioning services 	<ul style="list-style-type: none"> (M) 2 related projects implemented in late 2000s € 6 projects focused on provisioning services, especially food
Potential for Collaboration with Japanese Companies	Numerous Japanese companies engaged in extensive shrimp aquaculture, processing, and distribution <ul style="list-style-type: none"> 14 Japanese companies involved in mangrove reforestation in the past 4 years 	No Japanese companies confirmed to be engaged in extensive aquaculture <ul style="list-style-type: none"> 24 Japanese companies engaged in mangrove reforestation in the past 4 years 	No Japanese companies confirmed in extensive aquaculture <ul style="list-style-type: none"> Only 2 Japanese companies involved in mangrove reforestation in the past 4 years 	2 Japanese companies involved in extensive aquaculture shrimp production, processing, and distribution <ul style="list-style-type: none"> Only 2 Japanese companies engaged in mangrove reforestation in the past 4 years 	No Japanese companies confirmed in either extensive aquaculture or mangrove reforestation	No Japanese companies confirmed in extensive aquaculture <ul style="list-style-type: none"> Only 1 Japanese company engaged in mangrove reforestation in the past 4 years
Potential for Collaboration with International Organizations, Development Partners, and NGOs	MFF (Mangroves for the Future) supports platforms for collaboration among various institutions, sectors, and countries in relevant fields	MFF supports platforms enabling collaboration and knowledge-sharing among stakeholders	No identified platforms enabling on-the-ground collaboration or knowledge-sharing	MFF supports platforms for cross-sectoral collaboration and local action	No confirmed platforms for local collaboration or knowledge exchange	MFF provides platforms for multi-sector, multi-country cooperation in relevant areas
Overall Assessment	This country aligns well with all selection criteria and offers a strong foundation for smooth implementation and future expansion of the project.	While carbon offset efforts are relatively active, the shift toward intensive aquaculture and stagnation in shrimp aquaculture suggest limited suitability for pilot activities.	Despite high interest in climate and environmental issues, shrimp aquaculture is limited, and private-sector involvement in extensive aquaculture is lacking. The foundation for pilot activities and future development is weak.	Active engagement in extensive aquaculture and carbon offset markets, along with Japanese company involvement, give this country a clear advantage as a pilot site.	Forest and carbon initiatives are strong, but the lack of active shrimp aquaculture and private-sector involvement weakens its potential for pilot activities.	While there is some relevant cooperation and extensive aquaculture, low production levels and minimal private-sector activity suggest it's too early for private-sector collaboration. Recent political instability also poses challenges.
Priority	1	-	-	2	-	-

(1) Current Status of Mangroves

Southeast and South Asia account for the largest share of the world's mangrove forest area at 36.2%, with Indonesia alone possessing a dominant area of 2.8 million ha. Indonesia also has by far the largest area and rate of mangrove loss among the six countries studied, making efforts toward mangrove conservation and sustainable use an urgent priority. Given its large influence both regionally and globally, Indonesia's actions in this field are expected to have significant long-term impacts. The country also shows a high rate of mangrove regeneration after loss, which reflects a strong national commitment and indicates potential for future expansion of initiatives identified in this study. Although Malaysia does not match Indonesia in scale, it still possesses a substantial mangrove area. Its low loss rate and high regeneration rate suggest that active efforts are being made toward mangrove preservation and restoration. After Indonesia, Vietnam and Myanmar have the highest rates of mangrove loss, but their regeneration rates are quite low, indicating an urgent need for more proactive measures. Thailand and the Philippines, on the other hand, are maintaining or even increasing their mangrove areas.

(2) Current Status of GHG Emission Reductions

In Indonesia, agriculture and forestry account for the largest proportion of total GHG emissions, making it critical for the country to implement mitigation measures swiftly. Its NDC includes highly ambitious reduction targets for the forestry sector, indicating strong expectations for action in this area. Malaysia places high importance on forestry as a carbon sink and has taken proactive policy measures, such as maintaining a forest cover of over 50% at all times. In contrast, the Philippines and Vietnam appear to show limited interest in the forestry sector in connection to their GHG reduction efforts.

(3) Current Status of Carbon Offset Initiatives

The number of projects supported by the Japanese government's JCM is very high in Indonesia and Vietnam, with Thailand also having a relatively large number of JCM-supported projects. This suggests high expectations from Japanese private companies for market-based mechanisms. Although Malaysia has relatively few JCM-supported projects by the Japanese government, it has a large number of projects under the CDM and VCS, indicating active engagement in market-based mechanisms.

(4) Current Status of Shrimp Aquaculture

Indonesia and Vietnam are the largest producers of farmed shrimp in the region, and their production continues to increase steadily. There are many extensive (low-intensity) aquaculture operations, suggesting a foundation for implementing and expanding silvo-aquaculture practices that combine mangrove reforestation with extensive shrimp aquaculture. Thailand also has a relatively high shrimp production volume, but following disease outbreaks, it has fallen behind Indonesia and Vietnam. Thailand promotes modern, intensive aquaculture in cooperation with private companies and lacks the foundation for implementing or expanding extensive aquaculture practices. The Philippines, Malaysia, and Myanmar have

very low shrimp production volumes with no increasing trend, making them unsuitable for pilot projects aimed at verifying extensive shrimp aquaculture production involving private sector participation.

(5) JICA's Past Cooperation

In rolling plans, Indonesia, Thailand, Vietnam, and Malaysia have identified related fields as priority areas. In particular, compared to the other target countries, Indonesia places a relatively high priority on climate change and natural environment conservation as a key medium-term goal. All six target countries have undertaken mangrove-related initiatives, with Indonesia and Vietnam having ongoing cooperation since the 1990s and 2000s. Regarding ecosystem services, Vietnam has conducted the most initiatives (10 projects), followed by Myanmar and Indonesia.

(6) Potential for Collaboration with Japanese Companies

Indonesia has a very large number of companies engaged in extensive shrimp aquaculture, processing, and distribution, overwhelmingly more than the other five target countries. The involvement of Japanese companies in extensive shrimp aquaculture in Vietnam is also evident. For these two countries, collaboration with private companies to secure value chains and develop future initiatives is an important point highlighted in this study. Mangrove planting activities by Japanese companies can be seen as CSR activities, and these initiatives are particularly active in Thailand and Indonesia.

(7) Potential for Collaboration with International Organizations, Development Partners, and NGOs

The MFF initiative is an international NGO working on coastal ecosystem conservation and sustainable development in Southeast and South Asia. It is co-chaired by the International Union for Conservation of Nature (IUCN) and the UNDP, supporting 11 countries including Indonesia, Thailand, Myanmar, and Vietnam among the target countries of this study. MFF provides a platform for agencies, sectors, and countries addressing coastal ecosystem and livelihood issues to collaborate on climate change adaptation and mitigation, disaster risk reduction, ecosystem health promotion, development of sustainable livelihoods, and fostering active private sector engagement in sustainable business practices. In the four countries mentioned above, there is potential to leverage this initiative for on-the-ground collaboration with relevant agencies and for effective sharing of experience and knowledge.

Considering the above, Indonesia demonstrates strong alignment and validity with the selection criteria in terms of both implementation and future expansion. Indonesia has the necessary foundation for smooth project implementation and further development. Consequently, following discussions with JICA, Indonesia was selected as the pilot activity country.

Vietnam also demonstrated advantages as an implementation target country given its highly active shrimp aquaculture industry, the presence of Japanese companies engaged in extensive shrimp aquaculture with potential for collaboration, and very active efforts in carbon offset initiatives.

Thailand, while relatively active in carbon offset initiatives, is moving its shrimp aquaculture policies toward intensive aquaculture, and shrimp production itself has stagnated. Therefore, Thailand does not have a sufficient foundation for conducting pilot activities, which form the basis of this study.

Malaysia is very active in forest conservation and restoration efforts and is also engaged in carbon offset initiatives. However, shrimp aquaculture lacks vigor, and efforts by private companies toward extensive shrimp aquaculture, which is important for sustainable future expansion, could not be confirmed. Thus, Malaysia lacks a sufficient foundation for pilot activities to be carried out or expanded in the future.

JICA has been involved in mangrove-related initiatives and in some extensive aquaculture efforts in Myanmar in the past. However, given that shrimp production volume is currently very low, the absence of Japanese companies engaged in extensive shrimp aquaculture, and the political and economic situation following the coup, the possibility of linking efforts involving private companies remains uncertain.

The Philippines, being a disaster-prone country, has a strong interest in climate change and environmental protection. Nevertheless, shrimp aquaculture lacks vigor, and extensive shrimp aquaculture efforts involving private companies (which is important for sustainable future development) could not be confirmed. Furthermore, based on the information collected, carbon offset initiatives do not appear to be active. For these reasons, the Philippines does not have a foundation for pilot activities to be carried out or expanded in the future.

7.1.2 Selection of the Site of the Pilot Activities

As outlined above, based on previous research findings related to mangroves, Indonesia was selected as the target country for the pilot activities. In addition, based on the literature reviews and interviews conducted on Indonesia up to February 2022, as well as field activities carried out in South Sulawesi, the study team decided to select a pilot activity site within South Sulawesi Province for the following reasons.

- 1) In South Sulawesi, numerous Japanese companies, local enterprises, NGOs, and research institutions have collaborated with local governments over a long period in areas such as mangrove planting and management through silvo-fisheries, eco-shrimp production, processing, and distribution, awareness-raising activities, and research and dissemination of silvo-fishery techniques. To achieve the intended outcomes of the short-term pilot activities, it is essential to leverage the wealth of accumulated knowledge, experience, and networks in the region when planning the project, determining items for validation, and implementing the pilot activities.
- 2) South Sulawesi is home to the Research Institute for Coastal Aquaculture and Fishery Extension (RICAFE), a government institution responsible for coastal aquaculture information dissemination and education. RICAFE works closely with local government agencies and extension officers in each district, as well as universities and vocational training schools, to carry out educational activities related to coastal aquaculture. The ability to collaborate with both extension and educational practitioners during the

validation and consideration of the silvo-aquaculture model under this study's pilot activities is extremely valuable³⁰.

- 3) In recent years, Indonesia has undergone organizational restructuring in which all research institutions that were previously under various ministries have been consolidated under the National Research and Innovation Agency (Badan Riset dan Inovasi Nasional: BRIN). As part of this restructuring, many of the researchers originally affiliated with RICAFE have been reassigned to the Research Center for Fishery (RCF), now under the jurisdiction of BRIN. Although their organizational affiliation has changed, RCF researchers continue to be based in Makassar, where RICAFE is located, and remain engaged in fieldwork and research operations. Therefore, it is still considered feasible to work closely with them in validating the silvo-aquaculture model and exploring its future development. Moreover, BRIN actively promotes collaboration among research institutions, and it is expected that the knowledge and expertise of other institutions, particularly in areas such as carbon sequestration through mangroves and carbon credits, can be effectively applied to this study.
- 4) In South Sulawesi, the shrimp production model tends to be relatively simple, with pond owners and operators being either the same entity or not bound by strong hierarchical relationships. Compared to other regions where production systems are predominantly based on landlord-tenant dynamics, this simpler structure in South Sulawesi results in lower socioeconomic and coordination costs when forming the partnerships required for the development of silvo-aquaculture. This makes it easier to consider sustainable business development. On the other hand, silvo-aquaculture models involving the use of public forest land, where usage rights are obtained through concessions from public entities (landowners) and partnerships are formed with third parties, tend to involve complex relationships among investors, landowners, and third parties. Therefore, such areas are not considered suitable as pilot activity sites for this project.

7.2 Overview of Pilot Activities

7.2.1 Purpose of Pilot Activities

In this study, a pilot activity was conducted with the aim of examining whether silvo-aquaculture, a practice that integrates mangrove reforestation with shrimp aquaculture, could serve as a viable business model for attracting ESG investment from Japan. The pilot activity aimed to assess both the challenges and the potential of this model. The key perspectives in this pilot activity include an increase in mangrove forest area, an improvement in shrimp production productivity, the enhancement of biodiversity, the promotion of carbon sequestration and storage, an improvement in business profitability, and potential for scaling and dissemination of the model within the region.

³⁰ However, due to further organizational restructuring within the Indonesian government from November 2023 onward, it has become difficult to carry out activities in collaboration with RICAFE. Further details will be provided later.

The results of the pilot activities will be disseminated through the information platform proposed under this survey as a concrete case study of a business model suitable for ESG investment.

7.2.2 Selection of Sites for the Implementation of Pilot Activities

Based on the results of the literature review, interviews, and field surveys conducted by the study team up to February 2022, the following sites in South Sulawesi were selected as the sites for pilot activity implementation.

- Technical study site: The experimental aquaculture facility of RICAFE, located in Marana, Maros Regency, South Sulawesi Province (approximately 40 ha)
- Social study site: Bontomanai, Pangkajene and Kepulauan (Pangkep) Regency, South Sulawesi Province, Indonesia (approximately 1,200 ha)

The locations of both sites are shown in the figure below.



Figure 37: Location of the technical study site and social study site

7.2.3 Pilot Activity Implementation Period

The pilot activities were conducted over the period from April 2023 to June 2025. During the initial phase, from April 26, 2023 to July 2024, the pilot activities were implemented through a local subcontract agreement with the Center for Technology Services (CTS), an affiliate institution under the BRIN. The agreement was

signed on April 26, 2023. After that, for the period from August 2024 to June 2025, the activities were implemented directly by the study team (with direct financial management by the team) following the signing of a Memorandum of Understanding on January 15, 2025 with the RCF, another research institution under BRIN. Further details regarding changes in the implementation structure of the pilot activities are provided later.

7.2.4 Pilot Activity Implementation Structure (before institutional restructuring)

The pilot activities were initially conducted under a local subcontract agreement with an Indonesian research institution as the local subcontractor. After that, due to institutional restructuring in the government of Indonesia, the pilot activities were carried out directly by the study team, which assumed financial management responsibilities, while positioning the Indonesian research institution as a joint research partner. Details regarding changes in the implementation structure caused by institutional restructuring in the government of Indonesia are described later. The process of selecting the local subcontractor before restructuring and the implementation structure under the local subcontract agreement are outlined below.

(1) Selection of local subcontractor

At the start of this survey, the pilot activities were to be implemented by a local subcontractor. As a preparatory step for selecting the local subcontractor, interviews were conducted with research institutions and NGOs in Indonesia that are either currently engaged in or are deemed capable of undertaking mangrove planting and silvo-aquaculture activities. During these interviews, information was collected and assessed primarily based on the following five selection criteria: (1) experience in technical development and technical guidance/extension related to shrimp aquaculture and mangrove planting, (2) experience in collaborating with foreign aid agencies and international organizations, (3) experience in implementing projects in South Sulawesi, (4) availability of specialized personnel for this pilot activities, and (5) level of interest in the pilot activities. Based on these criteria, three candidates were shortlisted as appropriate. Subsequently, a competitive bidding process was conducted among the three shortlisted candidates, and BRIN received the highest evaluation score, making it the top choice for contract negotiations. After contract negotiations, a local subcontract agreement with BRIN was concluded on April 26, 2023.

(2) Implementation of the pilot activities through local subcontracting (before institutional restructuring)

After concluding the subcontract, the implementing structure was established, as shown below.

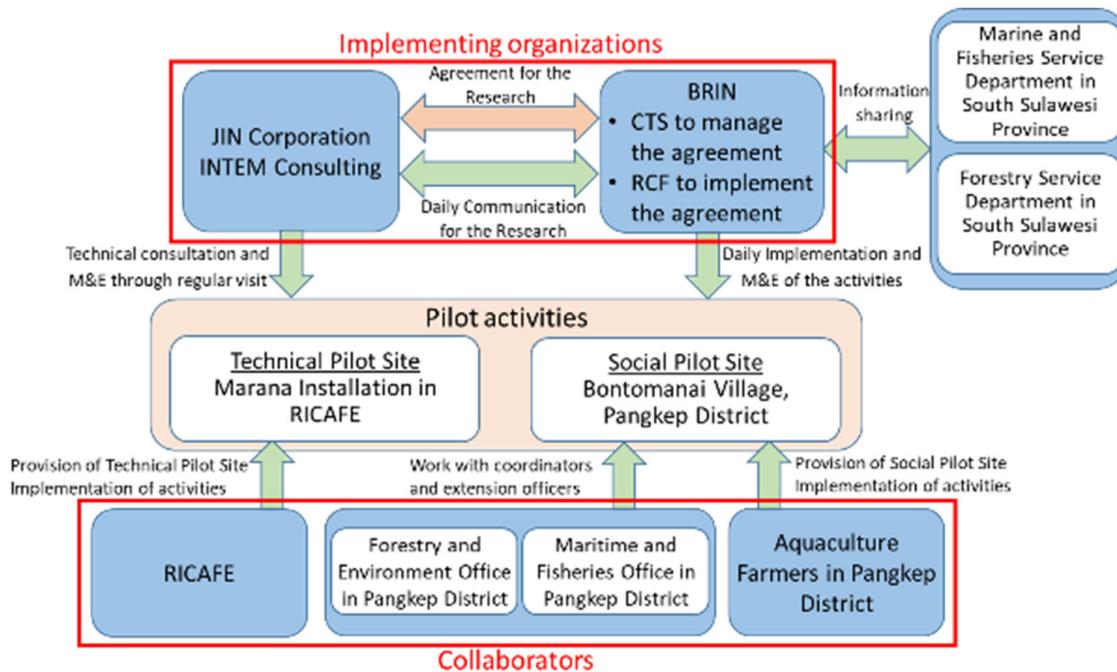


Figure 38: Implementation structure for the pilot activities (before institutional restructuring)

Under the local subcontracting arrangement, the CTS, an affiliated body under BRIN responsible for managing activities in collaboration with private companies, served as the contractual counterpart and official signatory. Meanwhile, the RCF, also under BRIN, was responsible for implementing the pilot activities in the field. RCF developed the work plans and carried out the pilot activities with approval from CTS. CTS received funding from the study team through the subcontract agreement and, based on the approved work plans, managed the contract by transferring the necessary funds to RCF as needed.

The pilot activities were implemented by the local subcontractor. The study team conducted periodic site visits to provide technical consultations and guidance regarding data collection methods, analysis techniques, and other aspects of implementation. For the technical study site, the local subcontractor conducted activities using the experimental aquaculture ponds at RICAFE. For the social study site, aquaculture ponds in Bontomanai Village, Pangkep Regency, were secured through lease agreements with local farmers. Activities were carried out in close coordination and collaboration with the Pangkep Regency Marine and Fisheries Office and the Environment and Forestry Office, including their local coordinators and extension officers.

7.2.5 Institutional Restructure of BRIN and Subsequent Change of the Implementation Structure for Pilot Activities

The pilot activities had initially been implemented under a local subcontract agreement. However, from December 2023, the effects of BRIN's ongoing institutional restructuring began to impact the subcontracting arrangement. As a result, from February 2024 onward, the BRIN/RCF research team became unable to conduct field activities.

In response to this situation, the study team held a series of consultations with BRIN in various forms to assess the status and discuss possible solutions. Ultimately, it was determined that continuing the subcontracting arrangement posed significant management risks and that, from a scheduling perspective, it was no longer feasible to wait for BRIN’s internal adjustments. Accordingly, at the end of April 2024, the study team decided to terminate the pilot activities under the local subcontracting arrangement. Instead, a new agreement was reached with BRIN/RCF to jointly continue the pilot activities under a direct implementation arrangement. This agreement clarified the scope of future activities, implementation structure, cost-sharing arrangements, and the roles and responsibilities of each party.

Key agreements on the continuation of the pilot activities are as follows:

- Following the termination of the subcontract agreement with BRIN/CTS, the study team and BRIN/RCF concluded an Agreement, under which the study team would directly manage the pilot activities with the cooperation of BRIN/RCF.
- All necessary expenses for the direct implementation, including per diem and travel costs for BRIN/RCF staff participating in the activity, would be covered directly by the study team from its project budget.
- After the termination of the contract with BRIN/CTS, RICAFE, now organizationally separate from BRIN, indicated that it could no longer continue to provide access to the technical verification ponds. Therefore, shrimp aquaculture activities would be limited to the social study site only.
- Due to the unavailability of the segmented technical verification ponds designed for comparative testing, certain comparative trials originally planned for shrimp aquaculture could no longer be conducted. However, the study team would adjust the scope of the verification activities based on the results of the first aquaculture cycle at the technical study site and implement what is feasible at the social study site.
- Mangrove monitoring of already-planted areas would continue at both the technical and social study sites, as RICAFE had expressed willingness to allow continued monitoring activities at its facility.

Based on the above discussions and agreements, the main changes associated with the direct implementation of the pilot activities are shown below.

Table 44: Points of change in the implementation of pilot activities

Item	Before change (local subcontract agreement)	After change (direct implementation by the Study team)
Period of the Local Subcontract Agreement	26th April 2023 to 15th January 2025	Shorten the contract period to 31st July 2024 for early termination.
Period of the Contract with JICA (Phase 2)	3rd March 2023 to 28th February 2025	Extend to the end of June 2025 for the achievement of the purpose of the pilot activities.

Implementing structure for the pilot activities	<p style="text-align: center; color: red;">Subcontract Agreement</p> <p style="text-align: center;">The work is carried out on a contract basis under the instruction of the study team</p>	<p style="text-align: center;">BRIN/RCF supports the direct implementation of activities by the study team.</p>
Silvo-aquaculture	Verification for the development of silvo-aquaculture techniques in the Technical verification ponds in RICAFE. Trial aquaculture for scaling up in local communities is conducted in the social verification ponds.	As the Technical verification ponds in RICAFE are not available, verification on the development of silvo-aquaculture techniques is conducted in the social verification ponds as much as possible. Trial aquaculture is continued in the Social verification ponds.
Mangrove planting	Mangrove planting and monitoring are conducted in both technical and social verification ponds.	Monitoring is continued in the social verification ponds. Monitoring is continued in the technical verification ponds, as well.

7.3 Fundamental Approach to Pilot Activities: Verification of the Silvo-Aquaculture Business Model

Prior to implementing pilot activities, preliminary surveys were first conducted on local aquaculture and mangrove planting. Based on the results of these surveys, a silvo-aquaculture business model was established that qualifies for ESG investment from Japan and benefits local residents' livelihoods. Subsequently, the effectiveness of this business model was verified.

7.3.1 Preliminary Survey on Aquaculture and Mangrove Planting in the Field

To conduct pilot activities in South Sulawesi, the study team carried out preliminary research on local aquaculture and mangrove afforestation through field surveys, interviews with stakeholders, and information gathering. Social conditions surrounding aquaculture revealed in the preliminary survey include the fact that the scale of aquaculture operations by local residents varies greatly, ranging from less than 1 hectare to several dozen hectares, that pond leasing occurs frequently, creating a division of labor system involving pond owners, managers, and producer, and that local operators manage approximately 20 hectares of aquaculture ponds consolidated through leased land. Technically, shrimp aquaculture density is extremely low and extensive (less than 3 black tiger shrimp per square meter). Mixed aquaculture with fish and seaweed is also practiced. Furthermore, it was confirmed that planting mangroves within shrimp ponds is rare locally, and there is insufficient scientific evidence demonstrating mutually beneficial relationships between mangroves and shrimp aquaculture in the same pond. Furthermore, from a management perspective, it was confirmed that a supply chain involving middlemen has been established, and that there are cases where price premiums are added for aquaculture using natural feed.

The preliminary survey also confirmed with regard to ESG investment from Japan to Indonesia that foreign capital investment in Indonesia requires paid-up capital of at least 10 billion rupiah (approximately 87.77 million yen according to the exchange rate on May 3, 2025)³¹, regardless of whether the investment is in manufacturing or non-manufacturing sectors. ESG investment from Japan must meet this condition. Furthermore, while 100% foreign-owned companies can be established for businesses involving brackish water fish breeding and fattening, as well as sea salt production/extraction, this is conditional upon forming partnerships with Indonesian small and medium-sized enterprises (SMEs), micro-enterprises, or cooperatives³². Partnership forms include subcontracting, franchising, general commerce, distribution and agency, supply chains, profit sharing, operational cooperation, joint ventures, outsourcing, and facility/equipment construction. It is recommended that partners are selected from lists of SMEs and micro-enterprises compiled by the government or industry associations. The large-scale business must prepare a Partnership Commitment detailing the type of work, estimated value, implementation schedule, etc., and submit it when applying for the business license³³.

7.3.2 The Concept of the Silvo-Aquaculture Business Model in Pilot Activities

The silvo-aquaculture business model is defined as “a profit-making business model that integrates mangrove restoration/conservation and aquaculture within the aquaculture ponds managed by a single management unit.” The requirements of the model include (1) converting part of the aquaculture ponds managed by the business unit for mangrove planting and conservation, (2) introducing aquaculture techniques that offset the opportunity cost of the converted ponds and improving the overall profitability of the business unit without changing the labor input, and (3) ensuring that the ecosystem service assessment is positive compared to not implementing this model, and disclosing ecosystem service assessment information and traceability information. This pilot activity will also verify whether the silvo-aquaculture business model can become a target for ESG investment from Japan and whether it has the potential to spread to surrounding areas.

Based on the findings confirmed in the preliminary survey, the pilot activities of this survey established a management unit of approximately 20 hectares as the medium-scale operational unit for the silvo-aquaculture business model. It was determined that this size meets the requirement of paid-in capital of 10 billion rupiah, the minimum investment threshold for foreign capital. It was confirmed in Bontomanai that the approximately 20-hectare aquaculture pond is at the scale of aquaculture operations consolidated through pond leasing, therefore it is judged to be a reasonable size.

Additionally, in the pilot activities, two types of technical package were proposed and implemented that allow mangrove planting and shrimp aquaculture to be conducted within the same management unit without

³¹ BKPM Regulation No. 4 of 2021 dated March 29, 2021

³² Attachment II to Presidential Regulation No. 49 of 2021 dated September 30, 2021

³³ Regulation of the Minister of Investment/Head of the Investment Coordinating Board No. 1 of 2022 dated February 10, 2022

mutual interference³⁴ (described later). Furthermore, we aimed to verify whether the model requirements could be met. This involved targeting a shrimp aquaculture density of six shrimp per square meter and introducing traceable eco-feed. The goal was to improve productivity and generate a price premium, thereby securing profits exceeding the opportunity cost of mangrove planting and enhancing the overall profitability of the management unit.

Specifically, in the pilot activities in this study, we verified the effectiveness and superiority of the With-action scenario by comparing silvo-aquaculture where the business model is applied (With-action scenario) with current aquaculture where it is not applied (Without-action scenario) within the approximately 20 ha of aquaculture management units established.

The primary technical and socioeconomic conditions related to aquaculture and mangrove afforestation confirmed through preliminary field surveys, along with the verification items established for the pilot activities based on these findings, are as follows:

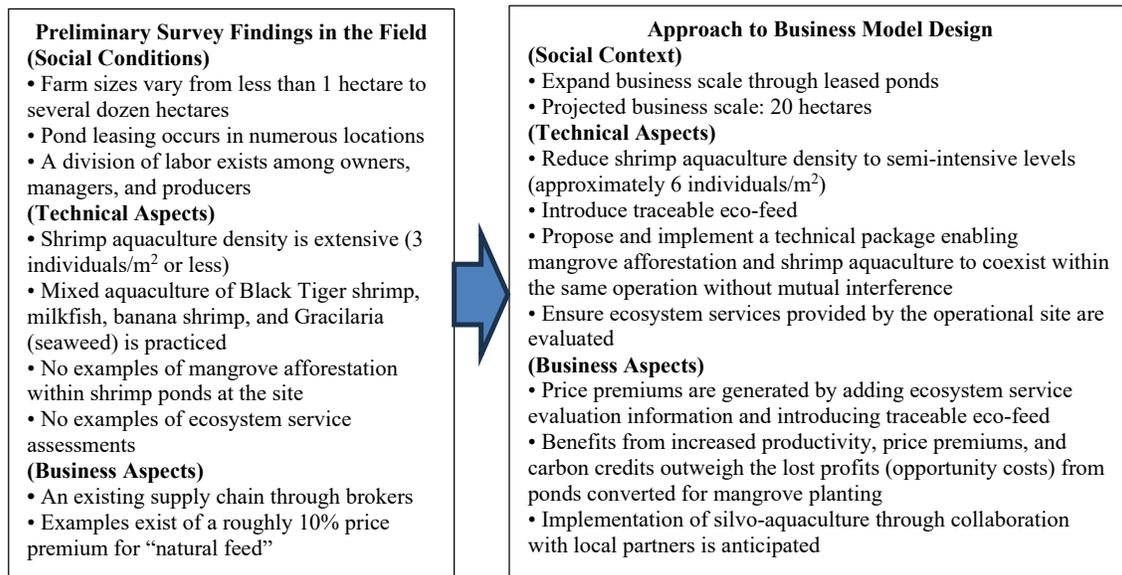


Figure 39: Findings from the preliminary survey conducted on-site and the approach to designing the business model during the pilot activities

The relationship between price, production volume, cost, and profit, modeled per unit area and per unit labor, as a concept of the silvo-aquaculture business model, can be illustrated as follows.

³⁴ This “mutual interference” does not refer to the mutual influence of natural phenomena, but rather to the disruption caused by one activity—mangrove planting or shrimp farming—to the other. For example, if mangroves are planted in a pond without developing a planting mound, as the mangroves grow and their roots develop, the roots become obstructive, reducing the efficiency of shrimp harvesting.

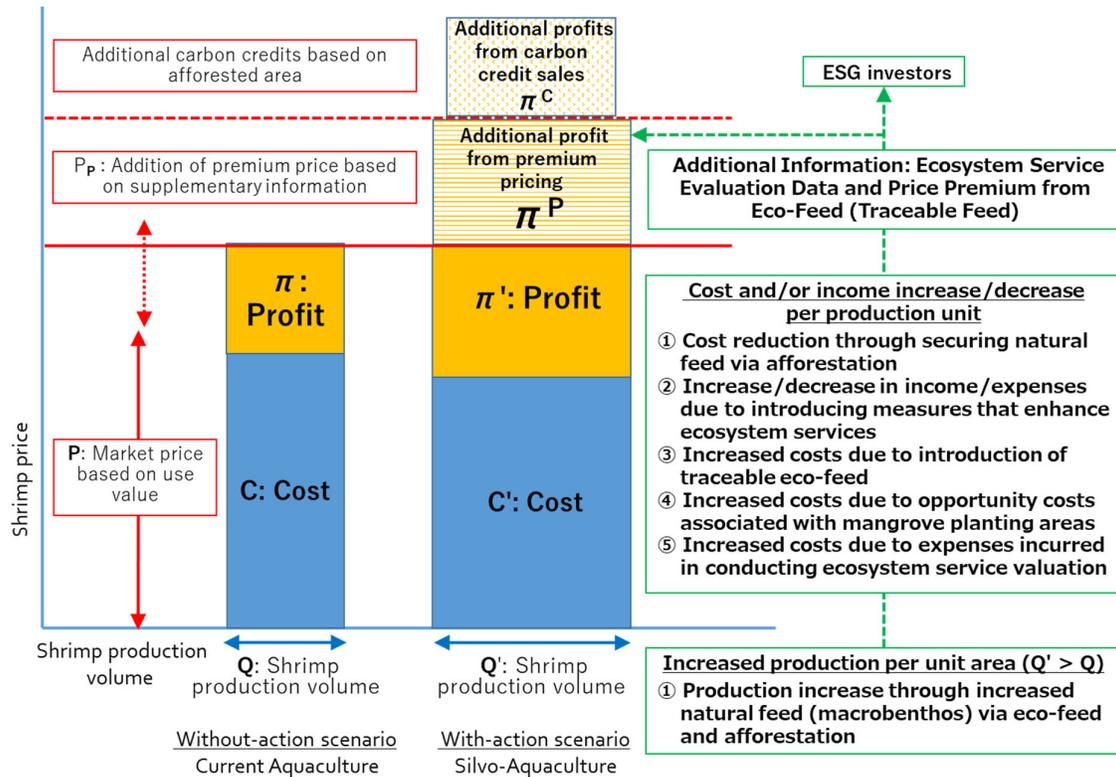


Figure 40: The relationship between price, production volume, cost, and profit in the silvo-aquaculture business model

Compared to the Without-action scenario, the With-action scenario is expected to result in the following changes in cost/revenue per unit of production: ① Cost reduction through securing natural feed via mangrove planting; ③ Cost increase due to introducing traceable eco-feed; ④ Cost increase due to opportunity costs associated with the mangrove planting area; and ⑤ Cost increase due to expenses incurred in conducting ecosystem service assessments. Furthermore, regarding the income/expense impact of ② Introducing measures to enhance ecosystem services, the specific measures will determine the increase or decrease, making it impossible to predict. Therefore, overall costs are expected to remain largely unchanged. On the other hand, productivity per unit area is expected to improve through the adoption of the silvo-aquaculture business model, which incorporates eco-feed and ecosystem service technologies. Furthermore, the silvo-aquaculture business model can generate additional profits through premium pricing resulting from the introduction of traceable eco-feed (additional information). Additionally, carbon credits generated based on the mangrove afforestation area can be sold, creating further anticipated profits.

Regarding the verification of whether action-oriented scenarios can be targets for ESG investment in Japan, the following points are confirmed for each “ESG” factor.

Environment: Environmental assessment by investors regarding mangrove afforestation and conservation, biodiversity enhancement, ecosystem service valuation, and environmental price premiums

Social: Introducing new aquaculture technology without changing the labor input, ensuring improved

profitability and sustainability of the business and consequently preventing local unemployment (no disadvantaged individuals), increasing local residents' income, and enhancing labor productivity (also increasing added value from the perspective of the entire region), which represents the investor's socio-economic evaluation

Governance: Investor assessment of corporate governance regarding disclosure of information related to ecosystem service valuation and traceability information for production processes

In pilot activities, we established and operated technical verification sites and social verification sites, and conducted socioeconomic surveys to verify whether environmental, socioeconomic, and corporate governance conditions could be met.

On the other hand, regarding the verification of whether the With-action scenario can be disseminated to surrounding areas, in addition to ensuring improved profitability and sustainability of the project, the following must be confirmed: 1) The feasibility of the operational scale (20ha) for this business model; 2) whether ponds of this scale can be secured as leased ponds or ponds for management services in addition to owned ponds; 3) whether potential local partners capable of becoming operators for this business model's management units can be identified; 4) whether the product value chain is already established or likely to be established; and 5) whether investment demand for ESG investments exists. Therefore, these matters were verified through a socioeconomic survey.

7.3.3 Setting Management Units and Management Scenarios for the Silvo-Aquaculture Business Model

A portion (25.59 ha) of the Bontomanai area, a social verification site, was designated as the management unit for the silvo-aquaculture business model (Figure 41). This designation enables a concrete and detailed estimation of management costs, yield of farmed fish species, and profits for each pond within the management unit, where current aquaculture is treated as the Without-action scenario. This facilitates a financial and economic analysis grounded in actual conditions. Furthermore, within the same management unit as the Without-action scenario, we conducted a financial and economic analysis for a With-action scenario by assuming the introduction of silvo-aquaculture and estimating its management costs and profits. By comparing the two scenarios, we verified the superiority of the With-action scenario. The specific composition of the Without-action scenario is shown in Figure 42, and that of the With-action scenario is shown in Figure 43. Table 45 compares the specific compositions of both scenarios, indicating which parts of the Without-action scenario were modified in the With-action scenario and how they were modified. In the With-action scenario, the extensive aquaculture ponds in production zones ②, ③, ⑤, ⑥, ⑧, ④, ⑬, ⑭, and ⑮ from the Without-action scenario were converted into semi-intensive black tiger shrimp ponds or managed mangrove plantation areas, where mangrove cultivation, natural regeneration, and conservation would be implemented. Furthermore, areas designated as natural mangrove forest management ponds and natural forest conservation zones in the Without-action scenario were maintained without change in the With-action scenario to preserve ecosystem conservation.

All 1,600 aquaculture ponds in the Bontomanai district were designated as the population for the socioeconomic survey and ecosystem services assessment (Figure 41).

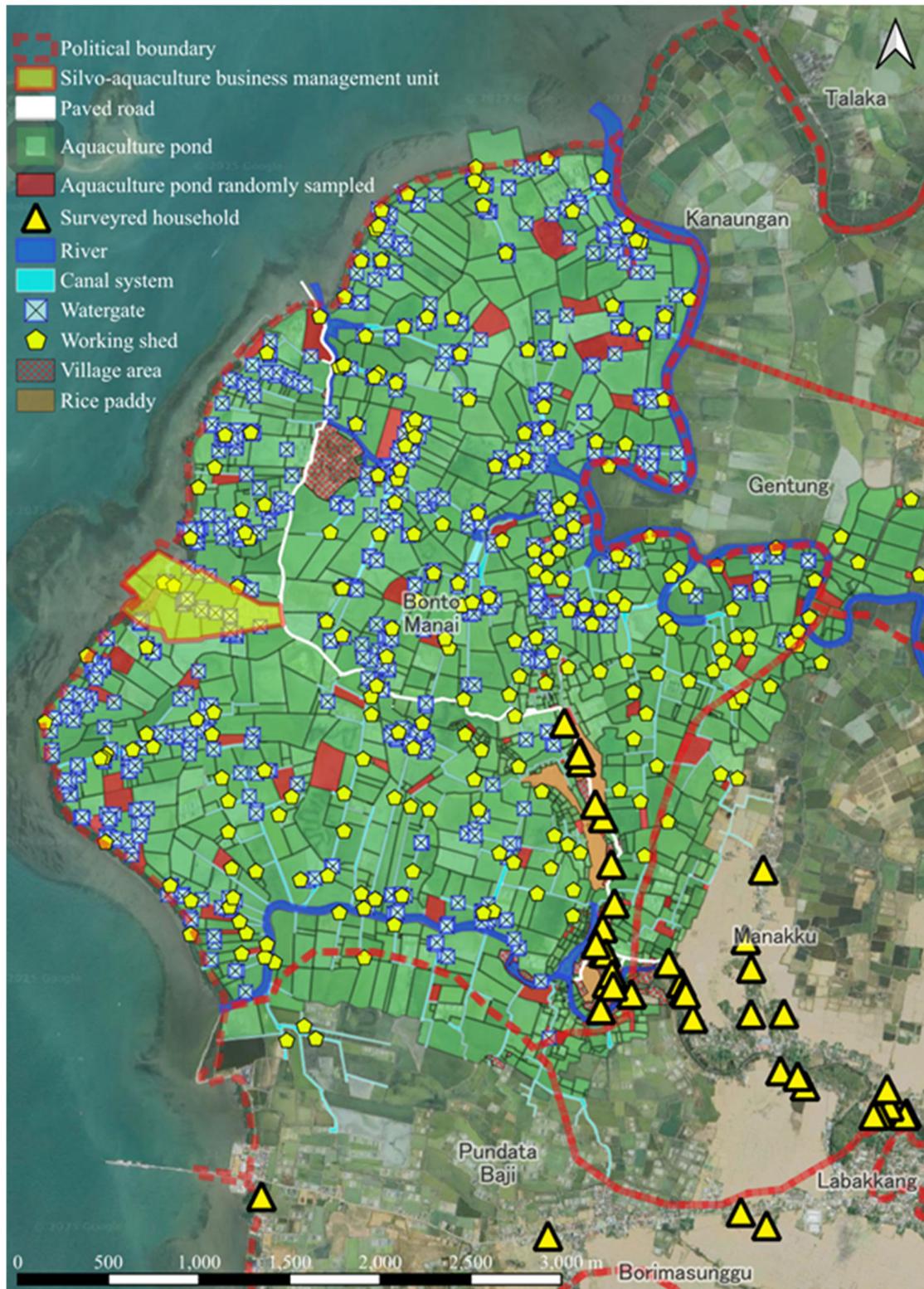


Figure 41: Management units and socio-economic survey target ponds for the silvo-aquaculture business model established in the Bontomanai District

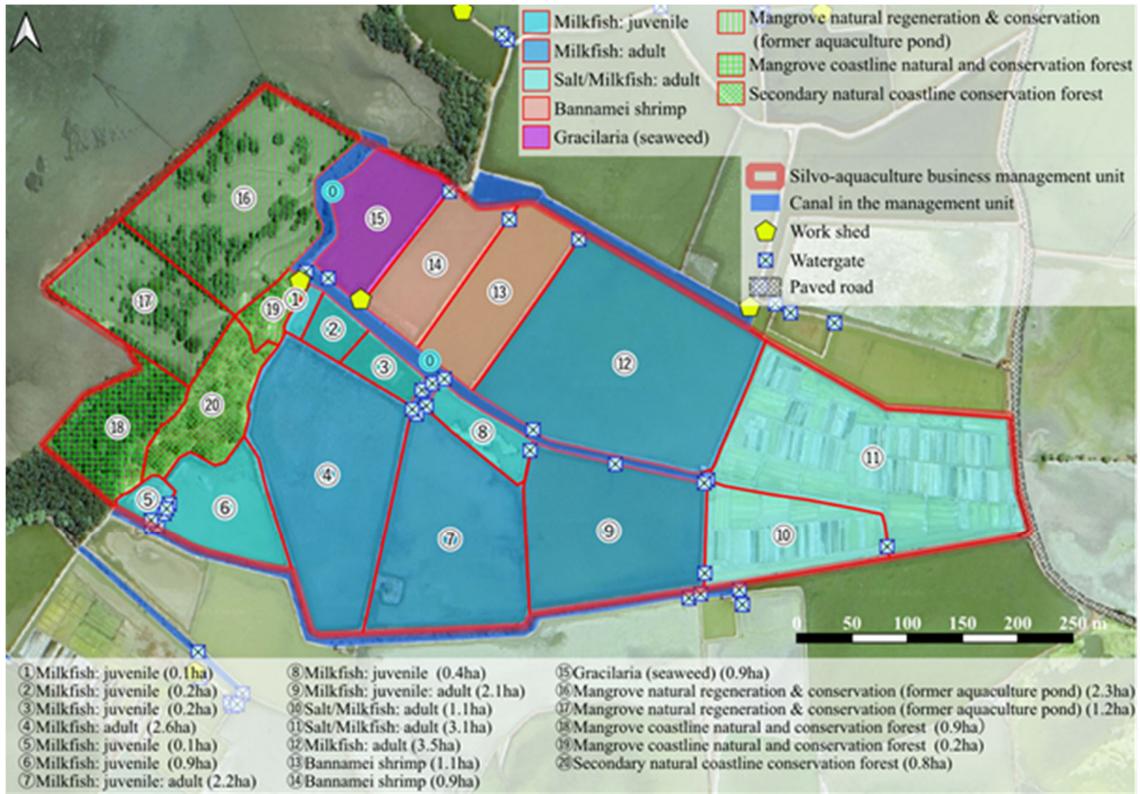


Figure 42: Specific structure of the Without-action scenario (conventional extensive aquaculture business)

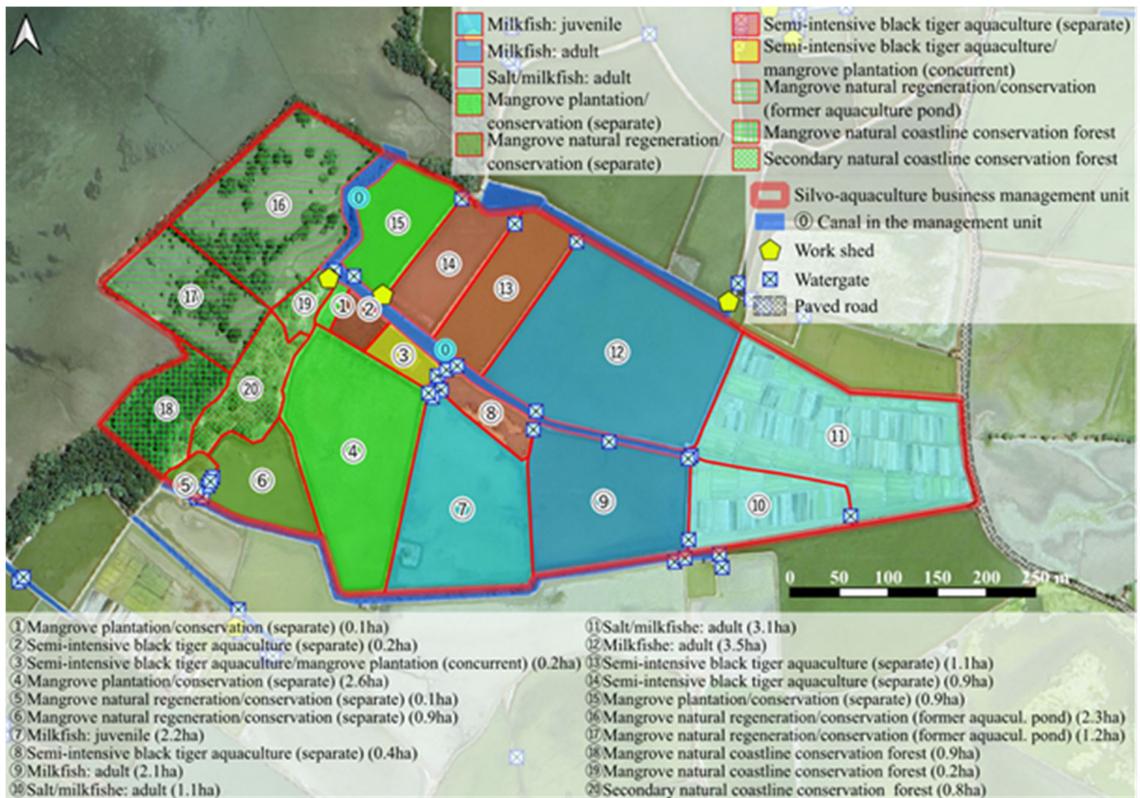


Figure 43: Specific structure of With-action scenario (introduction of silvo-aquaculture)

Table 45: Comparison of the specific structures of the Without-action scenario and the With-action scenario

Production site No.	Area (ha)	Without-action scenario (Extensive aq. business)		Change of production site type	With-action scenario (Silvo-aq. business)	
		Type of production site	Production and conservation activities in each production site		Type of production site	Production and conservation activities in each production site
0	0.73	Business infra. ^{*1}	Waterway		Business infra.	Waterway
1	0.08	Extensive aq. ^{*2} pond	Milkfish: juvenile fish	⇒	Plantation (Separate)	Mangrove plantation and conservation
2	0.21	Extensive aq. pond	Milkfish: juvenile fish	⇒	Aq. Pond (Separate)	Semi-intensive black tiger aquaculture
3	0.24	Extensive aq. pond	Milkfish: juvenile fish	⇒	Aq. Pond (Concurrent)	Semi-intensive black tiger aq./mangrove
5	0.14	Extensive aq. pond	Milkfish: juvenile fish	⇒	Plantation (Separate)	Mangrove NR&C
6	0.87	Extensive aq. pond	Milkfish: juvenile fish	⇒	Plantation (Separate)	Mangrove NR&C
8	0.37	Extensive aq. pond	Milkfish: juvenile fish	⇒	Aq. Pond (Separate)	Semi-intensive black tiger aquaculture
4	2.63	Extensive aq. pond	Milkfish: adult fish	⇒	Plantation (Separate)	Mangrove plantation and conservation
7	2.19	Extensive aq. pond	Milkfish: adult fish		Extensive aq. pond	Milkfish: juvenile fish
9	2.05	Extensive aq. pond	Milkfish: adult fish		Extensive aq. pond	Milkfish: adult fish
12	3.45	Extensive aq. pond	Milkfish: adult fish		Extensive aq. pond	Milkfish: adult fish
10	1.14	Salt/Ext. ^{*3} aq. pond	Salt production/milkfish: adult fish		Salt/Ext. aq. pond	Salt production/milkfish: adult fish
11	3.12	Salt/Ext. aq. pond	Salt production/milkfish: adult fish		Salt/Ext. aq. pond	Salt production/milkfish: adult fish
13	1.09	Extensive aq. pond	Vannam ei shrimp	⇒	Aq. Pond (Separate)	Semi-intensive farming: Black tiger
14	0.87	Extensive aq. pond	Vannam ei shrimp	⇒	Aq. Pond (Separate)	Semi-intensive farming: Black tiger
15	0.93	Extensive aq. pond	Glacilaria (seaweed)	⇒	Plantation (Separate)	Mangrove plantation and conservation
16	2.31	NF ^{*4} mgt. ^{*5} pond	Mangrove NR&C ^{*6} : aq. discontinued		NF mgt. pond	Mangrove NR&C: aq. discontinued
17	1.24	NF mgt. pond	Mangrove NR&C: aq. discontinued		NF mgt. pond	Mangrove NR&C: aq. discontinued
18	0.91	NF conservation site	Mangrove NFC ^{*7} : Coastal Forest		NF conservation site	Mangrove NFC*7: Coastal Forest
19	0.24	NF conservation site	Mangrove NFC: Coastal Forest		NF conservation site	Mangrove NFC: Coastal Forest
20	0.77	NF conservation site	Secondary forests and coastal forests		NF conservation site	Secondary forests and coastal forests
Total		25.59				

Note: 1) infra = infrastructure; 2) aq. = aquaculture; 3) ext. - extensive; 4) NF = natural forest; 5) mgt. = management; 6) NR&C = natural regeneration and conservation; 7) NFC: natural forest conservation

Table 46: Area ratio by production zone type in the Without-action scenario

Production site No.	Production site area (ha)	Type of production site	Production and conservation activities in each production site	Area and percentage by production site		Proportion of aquaculture and mangroves (%)
				area (ha)	ratio (%)	
0	0.73	Business infrastructure	Waterway	0.73	2.8%	2.8%
1	0.08	Extensive aquaculture pond	Milkfish: juvenile fish	12.25	47.9%	75.8%
2	0.21		Milkfish: juvenile fish			
3	0.24		Milkfish: juvenile fish			
5	0.14		Milkfish: juvenile fish			
6	0.87		Milkfish: juvenile fish			
8	0.37		Milkfish: juvenile fish			
4	2.63		Milkfish: adult fish			
7	2.19		Milkfish: adult fish			
9	2.05		Milkfish: adult fish			
12	3.45		Milkfish: adult fish			
10	1.14	Salt/extensive aquaculture pond	Salt/Milkfish: adult fish	4.26	16.6%	
11	3.12		Salt/Milkfish: adult fish			
13	1.09	Extensive aquaculture pond	Bannamei shrimp	1.96	7.7%	
14	0.87		Bannamei shrimp			
15	0.93	Extensive aq. ^{*1} pond	Glacilaria (seaweed)	0.93	3.6%	
16	2.31	Natural forest management pond	Mangrove NR&C ^{*2} : aq. discontinued	3.55	13.9%	21.4%
17	1.24		Mangrove NR&C: aq. discontinued			
18	0.91	Natural forest conservation area	Mangrove NFC ^{*3} : Coastal Forest	1.92	7.5%	
19	0.24		Mangrove NFC: Coastal Forest			
20	0.77		Secondary forests and coastal forests			
total	25.59			25.59	100.0%	100.0%

Note: 1) aq. = aquaculture; 2) NR&C = natural regeneration and conservation; 3) NFC = natural forest conservation

Table 47: Area ratio by production category for With-action scenario

Production site No.	Production site area (ha)	Type of production site	Production and conservation activities in each production site	Area and percentage by production site		Production site by group					
				area (ha)	ratio (%)	Production site group ratio (%)	Aquaculture/mangrove ratio (%)	Percentage to original pond size (%)			
⑩	0.73	Business Infrastructure	Waterway	0.73	2.8%	2.8%	2.8%				
⑦	2.19	Extensive aquaculture pond	Milkfish: juvenile fish	7.70	30.1%	57.6%	57.6%	76.0%			
⑨	2.05		Milkfish: adult fish								
⑫	3.45		Milkfish: adult fish								
⑩	1.14	Salt pond/extensive aquaculture pond	Salt/Milkfish: adult fish	4.26	16.6%	57.6%	57.6%	76.0%			
⑪	3.12		Salt/Milkfish: adult fish								
②	0.21	Aquaculture pond (Separate)	Semi-intensive black tiger aquaculture	2.54	9.9%	57.6%	57.6%	76.0%			
⑧	0.37		Semi-intensive black tiger aquaculture								
⑬	1.09		Semi-intensive black tiger aquaculture								
⑭	0.87		Semi-intensive black tiger aquaculture								
③	0.24	Aq. pond (Concurrent)	Semi-intensive black tiger aq./mangrove	0.24	1.0%						
①	0.08	Plantation (Separate)	Mangrove plantation and conservation	3.64	14.2%	18.2%	39.6%	24.0%			
④	2.63		Mangrove plantation and conservation								
⑮	0.93		Mangrove plantation and conservation								
⑤	0.14		Mangrove natural regeneration and conservation								
⑥	0.87	Mangrove natural regeneration and conservation	1.01	4.0%							
⑯	2.31	Natural forest management pond	Mangrove NR&C ² : aq. discontinued	3.55	13.9%	21.4%	39.6%	24.0%			
⑰	1.24		Mangrove NR&C: aq. discontinued								
⑱	0.91	Natural forest conservation site	Mangrove NFC ³ : Coastal Forest	1.92	7.5%				21.4%	39.6%	24.0%
⑲	0.24		Mangrove NFC: Coastal Forest								
⑳	0.77		Secondary forests and coastal forests								
Total	25.59			25.59	100.0%	100.0%	100.0%	100.0%			

Note: 1) aq. = aquaculture; 2) NR&C = natural regeneration and conservation; 3) NFC = natural forest conservation.

7.3.4 Setting Verification Items and Components for Management Scenario Comparison

(1) Setting Verification Items

Based on the management units of the silvo-aquaculture business model, we established the scope of verification necessary for comparing the Without-action and With-action scenarios. We defined specific verification items (a-l) for the pilot activities as shown in Table 48.

Table 48: Setting verification items necessary for comparing management scenarios

Items to confirm whether the With-action scenario can be a target for ESG investment		Verification item settings (Indicated as “under consideration” if not verified)
Evaluation of Environmental Aspects	Mangrove planting and conservation	a) Verify planting techniques by placing two mangrove species under different ground elevations and water management conditions b) Verify techniques from the perspective of interference between mangrove planting and shrimp aquaculture water management ³⁵ c) Investigate the carbon sequestration function of mangroves
	Enhancement of biodiversity	d) Verify the mutual relationship between mangroves and shrimp aquaculture in the same pond, focusing on macrobenthos e) Examine mangrove management approaches that enhance biodiversity based on surveys of existing mangrove plantations and natural forests

³⁵ The meaning of this “interference in water management” is that while concurrent and separate systems employ different water management methods, it involves verifying how each water management approach affects mangrove planting.

	Ecosystem service valuation	f) Verify the feasibility of implementing ecosystem service valuation
	Environmental price premium	Assuming a 10% price premium can be obtained, this case will not be verified
Socioeconomic Assessment	Introduction of profitable aquaculture technology	g) Verify semi-intensive aquaculture technology for black tiger shrimp targeting a farming density of 6 individuals/m ² h) If black tiger shrimp is not a suitable species for silvo-aquaculture, consider alternative farmed species i) Verify the introduction of traceable eco-feed
	Improving business profitability and sustainability	Financial analysis for both scenarios will be conducted based on the premise of improving business profitability and sustainability; therefore, this will not be a verification item
	Improving labor productivity and enhancing community benefits by avoiding unemployment	Since both scenarios maintain the same number of employees to avoid unemployment, and the With-action scenario further sets higher wages to meet this condition, this is not a verification item
Evaluation of Corporate Governance	Positive ecosystem service assessment in the With-action scenario, and disclosure of ecosystem service assessment information and production process traceability information	Assumes positive ecosystem service evaluation in the With-action scenario and incorporates information disclosure into the With-action scenario; therefore, not a verification item
With-action Scenario Validity and Dissemination Requirements	Appropriateness of setting the management unit for the silvo-aquaculture business model at approximately 20 ha	The management unit for the silvo-aquaculture business model was set using the local 25.59 ha for both scenarios and is already a prerequisite for verification; therefore, it is not a verification item
	Possibility of securing a 20ha management unit for the silvo-aquaculture business model	j) Verify the potential for expanding the management scale through leased ponds
	Existence of potential local partners to serve as managers of the silvo-aquaculture business model management units	k) Verify the existence of potential local partners
	Existence of a value chain for the produced goods	The product value chain is considered to already exist and is therefore excluded from verification items
	Verification of the existence of investment demand for ESG investments	l) Verify whether there is a demand for ESG investment

* Verification items are marked with a letter at the beginning of the sentence; items not subject to verification are unmarked.

(2) Water Management System for Aquaculture Ponds in the Pilot Activity

As previously stated, this pilot activity aimed to “establish and introduce a technical package enabling mangrove planting and shrimp aquaculture to be conducted within the same management unit without mutual interference.” Furthermore, verification item b) in Table 48 also specifies “verifying the technology from the perspective of interference between water management for mangrove planting and shrimp aquaculture.” For water management systems enabling mangrove planting/conservation and aquaculture within a single management unit, both approaches are viable: the separate system (described later), where mangrove planting and aquaculture occur in distinct ponds within the unit under independent water management, and the concurrent system (described later), where both activities occur in the same pond. In this pilot activity, both the concurrent and separate systems were implemented. Data was collected on mangrove survival rates, shrimp aquaculture productivity, water management methods, and the required labor patterns and quantities for each method. This allowed information to be gathered to make a comparison between the two methods from technical and management perspectives. The implementation methods and characteristics of silvo-

aquaculture under the concurrent and separate systems are as follows.

Concurrent System:

- Mangrove planting and shrimp aquaculture are conducted within the same pond.
- Mangroves supply nutrients to the shrimp pond, positively affecting seaweed growth. An increase in macrobenthos is expected in the soil around the mangroves and within the seaweed beds.
- Water management prioritizes shrimp aquaculture, maintaining a constant water level. This environment is not optimal for mangrove growth, raising concerns about reduced survival rates.
- The presence of mangroves within the ponds makes the silvo-aquaculture system visually recognizable.

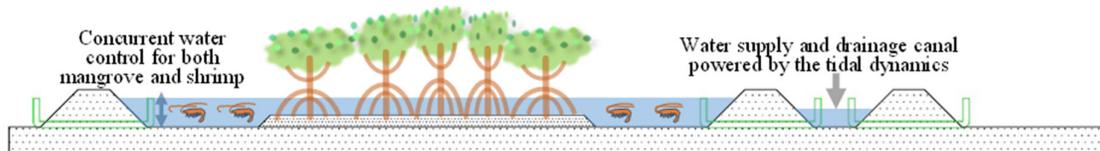


Figure 44: Schematic diagram of the concurrent system

Separate System:

- Mangrove planting and shrimp aquaculture are conducted in separate ponds.
- Nutrients from mangroves are not supplied to the shrimp ponds, potentially suppressing seaweed growth more effectively than in the concurrent system. The same applies to macrobenthos.
- Water management can be optimized separately for mangrove planting and shrimp aquaculture, potentially increasing shrimp production efficiency and mangrove survival rates compared to concurrent systems. However, there is no material cycle connection between mangroves and shrimp aquaculture; only the fact that mangroves were planted is emphasized. Consequently, concerns have been raised about the potential inability to obtain certifications like ASC certification and the possibility that carbon credits may not be recognized.

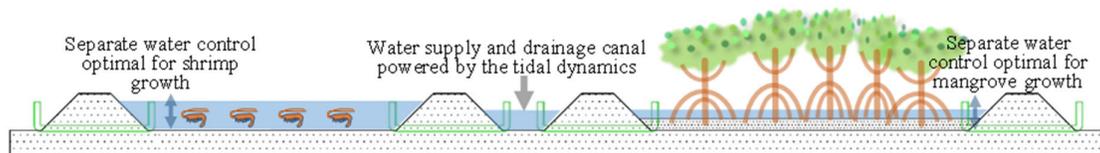


Figure 45: Schematic diagram of the separate system

(3) Pilot Activity Implementation Components and Verification Items for Each Component

To address the verification items set in the previous section, three components were organized based on the expertise of the study team members and BRIN researchers: the shrimp aquaculture component, the

mangrove planting component, and the socio-economic survey component. Pilot activities were conducted to verify the items assigned to each component as shown in the table below. Results verified in the Shrimp Aquaculture component are detailed in Section 7.6 of this report, results from the mangrove planting component are covered in Section 7.7, and findings from the socio-economic survey component are presented in Section 7.8. Furthermore, based on the verification results from these three components, we examined whether the With-action scenario adopting the silvo-aquaculture business model could be considered for ESG investment when compared to the Without-action scenario. The results of this examination are detailed in Section 7.7 of this report.

Table 49: Allocation of Verification Items by Component

Component/Verification Item (Indicated as "Under Consideration" if not verified)
<p>Shrimp Aquaculture Verification Component (Verification results described in Section 7.4 of this report)</p> <ul style="list-style-type: none"> d) Verify the mutual relationship between mangroves and shrimp aquaculture in the same pond, focusing on macrobenthos g) Verify semi-intensive aquaculture techniques for black tiger shrimp, targeting a stocking density of 6 individuals/m². h) If black tiger shrimp is not a suitable species for silvo-aquaculture, consider alternative species i) Verify the introduction of traceable eco-feed
<p>Mangrove Reforestation Verification Component (Verification results described in Section 7.5 of this report)</p> <ul style="list-style-type: none"> a) Verify planting techniques by placing two mangrove tree species under different ground elevations and water management conditions b) Verify techniques from the perspective of interference between mangrove planting and shrimp aquaculture water management c) Investigate the carbon sequestration function of mangroves e) Examine directions for mangrove management practices that enhance biodiversity based on surveys of existing mangrove plantations and natural forests
<p>Socioeconomic Survey Component (Verification results described in Section 7.6 of this report)</p> <ul style="list-style-type: none"> f) Verify the feasibility of implementing ecosystem service assessments j) Verify the potential for expanding management scale through leased ponds k) Verify the existence of potential local partners l) Verify whether there is a demand for ESG investment

*The initial letters at the beginning of each verification item correspond to the letters in the verification items in Table 48.

7.3.5 Establishment of Verification Sites and Design of Verification

As previously stated, the design and verification content for each verification site in this pilot activity were significantly altered due to the organizational restructuring in the government of Indonesia. Here, we first describe the design and verification content for the technical verification site and social verification site as outlined in the local subcontract agreement with BRIN prior to organizational restructuring. Subsequently, we describe the design and verification implementation policy for both sites during direct implementation by the investigation team following restructuring.

(1) Technical Verification Site Design (Design Prior to Organizational Restructuring)

Technical verification ponds, as shown in Figure 46 and Figure 47, were established at the RICAFE experimental aquaculture ponds in the Marana District, Maros Regency, South Sulawesi Province. These ponds were used to verify and systematize appropriate production technologies for silvo-aquaculture,

including mangrove planting, shrimp production, and water management, and to assess the technical feasibility of silvo-aquaculture. Figure 46 shows the overall layout of the verification ponds including the water management system, while Figure 47 show the 12 individual verification ponds. Each individual verification pond has an area of approximately 465 m². The silvo-aquaculture technologies verified and established in the technical verification ponds will be applied to the operation and management of the social verification ponds to be established in Pangkep Regency. The survey results will be reflected in the verification of the business model concerning the technical aspects and investment analysis³⁶.

³⁶However, due to the impact of organizational restructuring in the government of Indonesia after December 2024, implementing shrimp aquaculture in the technical verification ponds became difficult, making comparative shrimp aquaculture trials impossible. Therefore, based on the results of the first cycle of shrimp aquaculture, which could be verified in the technical verification ponds, it was decided to adapt the approach to what could be implemented in the social verification ponds. Regarding the monitoring of already planted mangroves, RICAFE permitted its continuation in the technical verification pond. Therefore, monitoring will continue in both the technical verification pond and the social verification pond. However, the cessation of shrimp aquaculture led to a lack of water management, resulting in the water environment of the technical verification pond becoming extremely harsh for mangrove planting.



Figure 46: Overall configuration including the water management system for the technical verification ponds

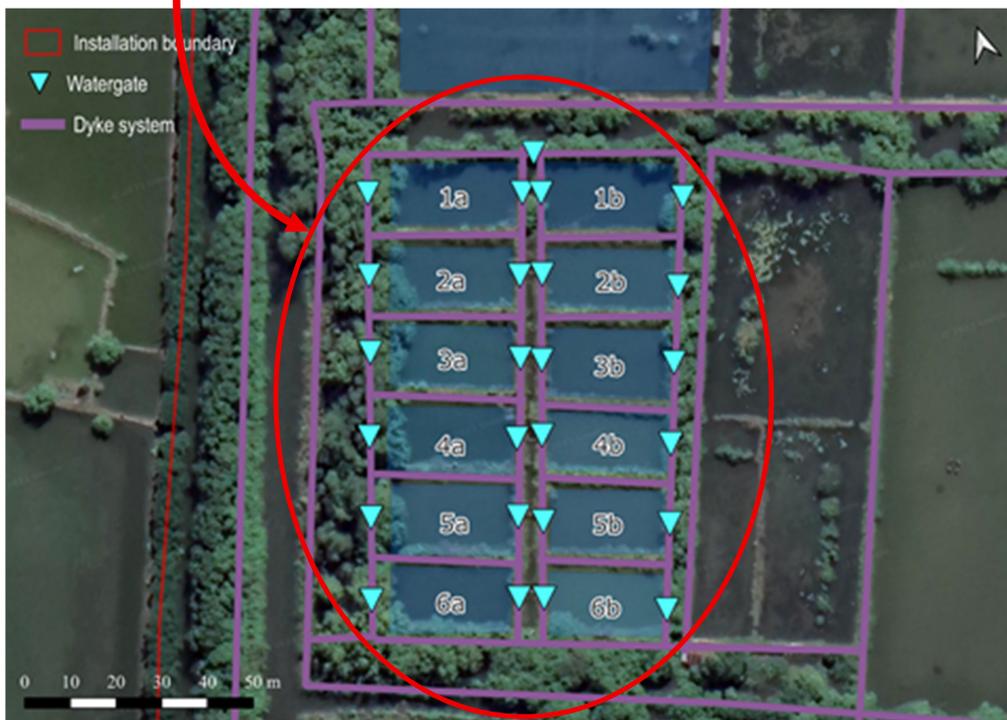


Figure 47: Installation of 12 technical verification ponds

Figure 48 shows the technical verification design for the 12 technical verification ponds. Regarding the technical verification conducted in each pond, the verification elements are two types of water management methods, two shrimp stocking densities (3 individuals/m² and 6 individuals/m²), and the presence or absence of traceable eco-feed. Combining these elements, the technical verification design shown below was

determined to enable verification of the differences in effects caused by these elements. The introduction of *Gracilaria* seaweed was implemented for two reasons: to purify the eutrophicated water in each pond and to provide shelter for macroinvertebrates, which serve as shrimp feed, thereby potentially increasing macroinvertebrate supply. Increased nighttime oxygen consumption was considered to be a potential negative impact of *Gracilaria* introduction on shrimp aquaculture. Therefore, monitoring was conducted to ensure dissolved oxygen levels did not fall below a certain threshold.

Regarding water management, we decided to evaluate two methods: the concurrent system and the separate system. Additionally, as shown in Figure 46, we applied a system circulating water in one direction. This ensures the pond receives fresh water rich in dissolved oxygen while reducing the amount of organic matter excreted by farmed shrimp that remains and settles in the pond. In other words, implementing this water management approach was expected to improve shrimp productivity.

1a Purification-grade <i>Gracilaria</i>	1b Purification-grade <i>Gracilaria</i>	} Concurrent System
2a 6 individuals/m ² , <i>Gracilaria</i> Eco-feed present Mangrove planting in pond center	2b 6 individuals/m ² , <i>Gracilaria</i> No eco-feed Mangrove planted in pond center	
3a 3 individuals/m ² , <i>Gracilaria</i> Eco feed present Mangrove planting in pond center	3b 3 individuals/m ² , <i>Gracilaria</i> No eco-feed Mangrove planted in pond center	
4a 6 individuals/m ² , <i>Gracilaria</i> Eco feed present No mangroves	4b 6 individuals/m ² , <i>Gracilaria</i> No eco feed No mangroves	
5a 3 individuals/m ² , <i>Gracilaria</i> Eco feed present No mangroves	5b 3 individuals/m ² , <i>Gracilaria</i> No eco feed No mangroves	
6a No shrimp aquaculture, no <i>Gracilaria</i> Mangrove planted across entire pond Water management by natural tides	6b 6 individuals/m ² , no <i>Gracilaria</i> No eco-feed No mangroves	

Figure 48: Technical verification design in the 12 technical verification ponds

For shrimp aquaculture, we aimed to improve aquaculture techniques by evaluating the contribution of two types of water management and improved feeding quality to increase ecosystem services within the ponds. We also planned to measure and analyze the increase in yield per unit area and the resulting improvement in labor productivity. Based on observations by an expert team of pond owners and operators in South Sulawesi, increased yield and labor productivity are considered the minimum requirements for this model to be adopted. Therefore, the target for increasing farmed shrimp yield was set at 100%, and a productivity comparison was conducted between juvenile shrimp stocking densities of 3 individuals/m² and 6 individuals/m². As a method to increase yield per unit area, the application of artificial pellet feed (eco-feed) manufactured through a traceable production process using locally available, inexpensive organic materials was verified.

For mangrove planting, we evaluated the survival rate and growth of two mangrove species (*Rhizophora*

mucronata and *Bruguiera gymnorrhiza*) planted using both the concurrent and separate systems. We also verified the potential of these methods to not interfere with the natural regeneration of *Avicennia* and other mangrove species. However, since the 1.5-year survey period only covered the early growth stage of the mangroves, the data obtained from this survey was supplemented by measurements of the condition of established mangrove plantations within the RICAFE area (27 years old as of 2023) by the study team. The data obtained was used to complement the verification.

(2) Design of the Social Verification Site (Design prior to organizational restructuring)

As shown in Figure 49, the social verification ponds were established within the management unit of the silvo-aquaculture business model set up in the Bontomanai District. Simultaneously, within this management unit, transect survey areas for natural mangrove forests and natural mangrove regeneration were established. The results of vegetation surveys in these areas were referenced to consider the direction of mangrove management practices.

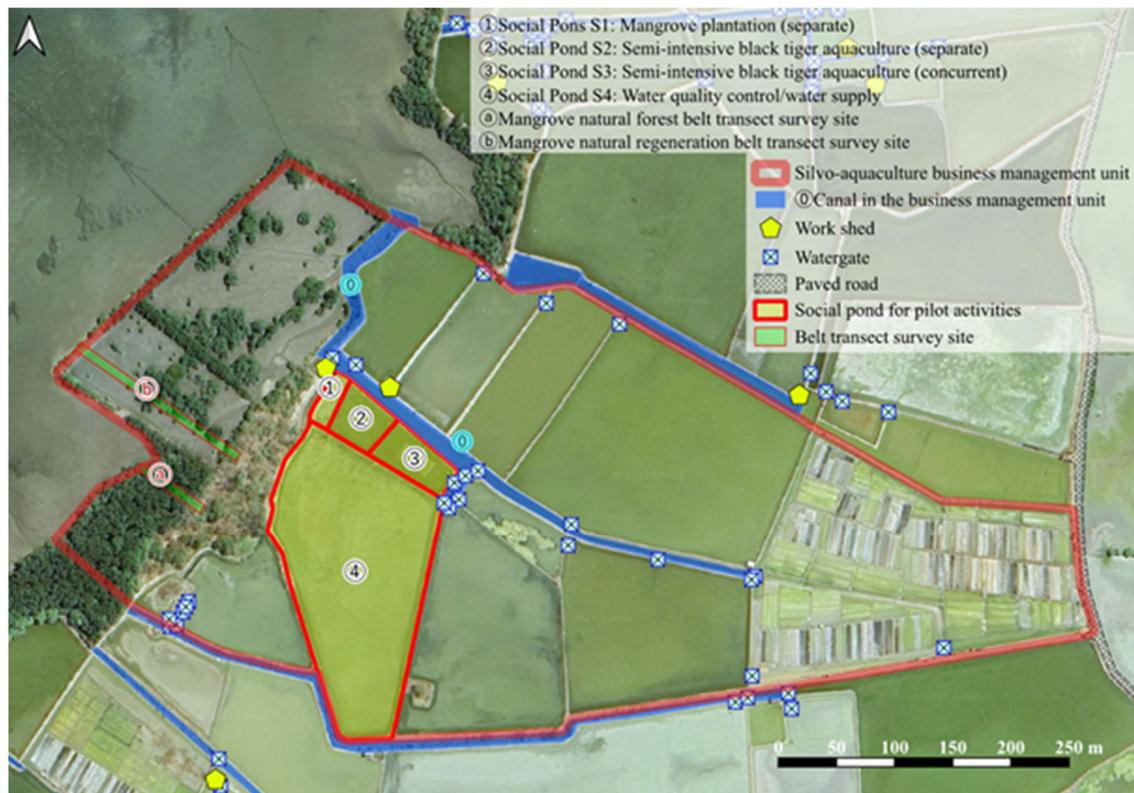


Figure 49: Social verification ponds and belt transect survey areas established within the business model management unit

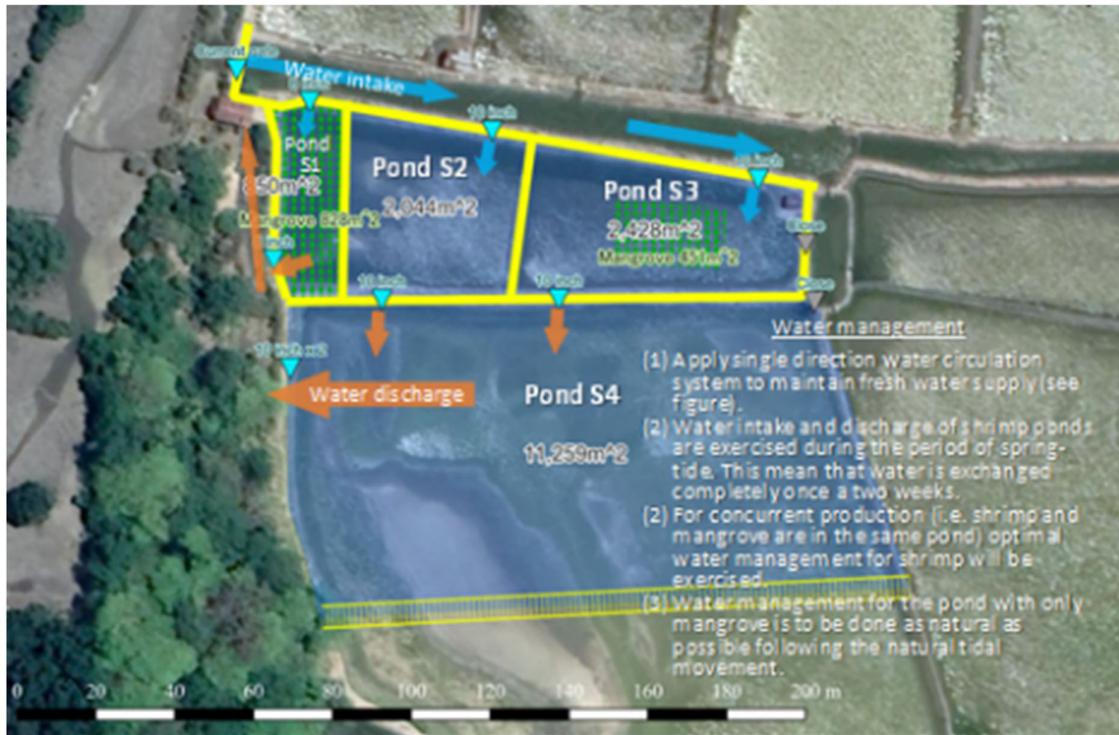


Figure 50: Technical verification design in the social verification pond

The candidate ponds for the social verification pond were privately owned. To implement pilot activities there, it was necessary to lease them for a certain period. Furthermore, it was necessary to modify the pond design from its current state to implement the pilot activities. Therefore, when negotiating to lease the privately-owned ponds, a trust-building meeting was held with participation from local residents, relevant individuals and companies, and the local government. The pilot activities were explained to seek their understanding and cooperation. Through these meetings, the pond owner and manager were identified, with the latter becoming the local partner for the pilot activity.

Figure 50 and Figure 51 show the technical verification design in the social verification pond. Here, too, since it was important to verify the effectiveness of the control method that circulates water in one direction, modifications and alterations to the pond were made to achieve this. In the verification pond, we verified the following components belonging to the shrimp aquaculture verification component: d) Verification of the mutual relationship between mangroves and shrimp aquaculture in the same pond, focusing on macrobenthos; g) Verification of semi-intensive aquaculture technology for black tiger shrimp, targeting a farming density of 6 individuals/m²; and i) Verification of the introduction of traceable eco-feed.

Additionally, for the mangrove planting component, the following verification items were addressed: a) Verifying planting techniques by placing two mangrove species under different water management systems (concurrent vs. separate systems); b) Verifying techniques considering interference between mangrove planting and shrimp aquaculture water management; c) Examining the carbon sequestration effect of mangroves; and e) Based on surveys of existing mangrove plantations and natural forests, exploring directions for mangrove management practices that enhance biodiversity.

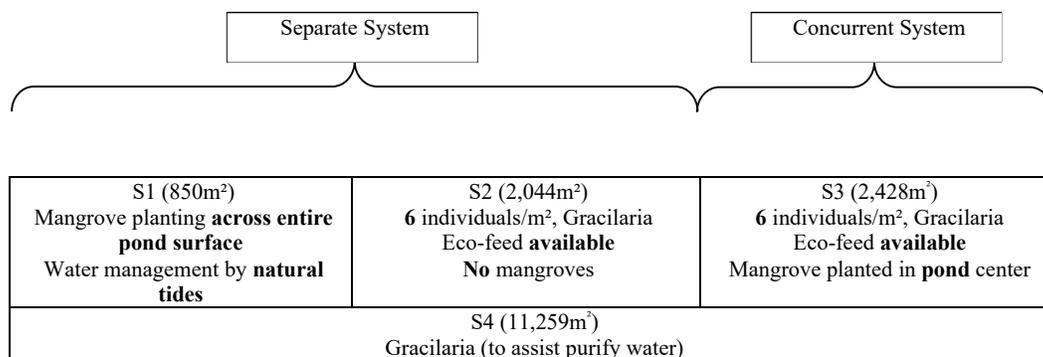


Figure 51: Technical verification design for social verification pond

(3) Verification Items in Each Verification Pond Following Organizational Restructuring in the Government of Indonesia

As previously stated, in the pilot activities directly managed by the study team after the termination of the local subcontracting agreement, technical verification tests for shrimp aquaculture could no longer be conducted in the technical verification ponds loaned by RICAFE. Therefore, based on the verification results from the first cycle in the technical verification ponds, adjustments were made to the verification items, and the decision was made to continue verifying the items to the extent possible in the social verification sites. The verification content is as shown in the table below.

Table 50: Initial Verification Items for the Technical Verification Pond and Verification Implementation Policy for the Social Verification Pond under Direct Management by the Investigation Team

Verification Items in the Technical Verification Pond	Continuation Feasibility	Verification Implementation Policy in the Social Verification Pond
1. Comparative verification test on shrimp rearing conditions and growth status		
① Relationship between shrimp growth and presence/absence of mangroves	△	Although the comparison is limited to specific conditions (one plot with mangroves and one without), verification will continue.
② Comparison of shrimp stocking Density (3 individuals/m ² vs. 6 individuals/m ²)	×	Due to the unavailability of the technical verification ponds, which were subdivided into small plots for comparative testing of verification items, comparative tests on growth conditions corresponding to items ② to ④ cannot be conducted. However, results from the first cycle revealed that cannibalism occurs as shrimp grow. This led to the conclusion that managing stocking density after release is more important than fixing the initial stocking density. Therefore, the initial stocking density will be set at 6 individuals/m ² . Shrimp that reach market size will be harvested to manage density, and feed will be provided according to shrimp size and density. The correlation between feed amount and harvest yield will be verified to achieve optimization.
③ Relationship between shrimp growth and presence/absence of feed supply		
④ Shrimp growth status under the conditions of mangrove presence, shrimp aquaculture density, and feed administration/non-administration Evaluation of optimal technology based on the results		
2. Measurement of Parameters Affecting Shrimp Growth		
① Measurement of seasonal variation in species composition and quantity of macroinvertebrates serving as natural shrimp feed	○	Based on results from the technical verification pond, data collection will continue in the social verification pond to verify the annual cycle of species composition and quantity of natural shrimp feed.

② Correlation between shrimp growth and dissolved oxygen	○	Based on results from the technical verification pond, we will also introduce Gracilaria (red algae) into the social verification pond, enhance dissolved oxygen monitoring, and verify measures to prevent shrimp mortality due to dissolved oxygen deficiency.
③ Correlation between shrimp growth and water temperature	○	Based on results from the technical verification pond, we will enhance water temperature monitoring in the social verification pond and verify measures to prevent shrimp mortality due to high water temperatures.
④ Correlation between shrimp growth and salinity	○	Based on results from the technical verification pond, we will strengthen salinity monitoring in the social verification pond and verify measures to prevent shrimp mortality due to high salinity.
⑤ Function of providing a habitat for Gracilaria	○	Gracilaria is expected to play a role in providing feeding and shelter for macroinvertebrates, as well as shelter for juvenile shrimp. Therefore, verification of these functions will also be considered.

7.4 Silvo-Aquaculture (Shrimp Aquaculture) in the Pilot Activity

7.4.1 Silvo-Aquaculture Method in the Pilot Activity

① Pond Types

There are three main types of silvo-aquaculture ponds in Indonesia:

- (1) Ponds that are separated from the mangrove forest by a dike (*kao-kao*) (Figure 52).
- (2) Ponds that use channels or ditches around a platform planted with mangroves (*empang parit*) (Figure 53).
- (3) Ponds that have a larger shrimp aquaculture area than *empang parit*. The mangrove planting area is located in the pond without separation by dykes (*komplangan*) (Figure 54).

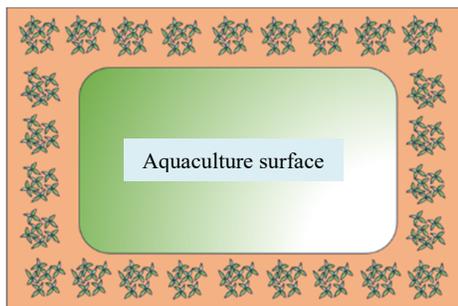


Figure 52: Kao Kao

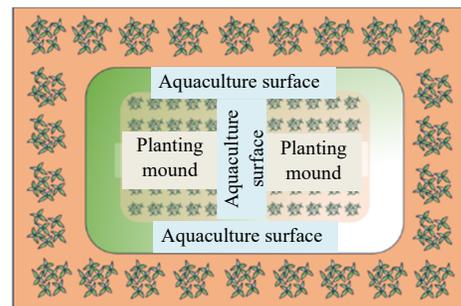


Figure 53: Empang Parit

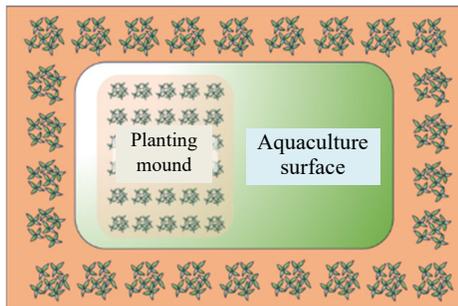


Figure 54: Komplangan

With regard to *empang parit*, it is not that starting by planting mangroves, but that a section of the area where mangroves originally existed was cleared to create a narrow aquaculture surface, resulting in a single clump of mangroves in the middle of the pond. For this reason, it is not expected to start by planting mangroves in an area where there are no mangroves at all, but the point is to utilize mangroves originally existed. *Komplangan* has been created to take advantage of the knowledge gained from *empang parit* that the presence of mangroves promotes the growth of target aquaculture species, and to ensure a large aquaculture surface. Therefore, it can be said that the any methods including mangrove planting in aquaculture surface are *komplangan*. The circumstances surrounding the formation of *kao kao*, which allow for the maximum amount of aquaculture surface, are unknown. It is also unclear whether the target aquaculture species and aquaculture methods differ for each of these types.

In this pilot activity, the "concurrent system" and "separate system" were adopted for the purposes of verifying how the presence of mangroves in direct contact with the culture water is related to promoting the growth of black tiger shrimp, obtaining a certain level of harvest, and confirming the survival and growth of mangroves in aquaculture ponds where the water level is kept constant and ponds where the water level fluctuates due to natural tides. The relationship between these methods and the three forms above can be summarized as follows:

Concurrent system: An application of the *komplangan* method that involves aquaculture and mangrove plantations in shared water. Furthermore, water levels are maintained at a certain level to prioritize shrimp culture and ensure a consistent shrimp harvest.

Separate system: From the perspective of aquaculture, this method is similar to the *kao kao* method in that aquaculture and mangrove plantations are separate and do not share water. However, from the perspective of mangrove plantations, the separate system, in which mangroves are planted in ponds, is completely different from the *kao-kao* method, in which mangroves are planted on dikes. The separate system optimizes water level management for aquaculture and mangrove plantations separately (keeping the water level constant for aquaculture, and relying on natural tides for mangrove plantations), thereby optimizing the growth of both. Additionally, by planting mangroves within the same management unit for aquaculture, the aim is to add value to the aquaculture species by contributing to the environment, while the mangrove plantations also aim to generate carbon credits through successful growth.

The monitoring items are qualitative and quantitative changes in the water quality of the farm ponds and the organisms that serve as food for the shrimp.

② Target species and conditions for culture

The target species was native black tiger shrimp. Post larvae 12-day-old (PL-12) (the typical growth stage of commercially available shrimp larvae) were purchased, and were reared in tanks for an additional 35 days (nursing) before being released into the ponds (nursing and rearing are described in the next section, ③). The *Gracilaria* was applied at a density of 100g per square meter to provide shelter for the shrimp and better quality of water. Furthermore, milkfish as an algal feeder, was released at a density of approximately 0.05 fish per square meter to suppress the growth of the green algae *Rhizoclonium*, which competes with *Gracilaria*. After release, the shrimp was allowed to feed on naturally-occurring plankton and macrobenthos for a period of time before being fed with formulated feed once they had reached a certain age.

③ Nursing and stocking

PL12 purchased from hatcheries are small and have a poor ability to capture prey and to escape from predators. Therefore, they require nursing in tanks before being released into earthen ponds. In this pilot project, circular canvas tanks with a capacity of approximately 5 tons were installed for post-larval nursing. A diaphragm air pump was



Figure 55: Shrimp nursing tank and brine shrimp larva

used for aeration to ensure sufficient dissolved oxygen and to promote water flow (Figure 55). Powdered formulated feed was used as larval feed, but live brine shrimp nauplii (*Artemia nauplii*) were provided to promote the post-larvae growth of the shrimp in the latter half of the nursing period.

Prior to stocking the pond with juvenile shrimp, the water temperature, salinity, and pH of the earthen pond was measured, and the water in the nursing tank was adjusted as close as possible to the water parameters of the earthen pond. Acclimation was also performed in the rearing pond just before releasing (Figure 56). After release, the juveniles were monitored by nighttime observation using flashlights (Figure 57). Black tiger shrimp are nocturnal, so they move around the pond after dark to search for food.



Figure 56: Shrimp acclimation at the stocking pond



Figure 57: Juvenile shrimp observed in a pond at night

7.4.2 Overview of the Aquaculture Cycle

① Layout of the Technical Verification Ponds and Aquaculture Conditions

The technical verification ponds consisted of small ponds arranged in rows (rows A and B), each approximately 500 m² in area. Ponds 2A and 2B and 3A and 3B had central terraces where mangrove seedlings were planted. On the other hand, mangroves were not planted in ponds 4A and 4B and 5A and 5B (details are provided in Figure 48 in 7.3.5).

② Water Quality Measurements

In-situ water quality measurements included water temperature, salinity, hydrogen ion concentration (pH), and dissolved oxygen (DO), and were measured daily. (Detailed water quality measurement results are provided in Appendix 6: Pilot Activity Data Collection.) The impact of each water quality parameter on shrimp survival is as follows:

Table 51: Water quality parameters and effects on shrimp survival

Water quality parameter	Effect on shrimp
Water temperature	Temperatures above 37°C are beyond the limit of shrimp survival.
Salinity	Normal seawater is 30 ppt, and anything above 45 ppt is dangerous for shrimp.
Dissolved oxygen (DO)	It fluctuates throughout the day, generally reaching its lowest point between 6 a.m. and 8 a.m. and its highest point between 3 p.m. and 5 p.m. Values below 3 mg/L are in the danger zone for shrimp.
Potential of hydrogen (pH)	Seawater is always slightly alkaline, at around pH 8 to 8.5. pH is also an indicator of the presence of harmful ammonia, and if it exceeds 8.5, ammonium ions convert into ammonia gas, which becomes toxic and dangerous.

③ First Culture Cycle

The first culture cycle took place for approximately three months from August 30 to November 27, 2023. Traps were set approximately every two weeks, and the shrimp were measured for weight (Figure 58). Samples could no longer be taken from shrimp in 4A after 30 days from stocking, and shrimp were assumed to have died. Samples taken 75 days after stocking showed that shrimp in 2B, 3A, 4B, 5A, and 5B had reached the retail size of 20 g. Shrimp surviving until the final day, day 105, were in 2A, 2B, 3B, 4B, and 5B, but most had died, making it impossible to accurately determine the harvest volume.

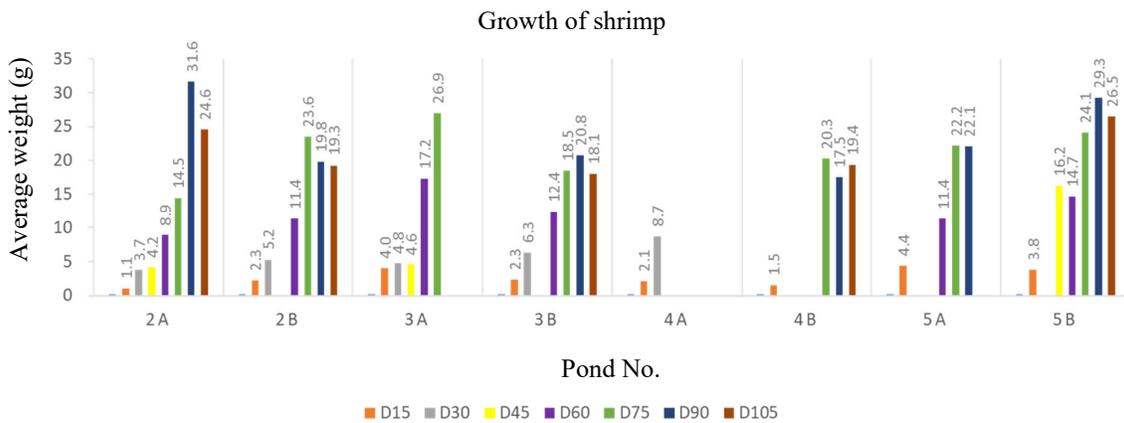


Figure 58: Weight of shrimp in each pond

The status of each water quality item in the first culture cycle and its impact on shrimp are shown below.

**Table 52: Status of Water Quality Parameters
(Technical verification pond, 1st aquaculture cycle)**

Water quality parameter	Status	Impact on shrimp
Water temperature	The temperature remained around 30°C until mid-October, but then rose. In November, there were days when it exceeded 35°C. In late November, there were several days when it exceeded 37°C.	The water temperature reached a dangerous level in late-November, and many shrimp died.
Salinity	When aquaculture started, the level was already high at 40 ppt. By October, it exceeded 50 ppt, and by November it exceeded 60 ppt.	Shrimp were exposed to dangerous salinity levels throughout the entire period.
Dissolved oxygen (DO)	When aquaculture began, many ponds had levels of around 4 mg/L, but, from October onwards, they have remained in the dangerous range below 3 mg/L.	It has been in the dangerous range since October.
Hydrogen ion concentration (pH)	It was neutral and there were no abnormalities in the pH value.	No impact on shrimp.

④ Second Culture Cycle

The second culture cycle was carried out for two months from December 18, 2023 to February 19, 2024, and all shrimp eventually died.

**Table 53: Status of Water Quality Parameters
(Technical verification pond, 2nd aquaculture cycle)**

Water quality parameter	Status	Impact on shrimp
Water temperature	From mid-December to mid-January, temperatures fluctuated between 30 and 35°C but remained stable, never exceeding 37°C. From mid-January to mid-February, temperatures were pleasant, fluctuating between 25 and 30°C.	The entire period was kept out of the danger zone.
Salinity	From mid-December to early January, salinity remained stable at approximately 30 ppt, but then began to decline, dropping to approximately 10 ppt by late January.	The entire period was kept out of the danger zone.
Dissolved oxygen (DO)	From mid-December to mid-January, there were many days when DO was below 3 mg/L. After that, it improved and was generally in the safe zone.	It appears that all the shrimp died during the first half of the hypoxic period.
Hydrogen ion concentration (pH)	It generally ranged from 7 to 8 throughout the entire period.	No impact on shrimp.

⑤ Social Verification Pond: First Aquaculture Cycle (September to November 2023)

Of the social verification ponds, S2 is a brackish pond with a water surface area of 2,044 m², and S3 is a

brackish pond with a water surface area of 2,428 m². A trapezoidal mound was constructed in the center of S3 for mangrove planting. The top of the mound is generally always submerged, but the water depth in that area is always shallow, just under 30 cm. Since technical data acquisition from the social verification ponds was not planned until early 2024, detailed data on water quality, etc., was not available.

From September to November 2023 (approximately two months), some data on water temperature, salinity, and pH was obtained. The details are as follows.

**Table 54: Status of Water Quality Parameters
(Social verification pond, 1st aquaculture cycle)**

Water quality parameter	Status	Impact on shrimp
Water temperature	The water temperature was 30 to 33°C.	No impact on shrimp
Salinity	The level was over 50 ppt.	Dangerous for shrimp
Dissolved oxygen (DO)	Not measured	Unknown
Hydrogen ion concentration (pH)	It was generally in the range of 8 to 9.	No impact on shrimp

⑥ Social Verification Pond: Second Aquaculture Cycle (Approximately three months from November 2024 to February 2025)

This was the first aquaculture cycle since the project shifted to a direct management system, and the social verification pond was renovated and staffing was improved. During this aquaculture cycle, disease outbreaks and flooding in December resulted in the loss of almost all shrimp. The water quality data was interpreted and analyzed as follows.

**Table 55: Status of Water Quality Parameters
(Social verification pond, 2nd aquaculture cycle)**

Water quality parameter	Status	Impact on shrimp
Water temperature	The lowest water temperature was recorded at 6:00 AM and the highest at 4:00 PM, with temperatures generally somewhere in between at 10:00 PM. In November, there were many days when the temperature exceeded 35°C at 4:00 PM, and on November 25th, both ponds reached nearly 39°C. In December, there were many days when the water temperature was around 31°C, and even on the hottest days, it rarely exceeded 35°C.	The high temperatures in November are harsh on shrimp, and the 39°C water temperature on the 25th in particular is thought to have been lethal.
Salinity	In November, the salinity was 45-50 ppt. Even the reservoir from which water was being taken was only 40 ppt, making it difficult to lower the salinity in the aquaculture ponds by supplying water. Rain began to fall in late November, causing a rapid drop in salinity, and on December 20th, heavy rain caused flooding. After that, the salinity in the aquaculture ponds stopped decreasing at around 5 ppt. This condition continued until the end of January 2025.	November is a tough month for shrimp, and the sudden drop in salinity from late November may have caused stress to the shrimp.

Dissolved oxygen (DO)	The lowest DO value was recorded at 6:00 and the highest value at 16:00, with an intermediate value at 22:00. In this pilot project, the pond water was agitated using a screw from night to early morning, and efforts were made to ensure that the minimum value did not fall below 3 mg/L. As a result, DO was consistently maintained at 3 mg/L or above from early November to the end of January.	No impact on shrimp
Hydrogen ion concentration (pH)	The pH was generally below 8.5 from early November to mid-December, but frequently exceeded 8.5 thereafter.	It had been in a dangerous state since mid-December.

⑦ Social Verification Pond: Third Culture Cycle (Approximately 3 Months from March 2025 to June 2025)

Purchased post-larvae (PL12) black tiger shrimp were nursed in campus tanks at the edge of the social verification pond starting in February, and then released into ponds S2 and S3 on March 12. Learning from previous lessons, the number of researchers was increased to improve data accuracy. Furthermore, since this was essentially the first and final trial during the optimal culture period between the rainy and dry seasons, the shrimp survived until the end of the 98-day monitoring period, allowing for the collection of ample growth data.

Shrimp Growth Test Monitoring (98 Days)

Sampling was conducted approximately every two weeks to monitor changes in average shrimp weight over time. A comparison of the pond without mangroves (S2) and the pond with mangroves (S3) revealed that shrimp were almost always larger in the pond with mangroves (S3) than in the pond without mangroves (S2) except on Day 70. In the final sample on Day 98, the average weight of shrimp in the pond without mangroves (S2) was 14.6 g, while that in the pond with mangroves (S3) was 25.85 g (1.77 times heavier). This demonstrates faster growth in the pond with mangroves (Figure 59).

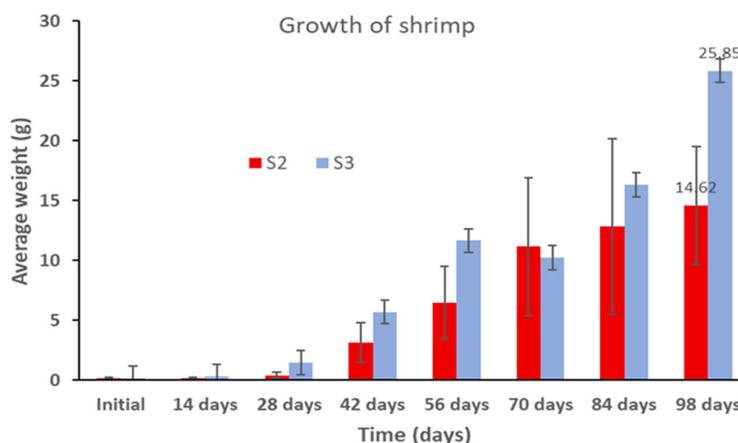


Figure 59: Growth of shrimp in S2 and S3 ponds

Frequency Distribution of Individual Weight Classes

Regular samples were divided into weight classes and frequency distributions were examined (Figure 60). Just before stocking (March 12), there was an approximately normal distribution of juvenile shrimp weights with a mode of 0.10–0.19 g. Two weeks later (March 27), the mode in the pond without mangroves was 0.10–0.19 g, with a range of 0–0.49 g. In contrast, in the pond with mangroves, the mode was 0.20–0.29 g, with many between 0.30–0.39 g, and the range was also wide, from 0.1–0.69 g. Two weeks later (April 10), the mode in the pond without mangroves was 0.90–0.99 g, with a range of 0.60–1.69 g. On the other hand, the mangrove pond showed no significant range and showed a wide range of 0.60 to 3.49 g. Two weeks later (April 24th), the same trend was observed, with the mangrove pond showing a wide range of 0.00 to 16.99 g, while the mangrove pond showed a range of 0.00 to 7.99 g.

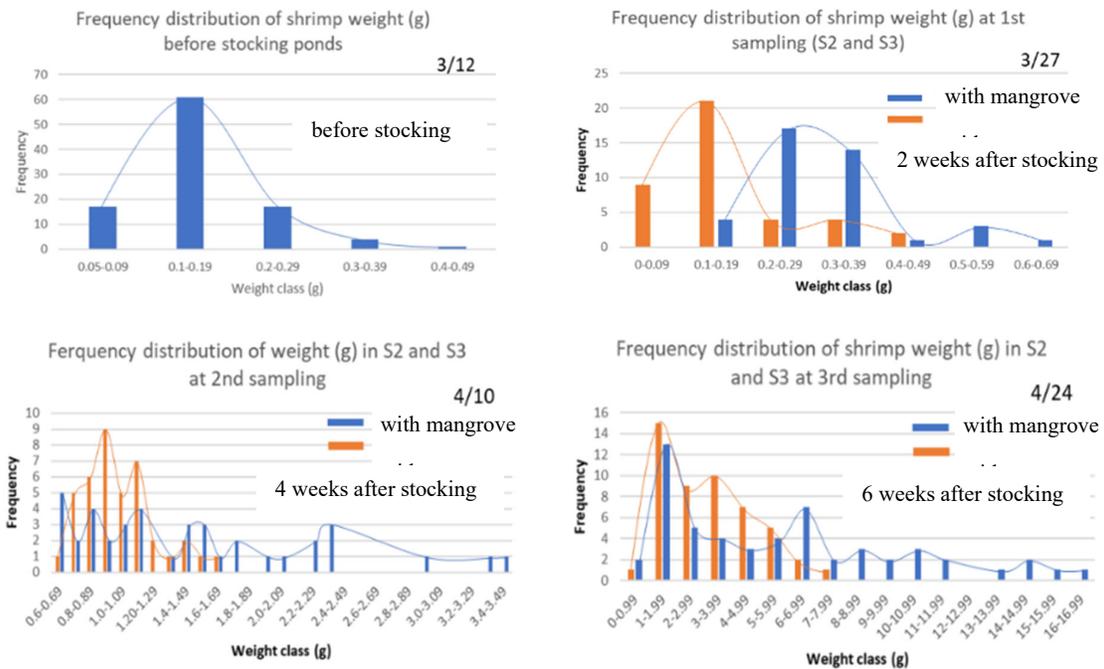


Figure 60: Frequency distribution of weight class (g) in S2 and S3 ponds from pre-stocking until 6 weeks after stocking

At the time of harvest (June 19th), the mode was in the 14g class for S2, and, in S3, the mode was in the 25g class (Figure 61). Even though the same batch of juvenile shrimp was used and there was not much difference in the water quality parameters, the reason for the difference in the mode between S2 and S3 can only be attributed to differences in the quantity and quality of food. In other words, there is a difference in the quantity and quality of the macrobenthos, which is the shrimp's main food source.

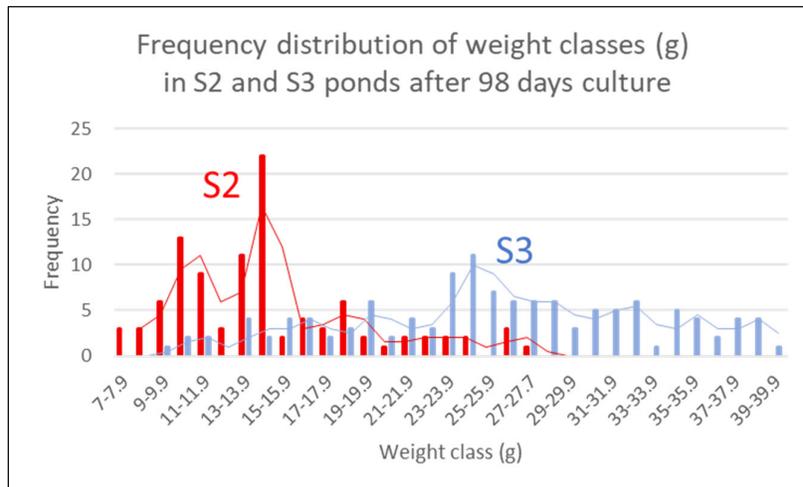


Figure 61: Frequency distribution of weight class (g) in S2 and S3 ponds after 98 days culture

Macrobenthos Occurrence Trends

Examining the macrobenthos occurrence trends during the cycle (March through June) in ponds S2 (without mangroves) and S3 (with mangroves) reveals that the stenothyrid snail occurred twice as much in pond S3 (with mangroves) as in pond S2 (without mangroves) (Figures 62 and 63). The snail may utilize mangrove trunks and aerial roots to remain near the water surface, where it feeds and reproduces. Indeed, numerous veliger larvae (a common larval form in mollusks) were observed more in pond S3 than in pond S2. There was also evidence of shrimp feeding on these veligers (Figure 64). Therefore, it is likely that the presence of mangroves indirectly promoted shrimp growth. On the other hand, it was also confirmed that tiger shrimp were preying on batillariid snails outside of this cycle. However, since this macrobenthos exists regardless of whether mangroves are present or not, the correlation between the total amount preyed on and the shrimp growth rate is still unknown.

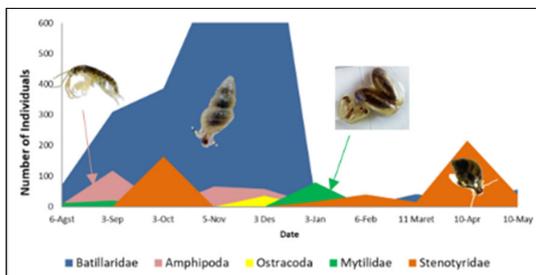


Figure 63: Macrobenthos in Pond S2

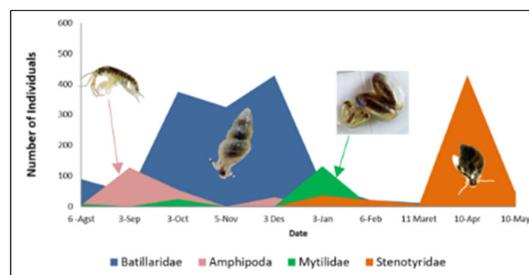


Figure 62: Macrobenthos in Pond S3

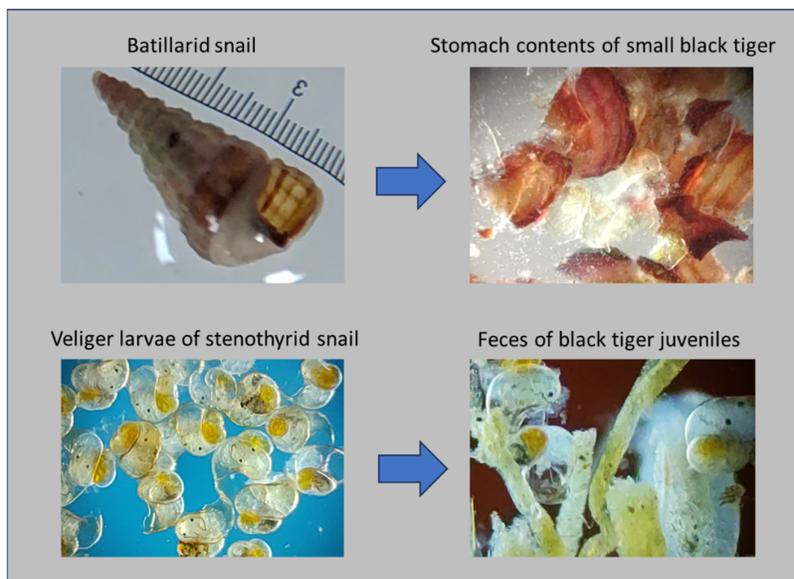


Figure 64: Snails found in the stomach contents and feces of black tiger shrimp

Water Quality Monitoring

Water quality monitoring analysis for the aquaculture cycle from March to June 2025 was conducted as follows.

**Table 56: Status of Water Quality Parameters
(Social verification pond, 3rd aquaculture cycle)**

Water quality parameter	Status	Impact on shrimp
Water temperature	Throughout the entire period, temperatures fluctuated between approximately 30°C and 35°C.	No impact
Salinity	Throughout the entire period, the salinity remained stable at a low level of around 10 ppt.	No impact
Dissolved oxygen (DO)	By using a screw to appropriately agitate the pond water, it was possible to maintain a constant concentration of 4 mg/L or more.	No impact
Hydrogen ion concentration (pH)	From early March to early April, the pH remained below 8.5, but from April 3rd it suddenly rose, reaching nearly 9.0 in S2 and exceeding 9.5 in S3.	It was in a dangerous state since April

The reason for the higher increase in pH in S3 is thought to be that the *Rhizoclonium* (a species of hair algae) that was only growing in S3 withered and decayed (Figure 65). Therefore, their regular removal and cleaning are necessary.



Figure 65: Emergence of green algae of the genus *Rhizoclonium* that grew and decayed among planted trees

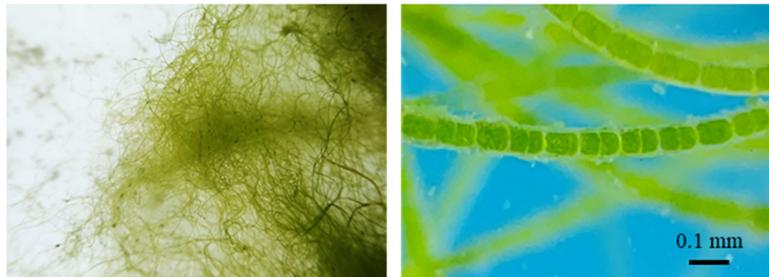


Figure 66: A thriving *Rhizoclonium* and its enlarged image

In the final cycle, 3.7 kg of shrimp were harvested in S2 and 5.8 kg in S3. Shortly after the start of cultivation, white spot virus was detected, and in April, shrimp turned to a red color with white spots on their shells. The onset of the disease coincided with the pH of the pond water rising to a dangerous level from early April. Everything that could be done was done, but it was still not possible to stop the onset of white spot disease.

⑧ *Gracilaria* Growth Test Results

In this pilot project, *Gracilaria* was selected as a mix culture species with black tiger shrimp aquaculture, and it was sprayed into the ponds prior to the release of juvenile shrimp. *Gracilaria* itself can be sold as agar, and it also serves as a daytime hiding place for nocturnal shrimp and a breeding ground for amphipods and gastropods, which are the shrimp's natural food source. It also has the beneficial function of purifying water by absorbing ammonia. To quantify the growth of *Gracilaria*, screened cages were set up at four to five fixed locations in the ponds, containing a fixed weight of algae, and monthly growth monitoring was conducted. The monitoring results and details of pond salinity are provided in the attached document.

Monitoring in the Technical Verification Pond from August 31 to October 12, 2023

Gracilaria was monitored in four net cages (P1-P4) in each of the technical verification ponds, Ponds 1A and 1B. 300g of algae were placed in each net cage, and their weights were measured approximately every two weeks. The average weights of the algae at the four locations were used for growth analysis. Monitoring

began on August 30 and continued for six weeks until October 12.

During the first two weeks, algae grew to 501g in Pond 1A and 572g in Pond 1B. However, growth then stagnated, and four weeks later, on October 12, it reached 606g in Pond 1A and 872g in Pond 1B. Between the second and fourth weeks after the start of the test, when growth slowed, salinity exceeded 50 ppt. The growth rate in 6 weeks was 2.0 times higher in 1A and 2.9 times higher in 1B.

Monitoring in the Technical Verification Pond from January 8 to February 12, 2024

Growth monitoring was conducted from January 8 to February 12 under the same conditions as before. The monitoring period was five weeks. Gracilaria ultimately grew 3.96 times larger in 1A and 2.91 times larger in 1B. The growth trend during this period was generally linear, and growth was better than before. During this period, there was a significant change in salinity, decreasing from approximately 30 ppt to approximately 10 ppt, but this did not appear to affect the growth of Gracilaria.

The results of Gracilaria growth over the two periods confirmed that Gracilaria grows poorly at high salinity concentrations and ceases to grow above 45 ppt. Furthermore, it was confirmed that growth rate did not change at low salinity concentrations of 30 ppt and 5 ppt, which are equivalent to the salinity of seawater.

Social Verification Pond Monitoring from October 29, 2024 to January 15, 2025

Five partitioned net cages were installed in each of S2 (no mangroves) and S3 (mangroves), each containing 100g of Gracilaria. Weights were recorded after two and four weeks.

S2: During the high salinity period (45-50 ppt), growth slowed, with an inflection point on November 5th, resulting in a final growth rate of approximately 2.7 times. During the decreasing salinity period (40-10 ppt), growth was nearly linear, but ultimately only reached 2.3 times growth. During the low salinity period (10-5 ppt), high growth rates of approximately 3.4 times were achieved. During the decreasing salinity period, flooding and other factors reduced nutrient (NO₃) dissipation, resulting in a decline in growth rate. Meanwhile, during the low salinity period, stable water flow increased nutrient levels, resulting in an improved growth rate.

S3: During the high salinity period (45-50 ppt), a decline in biomass was observed, with an inflection point on November 5th, and ultimately growth only reached about 2.0 times. During the decreasing salinity period, the growth rate was only about 1.9 times, but during the low salinity period, it improved to 2.9 times. The slow growth during the decreasing salinity period is thought to be for the same reasons as in S2.

The above monitoring showed that the conditions necessary for Gracilaria growth are satisfactory as long as the salinity is between 5 and 40 ppt.

Social Verification Pond Monitoring from March 4 to May 29, 2025

From March 4 to April 3, 2025, the weight of *Gracilaria* increased approximately threefold in S2 and approximately twofold in S3. This discrepancy is thought to be due to nutrient competition caused by the overgrowth of hair algae in S3. The hair algae in S3 were removed, and *Gracilaria* monitoring continued. In the month beginning on April 3, both ponds experienced growth of approximately 3.5 times their original size. In the month beginning on May 1, both ponds also experienced growth of just under three times their original size.

7.4.3 Obstacles and Countermeasures in Silvo-Aquaculture

① Diseases (Viruses and Bacteria)

The most significant problem in shrimp aquaculture, not just in this pilot project, is disease. Diseases can be bacterial, fungal, or viral.

White Spot Syndrome Virus (WSSV)

This is the most widespread and fatal disease in shrimp aquaculture worldwide. Symptoms include the appearance of white spots on the carapace, followed by reduced activity and subsequent death (Figure 67). There is no effective treatment. Infected juvenile shrimp appear reddish in color (Figure 68). A definitive diagnosis is made by amplifying deoxyribonucleic acid (DNA) using polymerase chain reaction (PCR) and comparing the resulting electrophoretic pattern with a control (Figure 69).



Figure 67: Shrimp infected with WSSV

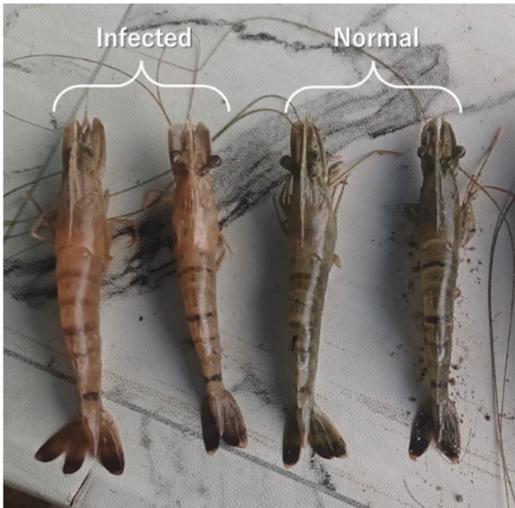


Figure 69: Shrimp infected with WSSV (body turned to red) and normal shrimp

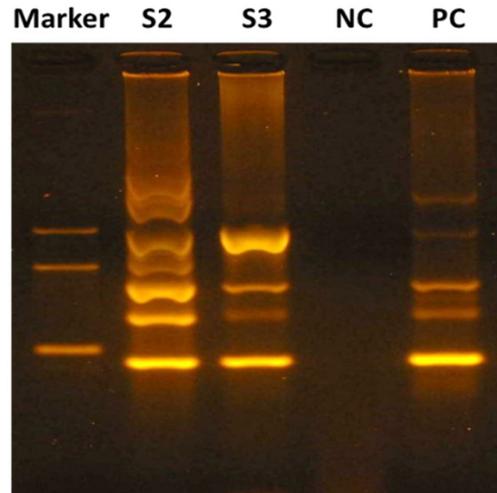


Figure 68: Electrophoretic image of WSSV

S2/S3 are aquaculture ponds, NC is a negative control, and PC is a positive control

WSSV Carrier

The origin of the WSSV is unknown, but it emerged in East Asia in the 1990s and spread worldwide over the next decade, causing significant damage to the shrimp aquaculture industry. Because the virus is genetically integrated into the genomes of not only black tiger shrimp but also many other shrimp and crab species, it is thought that it is impossible to eradicate it from infected areas. PCR tests were conducted on samples of aquatic organisms that could be prey for black tiger shrimp in the vicinity of the pilot site, in addition to the black tiger shrimp used in the aquaculture. A sample of amphipods tested positive in December 2024, followed by S2 and S3 samples of black tiger shrimp in March and May 2025 (see attached table). As a countermeasure, mass production of shrimp seeds derived from parent shrimp that survived the virus outbreak is proposed, as they are resistant to the virus.

② Improving the Immunity of Shrimp (Black Tiger Shrimp and Vannamei Shrimp)

In recent years, attempts have been made to use probiotics to increase the survival rates of shrimp species such as black tiger shrimp and vannamei shrimp, but the exact mechanism of action remains unclear. It is unclear whether probiotics suppress the growth of pathogenic bacteria in the culture water or enhance the shrimp's immune system. Therefore, in this pilot project, we tested whether adding RICA (*Brevibacillus* sp.), a probiotic widely used in Indonesia, to shrimp tanks during nursing would improve the shrimp's immune system.



Figure 70: Probiotic RICA, widely used in Indonesia

The immune system consists of cellular and humoral immunity. An indicator of cellular immunity is the increase or decrease in white blood cell count. On the other hand, indicators of humoral immunity include superoxide dismutase (SOD) and prophenoloxidase (ProPO). The mRNAs that produce these enzymes were amplified using real-time PCR to measure the fold change in their expression levels. The immune systems of shrimp reared without probiotics and those reared with probiotics were compared by measuring two humoral immunity parameters. Furthermore, a challenge test using the pathogenic bacterium *Vibrio* was also performed.

Experimental Procedure and Treatment

Ninety individuals of PL-12 were housed in 30 L of water and 200 mL of the probiotic RICA was added. Five days later, samples were taken to measure ProPO and SOD, parameters indicating humoral immunity. An equal amount of RICA was added immediately after sampling. This treatment and sampling were repeated three times every five days. The control group was untreated and the same sampling and parameter measurements were performed as in the experimental group. After the third sampling, a challenge test was performed by adding a *Vibrio* suspension adjusted to 10⁷ CFU (colony-forming units) to the experimental and control groups. Seven days later, survival rates were measured. Each treatment was performed in three tanks, and the average was calculated.

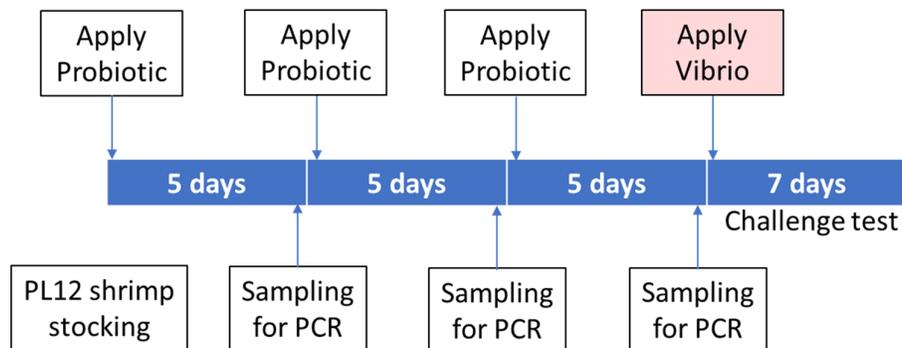


Figure 71: Experimental schedule and timing of each treatment

ProPO showed a significant increase of 2.22 times 5 days after probiotic addition, but fell to 0.63 times 10 days later, below the control level. However, it rose again to approximately 2.31 times on the 15th day (graph in the Appendix 6).

SOD fell to approximately 0.31 times 5 days after probiotic addition, rose to 0.70 times on the 10th day, and gradually increased to 1.32 times on the 15th day (graph in the Appendix 6).

Challenge Test (Artificial Vibrio Infection Experiment)

Vibrio, a common shrimp pathogen, was introduced into experimental and control groups at a virulent level of 107 CFU, and survival rates were monitored for 7 days. Results showed no significant difference in survival rates between the experimental and control groups, with survival rates at approximately 90% at 24 and 72 hours after introduction. However, after 96 hours, survival rates in the control group significantly decreased. At 168 hours, survival rates were significantly different: 81.7% in the experimental group and 68.3% in the control group. Therefore, adding probiotics during shrimp nursing improved immunity and increased shrimp survival (Figure 72).

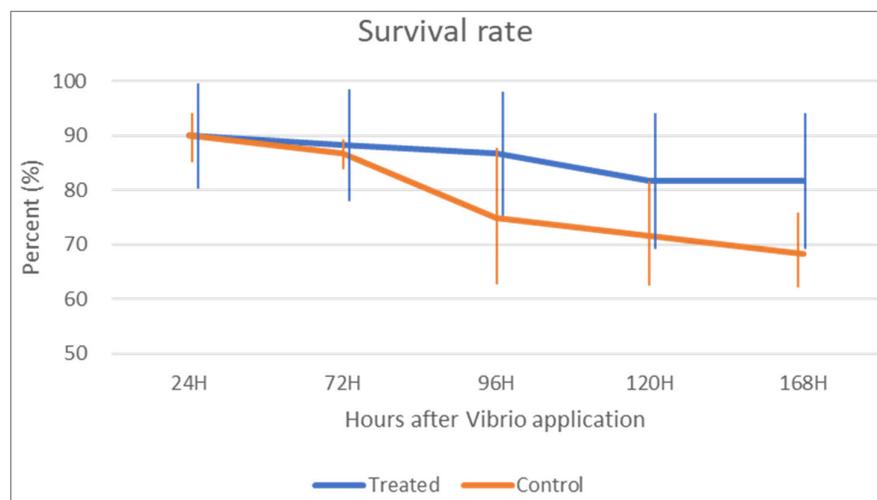


Figure 72: Chronological change of shrimp survival rate

The genes for ProPO and SOD, which are involved in immunity, are not normally expressed during the growth stage of juvenile shrimp, but it is thought that exposure to probiotics stimulates their expression, causing a temporary increase or decrease, ultimately resulting in the acquisition of resistance to pathogens.

③ Vibrio Reduction in Aquaculture Ponds (Effect of Probiotic Spraying)

In recent years, efforts have been made to reduce the risk of Vibrio infection in open-air shrimp aquaculture ponds by spraying probiotics. This approach was adopted in this pilot project to measure the effectiveness of probiotic spraying.

RICA, an active probiotic product from Indonesia, was cultured, expanded and sprayed into shrimp ponds S2 and S3. Spraying was performed approximately every two weeks, and samples were taken from both the pond soil and the culture water to measure the *Vibrio* count in CFU. Results showed that *Vibrio* counts in the culture pond water decreased after the start of probiotic spraying, with CFU suppressed to below 10² (see attached graph). Meanwhile, *Vibrio* counts in the soil consistently exceeded 10³ CFU. Probiotics are facultative aerobic bacteria, so they are only active in aerobic water, whereas *Vibrio* are facultative anaerobic bacteria, so they appear to remain constantly in anaerobic soil. Monitoring confirmed that the probiotic was working effectively. However, since black tiger shrimp are nocturnal and often burrow to the bottom of ponds during the day, they may be at a slightly higher risk of infection because they remain in areas with high concentrations of *Vibrio* for long periods of time.

7.4.4 Eco-Feed

The silvo-aquaculture aimed at in this pilot project is not completely extensive; rather, it involves a certain level of input. While relying heavily on natural feed, formulated feed is also used. However, environmental considerations are important. Generally available formulated feeds are criticized for being environmentally unfriendly because they are made from fish meal from wild fish. Therefore, using formulated feeds made from alternative ingredients to fish meal is one approach to environmentally friendly aquaculture. Currently, tofu is widely produced and sold in Indonesia, but the okara produced during this process is used exclusively for livestock feed. No one objects to recycling it and using it as fish feed. Therefore, we developed a prototype formulated feed using soy protein-based okara as the main ingredient and conducted growth tests in tanks to examine future potential use. This experiment was conducted in a rented space in the Malana research facility.

A standard commercially available shrimp feed was used as a control (K), and a feed mainly composed of okara (Eco Feed A) and a fermented okara feed (Eco Feed B) were prepared using okara fermented with tempeh fungus (*Rhizopus* sp.) and a comparison was conducted. Finally, survival rate, average weight gain, digestive enzyme activity, and digestive enzyme gene expression levels were determined.

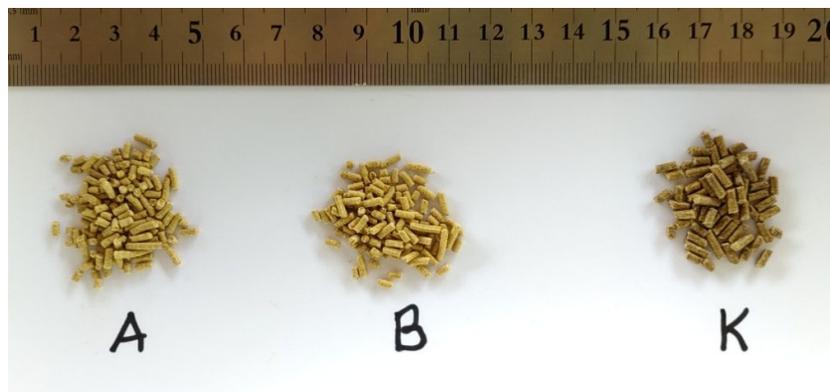


Figure 73: Formulated shrimp feed: A: Okara, B: Fermented Okara, K: Commercial shrimp feed

Tank-based Shrimp Rearing Experiment

A rearing experiment was conducted on shrimp that were fed okara feed and fermented okara feed. The rearing conditions were as follows:

Table 57: Rearing conditions and treatments

Rearing condition	Treatment	Remarks
Rearing density	10 juvenile shrimp (5-6g/individual) were reared in a 100L tank.	Each condition was triplicated
Feeding	The daily amount was 5% of the biomass, which was given twice a day.	
Water management	30 ppt seawater was. Water quality suitable for rearing was maintained by changing the water as needed.	
Rearing period	One month	
Replication	3 times	Used 9 tanks in total

Results

The results of the rearing experiment are as follows (graphs are provided in the Appendix 6).

Survival rate: 70%, in the control group, 33% in the okara diet group, and 50% in the fermented okara diet group. It was observed that all deaths during this period were due to attacks from other individuals immediately after molting.

Average weight change: Average weight decreased over one month in all treatment groups. The rate of decrease was particularly steep in the okara diet group.

Digestive enzyme activity: Enzyme activity was high for proteases and low for amylases in all groups including the control. Lipase was high in both the control and the okara diet group, but was lower in the fermented okara diet group.

Digestive enzyme mRNA expression: The fold change in all enzyme RNAs was lower in the okara diet compared to the control. On the other hand, the fermented okara group showed a remarkably high change in trypsin, at 1.83 times, but the changes in amylase and lipase were even lower than in the okara group.

Discussion

We observed that survival rates were not only affected by the quality of the food, but also by cannibalism among carnivorous organisms. Therefore, we believe that variation in survival rates cannot be used to determine the quality of food. Further refinement of experimental methods is necessary. Meanwhile, the activity of digestive enzymes and the expression of genes that produce these enzymes are possible considerations, as discussed below.

Fermenting boiled soybeans with tempeh bacteria apparently lowers the pH and makes them acidic, thereby

improving the shelf life. However, shrimp use a trypsin-like enzyme as a proteolytic enzyme, which is active near neutral pH, and therefore may not digest acidic foods well. However, when examining digestive enzyme activity, the proteolytic enzyme trypsin activity was slightly higher in fermented okara than in the other samples, and gene expression levels were also significantly higher (1.83-fold) than in the control. This suggests that fermented okara has higher digestive efficiency. Therefore, while further research is needed to explore the use of fermented okara as an eco-feed ingredient, it is believed to have great potential.

7.4.5 Risk Diversification through Mixed-Species Aquaculture

Aquaculture costs are required for pond preparation labor and supplies, and for seed and feed. To recoup such investments, risk diversification and hedging against losses are necessary. For this reason, mixed-species aquaculture is common. Because the regions where silvo-aquaculture is practiced generally have harsh natural environments with wide variations in salinity and water temperature, species that can withstand these environmental changes are selected for aquaculture. The species currently being cultured in Indonesia's silvo-aquaculture are summarized below.

Crustaceans

① Black tiger shrimp (*Penaeus monodon*)

Once a major aquaculture species, it is now rarely used due to a decline in seed producers. This is due to the spread of diseases such as white spot virus and vibriosis, which cause the shrimp to die before the aquaculture process is completed. Early development of disease control measures, such as the development of juvenile shrimp with virus-resistant genes, is desired.



Figure 74: *Penaeus monodon*

② Whiteleg shrimp (*Litopenaeus vannamei*)

This species is an invasive species introduced from Central and South America, but is now a central target species in shrimp aquaculture worldwide. It is often used in semi-intensive and intensive aquaculture. There is a market even for slightly smaller shrimp, making it a popular aquaculture commodity. However, as an invasive species, there are concerns about their release into the wild. It is susceptible to similar diseases to those of black tiger shrimp.



Figure 75: *Litopenaeus vannamei*

③ Mangrove crabs (*Scylla serrata* and *Scylla olivacea*)

Seed production has been successful in some areas, and if a stable supply of seed can be secured, they could potentially be used in silvo-aquaculture. However, because they are carnivorous and tend to cannibalize, special care must be taken, such as rearing them in individual cages. In Indonesia, the two species are found sympatric, and natural hybrids are occasionally observed. Taxonomic confusion is still seen.



Figure 76: *Scylla serrata*



Figure 77: *Scylla olivacea*

Seaweed

The red algae *Gracilaria vermiculophylla* is currently a popular target for brackish water aquaculture in South Sulawesi. Due to rising demand for this alga as a raw material for agar, the number of farmers specializing in this red algae cultivation is increasing. However, this pilot project is focused solely on providing shelter for black tiger shrimp, cleaning the water (absorbing ammonia), and promoting the growth of macrobenthos (e.g., amphipods, gastropods, polychaetes, etc.) that serve as shrimp food. During this pilot project, it was confirmed that the algae grew approximately two to three times its original size in one month.

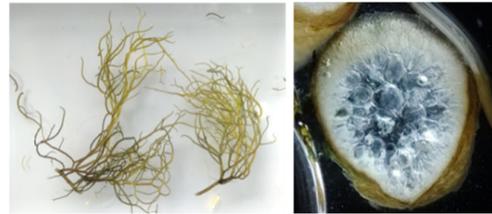


Figure 78: Thallus of *Gracilaria* (left) and its cross-section (right)

Fish

① Milkfish (*Chanos chanos*)

The most popular fish species for brackish water aquaculture in Indonesia is milkfish (*Chanos chanos*). This species is also a popular farmed fish in the Philippines, where it is designated as the national fish. This species is adaptable to a wide range of salinity levels, is omnivorous, and is resistant to low-oxygen environments and disease. Indonesia has a robust artificial seed production system and a sizable market, but it is not very popular in Peninsular Malaysia. In this pilot project, we found that when 100 juveniles weighing approximately 100g were released into a pond of approximately 0.2 hectares, their weight increased 2-2.5 times after one month, even without using formulated feed.



Figure 79: *Chanos chanos*

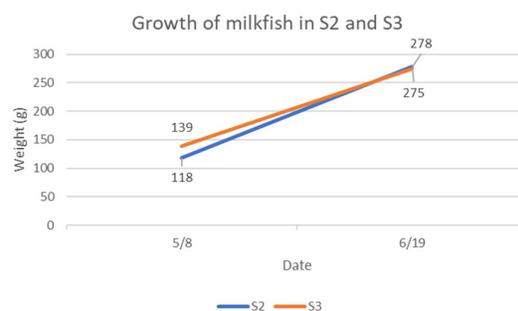


Figure 80: Growth of milkfish

② Mozambique tilapia (*Oreochromis mossambicus*)

Although there are no reliable records, it is believed to have been introduced to Indonesia in the 1930s and is now established in brackish waters throughout Southeast Asia. It can tolerate the highest salinity of any tilapia species (120 ppt). Due to its small size and tendency to reproduce prolifically, it is generally considered a small fish. However, it can be used as a target species for silvo-aquaculture if seeds are supplied using a seed production technique that uses hormones to reverse sex, even females, resulting in large, commercially viable individuals.



Figure 81: *Oreochromis mossambicus*

Table 58 shows the tolerance of high salinity and high temperature for the above aquaculture species.

Table 58: High salinity and high temperature tolerance of aquaculture species

Species	Salinity tolerance (ppt)	High temperature tolerance (°C)
Black tiger shrimp* ¹	45	37
Vannamei shrimp	78	43.8
Mozambique tilapia	120	42
Milkfish* ²	60	40
Gracilaria	50	36
Mangrove crabs	42	39

*1: Chen L.C. (1990) recorded a high salinity tolerance of 57 ppt. There is also a theory that high temperature tolerance is 35°C.

*2: According to Andre et al. (2024), a high salinity tolerance of 158 ppt has also been recorded.

7.4.6 Aquatic Fauna in Mangrove Ecosystems

Mangrove ecosystems are known to play an important role in maintaining marine biodiversity and abundant fisheries resources, yet few examples of actual inventory surveys have been conducted. Therefore, in this pilot project, aquatic fauna surveys were conducted in and around aquaculture ponds while conducting silvo-aquaculture.

During the pilot activities, 7 phyla, 11 classes, 34 orders (excluding Polychaeta), 64 families (excluding Ostracodida and Polychaeta), and 91 species (excluding Polychaeta) were collected and recorded (Table xx), and specimens were photographed (Fig xx). Many of these were in the larval or juvenile stage of development. Many arrived in mangrove areas passively or actively from the coast. Their migration objectives varied depending on the species, but many were foraging for food, which is necessary for early development, and

to escape prey. These survey results suggest that mangrove ecosystems are essential for the conservation of coastal biodiversity and the maintenance of coastal fisheries resources.

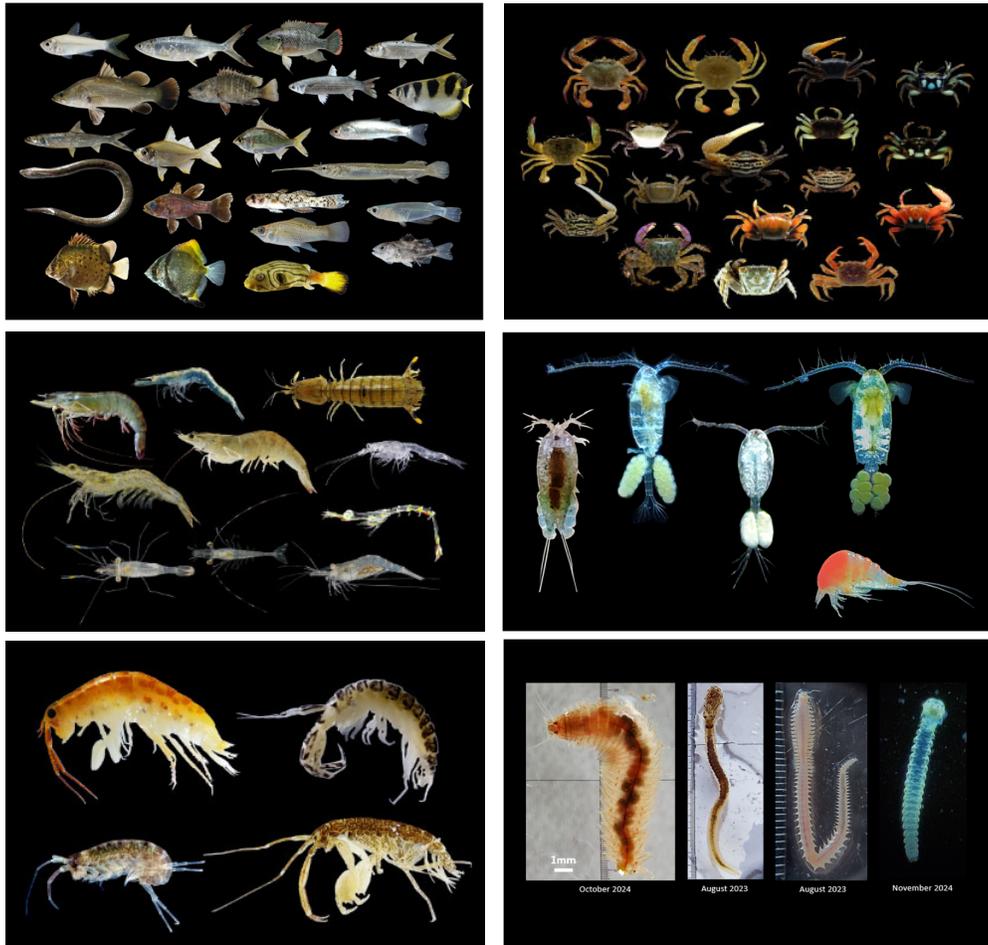


Figure 82: Some of the aquatic fauna in the mangrove ecosystem around the project

Table 59: Inventory of confirmed mangrove aquatic fauna

Phylum 門	Class 綱	Order 目	Family 科	Species 種		
Cnidaria 刺胞動物門	Scyphozoa 傘形綱	Scyphozoa 傘形目	Ulmaridae エゾクサゲ科	<i>Aurelia</i> sp. エゾクサゲ属の一種		
Cnidaria 刺胞動物門	Monogonozoa 楯形綱	Planula フムシ目	Bathypoda フムシ科	<i>Brachyopa ranaiformis</i>		
Cnidaria 刺胞動物門	Sarothozoa 楯形綱	Adreanophora 楯形目	Sarothozidae フムシ科	Undetermined 未特定		
Arthropoda 節足動物門	Malacostraca 軟甲綱	Decapoda 十脚綱	Portunidae フタリゴ科	<i>Thalassia areata</i> Rippeil, 1830 ミナメニツケガニ <i>Portunus pelagicus</i> (Linnaeus, 1758) タイワンガザミ <i>Scylla serrata</i> Forsk., 1775 アメノヘビガザミ <i>Scylla olivacea</i> (Herbst, 1796) アカタノヘビガザミ		
			Varunidae エゾクサゲ科	<i>Mitipiza elegans</i> de Man, 1888 ナナゴアシハラガニ属の一種 <i>Parasquilla</i> sp.		
			Sesamidae ベンケイガニ科	<i>Parasquilla bilens</i> (De Haan, 1835) カクベンケイガニ属の一種		
			Xanthidae オウゴンガニ科	<i>Zosima areata</i> (Linnaeus, 1758) クモレオウゴンガニ		
			Oithidae イソオウゴンガニ科	<i>Epithelium dentatum</i> (White, 1848) カノセビロガニ		
			Macrobrachmiidae オナガニ科	<i>Macrobrachium korei</i> (Desmarest, 1827) ノコハオナガニ		
			Gammaridae イワガニ科	<i>Mitropogon thalassia</i> (Owen, 1839) ハシリイワガニモドキ <i>Austrea sanguinaria</i> (A. Milne-Edwards, 1875) シモフリシオマホキ <i>Austrea perleata</i> (H. Milne-Edwards, 1852) オキナワハクセンシオマホキ <i>Tubia forficata</i> (Adams & White, 1849) <i>Tubia discolorata</i> (H. Milne-Edwards, 1852) ニヤマシオマホキ		
			Ocyropsidae スナゴニ科	<i>Paripalmonia laticornis</i> (De Haan, 1839) ホソカデヒシガニ <i>Lucicutia</i> sp. ニメビ属の一種		
			Parthenopidae ヒシゴニ科	<i>Paripalmonia laticornis</i> (De Haan, 1839) ホソカデヒシガニ		
			Lucicutidae ニメビ科	<i>Lucicutia</i> sp. ニメビ属の一種		
			Palaemonidae アナゴニ科	Undetermined 未特定		
			Penaeidae クルマニ科	<i>Penaeus merguensis</i> De Man, 1888 パナニエビ <i>Penaeus monodon</i> Fabricius, 1798 ブラックタイガー		
			Mysida アミ目	Mysidae アミ科	<i>Microdeutopus</i> sp.	
			Stomatopoda 口脚目	Squilla シヤ科	<i>Caridippa coarctata</i> (Latreille, 1828) コクタンシヤ <i>Gravidarella</i> sp. コクタンシヤ属の一種	
			Anthropoda 海鞘目	Aorida ニンボシムシ科	<i>Gravidarella</i> sp. コクタンシヤ属の一種	
	Talitridae ハマトビムシ科	Undetermined ハマトビムシ科の一種				
	Corophiidae ドコガムシ科	Undetermined ドコガムシ科の一種				
	Hexapoda 六脚生綱	Harpacticoida ソモエジ目	Harpacticoidae ソモエジ科	<i>Tigridia</i> sp. シオガマリメジ目属の一種		
		Cyclopoidea ケンメジ目	Cyclopoidea ケンメジ科	<i>Mysis</i> sp. ボウズノメジ目属の一種 <i>Oithona</i> sp. オイトナ属の一種 <i>Apoecyclops</i> sp.		
		Calanoida ヒゲナガメジ目	Paradiplosomidae	<i>Paradiplosoma nariva</i>		
	Ostracoda カイムシ綱	Podocopida カイメジ目	Astartidae	<i>Astartia</i> sp.		
		Colopocera 甲虫目	Hydrophilidae ガムシ科	Undetermined 未特定		
	Insecta 昆蟲綱	Diptera 双翅目	Chironomidae ムシ科	<i>Bequaqua</i> sp. ゴマフムシ属の一種 Undetermined 未特定		
		Chordata 脊索動物門	Actinopterygii 条鰭綱	Elopiiformes カレイ目	<i>Elops hawaiiensis</i> (Ruan, 1909) カレイ目	
	Gonorythmiformes スズメ目			Mormonidae イセゴイ科	<i>Megalops cyprinoides</i> (Broussonet, 1782) イセゴイ <i>Chanos chanos</i> (Forssk., 1775) サバヒ	
	Order: Aulopiformes ヒメ目			Family: Synbranchidae ニソ科	<i>Siniperca kneri</i> (Cuvier and Valenciennes, 1824) マダマシ <i>Siniperca kneri</i> (Cuvier and Valenciennes, 1824)	
	Betisiformes ゲツ目			Zenarchopterygidae ニソ科	<i>Zenarchopterygidae</i> ニソ科 <i>Zenarchopterygidae</i> ニソ科 <i>Oryzias latipes</i> (Bleeker, 1845) ジャワメダカ <i>Poecilia latipinna</i> (Lesauar, 1821) セイルフィンモーリー	
Cyprinodontiformes カダヤシ目	Adriariidae ニソ科			<i>Oryzias latipes</i> (Bleeker, 1845) ジャワメダカ		
Cichliformes カワスズメ目	Poeciliidae カダヤシ科			<i>Poecilia latipinna</i> (Lesauar, 1821) セイルフィンモーリー		
Perciformes スズメ目	Cichlidae カワスズメ科			<i>Oreochromis mossambicus</i> (W. K. P. Peters, 1859) カワスズメ <i>Luganus niloticus</i> (Forssk., 1775) ゴマフメダカ		
	Tetraodontidae シマイサキ科			<i>Tetraodon lineatus</i> (Forssk., 1775) ニトヒキ <i>Pleurogrammus</i> sp. ムシ目 <i>Pleurogrammus</i> sp. ムシ目		
Labriformes ペダ目	Centropomidae オニハタ科			<i>Centropomus viridis</i> (Cuvier and Valenciennes, 1824) オニハタ <i>Ctenopoma</i> sp. ムシ目 <i>Megalopterus</i> sp. ムシ目		
	Mugilidae ゴボ科			<i>Ctenopoma</i> sp. ムシ目 <i>Megalopterus</i> sp. ムシ目		
Mugiliformes ゴボ目	Ambassidae タカサゴイシモチ科			<i>Ambassis</i> sp. ムシ目 <i>Ambassis</i> sp. ムシ目 <i>Ambassis</i> sp. ムシ目		
	Apogonidae テンシグイ科			<i>Apogon</i> sp. ムシ目 <i>Apogon</i> sp. ムシ目 <i>Apogon</i> sp. ムシ目		
Gobiiformes ハゼ目	Gobiidae ハゼ科			<i>Gobius</i> sp. ムシ目 <i>Gobius</i> sp. ムシ目 <i>Gobius</i> sp. ムシ目		
	Carangiformes アジ目			Carangidae アジ科	<i>Caranx</i> sp. ムシ目 <i>Caranx</i> sp. ムシ目 <i>Caranx</i> sp. ムシ目	
Synbranchiformes ウグスグ目	Mulidae ヒメジ科			<i>Mulius</i> sp. ムシ目 <i>Mulius</i> sp. ムシ目		
	Batrachoididae ゴマアンコウ目			Leptacanthidae ヒイラギ科	<i>Leptacanthus</i> sp. ムシ目 <i>Leptacanthus</i> sp. ムシ目 <i>Leptacanthus</i> sp. ムシ目	
Acanthopterygii 二サメ目	Gerridae クロサギ科			<i>Gerrhonotus</i> sp. ムシ目 <i>Gerrhonotus</i> sp. ムシ目 <i>Gerrhonotus</i> sp. ムシ目		
	Leptacanthidae ヒメジ科			<i>Leptacanthus</i> sp. ムシ目 <i>Leptacanthus</i> sp. ムシ目 <i>Leptacanthus</i> sp. ムシ目		
Synbranchiformes タウナギ目	Monacanthidae カワハナ科			<i>Monacanthus</i> sp. ムシ目 <i>Monacanthus</i> sp. ムシ目 <i>Monacanthus</i> sp. ムシ目		
	Tetraodontiformes フグ目			Tetraodontidae フグ科	<i>Tetraodon</i> sp. ムシ目 <i>Tetraodon</i> sp. ムシ目 <i>Tetraodon</i> sp. ムシ目	
Mollusca 軟体動物門	Gastropoda 腹足綱			Sacoglossa 藻巻目	Limsiporidae ハダカモウモウシ科	<i>Limsipora</i> sp.
				Discopoda 盤足目	Stenotrypa科	<i>Stenotrypa</i> sp.
Bivalvia 二枚貝綱	Saracotheca 吸殻目			Bathypoda フムシ科	<i>Bathypoda</i> sp. ムシ目属の一種	
	Systellina 吸殻目			Onchididae ドロアモウシ科	<i>Onchidium</i> sp.	
Annelida 環形動物門	Polycheta 多毛綱			Undetermined 構属不明	Undetermined 構属不明	<i>Arenicola marina</i> (W. H. Benson, 1842) ホトトギスガイ Undetermined 不明種1 Undetermined 不明種2 Undetermined 不明種3 Undetermined 不明種4

7.4.7 Considerations Regarding Verification In the Shrimp Aquaculture Verification Component

In 7.3.4, the following are listed as verification items for the shrimp aquaculture verification component.

- d) Verify the mutual relationship between mangroves and shrimp aquaculture in the same pond, focusing on macrobenthos.
- g) Verify semi-intensive aquaculture techniques for black tiger shrimp with a target farming density of 6 individuals/m².
- h) If black tiger shrimp is not a suitable species for silvo-aquaculture, consider alternative farmed species.
- i) Verify the introduction of traceable eco-feed.

These findings are summarized and discussed as follows:

- (1) d) Verify the mutual relationship between mangrove and shrimp aquaculture in the same pond, focusing on macrobenthos.

Shrimp farmed in the social verification ponds from March to June 2025 demonstrated faster growth in S3, which was planted with mangroves. The reason for this is that the population of the stenothyrid snail in S3 during the same period was twice that of S2, where there were no mangroves. Stenothyrid snail larvae were found in shrimp excrement, confirming that the shrimp were preying on them. It has also been pointed out that water snails may be using the trunks and aerial roots of mangroves to remain near the water surface, where they feed and reproduce. From these findings, it can be inferred that there is a positive correlation between the presence of mangroves in the pond and the number of macrobenthos, and between shrimp predation on macrobenthos and rapid shrimp growth. Furthermore, the fact that the macrobenthos serve as a natural feed for the shrimp is also thought to be a positive correlation from an ESG perspective.

- (2) g) Verify semi-intensive aquaculture techniques for black tiger shrimp with a target stocking density of 6 individuals/m².

Initially, the plan was to identify necessary aquaculture techniques by setting two stocking densities in the technical verification ponds: 3 individuals/m² and 6 individuals/m². However, shrimp aquaculture in the technical verification ponds had to be discontinued midway, and shrimp aquaculture in the social verification ponds became the only verification site. The social verification ponds were divided into ponds with and without mangrove plantations, and further subdivision was not possible, making it impossible to simultaneously cultivate shrimp at different stocking densities. Through shrimp aquaculture in the technical verification ponds and social verification ponds, the importance of controlling water quality (e.g., salinity, water temperature, dissolved oxygen, and pH) and the techniques for doing so were established to a certain extent. However, controlling the outbreak of white spot syndrome virus (IPV) remained difficult. While shrimp aquaculture techniques were verified to a certain extent, the virus remains a major obstacle to shrimp aquaculture.

- (3) h) If black tiger shrimp is not a suitable species for silvo-aquaculture, consider alternative species.

While shrimp aquaculture presents many challenges, the Gracilaria and milkfish introduced into shrimp ponds in this pilot project showed good growth and are considered promising alternative species. The original purpose of co-cultivating Gracilaria with shrimp was to provide shelter for juvenile shrimp, purify water by absorbing ammonia, and promote the growth of macrobenthos, which act as food for shrimp. However, demand for Gracilaria itself is increasing as a source of agar, and it has been confirmed that it can grow approximately two to three times its size in one month. Milkfish is the most popular brackish water aquaculture species in Indonesia, adaptable to a wide range of salinity levels, omnivorous, resistant to low-oxygen environments, and resistant to disease. Furthermore, Indonesia has a robust artificial seed production system, and it was confirmed that 100 seeds weighing approximately 100g were released into a 0.2ha pond and grew 2-2.5 times their original weight one month later. These two species are considered promising candidates for alternative aquaculture.

(4) i) Verify the introduction of traceable eco-feed

A prototype of traceable eco-feed was created using ingredients such as okara, which are readily available locally, and feeding experiments were conducted in the laboratory. However, cannibalism of the shrimp occurred, and it was not possible to confirm survival rates or weight changes due to the eco-feed. Therefore, the effectiveness of introducing the eco-feed remains unverified.

7.5 Silvo-Aquaculture (Mangrove Planting) in Pilot Activities

7.5.1 Mangrove Monitoring in the Technical Verification Pond

In the technical verification ponds at Marana, mounds for mangrove planting were constructed in two tiers: low mounds where the ground remains submerged at all times, and high mounds approximately 60 cm higher than the low mounds, where the ground is exposed above the water surface during water exchange. In the concurrent system ponds, only *Rhizophora mucronata* (Rhizophora) was planted, with 140 trees on the low mounds and 80 trees on the high mounds in each pond (see figure below).

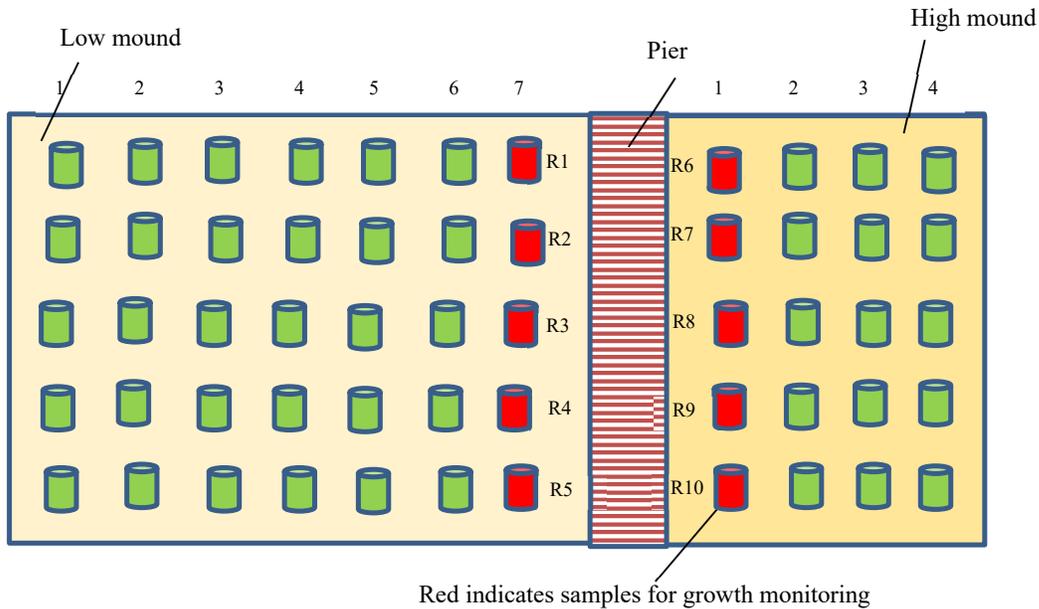


Figure 83: Concurrent system for mangrove planting in the technical verification pond

Rhizophora mucronata was planted in 7 columns x 5 rows on the low mound and 4 columns x 5 rows on the high mound. Subsequent monitoring confirmed the survival/death of all individuals and recorded the height and number of leaves for individuals marked in red.

In the separate-method ponds, two species, *Rhizophora mucronata* and *Bruguiera gymnorrhiza* (Bruguiera), were planted: 84 plants each on low mounds and 91 plants each on high mounds (Figure 84).

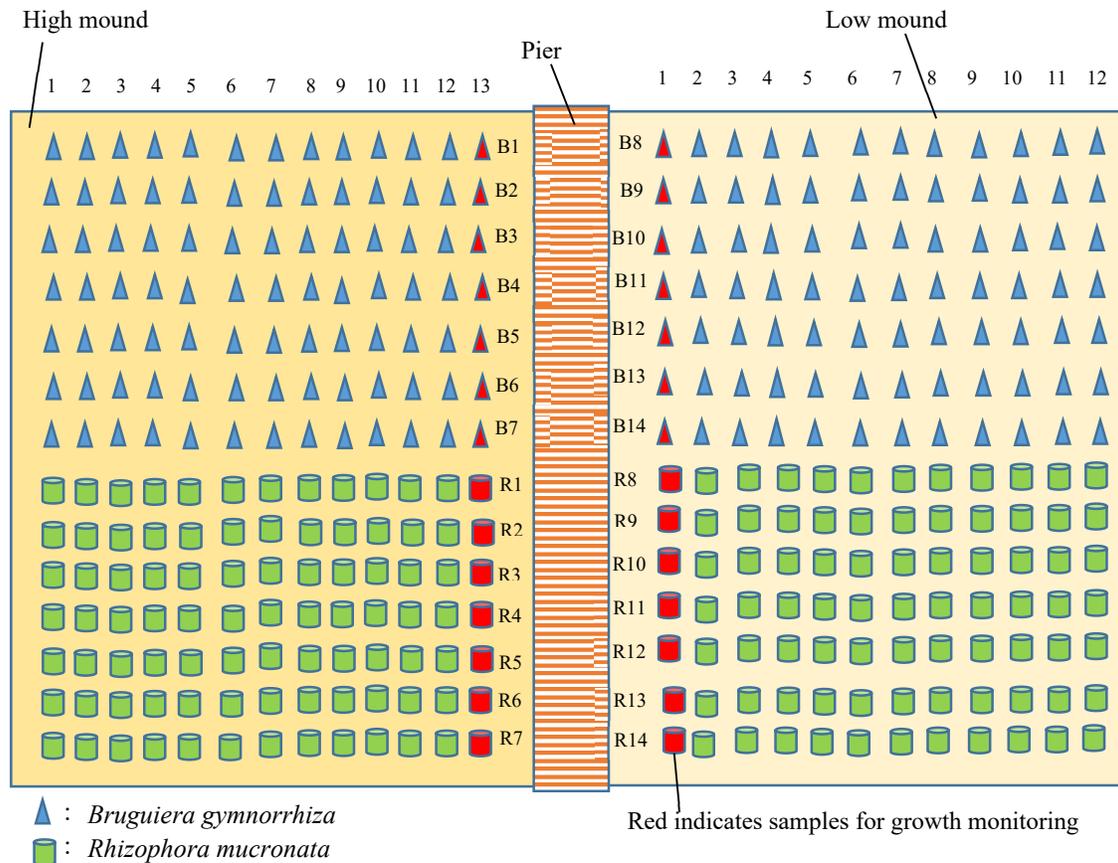


Figure 84: Mangrove planting method using the separate system in the technical verification pond

For each species, *Rhizophora mucronata* and *Bruguiera gymnorrhiza*, planting was conducted in 12 rows x 7 columns on the low mounds and 13 rows x 7 columns on the high mounds. Subsequent monitoring confirmed the survival/mortality of all individuals, and for the individuals marked in red, the seedling height and number of leaves were recorded.

Planting occurred in August 2023. However, from August to November of that year, an unusually dry drought persisted with high temperatures. This environment was considered harsh for the planted seedlings. Seedlings that died during this period were replanted in early September and late November. The replanting rates are as follows.

Table 60: Replacement Rate of Mangrove Seedlings in the Technical Verification Pond

	<i>Rhizophora mucronata</i>		<i>Bruguiera gymnorrhiza</i>	
	Concurrent system (Water management aligned with shrimp aquaculture)	Separate System (Water management based on natural tides)		
High Mound	66.3%	40.7%	86.8%	
Low Mound	33.6%	40.5%	56.0%	
Total	45.5%	40.6%	72.0%	

The higher mounds showed a higher replanting rate, likely because the impact of drought-induced water level drops was more pronounced on the higher mounds. Seedlings were planted in August almost simultaneously with the start of the pilot activity to maximize the limited pilot period. However, if it is possible to select the planting time, planting during the rainy season would be preferable.

To account for replanting effects in the analysis, both sets of data are presented below: one starting from August 2023 (including individuals that died by November 2023) for survival rates and seedling growth, and another starting from December 2023 (including replanted seedlings).

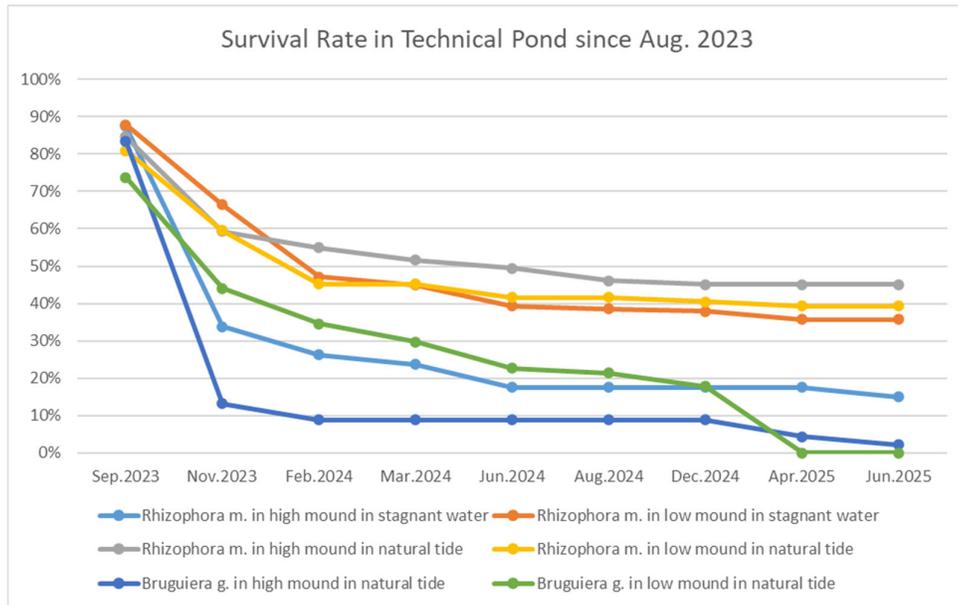


Figure 85: Survival rate of mangrove seedlings in the technical verification pond from August 2023

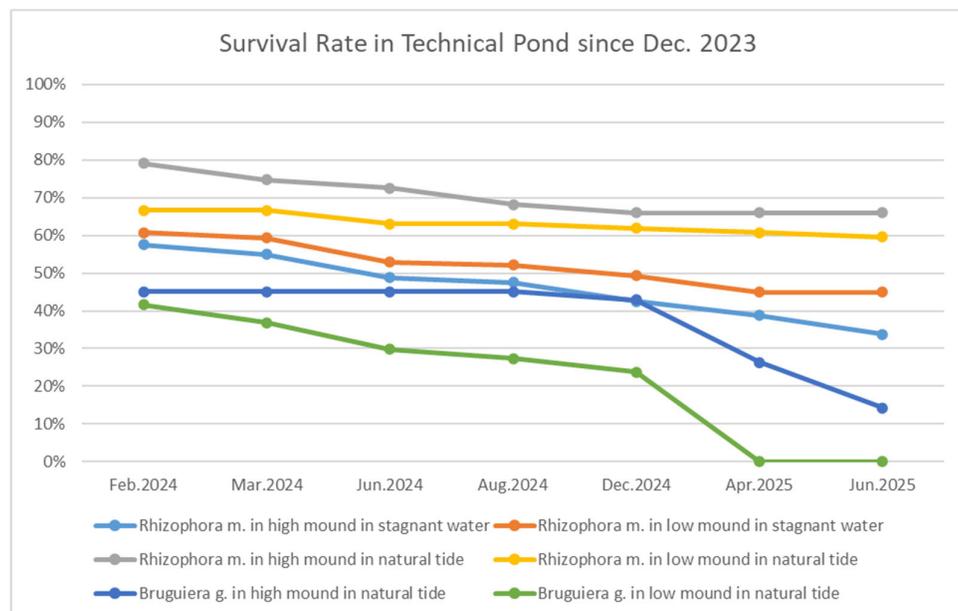


Figure 86: Survival rate of mangrove seedlings in the technical verification pond starting from December 2023

The survival rate starting from August 2023 declined significantly by November of the same year. Comparing survival rates after this point is considered less appropriate for analyzing differences in various conditions. Therefore, subsequent analysis uses the survival rate starting from December 2023.

Comparing survival rates between the two species under the same water management method (*separate system*), *Rhizophora* achieved 62.9%, while *Bruguiera* was less than one-eighth of that rate at 7.4%. Thus, *under the separate system*, *Rhizophora* showed a significantly higher survival rate.

Comparing water management systems, *Rhizophora* showed a survival rate of 40.9% under the concurrent system and 62.9% under the separate system, indicating a higher survival rate under the separate system.

Comparing survival rates by mound height, the concurrent system showed higher survival on low mounds (45.0%) than on high mounds (33.8%), whereas the separate system showed higher survival on high mounds (65.9%) than on low mounds (59.5%). This is thought to be because, in the concurrent system where water levels are kept relatively constant, the low mound where the ground is always submerged provided comparatively better growth conditions than the high mound where, once dried out by drought, the dry state persists for a long time. In contrast, under the separate system, while the ground was rarely exposed on the low mounds, the high mounds experienced alternating exposure and submersion due to water level fluctuations, which more closely resembled natural conditions, likely resulting in relatively superior growth conditions.

From this, it can be said that the survival rate was significantly higher for *Rhizophora mucronata* than for *Bruguiera gymnorhiza* in terms of *tree species*, that the survival rate was higher for the separate system than for the concurrent system in terms of water management method, and while the survival rate was higher for low mounds in the concurrent system, it was higher for high mounds in the separate system, indicating differing results depending on the water management method.

Next, the growth trend of seedlings starting from December 2023 is as follows.

The highest seedling growth was observed in the separate system's high mound *Bruguiera* (107.5%), followed by the Separate System's low mound *Rhizophora* (78.3%), then the separate system's high mound *Rhizophora* (66.8%). Next was the concurrent system low mound *Rhizophora* (50.6%) and concurrent system tall mound (40.7%). *Bruguiera* in the separate system low mound was completely destroyed, resulting in a value of "0" (graph included in the appendix).

Regarding leaf count, the trend starting from December 2023 is as follows.

The largest increases in leaf count for *Rhizophora*, from highest to lowest, were: separate system high mound (32.9 times), concurrent system low mound (19.0 times), separate system low mound (17.1 times), and concurrent system high mound (15.4 times). For *Bruguiera*, the increase was 1.2 times on the separate system high mound, while the low mound showed complete destruction (graph included in the appendix).

These results can be summarized as follows.

Table 61: Comparison of Mangrove Seedling Survival and Growth in Technical Verification Ponds (Through June 2025)

Growing Conditions			Survival Rate		Growth	
					Sapling Height	Number of Leaves
Concurrent System	High mound	<i>Rhizophora mucronata</i>	40.9%	33.8%	40.7%	15.4 times
	Low mound			45.0%	50.6%	19.0 times
Separate System	High mound		62.9%	65.9%	66.8%	32.9 times
	Low mound			59.5%	78.3%	17.1 times
Separate System	High mound	<i>Bruguiera gymnorrhiza</i>	7.4%	14.3%	107.5%	1.2 times
	Low mound			0%	-	-

For *Rhizophora*, the separate system with high mounds showed excellent survival and growth rates, followed by the separate system with low mounds, which also performed relatively well. The concurrent system yielded survival and growth rates far inferior to the separate system. Therefore, from the perspective of *Rhizophora* survival and growth, the separate system is preferable.

For *Bruguiera*, seedlings were completely lost on the low mounds using the separate system. Furthermore, even on the high mounds, the survival rate was only about 14%, which is by no means high.

7.5.2 Mangrove Monitoring in Social Verification Ponds

In the social verification ponds of Pangkep Regency, no elevation difference was created between mounds. Two water management systems—concurrent and separate—were implemented, and two species, *Rhizophora mucronata* and *Bruguiera gymnorrhiza*, were planted. For the concurrent system, mounds slightly below water level were constructed to allow the ground to be exposed during water exchange periods. Both *Rhizophora mucronata* and *Bruguiera gymnorrhiza* were planted in a 14-row x 14-column grid. Subsequent monitoring confirmed the survival/mortality status of all individuals and recorded the height and number of leaves for individuals marked in red.

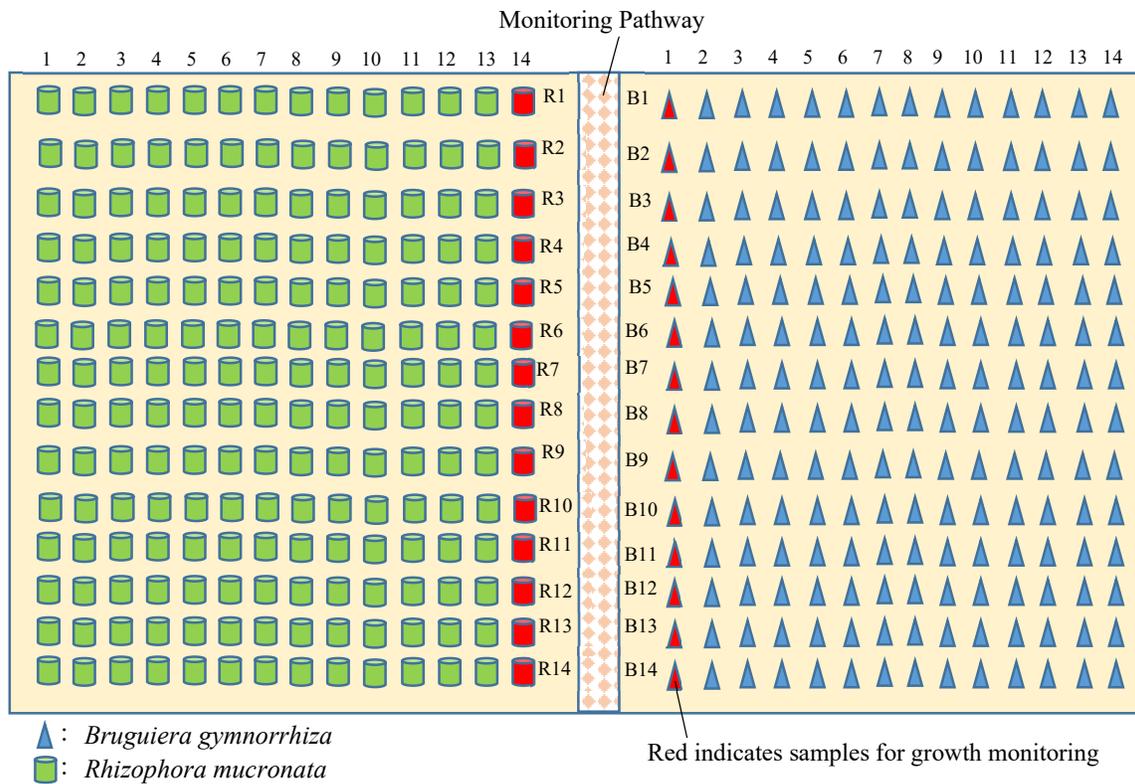


Figure 87: Concurrent system mangrove planting in the social verification pond

In the separate system, two species—*Rhizophora mucronata* and *Bruguiera gymnorrhiza*—were planted in 20 columns x 8 rows. Subsequent monitoring confirmed the survival/mortality of all individuals and recorded the height and number of leaves for individuals marked in red.

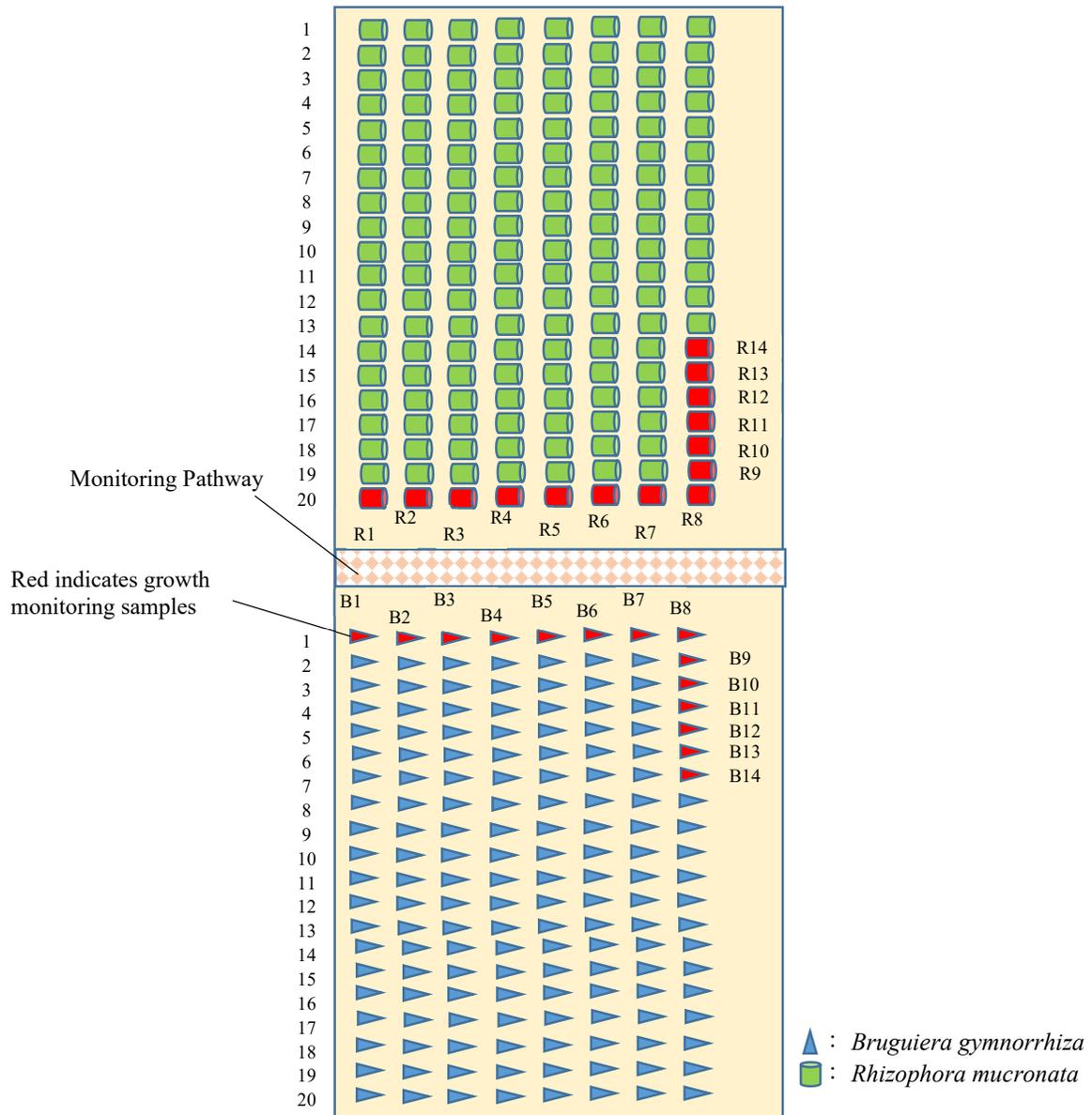


Figure 88: Mangrove planting method using the separate system in the social verification pond

While planting took place in August 2023, this year saw an abnormally dry drought with little rain from August to November coupled with persistently high temperatures, in the same way as the technical verification pond. This environment was considered harsh for the planted seedlings, and those that died during this period were replanted in late September. The replanting rates are as follows.

Table 62: Replacement Ratio of Mangrove Seedlings in the Social Verification Pond

	<i>Rhizophora mucronata</i>	<i>Bruguiera gymnorrhiza</i>
Concurrent System (Water management aligned with shrimp aquaculture)	34.2%	23.0%
Separate System (Water management based on natural tides)	8.8%	11.3%

For both species, the concurrent system showed a higher replanting rate, which was particularly noticeable for *Rhizophora*.

To account for the impact of replanting in the analysis, both sets of data are presented below: one starting from August 2023 (including individuals that died by September 2023) for survival rates and seedling growth, and another starting from September 2023 (including replanted individuals).

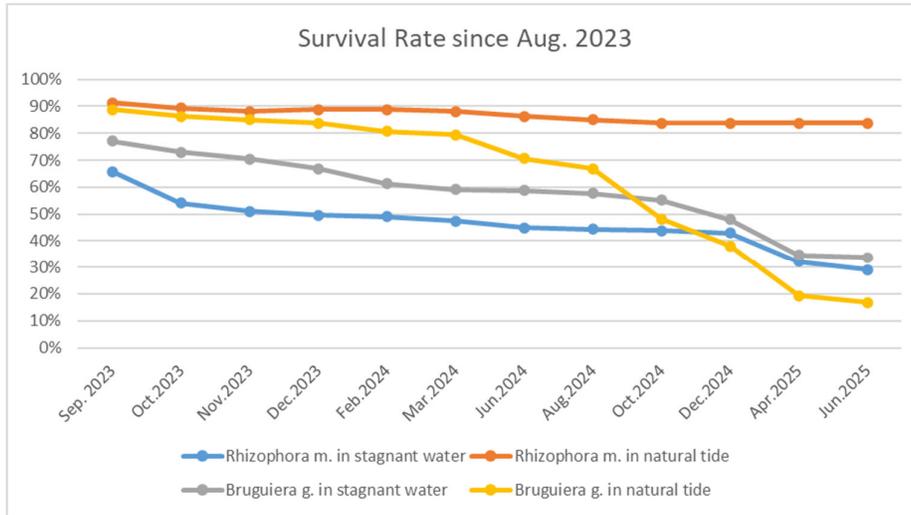


Figure 89: Survival rate of mangrove seedlings in the social verification pond from August 2023

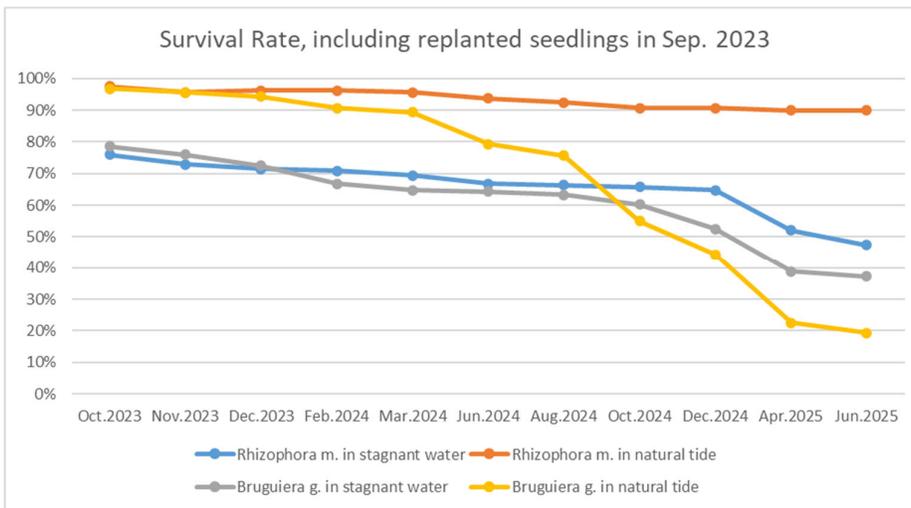


Figure 90: Survival rate of mangrove seedlings in the social verification pond from September 2023

Focusing on the survival rates of both species using the concurrent system, the difference observed between September and December 2023 gradually narrowed when using the August 2023 baseline, appearing nearly identical by April 2025. However, when survival rates are measured starting from September 2023, the two species showed almost no difference until August 2024, after which the *Bruguiera* survival rate declined, and a gap was created. This trend is closer to that observed for the separate system. Since the survival rate starting

from September 2023 is considered more appropriate for analyzing differences in growth conditions, subsequent analyses will use the survival rate starting from September 2023.

Comparing survival rates between the two species, *Rhizophora* showed 47.4% survival under concurrent management and 90.0% under separate management, while *Bruguiera* showed 37.2% under concurrent management and 19.4% under separate management. *Rhizophora* had higher survival rates under both water management systems. The difference between the two species was particularly pronounced under separate management.

Comparing the effects of water management methods, *Rhizophora* showed higher survival rates with the separate system than with the concurrent system, whereas *Bruguiera* showed higher survival rates with the concurrent system. The reason for this difference is unclear.

Thus, while *Rhizophora mucronata* showed a significantly higher survival rate than *Bruguiera gymnorrhiza* as a species, the optimal water management system differed depending on the species.

Next, the height trends of seedlings starting from December 2023 are as follows.

The highest seedling growth rate was observed in *Rhizophora* under the concurrent system (49.4%), followed by *Rhizophora* under the separate system (43.4%), *Bruguiera* under the separate system (40.2%), and *Bruguiera* under the concurrent system (30.7%). The sharp decline in growth of separate system *Bruguiera* in June 2025 is thought to be due to the death of larger individuals among the few remaining specimens, which had low survival rates (a graph is included in the attached materials).

The trend in leaf count starting from September 2023 is shown below.

The greatest increase in leaf count occurred in *Rhizophora* using the separate system (13.0 times), which was significantly higher than the concurrent system (9.4 times). Similarly, for *Bruguiera*, the separate system (5.8 times) showed a much higher increase than the concurrent system (2.1 times) (graph included in the appendix).

These results can be summarized as follows.

Table 63: Comparison of Mangrove Seedling Survival and Growth in Social Verification Ponds (Through June 2025)

Growing Conditions		Survival Rate	Growth	
			Sapling Height	Number of Leaves
Concurrent System	<i>Rhizophora mucronata</i>	47.4%	49.4%	9.4倍
	<i>Bruguiera gymnorrhiza</i>	37.2%	30.7%	2.1倍
Separate System	<i>Rhizophora mucronata</i>	90.0%	43.4%	13.0倍
	<i>Bruguiera gymnorrhiza</i>	19.4%	40.2%	5.8倍

For *Rhizophora*, the separate system showed better survival and growth. With the concurrent system, survival

rates were significantly lower than the separate system. Regarding growth, seedling height was comparable, but the separate system produced a significantly higher number of leaves. Therefore, the separate system is preferable for *Rhizophora* survival and growth.

For *Bruguiera*, survival rate was higher in the concurrent system, though still only 37%. In the separate system, survival was a mere 19%. Regarding growth, both seedling height and number of leaves in the separate system appear to exceed those in the concurrent system.

A summary of survival rates in the technical verification pond and social verification pond 1 year and 10 months after planting is shown below. No common factors between the two ponds based on species differences or water management methods were identified.

Table 64: Survival Rates at 1 year and 10 months After Planting in the Technical Verification Pond and Social Verification Pond

	Technical verification pond	Social verification pond
Concurrent system <i>Rhizophora</i>	40.9% (Low mound 45%, High mound 34%)	47.4%
Concurrent system <i>Bruguiera</i>	Not implemented	37.2%
Separate system <i>Rhizophora</i>	62.9% (Low mound 60%, High mound 66%)	90.0%
Separate system <i>Bruguiera</i>	7.4% (Low mound 0%, High mound 14%)	19.4%
Differences by tree species	<i>Rhizophora</i> showed a high survival rate of 63% with the separate system, while the concurrent system yielded roughly two-thirds of that at only 41%. <i>Bruguiera</i> was only tested with the separate system, yielding a low survival rate of just 7%.	<i>Rhizophora</i> showed higher survival rates with the separate system, reaching 90% in this method. In contrast, <i>Bruguiera</i> fell below 40% in both methods, with a particularly low survival rate of only 19% in the separate system.
Differences by water management system	Although only <i>Rhizophora</i> is comparable, survival rates were higher with the separate system.	<i>Rhizophora</i> showed higher survival rates with the separate system than with the concurrent system, while <i>Bruguiera</i> showed the opposite, though survival rates were low for both methods.

For *Rhizophora*, the separate system showed a tendency toward higher survival rates, while for *Bruguiera*, survival rates were low in both methods, with the separate system being lower. A possible cause is salinity concentration.

Salinity levels were measured in each pond where mangroves were planted during November 2024 to January 2025 and March to June 2025. Pond S1 (separate system) utilizes natural tides to introduce brackish water from the sea, whereas Pond S3 (concurrent system) introduces water stored in a reservoir. In November 2024, late in the dry season, the reservoir water salinity was higher than the brackish water. However, rainfall likely occurred afterward, causing the reservoir water salinity to drop to levels comparable to the brackish water. Subsequently, both S1 and S3 maintained similar salinity levels. By March, well into the rainy season, the

salinity in the S3 pond had decreased to a level below that of the brackish water (S1), reaching a low-level stable state. While *Rhizophora* can tolerate a wide range of salinity levels, *Bruguiera* prefers lower salinity. It is thought that the prolonged period of lower salinity promoted *Bruguiera* growth, though further verification is needed.

7.5.3 Survey for Mangrove Planting, Natural Regeneration, and Future Forest Structure

Within the RICAFE site where the technical verification ponds are located, there is an artificial mangrove forest (*Rhizophora mucronata*) planted in 1996 (27 years old at the time of the 2023 survey). Additionally, adjacent to the social verification pond, there is a natural mangrove forest (primarily *Rhizophora mucronata* and *Avicennia sp.*), and in a production plot also adjacent to the social verification pond, where shrimp aquaculture was previously attempted and subsequently abandoned, mangroves are naturally regenerating. In 2023, vegetation surveys using the belt transect method were conducted at these three locations. Based on these survey results, future forest conditions to be aimed for were examined from a biodiversity perspective regarding conservation management practices for the mangrove plantation and the naturally regenerated pond.

Figure 91 shows the belt transect survey results for the *Rhizophora mucronata* monoculture stand planted in 1996 (hereafter "Rhizophora plantation") at RICAFE. Figure 92 shows the belt transect survey results for the natural mangrove forest (hereafter "natural mangrove forest") adjacent to the social verification pond, and Figure 93 shows the results of the belt transect survey of natural mangrove regeneration in an abandoned aquaculture pond (hereinafter "natural mangrove regeneration site") also adjacent to the social verification pond. The estimated timber volume from these survey results is approximately 180 cubic meters per hectare (m^3/ha) for the artificial *Rhizophora* plantation, approximately 330 m^3/ha for the natural mangrove forest, and approximately 15 m^3/ha for the natural mangrove regeneration site.

exhibited a monotypic forest structure with trees of uniform height around 10 meters, a dark forest interior, no evidence of natural regeneration, and no invasion by tree species other than *Rhizophora mucronata*. Since there is no record of thinning after planting, assuming a high-density planting of 2m x 2m—a typical planting density—it is likely that the initial planting density decreased over time as planted trees lost competition and died. The dead trees scattered throughout the stand can be assumed to be the result of this process. Due to the high density of standing trees, there is a large amount of litter. Furthermore, as this is an area with slow brackish water inflow and outflow, anaerobic decomposition of the litter is progressing. Methane gas production resulting from this process was observed. Although the abundant organic supply and anaerobic decomposition likely promote carbon accumulation in the soil, the accompanying methane gas production—significantly more potent than carbon dioxide in terms of greenhouse effect—is a major concern. Considering this, the current verification results do not allow us to draw conclusions regarding the contribution of such planted forests to climate change mitigation.

is a mixed stand composed of *Rhizophora mucronata* and *Avicennia officinalis*, with tree heights ranging from 1 to 25 meters. Numerous naturally regenerated saplings are also present. Although the volume per

hectare is approximately 330 cubic meters, about twice that of the *Rhizophora* plantation, due to the presence of scattered large-diameter trees, the forest light conditions are favorable enough not to hinder the growth of naturally regenerated saplings. Although the high timber volume suggests greater litter accumulation than in *Rhizophora* plantations, the coastal location of the mangrove forest facilitates a smooth exchange of seawater and brackish water, likely promoting aerobic decomposition over anaerobic processes. Consequently, methane gas production has not been observed. Forming such a natural forest stand likely requires hundreds of years, but from a biodiversity perspective, it holds an advantage over artificial *Rhizophora* plantations.

Figure 93 consisted of *Rhizophora mucronata* with heights of 3 to 17 meters on the landward side, *Avicennia officinalis* with heights of 1 to 8 meters in the pond construction site from the landward to seaward side, and *Ceriops tagal* and *Avicennia alba* with heights of 1 to 5 meters on the seaward side. The taller *Rhizophora mucronata* trees appear to have been left standing during pond construction. *Avicennia officinalis* and *Ceriops tagal* are particularly noticeable in terms of natural regeneration. Although the exact abandonment date of the ponds is unknown, it is estimated to be about 10 years ago. It was confirmed that *Avicennia* acts as a pioneer species in natural regeneration and that the accumulation of timber volume is negligible compared to that achieved through planting.

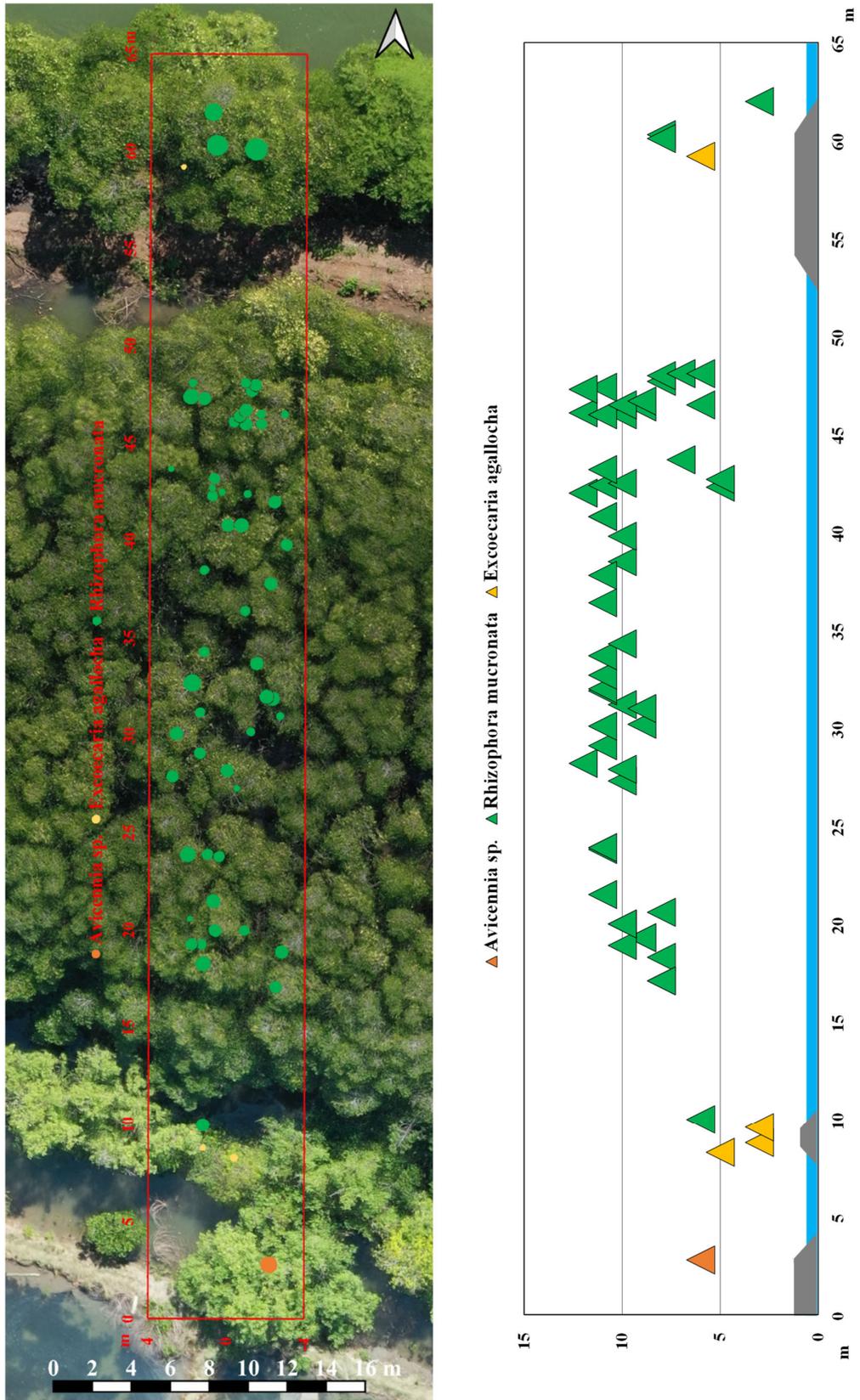


Figure 91: Belt transect survey results of a stand of *Rhizophora mucronata* planted in 1996

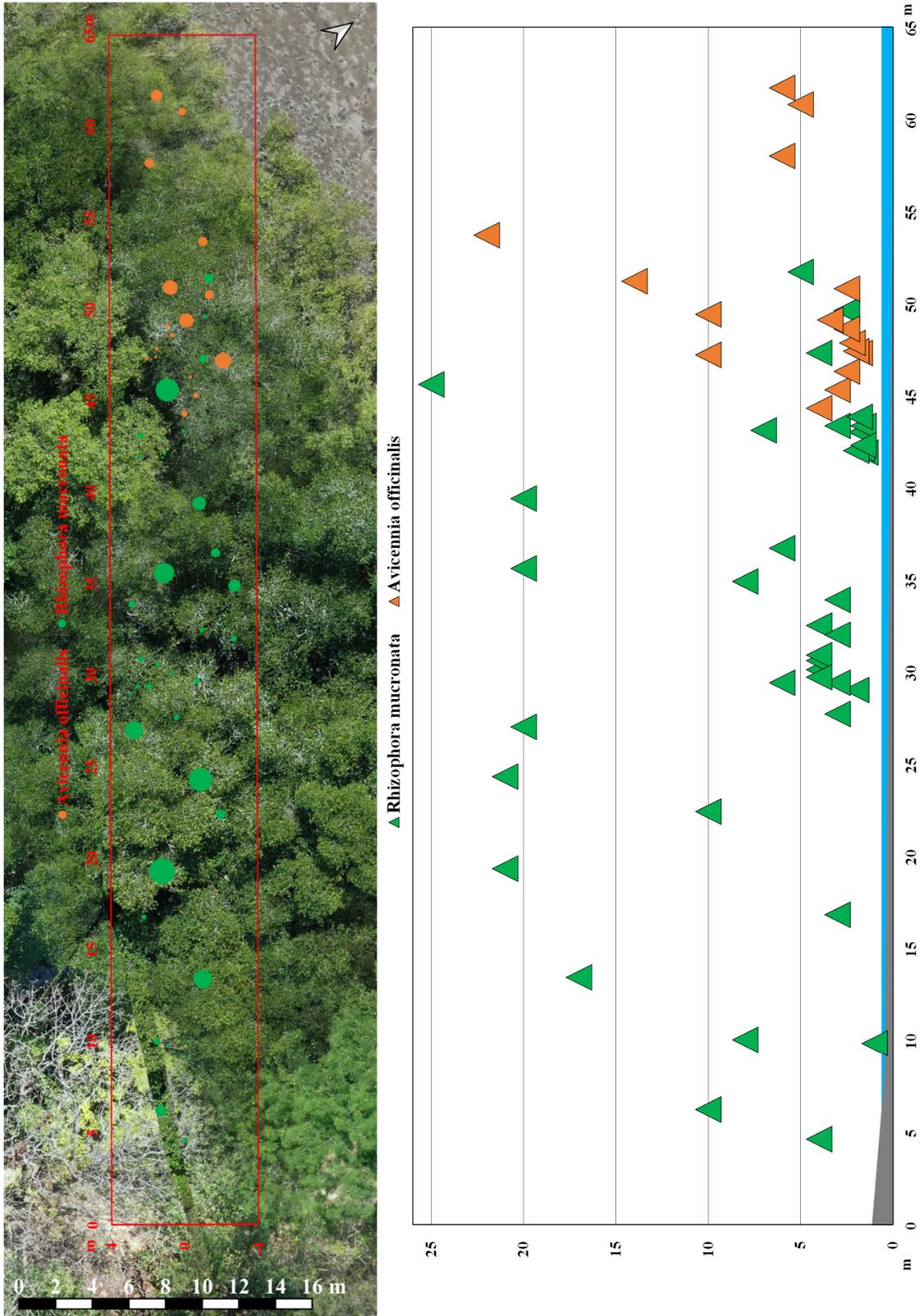
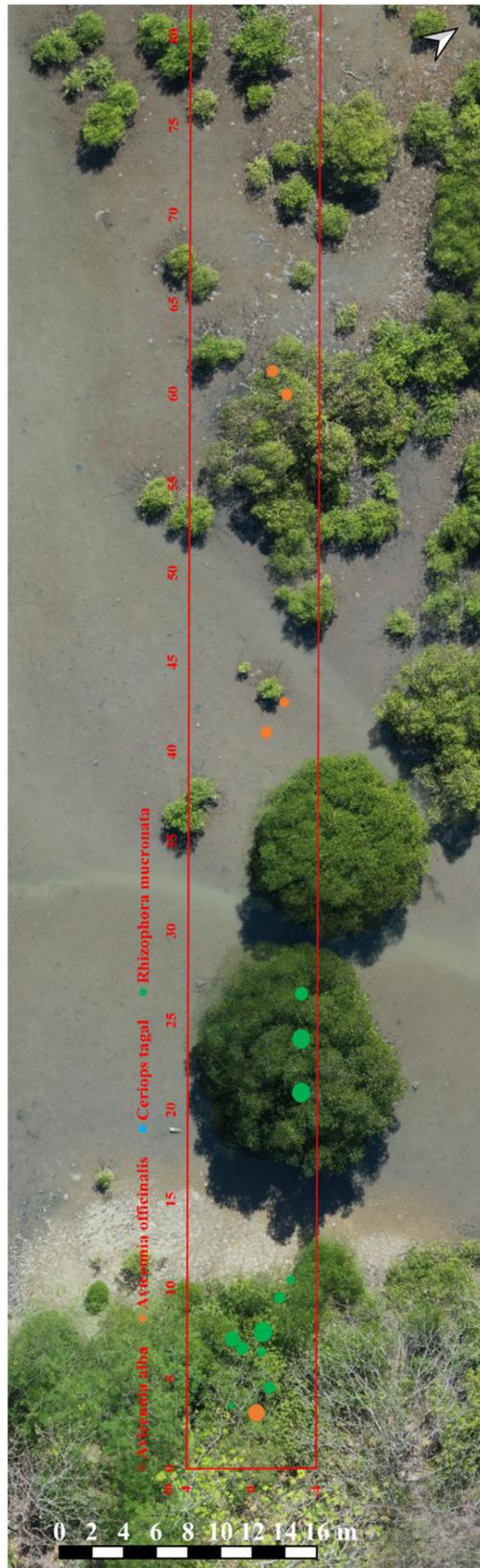


Figure 92: Results of belt transect survey of natural mangrove forest adjacent to the social verification pond



Figure 93: Results of belt transect survey of natural mangrove regeneration area adjacent to the social verification pond



Source: JICA Study team

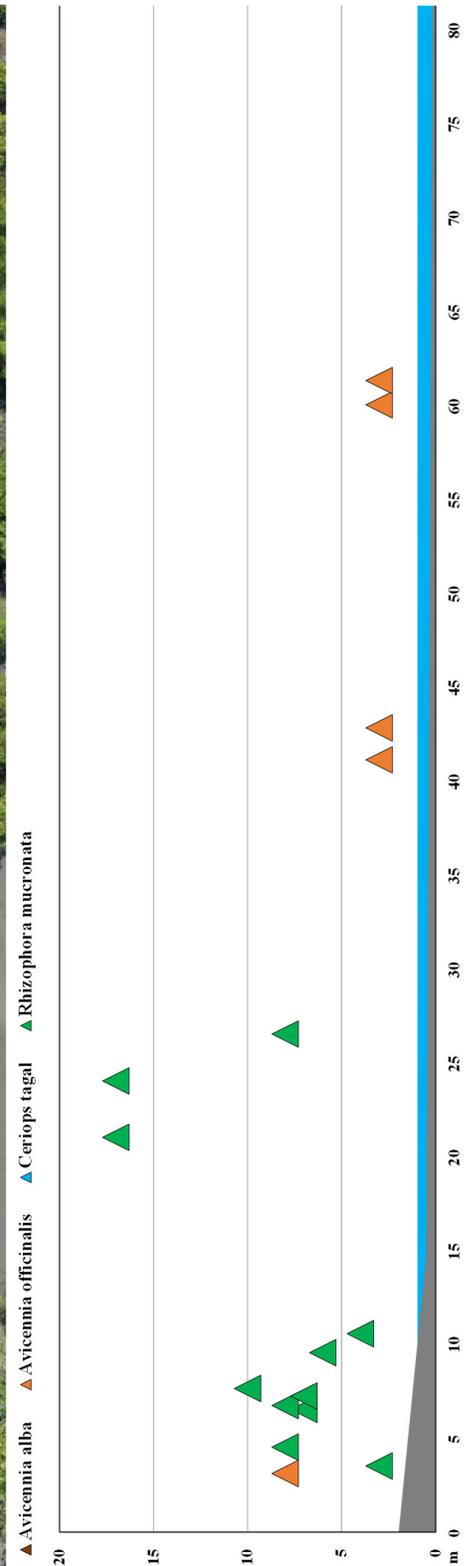


Figure 93: Results of belt transect survey of natural mangrove regeneration area adjacent to the social verification pond (continued)

7.5.4 Considerations Regarding Verification Items in the Mangrove Planting Verification Component

Section 7.3.4 lists the following as verification items under the responsibility of the Mangrove Planting Verification Component:

- a) Verify planting techniques by placing two mangrove species under different ground elevations and water management conditions
- b) Verify techniques from the perspective of interference between mangrove planting and shrimp aquaculture water management
- c) Investigate the carbon sequestration function of mangroves
- e) Examine mangrove management approaches that enhance biodiversity based on surveys of existing mangrove plantations and natural forests

These points are organized and examined as follows.

- (1) a) Verify planting techniques by placing two mangrove species under different ground elevations and water management conditions

When comparing *Rhizophora mucronata* and *Bruguiera gymnorhiza*, *Rhizophora* showed higher survival rates in the separate system than in the concurrent system, while *Bruguiera* exhibited low survival rates in both systems. Comparisons based on ground elevation differences were conducted only in the technical verification pond. While differences in mound height had little effect on *Rhizophora*, *Bruguiera* suffered complete mortality on low mounds. Conversely, on high mounds, it had a low survival rate of 14%. This indicates that in the technical verification pond, located approximately 2 km upstream from the river mouth, low mounds that remain constantly submerged are entirely unsuitable for *Bruguiera*, and survival rates remained low even on higher mounds experiencing periodic water loss due to tidal fluctuations. This indicates that careful verification of environmental suitability is essential for *Bruguiera* planting. In contrast, while *Rhizophora* showed higher survival rates in natural tidal environments, it also grew without fail in environments with a constant water level, demonstrating high adaptability to various conditions.

- (2) b) Verifying techniques from the perspective of interference between mangrove planting and shrimp aquaculture water management

The separate system has the advantage of good mangrove growth due to natural tidal water exchange. However, because the ponds are separate, no increase in macrobenthos or nutrient supply due to the presence of mangroves can be expected. Therefore, the separate system can be considered a water management approach that prioritizes mangroves.

The concurrent system is the exact opposite: the presence of mangroves positively impacts shrimp aquaculture, but mangrove survival rates drop to about half that of the separate system. Furthermore, mounds created within the ponds for mangrove planting result in shallower water depths only in those areas. This causes green algae to proliferate; as it decomposes, it generates ammonia, which negatively affects shrimp

aquaculture. To prevent this, simply co-cultivating milkfish is insufficient; manual removal of green algae is necessary, which requires significant labor. Furthermore, since green algae struggle to grow in shaded areas, once the mangroves reach a certain size and their canopy covers the water surface, green algae growth can be somewhat suppressed. Considering these factors, the following sequence is anticipated for long-term implementation of the concurrent system:

- (i) Construct mounds within the pond for mangrove planting and carry out the planting.
- (ii) Continuously remove green algae proliferating on the mounds.
- (iii) After one year or several years, remove dead seedlings in natural thinning. From a planting perspective, leave them in areas where removal prevents overcrowding and achieves appropriate planting spacing. In areas where large swaths have died, resulting in overly sparse planting spacing, perform replanting. This approach is expected to promote healthy mangrove growth and foster a more natural forest structure with multiple layers rather than a single layer.

Therefore, while the concurrent system has positive aspects for shrimp aquaculture, it also has the disadvantage of requiring labor-intensive maintenance.

- (3) c) Investigate the carbon sequestration function of mangroves

Since this verification item is analyzed and examined in detail in Section 7.9.2, it is omitted here.

- (4) e) Examine mangrove management approaches that enhance biodiversity based on surveys of existing mangrove plantations and natural forests

The artificial plantation of *Rhizophora mucronata* planted in 1996 at RICAFE is a single-layer stand with uniform tree height. The forest interior is dark, stand density is high, and there was an abundance of deadwood and litter. Water flow was not smooth, leading to advanced anaerobic decomposition of litter and methane generation. From the perspectives of climate change mitigation and biodiversity, even in planted forests, it is necessary to moderately adjust tree density through appropriate thinning to bring a certain level of light into the forest interior. Furthermore, it is necessary to ensure the smooth inflow and outflow of water to the extent possible to prevent litter from accumulating in place.

The natural mangrove forest adjacent to the social verification pond consisted of multiple tree species, including *Rhizophora mucronata* and *Avicennia officinalis*. Tree heights varied, and natural regeneration was confirmed. *Avicennia* dominated the coastal areas, while *Rhizophora* dominated inland sections, showing a good match between environment and tree species. Furthermore, due to the smooth flow of water facing the sea, little litter accumulation was observed. This demonstrates the importance of selecting tree species suited to the environment and ensuring smooth water flow.

In the mangrove natural regeneration sites within the abandoned aquaculture ponds adjacent to the social verification ponds, the invasion of pioneer species due to reliance on natural regeneration was confirmed, but they are few in number with slow growth and accumulation. Furthermore, tree species differed between the central and peripheral areas of the former aquaculture pond, possibly due to variations in soil quality. This

suggests that relying solely on natural regeneration results in extremely slow growth and accumulation, yielding far less biomass than can be expected from planting.

7.6 Socio-economic Survey in the Pilot Activity

7.6.1 Objectives of the Socio-economic Survey

The socio-economic survey was conducted with the aim of verifying the following items under the socio-economic survey component defined in Section 7.3.4. The results of these verifications will provide the basis for examining whether the silvo-aquaculture business model is a target for ESG investment in Section 7.7 based on a comparison of the Without-action scenario and With-action scenario established for the management unit of the silvo-aquaculture business model. The possibility of extending the With-action scenario (i.e. the management unit adopting the silvo-aquaculture business model) will be examined in Section 7.7 based on the results of the socio-economic survey, the verification results for black tiger shrimp aquaculture and mangrove plantation, and the assumptions set for the With-action scenario.

The following items were verified through the implementation of the socio-economic survey component:

- f) Verify the feasibility of ecosystem service valuation
- j) Verify the possibility of expanding the management scale through leased ponds
- k) Verify the existence of potential local partners
- l) Verify whether there is demand for ESG investment

7.6.2 Socio-economic Survey Methods

In this survey, 55 ponds were randomly sampled from the total survey population of approximately 1,600 aquaculture ponds in the Bontomanai area³⁷. For each sampled pond, one household related to the pond in some way (such as owner, tenant, or worker) was selected and a structured interview survey (hereafter referred to as the "sampling survey") was conducted. In this way, a total of 55 households living in the Bontomanai area and its vicinity were sampled. Furthermore, key informant interviews were also conducted to gather information on how they perceive the shrimp and carbon credit value chain. Since ecosystem service assessment is an important survey item in the sampling survey, and it is³⁸ considered desirable to set a maximum 10-year time horizon for the survey questions, the time horizon for the survey questions was set to 10 years. The socioeconomic survey was conducted from May to June 2024 using a questionnaire with the structure shown in Table 65.

Table 65: Questionnaire structure

Questionnaire components
Section I: Survey administration
01 Survey management items
Section II: Household composition and human resources (labor market dynamics)
02 Household structure and member characteristics
Section III: Dynamics of owned, rented, leased, managed, and operated aquaculture ponds and production environments after household formation
03 Characteristics of aquaculture ponds owned, rented, leased, managed, or operated after household formation

³⁷ Approximately 90% of the Bontomanai area of approximately 1,200 hectares is made up of aquaculture ponds.

³⁸ This is based on an interview conducted in March 2024 with Professor Kuriyama of Kyoto University, a member of the JICA technical support committee.

04 Deterioration of aquaculture ponds owned, rented, leased, managed, or operated after household formation and related market dynamics
05 Past (10 years ago and 5 years ago), present (2023/24), and future (5 years from now) dynamics of the aquaculture product market
06 Current (2023/24) production costs, sales and profits for the sampled ponds
Section IV: Land, buildings, machinery, equipment, and tools currently owned, rented, or leased by the household
07 Land and buildings currently owned, rented or leased by households.
08 Machinery, equipment, and tools currently owned, rented, or leased by the household
Section V: Valuing ecosystem services provided by silvo-aquaculture in Bontomanai
09 Valuing ecosystem services using market price survey, replacement cost, and travel cost methods
10 Contingent valuation method for the value of ecosystem services related to habitat provision and natural landscapes

7.6.3 Verification Results for "f) Verify the feasibility of ecosystem service assessments"

Based on the ecosystem services assessment protocol developed in this study, and using the results of the socio-economic survey, the parameters for ecosystem service assessment of the silvo-aquaculture business to be implemented in the Bontomanai area were determined, and an ecosystem services assessment was carried out. The details and results of the assessment are described in Chapter 6. Therefore, an ecosystem services assessment can be carried out in the silvo-aquaculture businesses as a part of the production operations.

7.6.4 Verification Results for "j) Verify the possibility of expanding the management scale through leased ponds"

The silvo-aquaculture business management unit established in Bontomanai includes multiple production units owned by a single absentee landowner and does not represent the small-scale household ownership common in the area. On the other hand, there is a case that Mr. E is contracted to manage a silvo-aquaculture production unit producing milkfish, vanamei shrimp, black tiger shrimp, Gracilaria, and salt. As this example shows, there are individuals contracted to manage medium-sized aquaculture operations of approximately 20 ha in Bontomanai. However, this example is not representative of the consolidation of ponds through leasing or contracting in the management of small aquaculture ponds owned by households in the area. There are varieties of combination of pond ownership, leasing/renting, and operating. For this reason, we conducted a socioeconomic survey to examine the possibility of this type of pond consolidation.

The following factors promote the establishment of a management unit in the silvo-aquaculture business model:

- 1) The existence of pond leasing and production service markets that allow for the accumulation of aquaculture pond management, and the possibility that this market will become more active in the future.
- 2) The possibility that the opportunity cost of aquaculture ponds will decrease, making it possible to lease ponds and outsource their management at lower costs, and the possibility that the opportunity cost of mangrove planting will decrease, making it possible to plant a larger area.

These possibilities will be examined below based on the results of the socio-economic survey.

- (1) The existence of pond leasing and production service markets that allow for the accumulation of aquaculture pond management, and the possibility that this market will become more active in the future

In the Bontomanai area, the labor shortage has become pronounced, and even households that own aquaculture ponds are increasingly leasing them out or using production management services due to the labor shortage. This is shown by the results of a socio-economic survey and provides supporting evidence for the expansion of the markets for pond leasing and aquaculture production services. The expansion of these markets suggests the possibility of a concentration of aquaculture ponds through leasing and provision of production management services. The evidence for the expansion of the markets for leasing and production services is presented below.

Survey Result 1: At the time of the survey, the market for leasing aquaculture ponds and the market for aquaculture production management services were developing. Table 66 indicates that pond owners operate 58% of their ponds themselves, outsource production for 20%, which incurs outsourcing fees, and lease 22% of ponds for share cropping or fixed rent arrangements. Forty-two percent (42%) of all ponds owned by residents inside or outside of the Bontomanai area are operated by third parties. There are 1,600 large or small ponds in the Bontomanai area, and over 40% of them are outsourced or leased and incur transactions for outsourcing fees and rent. Therefore, it can be concluded that the pond market is well developed in this area. Furthermore, pond lessees operate aquaculture in the leased ponds (63% of leased ponds), and either outsource production in the leased ponds (24% of leased ponds) or sublease leased ponds (13% of leased ponds), indicating the complex nature of the market.

Table 66 also shows the duration of outsourcing or leasing of ponds. Twenty-five percent (25%) of ponds related to the survey respondents were outsourced or leased on a permanent basis, 9% on a multi-year basis, and 14% on an annual basis. In total, 48% of the ponds was leased. Taking into account that 42% of the ponds are operated by third parties, this suggests that approximately 40-50% of ponds are subject to outsourcing or leasing in the market. The silvo-aquaculture business model requires the consolidation of aquaculture management by leasing ponds and/or the provision of production services to establish large-scale management units. This requires long-term leasing or service provision arrangements, and the fact that 25% of ponds are under long-term contracts suggests the feasibility of consolidating ponds to establish and secure management units.

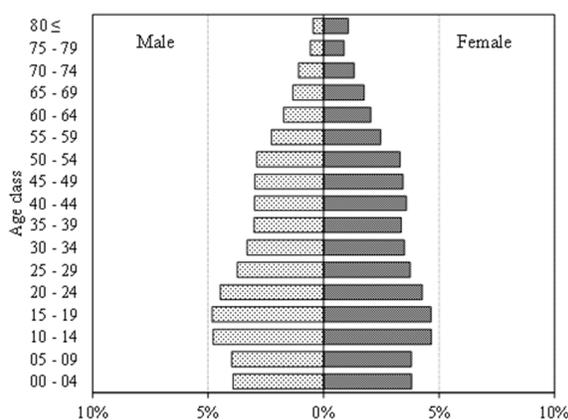
Table 66: Forms of production outsourcing, leasing of aquaculture ponds, and period of outsourcing or leasing

Types of outsourcing and leasing out of aquaculture ponds	Aquaculture pond owner			Aquaculture pond leasee			Conduct aquaculture as a contractor	Worked as a aquaculture worker	Other management or unknown	Total	Total outsourcing or leasing out cases	Total pond observations
	Conducting aquaculture	Outsourcing aquaculture	Leasing out aqua. pond	Conducting aquaculture	Outsourcing aquaculture	Sub-leasing aqua. pond						
Period of outsourcing or												
Long-term outsourcing or leasing out		5%	6%	6%	3%		1%	4%		25%		39
Multi-year outsourcing or leasing out		1%	1%	7%						9%	48%	14
One-year outsourcing or leasing out				6%	4%	4%				14%		21
No outsourcing or leasing	16%							15%	4%	34%		53
Unknown	3%							7%	7%	18%		27
Total %	19%	6%	7%	19%	7%	4%	1%	26%	11%	100%		154
% of ponds owned/leased out to Total		32%		30%								50
% of aquaculture/outsourcing/leasing to each owner/leasee Total	58%	20%	22%	63%	24%	13%						46
Total pond observations	29	10	11	29	11	6	1	40	17	154		

Source: JICA Study Team

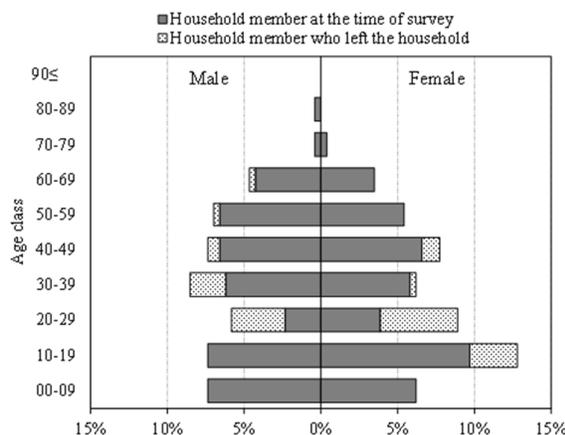
Survey Result 2: Information on population structure shows significant aging of the population and the migration of young workers to other industries, resulting in a shortage of labor in the aquaculture industry in recent years.

The population structure of the local community in Bontomanai and neighboring areas is currently undergoing rapid change. Compared to aquaculture, labor demand in the service sector in urban areas is rising, and in recent years, there has been a noticeable increase in young people moving out of the village to work in this sector. As a result, the local community is aging, the young labor force is decreasing, and the labor shortage for aquaculture is accelerating.



Source: Indonesian Government

Figure 94: Estimated population structure of Pangkep Province in 2024



Source: JICA Study Team

Figure 95: Age distribution of household members in households after the establishment of the household (proportion of the total 258 members as of 2024)

Table 67: Occupation of household members at the time of the survey

Gender	Age group	Self-employed											Employed			Not employed					No data	% to the total HH members	No. of current HH members observed									
		Aquaculture	Fisheries	Agriculture	Service	Processing	Transportation	Trading	Retailing	Artisan	Business owner	HH management	Other	Daily labor	Private firm	Public sector	Unemployed	Student	Child below 6	Retired				Unable to work								
Female	00-09																5%	9%	1%				15%	16								
	10-19											1%					22%						23%	25								
	20-29	1%									1%	1%	1%	1%	1%	2%						1%	9%	10								
	30-39	1%									8%				2%								3%	14%	15							
	40-49				1%						14%					1%								16%	17							
	50-59										13%													13%	14							
	60-69										1%	7%										1%		8%	9							
	70-79											1%												1%	1							
	80-89																															
	90≤																															
Total	2%			1%						2%	45%		1%	1%	3%	2%	29%	9%	1%	1%		4%	100%	107								
Totals of self-employed/employed/not employed											50%		5%																			
Male	00-09																12%	5%	1%				18%	19								
	10-19	1%														1%	16%						18%	19								
	20-29	1%								1%				1%			3%						6%	6								
	30-39	12%												1%								2%	15%	16								
	40-49	14%								2%													16%	17								
	50-59	13%								1%					1%	1%							16%	17								
	60-69	10%																					10%	11								
	70-79	1%																					1%	1								
	80-89	1%																					1%	1								
	90≤																															
Total	53%									3%	1%		1%	2%	1%	1%	31%	5%	1%		2%	100%	107									
Totals of self-employed/employed/not employed											57%		4%																			

Source: JICA Study Team

Table 68: Occupations of members who have already left the household at the time of the survey

Gender	Age group	Self-employed											Employed			Not employed					No data	% to the total HH members	No. of current HH members observed								
		Aquaculture	Fisheries	Agriculture	Service	Processing	Transportation	Trading	Retailing	Artisan	Business owner	HH management	Other	Daily labor	Private firm	Public sector	Unemployed	Student	Child below 6	Retired				Unable to work							
Female	00-09																														
	10-19																														
	20-29									4%	16%		4%				4%		4%					32%	8						
	30-39										24%		8%	8%	12%									52%	13						
	40-49														4%									4%	1						
	50-59										4%													8%	3						
	60-69																														
	70-79																														
	80-89																														
	90≤																														
Total										4%	44%		12%	8%	16%		4%		4%			8%	100%	25							
Totals of self-employed/employed/not employed											48%		36%																		
Male	00-09																														
	10-19																														
	20-29	5%												32%	11%									47%	9						
	30-39	11%					5%			5%				11%										32%	6						
	40-49	11%																						11%	2						
	50-59	5%																						5%	1						
	60-69																						5%	5%	1						
	70-79																														
80-89																															
90≤																															
Total	32%									5%			42%	11%								5%	100%	19							
Totals of self-employed/employed/not employed											42%		53%																		

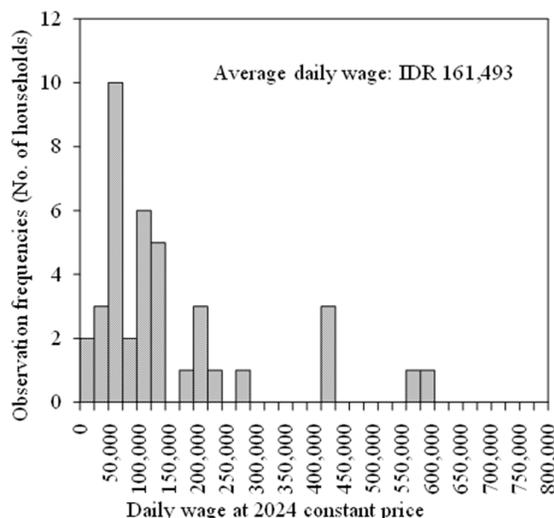
Source: JICA Study Team

Figure 94 shows the population structure of Pangkep Province, including the Bontomanai area and urban areas. Pangkep Province is already experiencing a declining birth rate, with the population of people under the age of 14 beginning to contract. Figure 95 shows the population structure of households that own or operate aquaculture ponds in the Bontomanai area, where a similar declining birth rate is occurring. Looking at the drop in the number of people in their 20s, it is unlikely that there will be enough people in their 20s to fill the gap as those in their 50s reach their 60s and retire from the aquaculture sector.

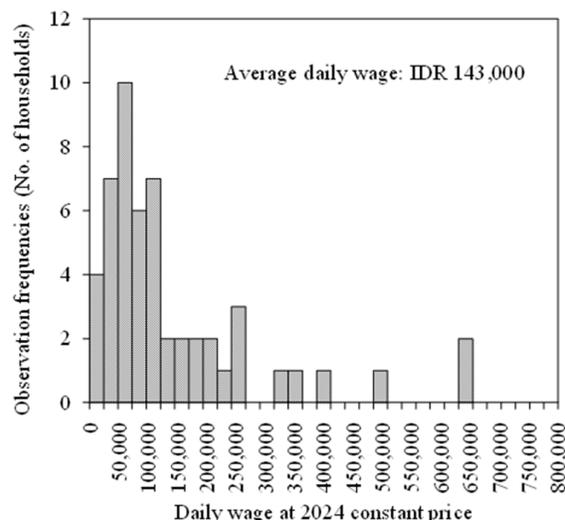
Table 67 shows the occupations of household members at the time of the 2024 survey, while Table 68 shows the occupational composition of household members who had already left the household at the time of the same survey. Nearly half (45%) of the women who left the household at the time of the survey were self-employed as household managers, and more than half (53%) of the men were self-employed as aquaculture workers. Noteworthy here is the low employment rate for both men and women. In contrast, Table 68 shows that 36% of women who left the household were employed, while 53% of men who left the household were employed. Given the limited employment opportunities in the private and public sectors in Bontomanai and surrounding areas, these members are thought to have left the village and taken up employment. Among the household members who left the household, none of the women were employed in aquaculture, and only 32% of the men were employed in aquaculture. This suggests that a continued decline in the aquaculture workforce in these areas is expected.

Survey Result 3: Stagnation or decline in real wages for households in aquaculture-dominated areas

The trend of declining aquaculture workers aligns with the recent perceived decline in real wages among survey respondents. Figure 96 shows the daily wages perceived by household heads from 2010 to 2015, adjusted to 2024 prices. The average real daily wage is approximately 161,000 rupiah. The average nominal daily wage mentioned was 110,000 rupiah. Figure 97 shows that the average real daily wage and nominal wage at the time of the 2024 survey were 143,000 rupiah. Although nominal daily wages increased during these periods, considering inflation, it is reasonable to conclude that household heads perceived stagnant or declining real wages, specifically, stagnant or declining labor productivity in the aquaculture industry, the primary industry in the Bontomanai region and surrounding areas.



Source: JICA Study Team



Source: JICA Study Team

Figure 96: Daily wages of household heads from 2010 to 2015 **Figure 97: Daily wage of household heads in 2024**

Table 69: Relationship between labor force of households that own aquaculture ponds and leasing of aquaculture ponds

Cases of household use or rental of aquaculture ponds	Number of cases	Par ha. aquaculture pond average number of working-age household members per household (Form 20 years old to 65 years old) ^{*1}	Standard deviation
Households that own aquaculture ponds and conduct aquaculture in all ponds by themselves	16	4.36	4.40
Households that own aquaculture ponds and conduct aquaculture themselves in some of the ponds and rent out others (1 case) and all households renting out their all aquaculture ponds (3 cases)	4	0.38	0.38

Note: People of working ages 15 to 19 were excluded because they were all students.

Survey Result 4: When comparing the labor force (per unit area of the pond) of households that own ponds and operate aquaculture themselves with the labor force (per unit area of the pond) of households that own aquaculture ponds but rent out their ponds or outsource the management of their aquaculture, the labor force of the latter tends to be smaller.

Table 69 shows the relationship between the labor force of households that own aquaculture ponds and leasing out the ponds by comparing the number of working-age household members per hectare of the pond in cases where the households themselves conduct aquaculture and cases where the ponds are rented out. Although there were only four cases in the latter case, the average number of working-age household

members (0.38 people/ha) was smaller than in the former case (4.36 people/ha). This suggests that households that own aquaculture ponds tend to decide to rent out or outsource the management of their ponds when their household labor force becomes smaller.

Summary A: Survey Result 4 suggests that households that own aquaculture ponds tend to rent out their ponds or outsource aquaculture operations when labor becomes tight. In other words, the market for aquaculture pond leasing and aquaculture management services is developing (Survey Result 1). This is due to the labor shortage among aquaculture pond-owning households, which is driven by the aging population (Survey Result 2) and the stagnant wage levels in the aquaculture industry (Survey Result 3). Survey Result 2 suggests that the labor shortage will accelerate in the future, and therefore the markets for aquaculture pond leasing and aquaculture management will expand accordingly. This trend may favor the accumulation of aquaculture ponds of approximately 20 hectares, which require the establishment of a management unit for the silvo-aquaculture business model through the leasing of aquaculture ponds and the outsourcing of aquaculture management. However, it may also increase conflicts between silvo-aquaculture businesses and self-aquaculture-operating households with their own ponds. If a region is to undertake silvo-aquaculture, it will be necessary to keep an eye on market trends and make efforts to gain the understanding of pond-owning households on the silvo-aquaculture business model through technology dissemination and educational activities.

(2) The possibility that the opportunity cost of aquaculture ponds will decrease, making it possible to lease ponds and outsource their management at lower costs, and the possibility that the opportunity cost of mangrove planting will decrease, making it possible to plant a larger area.

If the opportunity cost of aquaculture ponds is high, using part of the pond for mangrove planting represents a significant loss. Therefore, lowering the opportunity cost of aquaculture ponds is advantageous for expanding mangrove plantation areas. From the perspective of profit per unit pond area, aquaculture is becoming more extensive, which is thought to be positively correlated with the declining value of aquaculture ponds as property. Because the survey did not collect information on the opportunity cost of aquaculture ponds, we used trends in extensive aquaculture and property value as a proxy for trends in the opportunity cost of aquaculture ponds. In other words, lower land rents for leased ponds and lower aquaculture management fees (payments to contractors) lead to lower opportunity costs for aquaculture ponds, which in turn leads to larger mangrove plantation areas, favoring the establishment and management of management units in the silvo-aquaculture business model. (However, as mentioned above, attention must be paid to the risk of social disintegration between the silvo-aquaculture businesses and self-employed households that continue traditional aquaculture in their own ponds.) Based on these assumptions, a decline in the opportunity cost of aquaculture ponds was examined using the following steps.

With a focus on households engaged in milkfish production, following verifications were conducted; 1) verify

the correlation between the extensiveness of milkfish aquaculture and the size of aquaculture ponds, and 2) verify the correlation between the extensiveness of milkfish aquaculture and the price per unit area of the aquaculture ponds. The results show that the decline in land prices for aquaculture ponds is correlated with the size of the aquaculture ponds and the extensiveness of aquaculture. In addition, the following trends in the whole study area were recognized; 3) the trend of increasing extensiveness of milkfish aquaculture, and 4) the trend of increasing siltation in the aquaculture ponds and water channels, which is interpreted as proxy indicators of the decline in the property value of the aquaculture ponds. Finally, the trend of decline in per unit area leading decline in opportunity cost was verified. The details of these survey results are explained below.

Survey Result 5: Figure 98 shows the relationship between milkfish yield per unit area (kg/ha) and the size of the ponds where the milkfish are cultivated. The figure indicates that the larger the pond, the more extensive the milkfish production, and the lower the yield per unit area. Therefore, as a general trend, it can be assumed that the larger the pond, the lower the opportunity cost per unit area, and the more likely it is that the area will be suitable for mangrove planting due to the low opportunity cost. This also leads to the hypothesis that in the past, large ponds were constructed in areas with low productivity in terms of unit area output, or that such low productivity ponds have not been subdivided into small ponds.

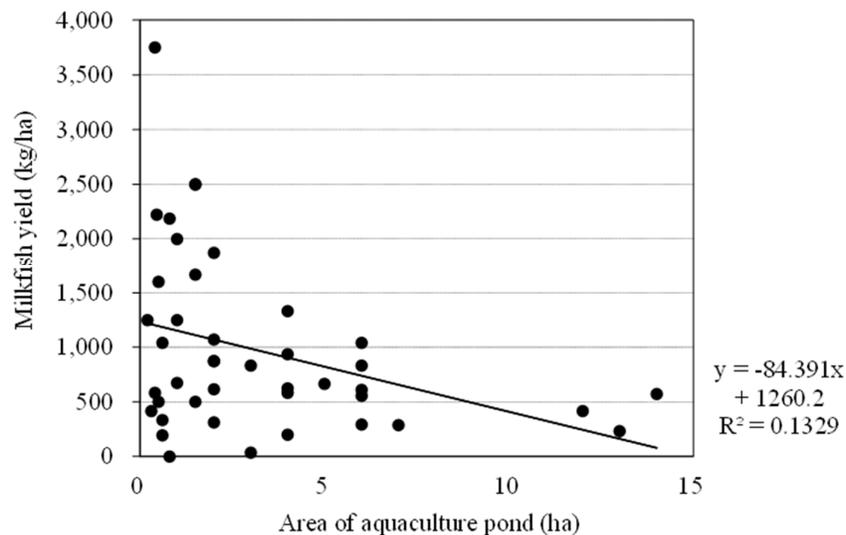


Figure 98: Relationship between milkfish yield per unit area and area of aquaculture ponds

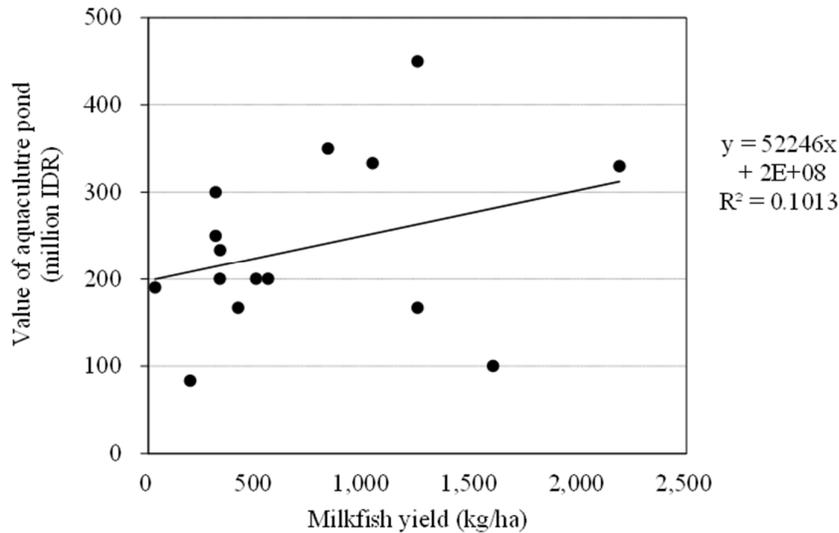


Figure 99: Relationship between per hectare land price for aquaculture ponds and milkfish yield per unit area

Survey Result 6: Using a household that owns aquaculture ponds and produces milkfish in the ponds as an example, the data suggests that the lower the profit per unit area (expressed by yield as a proxy for profit), the lower the perceived land price per unit area of the aquaculture pond.

Figure 99 shows the land price per hectare of the pond where milkfish are cultured, as perceived by the households that own aquaculture ponds and cultivate milkfish by themselves in the ponds. The greater the harvest per unit area, the greater the variation in the land price per unit area of the pond, but as a general trend, there was a positive correlation between land price and harvest.

Survey Result 7: It was confirmed that the overall trend perceived in the survey area was that aquaculture was becoming more extensive.

Gracilaria production in aquaculture ponds was recognized as an example of extensive aquaculture among the fisheries extension workers and the local aquaculture operators in the survey area. As shown in Table 70, no sampled households reported Gracilaria production. However, key informant interviews with businesses engaged in the collection, storage, and primary processing of Gracilaria in neighboring Bontomanai revealed that Gracilaria production in the area has been increasing in recent years. Furthermore, Table 70 indicates an increasing trend to select milkfish as an aquaculture species, both in the past and in the five-year forecast. The reasons cited for this include the low cost of labor and feed with respect to the sale value, as well as its disease resistance characteristics. Milkfish has been increasingly selected in the past as a product suited to extensive aquaculture, and it is recognized as a product that will continue to be selected more in the future.

On the other hand, in the surveyed area, black tiger shrimp aquaculture is considered sensitive to factors such as disease and extreme weather conditions, and the survey results indicate that selection of black tiger shrimp

as an extensive aquaculture species has been declining. Interviewees predicted that almost no black tiger shrimp aquaculture would be practiced in five years' time (Table 70). Conversely, this suggests that the verification and adoption of semi-intensive black tiger shrimp aquaculture techniques envisioned in the implementation of the silvo-aquaculture business model should be considered and explained as a new and corporate aquaculture business model subject to ESG investment, and that the model differs from the current trend toward extensive black tiger shrimp aquaculture.

Table 70: Percentage of products produced in the past and present, and those expected to be produced in the future in the Bontomanai area

Aquaculture products	1980-1990	2010-2015	2024 current	5-year forecast
Black Tiger	11%	6%	7%	1%
Vannamei shrimp	10%	11%	14%	10%
Milkfish	67%	70%	75%	84%
Tilapia				
Gracilaria (seaweed)				
Salt		1%	3%	4%
Mangrove				
Minor forest products				
Others				1%
Not known	12%	11%	1%	
Total %	100%	100%	100%	100%
Total observations	122	158	181	154

Source: JICA Study Team

Survey Result 8: Throughout the survey area, there is a strong awareness of the increasing siltation of ponds and waterways, the resulting deterioration of the production environment, and the expectation of further deterioration in the future.

Table 71 shows the awareness of increasing siltation and worsening of water quality trends in the past 15 years. The majority of survey respondents are concerned about further deterioration over the next five years. Since the creation of the aquaculture ponds, there has been almost no dredging of the ponds or channels, which has led to increased siltation and has hindered smooth water management, while the accumulation of undecomposed organic matter has led to a deterioration in water quality, which is a problem that is widely shared by those involved.

Table 71: Perceived changes in production infrastructure, labor and product markets, and transportation infrastructure

Answers about change	Sedimentation in aquaculture ponds			Sedimentation in water channels			Water quality			Labor market			Produce Market			Roads and transportation		
	1980-1990 era	2010-2015 year	5-year forecast	1980-1990 era	2010-2015 year	5-year forecast	1980-1990 era	2010-2015 year	5-year forecast	1980-1990 era	2010-2015 year	5-year forecast	1980-1990 era	2010-2015 year	5-year forecast	1980-1990 era	2010-2015 year	5-year forecast
Worthened		56%	85%		56%	85%		56%	82%		16%	31%	2%	40%	40%	75%	2%	2%
Unchanged	2%	22%	7%	2%	22%	7%	2%	22%	11%	36%	56%	51%		20%	25%	9%	53%	72%
Improved	91%	16%	4%	91%	16%	4%	91%	16%	4%	58%	22%	15%	91%	34%	31%	9%	39%	22%
Do not know	7%	6%	4%	7%	6%	4%	7%	6%	4%	7%	6%	4%	7%	6%	4%	7%	6%	4%
Total %	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Total observations	45	50	55	45	50	55	45	50	55	45	50	55	45	50	55	44	49	54

Source: JICA Study Team

Summary B: Based on the population structure shown in Survey Result 2, it is expected that the labor shortage will worsen in the future. Survey Result 8 shows that siltation in aquaculture ponds and waterways has been observed in the past and is expected to continue in the future, which will lead to a further decline in pond productivity. Survey Result 6 confirms that the decline in pond productivity is related to a decline in labor productivity, which is consistent with the outflow of young labor shown in Survey Result 2. From this, it is concluded that the opportunity cost of aquaculture ponds will further decrease in the future.

Survey Result 5 confirmed a positive correlation between labor shortage and the degree of extensive milkfish aquaculture, and Survey Result 6 confirmed a positive correlation between the degree of extensive aquaculture and the price per unit area of aquaculture ponds. This confirms that the decline in land prices for aquaculture ponds is positively correlated with the shortage of labor and the extensiveness of aquaculture. Additionally, Survey Results 7 and 8 indicated that there was a trend across the survey area toward the increasing extensiveness of aquaculture and a recognition of increased silting in aquaculture ponds and waterways. These findings are taken as an indication of a decline in the property value of aquaculture ponds, and based on these results, we conclude that there is a trend toward a decline in unit area opportunity costs, which is favorable socio-economic condition for the expansion of mangrove plantation.

7.6.5 Verification Results for "k) Verify the existence of potential local partners"

In Section 7.6.4, the factors examined as facilitating the establishment of a management unit for the silvo-aquaculture business model were (1) the existence of a land (or aquaculture pond) market that allows for the accumulation of aquaculture ponds, with the expectation of future expansion, and (2) the declining opportunity cost of aquaculture ponds. In this section, based on the results of a socio-economic survey, we will examine whether there are people in the Bontomanai area and/or surrounding areas who could be managers and/or partners in ESG investment if management units for the silvo-aquaculture business model are established.

As a result of the verification presented in Section 7.6.4, it was predicted that the market for leasing

aquaculture ponds and the market for outsourcing and contract management would expand. This section further introduces the results of the observations that the division of labor in the aquaculture industry in this area has progressed, that businesses specializing in aquaculture management have emerged, and that consolidating aquaculture ponds and managing them through leasing and contracted management has progressed in the Bontomanai area. Based on this, we conclude that these businesses are candidates for local partners.

It was reported that there are approximately five individual entrepreneurs specializing in aquaculture management who are driving the aquaculture outsourcing market and the aquaculture pond leasing market in the Bontomanai area and surrounding areas. Key informant interviews were conducted with these individual entrepreneurs. Mr. F, who is cooperating with us in the social verification pond verification activity, is responsible for aquaculture in the production area, which is the management unit for the silvo-aquaculture business model. He is one of the five individuals. In the survey, Mr. F and one other aquaculture management business owner (who also acts as a broker for seafood products such as milkfish, vannamei shrimp, and black tiger shrimp) were interviewed. The interview results confirmed that these individual entrepreneurs, who engage in medium-scale operations, are responsible for securing market access, financial management, human resource management, and production management for their businesses. Since it was assumed that local partner candidates possess these management qualities, it was concluded that local partner candidates can be found in Bontomanai and its vicinity areas, which is a requirement for foreign investment in Indonesia's aquaculture industry. However, to make a final decision on ESG investment for the establishment and operation of a silvo-aquaculture joint venture firm(s), it will be necessary to assess detailed information about these candidates.

Individual business operators who specialize in aquaculture management are significantly concerned about the productivity of the aquaculture ponds they manage. For example, with regard to the decline in productivity due to siltation in aquaculture ponds and irrigation channels, these operators carefully select ponds for contract production and leasing (or in some cases purchasing) that are located along coasts or near brackish rivers close to the sea, where siltation is less likely to affect productivity, and that offer convenient access to fresh seawater and brackish water. As this example shows, the deterioration of water quality due to siltation leads to extensive aquaculture practices and narrows the range of products that can be produced. However, even the business operators specializing in aquaculture management have not taken proactive measures to improve the production environment through investment due to financial constraints. They instead are responding passively by selecting favorable locations and continuing extensive aquaculture practices. In this regard, forming partnerships as a condition for ESG investment from Japan could potentially alleviate these investment constraints. This issue will be discussed in the results of the ESG investment demand analysis below.

7.6.6 Verification Results for "1) Verify whether there is demand for ESG investment"

This section presents the results of an examination of the demand and supply potential for ESG investment, from the perspectives of both seeking capital and wishing to commit capital as ESG investment. The latter investment commitment can be seen as a willingness to provide capital in the hope of improving the aquaculture industry in the Bontomanai region, which is currently experiencing a cycle of low investment and low return on extensive aquaculture. ESG capital injection will stimulate the aquaculture industry by improving production infrastructure and introducing technological innovation. This will lead to a shift to silvo-aquaculture, which will have two objectives: productivity improvement and mangrove restoration and conservation. This mutually beneficial scenario for the local aquaculture industry and ESG investors is the focus of this section, which will explore the demand and supply opportunities for ESG investment.

(1) Demand for funds that require ESG investment is confirmed

Survey Result 9: Throughout the survey area, there is a strong awareness of the increasing siltation of ponds and waterways, a resulting deterioration of the production environment, and an expectation of further deterioration in the future.

The results of this survey introduced in the previous section support the finding that the opportunity costs of aquaculture ponds are declining, but they also suggest the possibility of potential demand for large ESG investments.

It is recognized that the long-term continuation of extensive aquaculture has led to a lack of investment in dredging and repairs to the aquaculture ponds and irrigation channels that serve as the production base, resulting in a deterioration of the aquaculture environment due to sediment accumulation, brackish water stagnation, and water quality deterioration. This deterioration is said to be related to the decline of black tiger shrimp aquaculture, which was popular in the 1980s, and the need for investment to improve the aquaculture environment is widely shared by the local government of Bontomanai and by fisheries officials at the prefecture and state levels.

The study team believes that an integrated fresh sea and brackish water supply and drainage system driven by tidal power is formed by the waterway network connecting the aquaculture ponds, the water supply and drainage weirs, the brackish rivers that form the backbone of the waterway network, and the coastline. Investment in the introduction of individual silvo-aquaculture businesses alone would only produce limited improvements. Instead, effective and efficient investment guided by a well-defined silvo-aquaculture development plan is required. In the plan, multiple silvo-aquaculture business management units connected by the rivers and waterway networks coordinate with each other to maintain and improve an integrated water management system that improves productivity and restores and conserves mangroves. However, no such examples of proactive implement measures were found in the study area due to perceived financial constraints and the high cost of coordinating conflicting interests and technology development. These

findings suggest that if the financial viability of the With-action scenario can be ensured and the development of multiple silvo-aquaculture businesses can be envisioned, it should be possible to stimulate demand for ESG investment to improve aquaculture infrastructure and mangrove environment in an integrated manner.

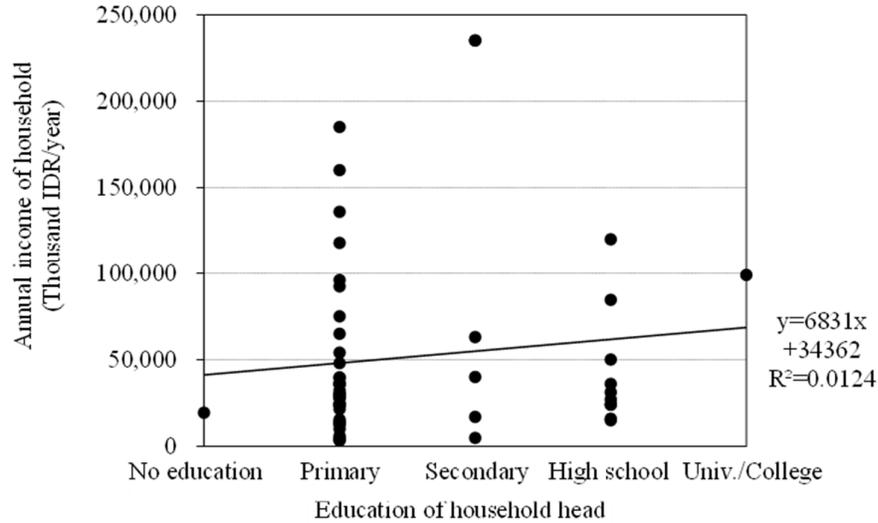
(2) Investment commitment from the perspective of ESG investment fund providers

As discussed in Section 7.6.4, even if the feasibility of consolidating silvo-aquaculture operations through pond leasing pond and outsourcing operations is verified, implementation of the With-action scenario to achieve higher labor productivity requires technological breakthroughs in the simultaneous introduction of semi-intensive aquaculture with black tiger shrimp or other appropriate species and mangrove plantation and conservation. Furthermore, in addition to the investment for such technological breakthroughs, implementing the With-action scenario would further require investment in the development of aquaculture infrastructure. However, as long as the current extensive aquaculture system remains in place, investment needs will not emerge from those involving extensive aquaculture. In fact, the production method used by existing business operators who are contracted to manage the aquaculture ponds under consolidated management is extensive aquaculture, an extension of traditional aquaculture.

From the perspective of such individual business owners, it is natural that they prioritize traditional technologies that are well-established and low risk. To select the With-action scenario for a new business model, they must first be confident that (1) the technology in the With-action scenario is acceptable and that environmental considerations are of interest, (2) the necessary investment funds are available, and (3) that higher profits are likely to be secured. From the perspective of the fund provider, actively committing to implementing the With-action scenario through ESG investment can alleviate local partners' concerns about the prospects for securing the necessary funds, and concern about the business prospects, since it is assumed that the management and technology package already exists, which can provide confidence that profits are likely to be secured. Therefore, whether a commitment to ESG investment can increase the acceptability of the technology in the With-action scenario and the level of environmental concern of local communities which in turn will stimulate willingness of ESG investors to invest.

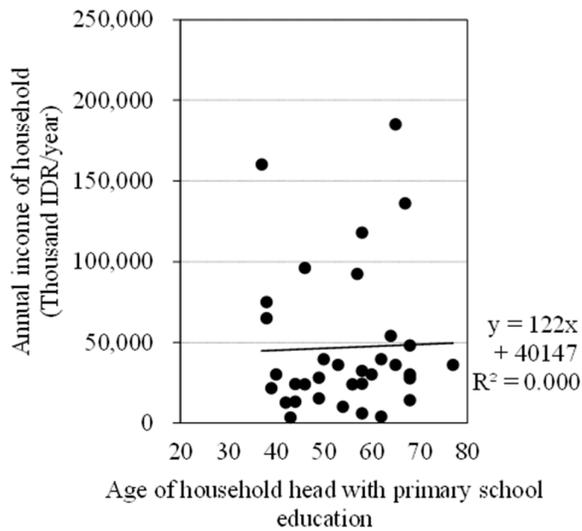
Survey Result 10: There is no correlation between the income of aquaculture households and the highest level of education of the heads of the households.

Figure 100 shows that there is no correlation between the annual income of household heads whose main occupation is aquaculture and their level of education. Furthermore, even for household heads with the same level of education, there is no correlation between the age of the household head, which is thought to indicate the length of time the household heads have been engaged in aquaculture, and annual income. Figure 101 shows that there is no correlation between the age of primary school graduates and annual income, and Figure 102 shows that there is no correlation between the age of high school graduates and annual income.

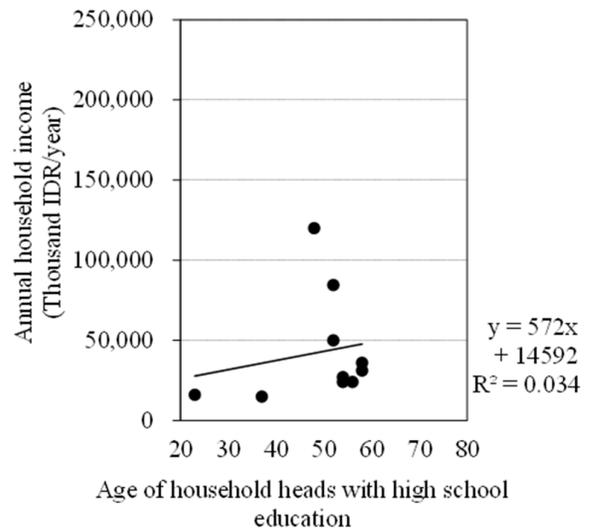


Source: JICA Study Team

Figure 100: Educational level of aquaculture household heads and annual income in 2024



Source: JICA Study Team



Source: JICA Study Team

Figure 101: Age of aquaculture household heads with elementary school education in 2024

Figure 102: Age of high school graduate aquaculture household heads and annual income in 2024

This suggests that extensive aquaculture techniques are passed down from parents to children through non-formal education, regardless of the length of formal education. It can also be assumed that there are few opportunities for exposure to new technologies. Conversely, these findings suggest that circumstances such as ESG investor investment commitments may act as a catalyst for increasing interest in new technologies.

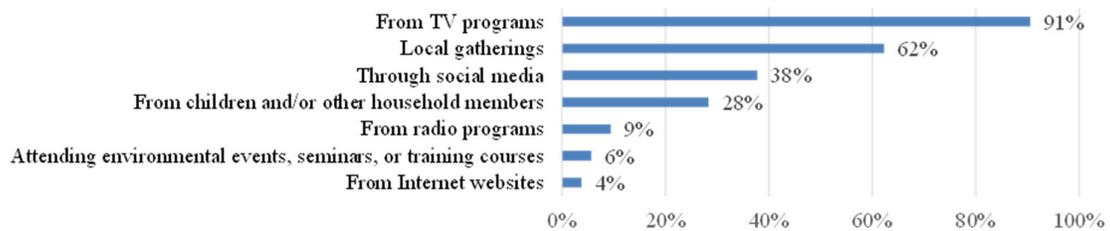
Survey Result 11: Confirmation of awareness of environmental considerations and recognition of environmental value

The silvo-aquaculture business model proposes offsetting the opportunity cost of planting mangroves in aquaculture ponds with semi-intensive aquaculture, which is assumed to have higher labor productivity than that of extensive aquaculture. However, there are still opportunity costs. Therefore, if the aim is to achieve higher profits by adopting the With-action scenario, there is an incentive to avoid or minimize mangrove planting. Based on the survey results on household environmental awareness and attitudes toward ecosystem services, this section demonstrates that, even though opportunity costs do arise, there is a certain level of environmental awareness and value preference. Furthermore, with a commitment to ESG investment, 24.0% of production areas are likely to accept mangrove planting or natural regeneration in the With-action scenario, which is demonstrated in Section 7.7 regarding the financial and economic analysis of the scenario.

Extensive aquaculture can be seen as a production method that relies heavily on ecosystem services, so it can be inferred that residents who adopt such a production method are highly sensitive to environmental considerations and ecosystem services. Local residents forecast increase in salt production in the future, as they are aware that the dry season has seen a trend toward less rain in recent years, which is possibly reflected in their awareness of climate change. It shows that they have a deep interest in the environment, as the performance of extensive aquaculture is heavily dependent on various environmental factors.

Survey Result 12: Sources of environmental information

While households engaged in extensive aquaculture experience environmental conditions through their daily aquaculture activities, they also receive structured and formalized environmental information from external sources. Figure 103 shows the sources of such information. Most information comes from television programs, community meetings, social media, children or other family members, and these sources can be considered sufficient for those interested in environmental issues.



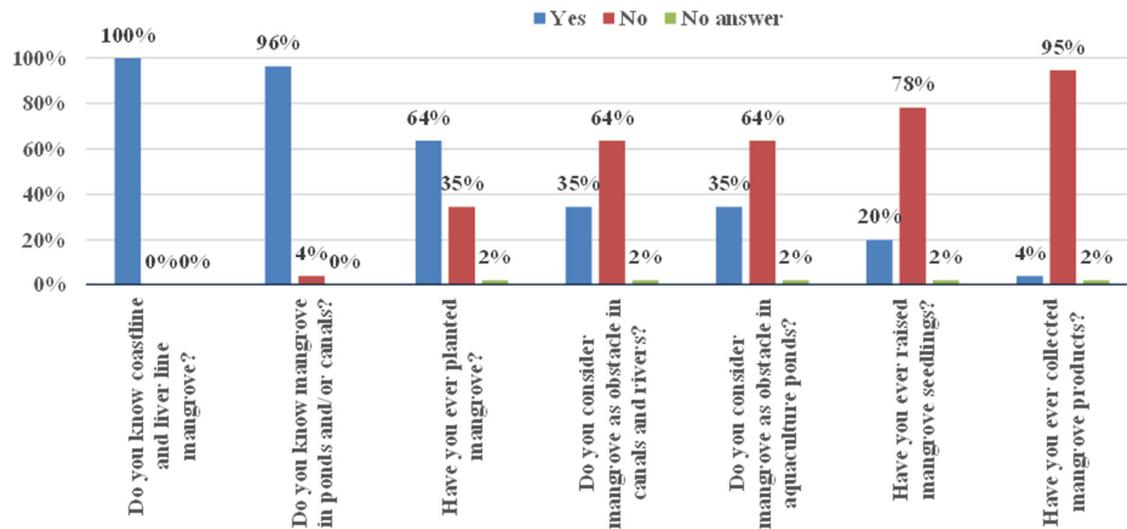
Source: JICA Study Team

Figure 103: Sources of environmental information

Survey Result 13: Local people’s awareness of mangroves

Figure 104 shows the surveyed households' attitudes toward mangroves. In the Bontomanai area, the presence of mangroves along coastal lines, river systems, and canals, as well as in aquaculture ponds, is well-known

(96%-100%). Furthermore, a high percentage (65%) of households have planted mangroves, suggesting that government and NGO planting programs are actively underway. Reflecting various local conditions, perceptions of mangroves along rivers and waterways are divided between those perceived as a nuisance and those not. Furthermore, a high percentage (20%) of households have experience raising mangrove seedlings. By securing such interested parties, in the implementation of the silvo-aquaculture business model, consideration could be given to obtaining mangrove seedlings from the households interested in mangrove seedling production.



Source: JICA Study Team

Figure 104: Household heads' awareness of mangroves and their experience in cultivating seedlings

Survey Result 14: Recognition of ecosystem services, types of services, and where they occur

As shown in Table 72, the surveyed households regard the mangroves, rice paddies, crabs, milkfish, fish, vannamei shrimp, and black tiger shrimp that they encounter daily as blessings from ecosystem services. However, there is a significant discrepancy in the economic valuation of ecosystem services, with a tendency to place a high value on aquaculture products such as milkfish, which generate economic value through daily market transactions. However, households have a low regard for the economic value of mangroves given their lack of experience with market transactions.

Table 72: Percentage of mentions of ecosystem services and their value

Elements of ecosystem	% of households mentioned about each ecosystem element to the total number of households	Average ecosystem service values reported by households (IDR/ha)
Mangrove (tree/wood/leaves/etc.)	87%	4,652
Paddy/Rice	51%	1,909,257
Crab	24%	37,827
Milkfish	16%	43,226,004
Fish	15%	4,228,564
Shrimp (Vannamei/tiger shrimp)	11%	6,598,657
Seaweed	7%	12,293
Research subjects	5%	5,423,554
Fish and shrimp	5%	3,579,545
Tourism	4%	
Salt making	2%	2,440,599
Honey	2%	
Aquaculture pond	2%	

Source: JICA Study Team

Conversely, as shown in Table 73, the surveyed households recognize the high importance and necessity of mangroves for flood and tsunami control. It is not necessary to expect the surveyed households, who are unfamiliar with ecosystem service valuation methods, to convert the necessity of mangroves into monetary terms, but from the perspective of the feasibility of implementing the silvo-aquaculture business model, the results of this survey suggest that there is a shared awareness of the significance of mangroves being planted and conserved in the aquaculture production ponds.

Table 73: Types of ecosystem services identified by surveyed households and where they occur

Household-recognized ecosystem services (including negative services)	Carbon emissions by aquaculture	Carbon sequestration by mangrove	Soil carbon sequestration	Soil carbon emission	Flood mitigation by ponds	Tidal wave mitigation by mangrove	Purification of domestic wastewater	Purification of production wastewater	Pollution in the production process	Soil erosion control by mangrove
Household-recognized location of ecosystem services										
The sampled pond	2%				7%	4%	2%	4%	51%	7%
Canals to the sampled pond					25%	35%	2%	2%	7%	20%
Agriculture area									2%	
River line area with mangrove					44%	25%	2%	2%		7%
Coastline area with mangrove		4%			64%	56%	2%	2%		9%
Village area	2%						2%			
Road and other infrastructure					2%					
Total % of household surveyed	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Total no. of households surveyed	55	55	55	55	55	55	55	55	55	55

Source: JICA Study Team

Summary C: In this section, the survey results point out that a commitment from the supply side to ESG investment may have the effect of increasing interest in new technologies among local aquaculture communities and improving the existing environments. It is concluded that the investors' expectation of this effect is likely to increase their willingness for ESG investment.

Survey Result 10 showed no correlation between the income of households that make a living from aquaculture and their highest level of education, suggesting that the level of skill that affects income is unrelated to educational background. This suggests that skills are passed down within the household, meaning that opportunities to encounter new technology are limited. Therefore, the study concluded that households engaged in aquaculture, who have had few opportunities to encounter technologies beyond traditional methods, may gain rare exposure to new technologies when presented with options for income enhancement through such innovations, and this exposure, coupled with the potential for these new technologies to boost income, could serve as a catalyst for heightened interest among these households.

Furthermore, Survey Results 11, 12, and 13 demonstrated a high level of environmental awareness, which indicates active participation in obtaining environmental information, a high level of awareness of the disaster prevention effects of mangroves, and recognition of ecosystem services, but not the monetary value of mangroves. Therefore, we concluded that a commitment to ESG investment further strengthens these awarenesses and increases the incentive to accept the silvo-aquaculture business model.

7.7 Validation of the Silvo-Aquaculture Business Model Based on the Results of Pilot Activities

The method for verifying the silvo-aquaculture business model through pilot activities was explained in Section 7.3. In that section, a management unit for the silvo-aquaculture business model was established as a verification method, after which a Without-action scenario with the current aquaculture methods applied to the unit and a With-action scenario with the silvo-aquaculture business model applied to the unit as an ESG investment target were established.

In this section, the technical specifications for the With-action scenario are established. These are based on the results of the black tiger shrimp aquaculture, mangrove plantation, and socio-economic surveys, as explained in Sections 7.4, 7.5, and 7.6. In accordance with the specifications, the With-action scenario is demonstrated to be superior in terms of profitability, return on investment, and enhancing biodiversity through mangrove afforestation and conservation. If the With-action scenario is found to be superior, it can be concluded that the silvo-aquaculture business model is a suitable target for ESG investment.

7.7.1 Technical Specifications Adopted in the With-action scenario

The technical specifications for black tiger shrimp aquaculture adopted in the With-action scenario were determined based on the verification results for Item (3) of Section 7.3.4. In the black tiger shrimp aquaculture verification component, black tiger shrimp was selected as the aquaculture species and verification was conducted through pilot activities for the following four items. This section provides an overview of the verification, and explains the verification results and the technical specifications adopted for the four items in the following order:

- g) Verify semi-intensive aquaculture technology for black tiger shrimp with a target density of 6 individuals/m².
- d) Verify the mutual relationship between mangroves and black tiger shrimp aquaculture in the same pond, focusing on the macrobenthos as natural feeds of the black tiger.
- h) If black tiger is not suitable as an aquaculture species for silvo-aquaculture, consider alternative farmed species
- i) Verify the introduction of traceable eco-feed

Overview of the verification: The pilot project focused on verifying semi-intensive black tiger shrimp aquaculture techniques with a target harvest density of 6 individuals/m². As a result, factors such as unusual weather conditions, and difficulties with water supply and drainage management due to the location of the verification ponds resulted in extremely high water temperatures, salinity, excessive fluctuations in salinity, a lack of dissolved oxygen, and high pH, creating a water environment that was critical for black tiger shrimp aquaculture. This resulted in the death of released black tiger shrimp and a production cycle that did not lead to harvest. Furthermore, during the verification, it was discovered that the area around the social verification

ponds was infected with viruses, which could not be controlled with chemicals, and shrimp mortality due to viral infection was also a problem. The black tiger species is particularly sensitive to its habitat and viruses. To develop virus-resistant strains, long-term breeding programs are likely to be necessary. Therefore, it was determined that black tiger was not a suitable option for aquaculture in the With-action scenario, and alternative species were also considered. In the financial and economic analysis, a sensitivity analysis was conducted using black tiger and alternative aquaculture species.

In the final verification production cycle, which was conducted in the Social Verification Pond from March to June 2025, black tiger shrimp was harvested despite infection with the virus. Table 74 shows the harvest results for the final cycle. Due to the short culture period, and in order to minimize the impact of viral disease and verify culture density, harvesting was completed before the shrimp reached a size of approximately 40g/individual, which is a favorable harvest size in terms of market price. As a result, the average weight was 10.5g/individual in Social Verification Pond S2 and 21.0g/individual in S3.

Table 74: Harvest yield of black tiger shrimp in Social Verification Ponds S2 and S3 (March-June 2025 production cycle)

Aquaculture pond	Measured items	Harvest yield in 2025				Total
		May 6	May 22	June 5	June 19	
Social Verification Pond S2 Pond area:1,800m ² / Last harvest date: June 5, 2025	Number of heads harvested (heads)	40	40	271		351 heads
	Harvested weight (g)	239	446	3,011		3,697 g
	Average weight (g/head)	6.0	11.2	11.1		10.5 g/head
	Estimated no. of heads harvested per ha					1,950 head/ha
	Estimated no. of heads harvested per m ²					0.20 head/m ²
	Estimated harvested kg per ha					20.5 kg/ha
	Estimated harvested kg per ha (40g/head assumed)					78.0 kg/ha
Social Verification Pond S3 Pond area:2,000m ² / 0.3m high mangrove mound area:500m ² / Effective aquaculture area:1,500m ² /Last harvest date: June 19, 2025	Number of heads harvested (heads)	40	40	40	127	247 heads
	Harvested weight (g)	466	409	807	3,498	5,181 g
	Average weight (g/head)	11.7	10.2	20.2	27.5	21.0 g/head
	Estimated no. of heads harvested per ha					1,647 head/ha
	Estimated no. of heads harvested per m ²					0.16 head/m ²
	Estimated harvested kg per ha					34.5 kg/ha
	Estimated harvested kg per ha (40g/head assumed)					65.9 kg/ha

- (1) g) Verify semi-intensive aquaculture technology for black tiger shrimp targeting a density of 6 individuals/m²

Verification Results: As shown in Table 74, 351 shrimp with an average weight of 10.5g were harvested in Social Verification Pond S2 (a pond without mangrove plantings and using separate water management for black tiger shrimp aquaculture). This translates to 1,950 individuals/ha, or a yield of 20.5kg per hectare. This results in a stocking density of 0.2 individuals/m². When designing the verification project, the extensive black tiger shrimp aquaculture density in the Bontomanai area was assumed to be 1.0 individuals/m², the

semi-intensive black tiger shrimp aquaculture density at harvest was targeted at 6 individuals/m² and the juvenile shrimp stocking density in the final cycle was set at 8 individuals/m². As a result, the stocking density at harvest was 0.2 individuals/m², which was one-thirtieth of the target of 6.0 individuals/m². Assuming these black tiger shrimp grow to 40g each, the assumed yield per hectare would be 78 kg. In the socio-economic survey, five cases of black tiger shrimp aquaculture were observed, with an average production volume per hectare of 52 kg/ha (with a standard deviation of 50 kg/ha which is a fairly large degree of variation). Assuming that the black tiger shrimp were able to continue growing without contracting the virus, this falls within the range of average results for extensive black tiger shrimp aquaculture in the Bontomanai area.

In Social Verification Pond S3, a black tiger shrimp aquaculture pond with concurrent water management, mangrove plantations were present, and therefore, the effective aquaculture area was calculated by subtracting the mangrove plantation area from the total pond area. In the S3 Social Verification Pond, 247 shrimp with an average weight of 21.0g were harvested from an initial juvenile stocking density of 8 individuals/m². This translates to the harvest of 1,647 individuals/ha, or a yield of 34.5 kg/ha. This resulted in an aquaculture density of 0.16 individuals/m² which is 1/37 of the target of 6 individuals/m². Assuming these shrimp grow to 40g each, the estimated yield would be 65.9kg/ha. Based on the socioeconomic survey results mentioned earlier, assuming the shrimp were able to continue growing without contracting the virus, this also falls within the range of average extensive black tiger shrimp aquaculture in the Bontomanai area.

Technical specifications adopted: The results of the technical verification regarding the stocking density of black tiger shrimp aquaculture at the time of harvest did not achieve the initial verification target, but overall, it can be said to have achieved the level of extensive black tiger shrimp aquaculture practiced in the Bontomanai area. The highest annual profit per hectare from black tiger shrimp aquaculture observed in the socio-economic survey was 13,875,000 rupiah. This profit level is lower than the annual profit of 15,892,423 rupiah from extensive milkfish aquaculture (Table 75), which was considered an alternative aquaculture species (described later). Therefore, it was concluded that the verified stocking densities (0.2 individuals/m² in Social Verification Ponds S2 and 0.16 individuals/m² in S3) were not expected to offset the opportunity cost of mangrove planting in the aquaculture ponds nor to make further improvements to profitability in the With-action scenario. Based on these results, we decided to conduct a financial and economic analysis assuming the adoption of black tiger shrimp aquaculture technology that can ensure a yield of 1 individual/m² (about five times the verified aquaculture density) by feeding artificial feed. In addition, as will be described later, realistic alternative aquaculture species were selected and the technical specifications for the species were established.

Solutions to many issues of black tiger shrimp aquaculture were tested through pilot activities. The following findings obtained from the trials will be adopted as technical specifications. Detailed technical specifications of black tiger shrimp aquaculture are provided in "Appendix: Silvo-aquaculture Technical Guidelines."

- The pond bottom, which maintains the ground level of the original mangrove forest, will be excavated and cut 40cm to maintain a water depth in the aquaculture pond of 1.2m, mitigate sudden changes in water temperature and salinity, and maintain a stable shrimp growth environment. The excavated soil will be used to raise and reinforce the embankment, preventing overflow during floods. The remaining soil will also be used to raise the pond bottom to establish mounds allocated for mangrove plantation where a variety of mangrove species can be planted.
- Waterways and sluice gates will be developed for the supply and drainage of seawater and brackish water, and a monitoring system will be established to enable efficient water circulation and management of dissolved oxygen, salinity, and pH. In addition, for the production area designated for mangrove plantation the configuration and structure of the sluice gates will be designed to facilitate the flow of seawater and brackish water in accordance with the natural tides.
- Black tiger shrimp are susceptible to disease, so it is necessary to control harmful organisms and pathogens in advance by draining the ponds and spraying lime and saponin. Furthermore, since there are no chemicals or other countermeasures for viral diseases, rearing methods to strengthen the immune system must be considered. While the use of chemicals is a negative aspect from the perspective of biodiversity, inadequate chemical measures can lead to significant reductions in shrimp yields. Furthermore, since it is recommended to cultivate natural food such as macrobenthos during the shrimp growth period, these treatments in the early stages of aquaculture can offset the negative impact on biodiversity.
- To prevent cannibalism of black tiger shrimp, it is essential to ensure that juvenile prawns of the same size are raised in tanks, and that the same rate of growth in the raising ponds is maintained by applying appropriate feeding schedules. This process requires close monitoring of their growth. It is essential to ensure the proper training of personnel who can execute these tasks.

(2) d) Verify the mutual relationship between mangroves and black tiger shrimp aquaculture in the same pond, focusing on macrobenthos

Verification Results: As explained in Section 7.4, the mangrove-planted Social Verification Pond S3 showed a higher abundance of macrobenthos than the unplanted Social Verification Pond S2. Furthermore, the frequency distribution of the weight of black tiger shrimp harvested from pond S3 was significantly higher than that of black tiger shrimp harvested in S2, with the average weight being approximately twice as much (Table 74). However, because the density of black tiger shrimp in Social Verification Pond S3 was slightly lower, the difference in average weight may also be due to a density effect. With this in mind, Section 7.4 concluded that there is a positive correlation between mangrove plantation, increased macrobenthos production and biodiversity, and the growth of black tiger that feed on macrobenthos.

Technical specifications adopted: It is understood that the above-mentioned positive correlation holds under the conditions of black tiger shrimp aquaculture using natural feed under concurrent water management with

a low culture density (0.16 individuals/m² in the example of social verification pond S3). Considering these conditions, if the technical specifications were to use artificial feed to harvest at a culture density of 1 individual/m², which is more than five times higher than the culture density under the concurrent water management, it is unlikely that a clear positive correlation would be observed between macrobenthos and improved aquaculture productivity under the culture density. For this reason, the technical specifications for ponds using concurrent water management would limit feeding at a low culture density. Therefore, in the With-action scenario, a technical specification of 0.16 individuals/m² is adopted, hoping not to offset opportunity costs and improve profitability, but to increase biodiversity, disclose information about silvo-aquaculture using biodiversity to the market, and improve ecosystem service value as recognized by the market.

(3) h) If black tiger shrimp is not a suitable species for silvo-aquaculture, consider alternative species

Verification results: Black tiger shrimp aquaculture revealed that it is currently difficult to control viral diseases, and that it is sensitive to other environmental and aquaculture factors. The actual yield would not be able to contribute to examining profitability in the With-action scenario, and a financial and economic analysis of the *scenario* was conducted based on hypothetical yields. In this section, milkfish is selected to replace black tiger shrimp as an alternative aquaculture species from among the other potential species (vanamei shrimp, mud crab, and Mozambique tilapia) introduced in Section 7.4. The selection was based on the information on input costs for materials and labor, production volume, sales, and net profits for each potential aquaculture species.

Figure 105 shows the frequency distribution of milkfish yield per hectare, which was created from the socio-economic survey results. Based on the observation of the frequency distribution shown in the figure, three levels of intensity were hypothesized in terms of yield per hectare: extensive aquaculture (200 kg/ha to less than 1,000 kg/ha), semi-intensive aquaculture (1,000 kg/ha to less than 2,000 kg/ha), and intensive aquaculture (2,000 kg/ha or more). The observation frequencies and average profits per hectare per year corresponding to these hypothesized levels of intensity are shown in Table 75.

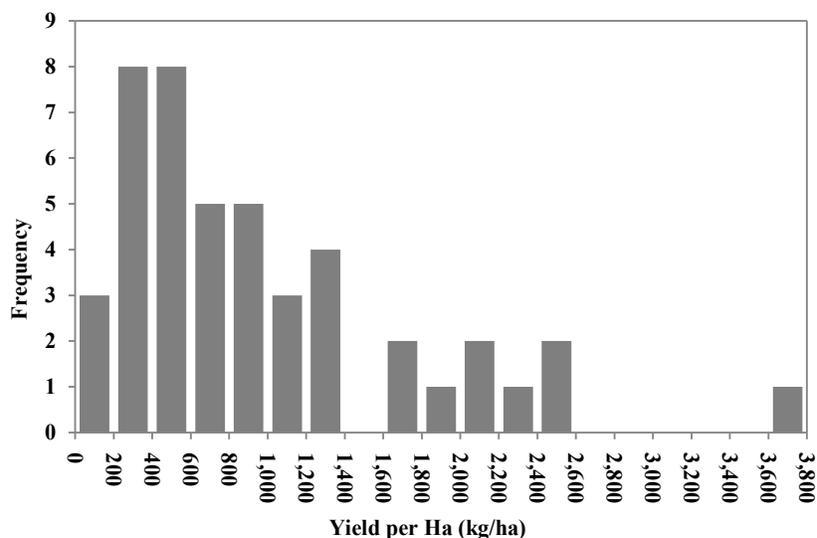


Figure 105: Distribution of milkfish yield per hectare (45 samples)

Table 75: Observation frequency and average profit at hypothetical aquaculture intensities

Provisional aquaculture intensity	Observation frequency	Annual average profit (Rp./ha/year)
Extensive aquaculture ($200\text{kg/ha} \leq$ and $<1,000\text{kg/ha}$)	26	15,892,423
Semi-intensive aquaculture ($1,000\text{kg/ha} \leq$ and $<2,000\text{kg/ha}$)	10	48,808,874
Intensive aquaculture ($2,000\text{kg/ha} \leq$)	6	69,464,259
Total/average	42	31,760,606

Technical specifications adopted: The alternative aquaculture species is milkfish. The milkfish intensity adopted in the Without-action scenario is set by a hypothetical extensive aquaculture (average annual profit per hectare is 15,892,423 rupiah/ha/year), while the milkfish intensity adopted in the With-action scenario is a hypothetical semi-intensive aquaculture (average annual profit per hectare is 48,808,874 rupiah/ha/year) (Table 75). When transitioning from the Without-action scenario to the With-action scenario, in the management policy established in the With-action Scenario, persons employed in the Without-action scenario shall not be laid off, and the same level of labor input shall be maintained. The labor required per unit pond area for extensive aquaculture and semi-intensive aquaculture is approximately the same. Therefore, it is assumed that the transition from extensive aquaculture to semi-intensive aquaculture is not a labor-saving transition.

The technical specifications to be adopted will be based on the knowledge gained from solutions to the challenges through the black tiger shrimp aquaculture pilot activities mentioned above.

- (4) i) Verify the introduction of traceable eco-feed

Verification results: As explained in Section 7.4, a traceable eco-feed was prototyped using ingredients such

as okara (i.e., soy pulp) available in the Bontomanai area, and a feeding test was conducted in the experimental laboratory. The feeding test only attempted to identify the appropriate ingredient ratio to promote the growth of black tiger shrimp but did not proceed to a demonstration test of feeding the eco-feed in Social Verification Ponds S2 and S3. As a result, the effectiveness of the prototype eco-feed in improving the productivity of black tiger shrimp has not been verified.

Technical specifications to be adopted: Although the effectiveness of eco-feed made from okara in on-site aquaculture has not been verified, in the With-action scenario, it is assumed that it can be introduced at the same cost as commercially available artificial feed and has the same level of feeding effect, and the technical specifications will include the introduction of eco-feed with traceability. The expected effect of introducing eco-feed is not to improve the profitability of shrimp aquaculture, but to increase the possibility of obtaining a premium price in the market.

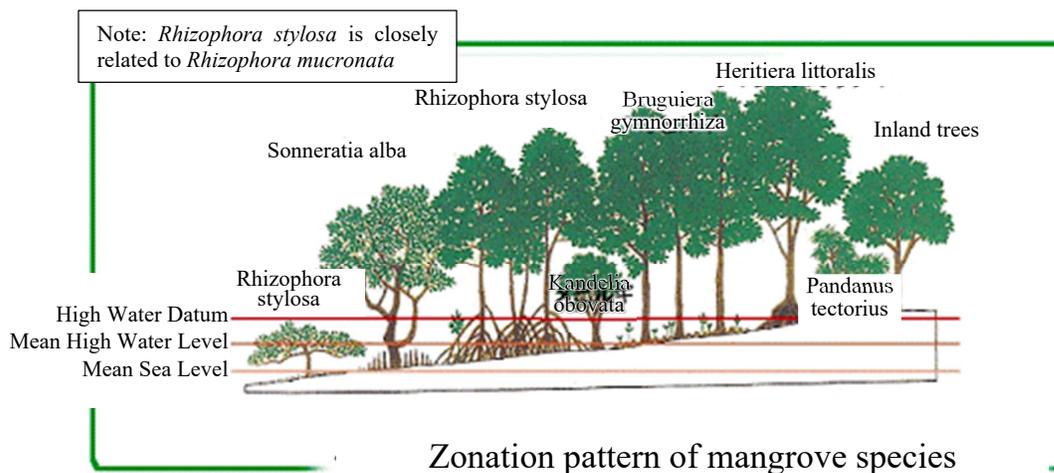
7.7.2 Technical Specifications Adopted in the With-action scenario Based on the Results of the Mangrove Plantation Verification Component

The technical specifications for mangrove planting adopted in the With-action scenario were determined based on the results of the verification items set in Section 7.3.4 (3). In the mangrove planting verification component, *Rhizophora mucronata* and *Bruguiera gymnorrhiza* were selected as mangrove plantation species for the following four verification items, and the verification was conducted through pilot activities. This section provides an overview of the verification, and explains the verification results and the technical specifications adopted for the following four items:

- a) Verify planting techniques by placing two mangrove species under different ground elevations and water management conditions
- b) Verify techniques from the perspective of interference between mangrove planting and shrimp aquaculture water management
- e) Examine mangrove management approaches that enhance biodiversity based on surveys of existing mangrove plantations and natural forests
- c) Investigate the carbon sequestration function of mangroves

Verification Overview: While mangrove plantations often consist of uniform stands of *Rhizophora mucronata*, for which seedlings are easily prepared, it is necessary to plant multiple mangrove species to ensure biodiversity. However, as shown in Figure 106, the optimum ground elevation relative to the tide level for each mangrove species varies. Therefore, when planting multiple mangrove species, it is necessary to select ground elevations appropriate for each species. The Figure 106 shows that *Rhizophora mucronata* is best suited to low-lying areas and can tolerate prolonged immersion in brackish and seawater. In contrast, *Bruguiera gymnorrhiza* thrives in higher ground elevations and favors areas with a supply of freshwater. *Bruguiera gymnorrhiza* was confirmed its natural existence near the Social Verification Pond, and a certain

amount of freshwater supply can be expected in the Technical Verification Pond located upstream of the river, which are the reasons to select *Bruguiera gymnorrhiza* as a control species to compare its growth conditions. In the Technical Verification Pond, mounds of varying heights were constructed for planting this mangrove species, to verify the possibility that the growth of *Bruguiera gymnorrhiza* might be superior to that of *Rhizophora mucronata* on higher mounds.



Source: OISCA International
<https://oiscathailand.wordpress.com/%E3%82%BF%E3%82%A4%E7%8E%8B%E5%9B%BD%E6%A6%82%E8%A6%81%E3%83%9E%E3%83%B3%E3%82%B0%E3%83%AD%E3%83%BC%E3%83%96%E3%81%AB%E3%81%A4%E3%81%84%E3%81%A6/>

Figure 106: Zonation pattern of mangrove species relative to the tidal level

Table 73 shows an overview of the verification results.

Table 76: Survival rate and growth status of mangroves depending on water management methods and ground level (as of June 2025)

Verification pond name	Social Verification Pond S1	Social Verification Pond S3	Technical Verification Pond		Technical Verification Pond	
	Separate	Concurrent	Separate	Concurrent	Separate	Concurrent
Water management method	Separate	Concurrent	Separate	Concurrent	Separate	Concurrent
Mound elevation relative to mean sea level	Low	Medium	Low	Medium	Low	Medium
(Mound height)	(0cm)	(30cm)	(0cm)	(30cm)	(0cm)	(30cm)
<i>Rhizophora mucronata</i>						
survival rate	90%	47%	60%	66%	41%	34%
Growth status	Good	Fair	Fair	Fair	Fair	Poor* ¹
<i>Bruguiera gymnorrhiza</i>						
survival rate	19%	37%	0%	14%	(No plantation)	(No plantation)
Growth status	Poor	Fair	Poor	Poor* ¹	(No plantation)	(No plantation)

Notes: 1) The low survival rate and poor growth conditions are thought to be due to the high salt concentration in the soil caused by the dry season.

Source: Study Team

(1) a) Verify planting techniques by placing two mangrove species under different ground elevations and water management conditions

Verification results: The verification results summarized in Table 76 verified that the survival rate and growth of *Rhizophora mucronata* and *Bruguiera gymnorrhiza* are determined by their relationship with their growth conditions, water management methods, ground level, and fluctuations in natural tide levels.

Adopted technical specifications: From the perspective of biodiversity, the technical specifications adopted in the With-action scenario for infrastructure development that are based on water management methods for aquaculture ponds, planted mangrove species, and natural regeneration are shown in Table 77. Detailed technical specifications for mangrove plantation and silviculture are provided in the "Appendix: Silvo-Aquaculture Technical Guidelines."

In mangrove plantation ponds that use the separate system, water management based on natural tides is utilized. In order to reproduce the diversity of natural mangrove vegetation environments to the extent possible, continuous mounds from low (0cm) to high (60cm) are created on a sloped surface through earthworks. In this case, *Rhizophora mucronata* is planted from low (0cm) to medium (30cm) heights, while *Bruguiera gymnorrhiza* is planted from medium (30cm) to high (60cm) heights. The middle zone is planted with a mixture of both species. In addition, because an inflow of seeds of *Avicennia officinalis* and other species has been observed in incoming brackish water, where the seeds germinate and grow, the aquaculture ponds with the separate system are managed with natural regeneration treatment.

In addition, in ponds using the concurrent system, a medium-height (30 cm) mound is installed and both species are planted together. In this case, the growth of both species is not expected to be high. For black tiger shrimp aquaculture, extensive culture is used, with natural food provided by macrobenthos, and pond management focuses on the effects of mangroves to enhance biodiversity. In this case, since the concurrent system of silvo-aquaculture does not contribute to improving profitability in the With-action scenario, the pond area should be limited. Furthermore, the growth of mangroves and crown closure could have negative effects on shrimp aquaculture, such as a deterioration in the light environment and a decrease in dissolved oxygen due to the decomposition of large amounts of litter. However, the closed tree crowns prevent direct sunlight from reaching the water surface, potentially suppressing the overgrowth of green algae and reducing ammonia production due to the algae's decay. Therefore, pond conditions and mangrove growth are closely monitored, with thinning and pruning performed as needed.

The soil used to build the mound will be made from the soil left over from cutting during the construction of semi-intensive aquaculture ponds.

Table 77: Technical specifications for infrastructure development, mangrove plantation species, and natural regeneration based on water management methods for aquaculture ponds

Technical specifications for infrastructure development based on water management methods for aquaculture ponds	Separate system for afforestation and aquaculture ponds (The mound should be set on a slope with a height of 0cm to 60cm.)			Concurrent system (The mound should be set on a level surface 30cm high.)	
	Low (0cm)	Medium (30cm)	High (60cm)	Low (0cm)	Medium (30cm)
Ground elevation relative to mean sea level (Mound height)					
<i>Rhizophora mucronata</i>	Planting	Planting			Planting
<i>Bruguiera gymnorrhiza</i>		Planting	Planting		Planting

Naturally regenerated tree species	Natural regeneration	Natural regeneration	Natural regeneration		
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(2) b) Verify techniques from the perspective of interference between mangrove planting and shrimp aquaculture water management

Verification results: Both the separate and concurrent water management methods were examined, and their respective advantages and disadvantages were tested. However, no clear conclusions were reached on these points, as the production of black tiger shrimp did not reach the target production density. Regarding mangroves, as shown in Table 77, differences in species growth characteristics were confirmed between the separate and concurrent systems. Furthermore, regarding the direct relationship between mangrove plantation and extensive black tiger shrimp aquaculture, an increase in macrobenthos was observed under the concurrent water management system, and a positive correlation was confirmed between macrobenthos and shrimp growth.

For the simultaneous selection of separate and concurrent water management systems in an With-action scenario, good water management infrastructure and systems are required. Pilot studies confirmed that for these water management strategies to function, the essential water management elements, such as the headrace, reservoir ponds, and water supply and discharge weirs, must be fully functional. In particular, the quality of the brackish water intake is largely influenced by the distance from the coast or river that serves as the water source for the waterway, as well as the river's brackish water conditions throughout the season. In the case of the Technical Verification Pond, the source river's distance from the sea and the extremely low freshwater supply during the dry season resulted in high salinity, hindering shrimp aquaculture. The location of Social Verification Ponds along the coast is favorable to maintaining good water conditions. However, the poor condition of the intake and discharge channels and weirs hindered the maintenance of good water conditions in both concurrent and separate water management systems. Therefore, these facilities were improved as a part of verification activities.

Technical specifications to be adopted: In the With-action scenario, initial investment will be made to develop aquaculture infrastructure, including dredging ponds to a depth of 1.2m, dredging and repairing water channels, repairing water supply and discharge weirs, and installing water supply and discharge pumps, to ensure semi-intensive aquaculture of black tiger shrimp or milkfish, which has been selected as an alternative species.

(3) e) Examine mangrove management approaches that enhance biodiversity based on surveys of existing mangrove plantations and natural forests

Verification results: Belt transect surveys were conducted on the *Rhizophora* afforestation plantation established in 1996 within the Technical Verification Pond site, the natural mangrove forest adjacent to the Social Verification Pond, and the natural mangrove regeneration area in the abandoned aquaculture pond

adjacent to the Social Verification Pond. The results are shown in Section 7.5.3. They are summarized as follows:

Table 78: Comparison of artificially planted mangrove, natural mangrove forests, and naturally regenerated areas

	<i>Rhizophora</i> artificial plantation	Natural mangrove forests	Mangrove natural regeneration area
Background	Planted in 1996 (27 years old at the time of the 2023 survey)	Natural forest	The shrimp aquaculture pond has been abandoned for about 10 years since its construction.
Wood volume	Approximately 180m ³ /ha	Approximately 330m ³ /ha	Approximately 15m ³ /ha
Dominant species	<i>Rhizophora mucronata</i>	<i>Rhizophora mucronata</i> and <i>Avicennia officinalis</i>	<i>Rhizophora mucronata</i> , <i>Avicennia officinalis</i> , and <i>Ceriops tagal</i>
Characteristics of forest types	The forest is a single-layered forest, with trees of uniform height, dark interiors, and no sign of natural regeneration. There is a lot of dead wood and litter, and carbon accumulation is high, but water flow is not smooth, and methane emissions have also been confirmed.	The area is made up of multiple tree species, with varying heights (multi-layered forest), and naturally regenerated seedlings were also found. The area faces the coast, and it is thought that the smooth flow of water causes litter to wash away into the sea.	Because natural regeneration is occurring in the pond, pioneering species are prominent, but their growth is slow. Also, there are different tree species in the center and at the edges of the abandoned pond.

Technical specifications to be adopted: Based on the results of the verification and taking into consideration the contribution of planted mangroves to biodiversity and climate change mitigation, the following technical specifications and guidelines will be adopted for the management of mangrove plantation areas. In addition, areas targeted for natural regeneration in aquaculture ponds will basically be managed in a conservation manner.

- For example, *Rhizophora mucronata* is to be planted on the land side and *Avicennia sp.* is to be planted on the seaside, with the mangrove species selected depending on the ground level and tidal environment.
- To avoid establishing even-aged monoculture mangrove forests, multiple tree species will be planted and thinning and other practices will be carried out to improve the light environment, create multi-storied forests, and promote natural regeneration.
- When selecting aquaculture ponds to be converted into mangrove plantations, select ponds with smooth water flow so that organic matter such as litter does not easily remain in the pond, thereby suppressing methane generation.

(4) c) Investigate the carbon sequestration function of mangroves

Verification results: To investigate the carbon sequestration effect of mangroves, a *Rhizophora mucronata* plantation (27 years old at the time of the 2023 survey) that was planted in 1996 within RICAFE, where a Technical Verification Pond was established, was selected as an indicator of carbon accumulation. As shown in Table 78, the estimated timber volume of this plantation was approximately 180 m³/ha. Using this measurement value and the coefficients shown in the following formula, the amount of accumulated carbon for *Rhizophora mucronata* was calculated as 117.1 tons per hectare. In summary, an average of 4.3 tons of

carbon has accumulated per year over the past 27 years, according to a simple calculation. Since accumulation per hectare follows a growth curve, it is necessary to measure stem volume every year and monitor the amount of accumulated carbon.

Formula A: Absorption amount (tons of carbon) = stem volume (m³) x expansion factor x (1 + above-ground/underground ratio) x wood density (tons/m³) x carbon content³⁹

$$117.1\text{ton} = 180\text{m}^3 \times 1.37 \times (1 + 0.26) \times 0.785\text{ton/m}^3 \times 0.48$$

The following parameters were used:

Trunk volume: 180m³ (measured by the study team)

Magnification factor: 1.37⁴⁰

Above ground/underground ratio: 0.26⁴¹

Volume density: 0.785⁴²

Carbon content: 0.48⁴³

The results of soil organic carbon and soil organic matter measurements at the Technical Verification Pond are shown in Table 79. Soil samples were collected on August 22, 2024, at Technical Verification Pond 3A, which had two mounds with different elevations. Sampling was conducted at three locations: the pond bottom, a 30cm mound (30 cm above the pond bottom), and a 60cm mound (60 cm above the pond bottom), at soil depths of 0 to 10 cm, 10 to 20 cm, and 20 to 30 cm. The soil at the pond bottom, 30cm mound, and 60cm mound was disturbed by the installation of the mounds at the time of sampling. Therefore, the results shown in the table can be considered to represent the range of measured soil organic carbon and soil organic matter content at the bottom of Technical Verification Pond 3A. However, because the relationship between soil depth and soil organic carbon and soil organic matter was also disturbed, the relationship between depth and measured values should be understood as reference value.

The results of soil organic carbon and soil organic matter measurements in the Social Verification Ponds are shown in Table 80. Soil samples were collected from the bottom of four Social Verification Ponds (S1, S2, S3, and S4) at soil depths of 0 to 20 cm. Because these ponds underwent embankment reinforcement and other construction work, the first sampling on July 22, 2024, was conducted immediately after soil disturbance. The second sampling was conducted seven months later in February 2025, near the first sampling locations. No earthwork that could have disturbed the soil was carried out between the two sampling occasions. When comparing the initial values with the values seven months later, a possible explanation for

³⁹ Reference: https://www.rinya.maff.go.jp/j/sin_riyou/ondanka/con_5.html

⁴⁰ Source: https://www.rinya.maff.go.jp/j/sin_riyou/ondanka/con_5.html, Other broad-leaved trees

⁴¹ Source: https://www.rinya.maff.go.jp/j/sin_riyou/ondanka/con_5.html, Other broad-leaved trees

⁴² Source: <https://repository.kulib.kyoto-u.ac.jp/server/api/core/bitstreams/b75f115a-85be-42f4-b667-370ce00d0dda/content>

⁴³ Source: https://www.rinya.maff.go.jp/j/sin_riyou/ondanka/con_5.html, Hardwood

the changes in soil organic carbon measurements is the mangrove plantation in Social Verification Ponds S1 and S3. The proportions of soil organic carbon and soil organic matter in these ponds increased slightly. On the other hand, there was a slight decrease in Social Verification Ponds S2 and S4, which do not have mangrove plantations. Although it may be possible to interpret this as indicating that mangrove planting contributed to an increase in soil carbon, because the measurement interval was short at seven months, litter accumulation could not be visually observed, and the differences could well be within the range of actual content variation in these ponds. Therefore, it is not possible to conclude that these differences are the result of mangrove plantation. The measurement results shown in the table should be within the range of soil organic carbon and soil organic matter proportions in the Social Verification Ponds.

Table 79: Soil organic carbon and soil organic matter measurement in Technical Verification Ponds

Sampling date	Soil depth	Technical Pond 3A (Pond bottom)		Technical Pond 3A (30cm mound)		Technical Pond 3A (60cm mound)	
		Organic carbon %	Organic matter %	Organic carbon %	Organic matter %	Organic carbon %	Organic matter %
		Aug 22, 2024	00-10cm	1.66%	2.87%	0.70%	1.21%
	10-20cm	1.02%	1.75%	0.63%	1.08%	1.42%	2.45%
	20-30cm	1.95%	3.35%	1.25%	2.15%	1.02%	1.76%

Table 80: Soil organic carbon and soil organic matter measurement in Social Verification Ponds

Sampling date	Soil depth	Social Pond S1		Social Pond S2		Social Pond S3 (with 30cm mound)		Social Pond S4	
		Separate: Mangrove		Separate: Black tiger		Concurrent: Black tiger		Reservoir/Water treatment pond	
		Pond bottom		Pond bottom		Pond bottom		Pond bottom	
		Organic carbon %	Organic matter %	Organic carbon %	Organic matter %	Organic carbon %	Organic matter %	Organic carbon %	Organic matter %
Jul 22, 2024	00-20cm	1.49%	2.56%	1.39%	2.39%	1.31%	2.26%	1.47%	2.53%
Feb 20, 2025	00-20cm	1.58%	2.72%	1.35%	2.32%	2.32%	4.00%	0.54%	0.93%
Change in %		0.09%	0.16%	-0.04%	-0.07%	1.01%	1.74%	-0.93%	-1.60%

Technical specifications to be adopted: In the With-action scenario, trunk volume per hectare will be estimated using data collected through mangrove surveys or mangrove sampling surveys to measure diameter at breast height and tree height. The estimated value will be substituted into Equation A to calculate the amount of carbon absorbed. This estimation will be carried out once a year, and the amount of carbon absorbed will be monitored.

7.7.3 Technical Specifications Adopted in the With-action scenario Based on the Results of the Socio-economic Survey

The technical specifications for management adopted in the With-action scenario were determined based on

the verification results for the items set in (3) of Section 7.3.4. Details of the verification results for the following four items under the socio-economic survey component are described in Section 7.6. In this section, the technical specifications adopted for the four items based on the review of the verification results are presented in the following order:

- f) Verify the feasibility of implementing ecosystem services assessments
- j) Verify the potential for expanding the management scale through leased ponds
- k) Verify the existence of potential local partners
- l) Verify whether there is a demand for ESG investment

(1) f) Verify the feasibility of implementing ecosystem service assessments

Verification results: Following the ecosystem service assessment protocol and utilizing the results of the socio-economic survey, an ecosystem service assessment was conducted for the Bontomanai area, and the results are reported in Chapter 6 of the report. This verified that ecosystem service assessments can be conducted based on socio-economic surveys.

Technical specifications to be adopted: Utilizing the parameters calculated in the ecosystem service assessment that has already been conducted in the Bontomanai area, regular implementation of ecosystem service assessments for the management unit of the silvo-aquaculture business will be introduced as an activity in the With-action scenario.

(2) j) Verify the potential for expanding the management scale through leased ponds

Verification results: The results of the survey showed that there is a possibility of expanding the business by leasing ponds and/or outsourcing production services.

Technical specifications to be adopted: The establishment of the With-action scenario presupposes the possibility of expanding the business pond area through leasing ponds and/or outsourcing production services. The establishment of multiple With-action scenarios will further promote the clustering of silvo-aquaculture businesses and raise market awareness, which will be key to expanding mangrove plantation and conservation over a wider area. From this perspective, the technical specifications for the With-action scenario will support the formation of other With-action scenarios through the consolidation of aquaculture ponds.

On the other hand, it is necessary to consider how to view and understand the intentions of those who operate small-scale, independent aquaculture operations without leasing their own ponds or outsourcing production activities. As mentioned above, it is likely that there will be a greater labor shortage and declining opportunity cost for pond leasing and outsourcing of production services. This is thought to be a management strategy aimed at increasing profits by reducing costs, given the low prospects for increased income in a Without-

action scenario. The technology of silvo-aquaculture has already been established, and if it were to be introduced in this kind of situation, the expected increase in profits would make the industry more attractive. It is also expected that laborers who had previously migrated to urban areas would return. Furthermore, the leasing of ponds and outsourcing of production activities would expand the business area, potentially establishing management units of around 20 hectares. However, this would require significant initial investment, including investments for expanding the business area and improving aquaculture infrastructure. It is expected that this will be undertaken by businesses of a certain size or larger (who may partner with Japanese companies).

It is likely that there will be a certain number of owners who, for personal reasons or other reasons, do not wish to rent out their aquaculture ponds or outsource production activities. It is expected that silvo-aquaculture business operators will attempt to persuade such owners to cooperate. However, if this persuasion is unsuccessful, there are concerns that the consolidation of ponds will proceed in an uneven manner, with some ponds being omitted, resulting in patchy and uneven pond consolidation. There are also concerns that some owners will not participate in the silvo-aquaculture business, leading to conflicts within the region. There is also a "free-rider problem" in which even pond owners who do not participate in the business benefit from the aquaculture infrastructure improved through initial investment in the silvo-aquaculture businesses. In connection to the promotion of silvo-aquaculture businesses and the expansion and conservation of mangroves, this suggests the need for a broader and cluster-level perspective that looks at the benefits to the region rather than just the perspective of the silvo-aquaculture business.

(3) k) Verify the existence of potential local partners

Verification results: Based on the analysis of the results of the socio-economic survey, we verified the existence of human resources who could be potential local partners.

Technical specifications to be adopted: The establishment of the With-action scenario presupposes the possible existence of local partners. Here, as with the previous section, the establishment of multiple With-action scenarios will promote the clustering of silvo-aquaculture businesses and increase market awareness, which will be the key to spreading mangrove planting and conservation over a wider area. From this perspective, the business activity for the With-action scenario will support other potential local partners in formulating silvo-aquaculture businesses.

(4) l) Verify whether there is demand for ESG investment

Verification results: An analysis of the results of the socio-economic survey verified that there is potential demand for ESG investment from the perspective of both capital demand and capital supply. However, for this potential demand to materialize, the silvo-aquaculture business model must first be verified in terms of its financial viability, economic viability, contribution to the environment, contribution to the local

community, and transparency, and must have the impact of being established as a proven model. At present, the model has not yet reached this stage.

Technical specifications to be adopted: It is assumed that the establishment of the With-action scenario itself will result in the recognition of the silvo-aquaculture business model as a target for ESG investment. As mentioned above, the establishment of multiple With-action scenarios will promote the clusters of silvo-aquaculture businesses and increase market awareness, which will be key to spreading mangrove plantation and conservation over a wider area. From this perspective, the technical specifications for the With-action scenario will include support for technical and management know-how to expand ESG investment in other With-action scenarios.

7.7.4 Financial and Economic Analysis of Without-action scenario and With-action scenario

(1) ESG investment costs for the With-action scenario

Table 81 shows the amount of earthwork and the number of improvements and installations of water supply and drainage facilities required from initial investment in the With-action scenario. ESG investment funds are only used for this initial investment and working capital investments are not considered. Bank loans shall not be used in either the With-action scenario or the Without-action scenario. Infrastructure improvement through earthwork includes improving water conduits, installing water supply and drainage weirs and pipes, raising dikes, ensuring depth in production areas for semi-intensive aquaculture, and constructing mounds to ensure biodiversity for mangrove plantation and natural mangrove regeneration. In addition, there are costs relating to the renovation of deteriorated, rudimentary work facilities and purchasing additional equipment necessary for semi-intensive aquaculture. Table 82 shows the estimated cost of these improvements, including earthwork and mangrove plantation. The total cost will be 24.05 million yen. Considering that a minimum of 87.77 million yen in ESG investment funds will be required by law to start a business in Indonesia, this amount will be enough to set up around three to four With-action scenarios around the Bontomanai area.

(2) Management costs in the Without-action scenario and the With-action scenario

Table 83 shows annual management costs of 2.1 million yen in the Without-action scenario and With-action scenario. Management costs were set at the same amount in both scenarios to avoid job losses when switching from the Without-action scenario to the With-action scenario and to improve labor productivity. While two people (a manager and an assistant) were employed permanently, the labor cost for temporary employees required for production was included in production costs and excluded from management costs. Attention will be paid to reducing expenses by adapting to market and distribution conditions, and it is assumed that the transportation cost for harvested goods will be borne by middlemen who purchase aquaculture products at the harvest site. Given the possibility of a price premium for environmentally friendly products, costs for

biodiversity monitoring and ecosystem service assessment are included in the management costs. Ten (10) percent tax on profits is assumed.

Table 82: Costs of earthwork and mangrove plantations in the With-action scenario to be funded by ESG investment funds

(Confidential)

Source: JICA Study Team

Table 83: Breakdown of management costs in the Without-action scenario and With-action scenario

Total Management Costs						2,100,000
Activity management expenses						1,980,000
Labor costs						960,000
	Manager	50,000 yen/man month	1 people	12 month	1 unit	600,000
	Assistant	30,000 yen/man month	1 people	12 month	1 unit	360,000
Office rental and maintenance costs						540,000
	Office rental	30,000 yen/month	12 month	1 unit	1 unit	360,000
	Internet	5,000 yen/month	12 month	1 unit	1 unit	60,000
	Consumables	5,000 yen/month	12 month	1 unit	1 unit	60,000
	Water and utility	5,000 yen/month	12 month	1 unit	1 unit	60,000
Transportation expenses						480,000
	Vehicle fuel	20,000 yen/month	12 month	1 unit	1 unit	240,000
	Other transportation	20,000 yen/month	12 month	1 unit	1 unit	240,000
Costs for obtaining ecosystem service evaluation information generated by silvo-aquaculture						120,000
Workers (daily wage)						120,000
ts	For supply services	1,000 yen/man day	10 man day	1 unit	2 times	20,000
	For regulating and carbon storage service	1,000 yen/man day	10 man day	1 unit	2 times	20,000
	For habitat Services	1,000 yen/man day	30 man day	1 unit	2 times	60,000
	For cultural services	1,000 yen/man day	10 man day	1 unit	2 times	20,000

Source: JICA Study Team

(3) Annual production volume and profits

Based on the results of the socio-economic survey, yields per hectare per production cycle and annual profits per hectare were calculated for semi-intensive black tiger shrimp aquaculture, semi-intensive milkfish aquaculture, extensive milkfish aquaculture, vanamei shrimp aquaculture, and salt production, which are shown in Table 84. Regarding semi-intensive black tiger shrimp aquaculture, the verified stocking densities ranged from 0.2 to 0.16 individuals/m², and there was no comparative advantage to the current extensive black tiger shrimp aquaculture. Therefore, yields and annual profits are calculated on the assumption that semi-intensive aquaculture yields 40g of shrimp per head at a stocking density of 1 individuals/m² (10,000 heads per hectare). The figures for semi-intensive milkfish aquaculture are calculated based on the selection of the existing semi-intensive milkfish aquaculture as an alternative production option to black tiger shrimp aquaculture, as discussed in the previous section.

For this reason, the results of the financial and economic analysis are presented using two scenarios: the With-action scenario for the hypothetical semi-intensive black tiger shrimp aquaculture (With-action scenario-black tiger), and the With-action scenario for the semi-intensive milkfish aquaculture (With-action

scenario-milkfish). With-action scenario-milkfish assumes that semi-intensive milkfish aquaculture will be carried out in a total of 10.48 hectares of ponds, consisting of an improved black tiger shrimp aquaculture pond (2.78 ha) and an unimproved pond (7.70 ha) originally intended for extensive milkfish aquaculture. This is because socio-economic survey results indicate that semi-intensive milkfish production has been carried out in unimproved ponds.

Table 84: Yield and annual profit of the target aquaculture species

Management options	Black tiger	Milkfish		Vannamei shrimp	Salt processing	Seaweed	Total
	Semi-intensive	Extensive*1	Semi-intensive*2				
No-Action Scenario A (Production by the current extensive aquaculture method)							
Total area of production areas (ha)		12.25		1.96	4.26	0.93	19.40
Yield and profit							
Yield/ha/production cycle (kg/ha/cycle)		537		260	25,000	(No production)	
Annual profit/ha (yen/ha/year)		145,802		309,403	224,862	(No production)	
Annual Profit (yen/year)		1,785,722		606,761	957,187		3,349,669
Action Scenario B1 (Semi-intensive aquaculture of black tiger) (Adoption of the silvo-aquaculture business model)							
Total area of production areas (ha)	2.78	7.70			4.26		14.74
Annual production cost per hectare							
Production cost/cycle/ha (yen/ha/cycle)	100,000						
Annual production cycle (cycle/year)	3						
Annual production cost/ha (yen/ha/year)	300,000						
Annual production volume and sales amount per hectare							
Black tiger density/ha (head/ha)	10,000						
Black tiger kg at harvest (kg/head)	0.04						
Yield/ha/cycle (kg/ha/times)	400	537			25,000		
Annual production (cycle/year)	3						
Annual production/ha (kg/ha/year)	1,200						
Price per kg (yen/kg)	1,000						
Annual sale/ha (yen/ha/year)	1,200,000						
Annual profit/ha (yen/ha/year)	900,000	145,802			224,862		
Annual Profit (yen/year)	2,502,900	1,122,973			957,187		4,583,060
Difference in profit between Action Scenario B1 and Non-Action Scenario (B1-A)							1,233,390
Action Scenario B2 (Semi-intensive farming of milkfish) (Adoption of the silvo-aquaculture business model)							
Total area of production areas (ha)			10.48		4.26		14.74
Yield and profit							
Yield/ha/cycle (kg/ha/cycle)			1,338		25,000		
Annual profit/ha (yen/ha/year)			447,788		224,862		
Annual Profit (yen/year)			4,694,160		957,187		5,651,347
Difference in profit between Action Scenario B2 and Non-Action Scenario (B2-A)							2,301,677

Note 1) Extensive aquaculture is defined with production between 200kg/ha and 1,000kg/ha

Note 2) Semi-intensive aquaculture is defined with production between 1,000kg/ha and 2,000kg/ha.

Source: JICA Study Team

Based on the above results, the annual profits to be used in the financial and economic analysis are as follows:

Without-action scenario (current extensive aquaculture):	3,349,669 yen/year
With-action scenario-black tiger (semi-intensive black tiger shrimp aquaculture):	4,583,060 yen/year
With-action scenario-milkfish (semi-intensive milkfish aquaculture):	5,651,347 yen/year

Since the management costs for these three scenarios are the same, With-action scenario-black tiger and With-action scenario-milkfish are more advantageous than the Without-action scenario. Regarding With-action scenario-black tiger, since the technology for semi-intensive aquaculture of black tiger shrimp has not yet been established, achieving such results remains a challenge. Meanwhile, regarding With-action scenario-milkfish, since semi-intensive milkfish aquaculture is being practiced in the Bontomanai area, it should be possible to extract technologies and production systems applicable to silvo-aquaculture from these semi-intensive and/or intensive production examples. If milkfish proves to be a promising alternative aquaculture species, silvo-aquaculture could become widespread in the Bontomanai area, potentially resulting in the expansion and conservation of mangrove plantations.

(4) Results of financial and economic analysis

Table 85 shows the results of the financial and economic analysis of the Without-action scenario, which assumes production by the current extensive aquaculture. Because there is no negative net cash flow or net benefit associated with the initial investment, it is not possible to calculate the financial internal rate of return (FIRR) and the economic internal rate of return (EIRR). However, because sufficient profits are secured every year, business sustainability can be ensured unless there are weather or market shocks.

Table 86 shows the results of the financial and economic analysis for the With-action scenario-black tiger, which assumes production by semi-intensive black tiger shrimp aquaculture. Given that Indonesia's official discount rate is currently approximately 5% per year (as of July 2025), the net cash flow and net benefits are discounted at 5% to calculate the FIRR and the EIRR. Currently, commercial banks offer loans at an annual interest rate of approximately 8%. The FIRR is 6% for a 10-year business period and 12% for a 20-year business period. The EIRR is 13% for a 10-year business period and 17% for a 20-year business period. The initial investment is expected to be recouped by the ninth year. While this scenario assumes the establishment of semi-intensive black tiger shrimp aquaculture technology, a 20-year business period is still worthy of ESG investment, even when considering weather and market risks.

The results of financial and economic analysis of With-action scenario-milkfish, which assumes production by semi-intensive milkfish aquaculture, are shown in Table 87. Net cash flows and net benefits are discounted at 5%. The FIRR is 12% for the 10-year business period and 17% for the 20-year business period. The EIRR is 21% for the 10-year business period and 24% for the 20-year business period. The initial investment has a cash flow that will allow it to be recovered in the seventh year. As semi-intensive milkfish aquaculture has already been implemented in the Bontomanai area, it is believed to be a viable target for ESG investment, even when considering weather and market risks.

Table 86: Financial and economic analysis of With-action scenario-black tiger (with semi-intensive black tiger shrimp aquaculture)

Year no.	Year	ESG investment (yen)	Management costs (yen)	ESG total investment & business costs (yen)	Profit					Tax (yen)	Profit after tax (yen)	Net cash flow (Discount by 5%) (yen)	Net Benefits (Discount by 5%) (yen)		
					Black tiger (semi-intensive) (yen)	Milkfish (Extensive) (yen)	Milkfish (Semi-intensive) (yen)	Vannamei shrimp (yen)	Salt processing (yen)					Total (yen)	
1	2025	24,052,572	2,100,000	26,152,572	2,502,900	1,122,973			957,187	4,583,060	916,612	3,666,448	-19,469,512		
2	2026		2,100,000	2,100,000	2,502,900	1,122,973			957,187	4,583,060	916,612	3,666,448	3,491,855		
3	2027		2,100,000	2,100,000	2,502,900	1,122,973			957,187	4,583,060	916,612	3,666,448	3,325,576		
4	2028		2,100,000	2,100,000	2,502,900	1,122,973			957,187	4,583,060	916,612	3,666,448	4,156,970		
5	2029		2,100,000	2,100,000	2,502,900	1,122,973			957,187	4,583,060	916,612	3,666,448	3,959,019		
6	2030		2,100,000	2,100,000	2,502,900	1,122,973			957,187	4,583,060	916,612	3,666,448	3,770,495		
7	2031		2,100,000	2,100,000	2,502,900	1,122,973			957,187	4,583,060	916,612	3,666,448	3,590,947		
8	2032		2,100,000	2,100,000	2,502,900	1,122,973			957,187	4,583,060	916,612	3,666,448	3,419,950		
9	2033		2,100,000	2,100,000	2,502,900	1,122,973			957,187	4,583,060	916,612	3,666,448	3,257,095		
10	2034		2,100,000	2,100,000	2,502,900	1,122,973			957,187	4,583,060	916,612	3,666,448	3,101,995		
11	2035		2,100,000	2,100,000	2,502,900	1,122,973			957,187	4,583,060	916,612	3,666,448	2,954,281		
12	2036		2,100,000	2,100,000	2,502,900	1,122,973			957,187	4,583,060	916,612	3,666,448	2,813,601		
13	2037		2,100,000	2,100,000	2,502,900	1,122,973			957,187	4,583,060	916,612	3,666,448	2,679,620		
14	2038		2,100,000	2,100,000	2,502,900	1,122,973			957,187	4,583,060	916,612	3,666,448	2,552,019		
15	2039		2,100,000	2,100,000	2,502,900	1,122,973			957,187	4,583,060	916,612	3,666,448	2,430,494		
16	2040		2,100,000	2,100,000	2,502,900	1,122,973			957,187	4,583,060	916,612	3,666,448	2,314,757		
17	2041		2,100,000	2,100,000	2,502,900	1,122,973			957,187	4,583,060	916,612	3,666,448	2,204,530		
18	2042		2,100,000	2,100,000	2,502,900	1,122,973			957,187	4,583,060	916,612	3,666,448	2,099,553		
19	2043		2,100,000	2,100,000	2,502,900	1,122,973			957,187	4,583,060	916,612	3,666,448	1,999,574		
20	2044		2,100,000	2,100,000	2,502,900	1,122,973			957,187	4,583,060	916,612	3,666,448	1,904,356		
		24,052,572	42,000,000	66,052,572	50,058,000	22,459,462			19,143,735	91,661,197	18,332,239	73,328,958	23,924,075	35,918,237	
													FRR=>	6%	13%
													ERR=>		
													FRR=>	12%	17%
													ERR=>		
													period10yea		
													period20yea		

Source: JICA Study Team

Table 87: Financial and economic analysis of With-action scenario-milkfish (with semi-intensive milkfish aquaculture)

Year no.	Year	ESG investment (yen)	Management costs (yen)	ESG total investment & business costs (yen)	Profit				Tax (yen)	Profit after tax (yen)	Net cash flow (Discount by 5%) (yen)	Net Benefits (Discount by 5%) (yen)		
					Black tiger (semi-intensive) (yen)	Milkfish (Extensive) (yen)	Milkfish (Semi-intensive) (yen)	Vannamei shrimp (yen)					Salt processing (yen)	Total (yen)
1	2025	24,052,572	2,100,000	26,152,572			4,694,160		957,187	5,651,347	1,130,269	4,521,077	-19,531,495	-18,401,226
2	2026		2,100,000	2,100,000			4,694,160		957,187	5,651,347	1,130,269	4,521,077	4,305,788	5,382,235
3	2027		2,100,000	2,100,000			4,694,160		957,187	5,651,347	1,130,269	4,521,077	4,100,750	5,125,938
4	2028		2,100,000	2,100,000			4,694,160		957,187	5,651,347	1,130,269	4,521,077	3,905,477	4,881,846
5	2029		2,100,000	2,100,000			4,694,160		957,187	5,651,347	1,130,269	4,521,077	3,719,501	4,649,377
6	2030		2,100,000	2,100,000			4,694,160		957,187	5,651,347	1,130,269	4,521,077	3,542,382	4,427,978
7	2031		2,100,000	2,100,000			4,694,160		957,187	5,651,347	1,130,269	4,521,077	3,373,697	4,217,122
8	2032		2,100,000	2,100,000			4,694,160		957,187	5,651,347	1,130,269	4,521,077	3,213,045	4,016,307
9	2033		2,100,000	2,100,000			4,694,160		957,187	5,651,347	1,130,269	4,521,077	3,060,043	3,825,054
10	2034		2,100,000	2,100,000			4,694,160		957,187	5,651,347	1,130,269	4,521,077	2,914,327	3,642,908
11	2035		2,100,000	2,100,000			4,694,160		957,187	5,651,347	1,130,269	4,521,077	2,775,549	3,469,437
12	2036		2,100,000	2,100,000			4,694,160		957,187	5,651,347	1,130,269	4,521,077	2,643,380	3,304,225
13	2037		2,100,000	2,100,000			4,694,160		957,187	5,651,347	1,130,269	4,521,077	2,517,505	3,146,881
14	2038		2,100,000	2,100,000			4,694,160		957,187	5,651,347	1,130,269	4,521,077	2,397,624	2,997,030
15	2039		2,100,000	2,100,000			4,694,160		957,187	5,651,347	1,130,269	4,521,077	2,283,451	2,854,314
16	2040		2,100,000	2,100,000			4,694,160		957,187	5,651,347	1,130,269	4,521,077	2,174,715	2,718,394
17	2041		2,100,000	2,100,000			4,694,160		957,187	5,651,347	1,130,269	4,521,077	2,071,158	2,588,947
18	2042		2,100,000	2,100,000			4,694,160		957,187	5,651,347	1,130,269	4,521,077	1,972,531	2,465,664
19	2043		2,100,000	2,100,000			4,694,160		957,187	5,651,347	1,130,269	4,521,077	1,878,601	2,348,251
20	2044		2,100,000	2,100,000			4,694,160		957,187	5,651,347	1,130,269	4,521,077	1,789,144	2,236,430
		24,052,572	42,000,000	66,052,572			93,883,197		19,143,735	113,026,933	22,605,387	90,421,546	35,107,175	49,897,112
										period10yca	FRR=>	12%		21%
										period20yca	FRR=>	17%		24%

Source: JICA Study Team

8. Recommendations

8.1 Recommendations for Ecosystem Service Valuation for Silvo-aquaculture

When conducting an ecosystem service assessment, it is necessary to identify the objects and events to be assessed in both the Without-action scenario and the With-action scenario. While the Without-action scenario allows the objects and events to be identified based on the current situation, the With-action scenario must be based on a certain degree of assumptions, and these assumptions can have a significant impact on the values calculated as ecosystem service assessments. For that reason, it is important to be able to confirm whether the assumptions are reasonable. Therefore, when conducting an ecosystem service assessment, it is essential to disclose the detailed settings and assessment methods of each scenario and to combine them to interpret the values of the ecosystem service assessment.

In this study, silvo-aquaculture was implemented as a pilot activity identifying the objects and events to be evaluated as ecosystem services and calculating their economic value. Because it was based on pilot activities, specific figures and initiative details were clear, and sufficient financial resources were allocated to information gathering and analysis. If a With-action scenario based on the pilot activities is implemented and operated as the same economic activity as the Without-action scenario, it is highly likely that the resources and efforts required for information gathering and analysis implemented in the pilot activities will no longer be necessary. Therefore, it is important to consider whether the With-action scenario is set up to reflect the pilot activities or to anticipate future operations.

As an example, a specific summary based on an ecosystem service assessment is shown below in which the concurrent system implemented in this pilot activity was used as a With-action scenario. In the pilot activity, aquaculture workers were employed full-time to monitor water quality, and the settings in this case are as shown in Table 88. On the other hand, if we assume that aquaculture workers are employed on a day-to-day basis, as in normal aquaculture (shrimp aquaculture, 3 cycles per year), the settings in this case are as shown in Table 89 (red text indicates differences.)

Table 88: Concurrent shrimp aquaculture: 1 cycle (98 days) in a 0.25 ha pond (full-time staff)

Item	Unit price	Quantity	Subtotal (IDR)	Remarks
Tiny baby shrimp	50 IDR/piece (PL12)	25,000 shrimp 12,000 shrimp released after nursing	1,250,000	Needs to be nursed before culturing Survival rate during nursing period: 50% Stocking density 6 individual/ m ²
Juvenile fish (milkfish)	1,000 IDR/fish	100 fish	100,000	
Seaweed	3,000 IDR/kg	200 kg	600,000	
Baby shrimp rearing food	26,500 IDR/kg	9 kg	238,500	
Ground tea seeds (saponin)	2,400 IDR/kg	67.5kg	162,000	
Harvest pump fuel	10,000 IDR/L	100 L	1,000,000	
Aquaculture worker	1,500,000 IDR/month	4 months	6,000,000	Full-time work to obtain data
Pond rental fee	200,000 IDR/month	4 months	800,000	Not required if the land is owned
		Total cost	10,150,500	
Fish (average 250g/fish)	7,000 IDR/tail	90 fish	630,000	
Shrimp 20g or more per piece	90,000 IDR/kg	5.2 kg (approximately 200 shrimp)	468,000	Average about 25g/shrimp
Gracilaria (wet weight)	3,000/kg	600kg	1,800,000	200kg x 3 in one month
		Sales	2,898,000	
		profit	-7,252,500	

Economic value of food provisioning services: -7,252,500 IDR/cycle/0.25ha x 3 cycles/year x 4 =
-87,030,000 IDR/ha /year

Table 89: Concurrent shrimp aquaculture: 1 cycle (98 days) in a 0.25 ha pond (daily labor)

Item	Unit price	Quantity	Subtotal (IDR)	Remarks
Tiny baby shrimp (PL12)	50 IDR/pet	25,000 shrimp 12,000 shrimp released after nursing	1,250,000	Needs to be nursed before culturing Survival rate during nursing period: 50% Stocking density 6 individual/ m ²
Juvenile fish (milkfish)	1,000 IDR/pet	100 fish	100,000	
Seaweed	3,000 IDR/kg	200 kg	600,000	
Baby shrimp rearing food	26,500 IDR/kg	9 kg	238,500	
Ground tea seeds (saponin)	2,400 IDR/kg	67.5kg	162,000	
Harvest pump fuel	10,000 IDR/L	100 L	1,000,000	
Aquaculture worker	500,000 IDR/month	4 months	2,000,000	Regular work and daily labor during harvest
Harvesters	20,000/day	6 people	120,000	
Pond rental fee	200,000 IDR/month	4 months	800,000	Not required if the land is owned
		Total cost	6,270,500	
Fish (average 250g/fish)	7,000 IDR/tail	90 fish	630,000	
Shrimp 20g or more per piece	90,000 IDR/kg	5.2 kg (approximately 200 shrimp)	468,000	Average about 25g/shrimp
Gracilaria (wet weight)	3,000/kg	600kg	1,800,000	200kg x 3 in one month
		Sales	2,898,000	
		profit	-3,372,500	

Economic value of food provisioning services: -3,372,500 IDR/cycle/0.25ha x 3 cycles/year x 4 =
-40,470,000 IDR/ha /year

In this way, if the employment of aquaculture workers is changed from full-time to day labor, which is normal in aquaculture, the negative margin of the economic value of "Food supply and provision of raw materials" will be greatly reduced. However, further improvement is required to make it positive, suggesting that shrimp aquaculture itself is not sustainable.

In the case of milkfish aquaculture, milkfish were used in the pilot activity because they remove green algae.

Milkfish are adaptable to a wide range of salinity levels, omnivorous, resistant to low-oxygen environments and disease, and have a robust artificial seedling production system and a substantial market. Therefore, if silvo-aquaculture is introduced, they are likely to be used as one of the aquaculture species in mixed culture. In this pilot activity, the milkfish culture density using the concurrent system was 400 fish/ha. However, according to BRIN researchers, the maximum culture density for milkfish in brackish water monoculture is 5,000 fish/ha. This means that it is possible to increase the culture density. Assuming a density of 3,000 fish/ha, the profits from milkfish are estimated to be as follows:

Table 90: Estimated profits (IDR) from raising milkfish at a density of 3,000 fish/ha

	Item	Unit price	Current aquaculture density		3,000 fish/ha	
			quantity	Subtotal (IDR)	quantity	Subtotal (IDR)
Concurrent system (0.25ha)	Juvenile fish (milkfish)	1,000 IDR/pet	100 fish	100,000	750 fish	750,000
	Fish (average 250g/fish)	7,000 IDR/tail	90 fish	630,000	675 fish	4,725,000
	profit			530,000		3,975,000
Concurrent system profit per hectare x 3 cycles				6,360,000		47,700,000

In this way, the concurrent system can increase profits by $(47,700,000 - 6,360,000 =) 41,340,000$, which can turn the economic value of "Food supply and provision of raw materials" into a positive. If shrimp aquaculture is discontinued as the aquaculture density of milkfish increases, the negative economic value of "Food supply and provision of raw materials" from shrimp aquaculture changes to positive.

The ecosystem service valuation of the With-action scenario can vary greatly depending on the settings. Therefore, it is important to confirm whether the settings are appropriate. However, since it is necessary to enter figures that have been estimated to a certain degree when setting activities that have not yet been implemented, these settings may vary greatly depending on the management decisions of each business operator, and there is room for educated value judgments. This is something that should be kept in mind when conducting an ecosystem service assessment and when interpreting its results.

If economic value of ecosystem services provided by silvo-aquaculture to be increased in the case of With-action scenario compared to the Without-action scenario, determining the labor costs of aquaculture workers and establishing aquaculture techniques for shrimp, fish, and seaweed are not sufficient. It is also necessary to accumulate knowledge about which target species to farm and at what density to stock them in order to optimize them. Once such knowledge has been accumulated, it will likely become possible for third parties to judge whether the settings of the With-action scenario are appropriate.

Through the pilot activities, an ecosystem service assessment protocol was developed, an assessment based on this protocol was conducted, and the extent to which various services improved because of silvo-aquaculture practices (With-action scenario) was calculated. It was also found that the With-action scenario was not viable from a management perspective due to the low yield from black tiger shrimp aquaculture. To make the With-action scenario better than the Without-action scenario in terms of both ecosystem service assessment and management, business simulations may be used to gain some insights into the ideal

management method. However, whether such settings are technically feasible is another matter. In this sense, the accumulation of various technical knowledge related to the With-action scenario is necessary for the development of ecosystem service assessments (i.e., the adoption of ecosystem service assessments in various initiatives), which will likely directly lead to the promotion of silvo-aquaculture practice.

Furthermore, the pilot activities in this study have pointed out the possibility of silvo-aquaculture using not only black tiger shrimp and milkfish but also tilapia and vanamei shrimp. Regarding silvo-aquaculture using these target aquaculture species, it would be important to conduct an ecosystem service assessment using the protocol developed in this study, or to simulate just the aquaculture operation to further improve silvo-aquaculture practices.

8.2 Recommendations From the Perspective of Shrimp Aquaculture in Silvo-aquaculture

The purpose of silvo-aquaculture, particularly in this pilot activity, was to explore what type of aquaculture would be suitable for increasing mangroves. Therefore, it was important to explore and emphasize the benefits of having mangroves to aquaculture operators. In this pilot activity, it was confirmed that the presence of mangroves increases the population and diversity of macrobenthos, and that this also has benefits for shrimp aquaculture, which feeds on them. This made it possible to motivate local aquaculture operator to plant mangroves. However, at the same time, current difficulties with shrimp aquaculture were also highlighted.

Environmental conditions important for shrimp survival were confirmed to include salinity, water temperature, dissolved oxygen, pH, vibrio, and viruses. While all but viruses were controllable, no measures are currently available for viruses. Black tiger shrimp, once a major aquaculture commodity, have seen a near-total disappearance of aquaculture operators adopting them for cultivation and a complete loss of seed producers due to the lack of effective countermeasures since the global spread of a viral disease in 1993. Although seed production for vanamei shrimp continues, the risk of losses due to disease is increasing year by year even when adopted as an aquaculture commodity. Until progress is made in controlling shrimp diseases, it is necessary to maintain the livelihoods of local residents by practicing mixed culture involving multiple species alongside alternative commodities. Therefore, shrimp were deemed difficult to cultivate, while milkfish and *Gracilaria* were deemed more suitable as aquaculture commodities.

Milkfish have been confirmed to be a commodity with an extremely low risk of mortality due to high temperatures, high salinity, or disease. They feed on small plankton and organic detritus, and the presence of mangroves increases the availability of such natural food. Therefore, the presence of mangroves is considered beneficial for milkfish aquaculture. It is highly likely that silvo-aquaculture is viable, but specific verification is required. With regard to *Gracilaria*, by positioning it as a commodity within integrated aquaculture systems, it has been found to offer significant benefits from multiple perspectives: providing raw materials for agar production, serving as shelter for juvenile shrimp and other organisms, purifying water quality, and promoting the proliferation of macrobenthos. Mixed aquaculture with milkfish and *Gracilaria* is possible,

however, the benefits of mangroves to *Gracilaria* are still unclear and need to be confirmed.

Furthermore, surveys of the surrounding aquatic fauna indicate that mangrove areas serve as critical early life stages habitats for numerous coastal organisms. This demonstrates their importance for biodiversity conservation and the maintenance of coastal fishery resources. It also suggests that coastal mangrove afforestation holds significant value for sustaining fishery resources.

The disadvantages of the presence of mangroves in aquaculture were also identified. Because the water depth in the mounds used for mangrove planting is shallow, *Gracilaria* does not grow, and instead green algae flourishes, blocking sunlight from reaching other algae and suppressing the growth of *Gracilaria*. Furthermore, as the green algae decays, it produces ammonia, which is toxic to animals, including milkfish. One solution to this green algae problem is to periodically collect the algae by hand, but there are many unknowns, such as the frequency and cost of collection, and the impact of walking around the mounds to collect it from the mangroves.

Empang parit is a method of silvo-aquaculture that has been traditionally practiced in Indonesia, which is a system of clearing a section of existing mangroves to create a trench rather than planting mangroves, resulting in a single mangrove clump in the middle of the pond. Therefore, *empang parit* is not a method to include planting mangroves. Furthermore, with the *kao kao* system, there are no obvious benefits from mangroves to aquaculture. Therefore, *komplangan* appears to be the only method to promote silvo-aquaculture to increase mangrove cover by planting mangroves. The concurrent system implemented in this pilot project is a typical *komplangan*, but its suitability for mangrove growth was found to be insufficient. Because the separate system provides a superior mangrove growth environment, combining these two methods, such as connecting aquaculture ponds and mangrove plantation ponds with a waterway, could be a viable *komplangan*. However, more intensive and sophisticated skills, time and efforts would be required to manage such a separate *komplangan* with a waterway connecting the two ponds, and technical and management know-how is needed to successfully implement such a complicated water management system.

While this study has provided valuable insights into the advantages and disadvantages of silvo-aquaculture compared to ordinary aquaculture, as well as pond management methods, many issues remain for further attention. One possible explanation is that aquaculture stakeholders have not been sufficiently involved in silvo-aquaculture, resulting in a lack of perspective from aquaculture stakeholders and fishermen. Silvo-aquaculture has been promoted by forestry professionals, often with passive participation from aquaculture stakeholders. While the appeal of silvo-aquaculture is explained from the perspective of forestry professionals, it is possible that the benefits and attractiveness of silvo-aquaculture are not fully explained from the perspective of aquaculture stakeholders. To further develop and expand silvo-aquaculture, closer collaboration between forestry and aquaculture stakeholders and a re-examination of silvo-aquaculture from the perspective of aquaculture stakeholders could lead to a breakthrough.

8.3 Recommendations From the Perspective of Mangrove Plantation in Silvo-aquaculture

To promote mangrove plantation and increase mangrove area through silvo-aquaculture, it is necessary to address how to provide a suitable environment for mangroves through water management for aquaculture. As mentioned in Section 8.2, it is necessary to develop and accumulate technical and management know-how to establish a *Komplangan* system, which separates the aquaculture ponds and connects them with a waterway. This approach is also important from the perspective of mangrove plantation. Furthermore, while smooth tidal water flow is key to healthy mangrove growth, it also plays a key role in preventing litter accumulation and the anaerobic environment that would result in litter decomposition and the generation of methane. Bosma et al. (2020) recommend⁴⁴ establishing a mangrove belt between the waterway and the aquaculture pond, allowing water passing through the mangrove belt to be provided to the aquaculture pond. This differs from the *Komplangan*, which uses a separate system and connects both ponds (for aquaculture and mangrove plantation) with a waterway, in that mangroves are planted along the waterway rather than in the pond itself, but the concept is similar. There are concerns that planting along the waterway may impede the smooth flow of water once the mangroves have matured to a certain extent, but it seems like there is room for consideration.

Furthermore, to ensure good mangrove growth, it is necessary to consider thinning mangroves at appropriate times. If mangroves become overcrowded when growing, they will become spindly and slender, which could weaken their effectiveness in terms of carbon accumulation and disaster prevention services. On the other hand, thinning can cause problems, such as a reduction in the volume of mangrove trees relative to the area of the aquaculture ponds provided for mangrove plantation. Further discussion is needed on how to manage mangroves in their mature state, including what planting intervals are appropriate for silvo-aquaculture and how to utilize the mangrove timbers produced by thinning.

8.4 Recommendations for the Introduction of the Silvo-aquaculture Business Model

The silvo-aquaculture business model examined in Section 7.7 technically consists of the following components:

- 1 individual/m² through the adoption of artificial feed.
- By combining multiple mangrove species suited to the environment and adopting them as plantation species, ensure as much biodiversity as possible.
- In the separate mangrove plantation pond, low to high mounds are constructed.
- In mangrove plantation ponds using the concurrent system, a medium-sized mound is installed and multiple tree species are planted together, but the growth of these tree species is not expected to be very strong. Shrimp aquaculture involves extensive aquaculture using natural food from

⁴⁴ Bosma, RH, Debrot, D., Rejeki, S., Tonnejck, F., Yuniati, A., & Sihombing, W. (2020) Associated Mangrove Aquaculture Farms: Building with Nature to restore eroding tropical muddy coasts. Ecoshape technical report, Dordrecht. The Netherlands.

macrobenthos, and pond management is carried out with an emphasis on the effect of improving biodiversity. However, because silvo-aquaculture using the concurrent system does not contribute to improving profitability, the area of the target aquaculture pond is limited.

- To prevent reforestation areas from becoming single-layer forests all at once, operations such as thinning and pruning to improve the light environment, staggering the timing of reforestation to create multi-layer forests, and thinning to promote natural regeneration will be performed.
- When selecting a pond for planting mangroves, choose one with smooth water flow so that organic matter such as litter does not easily remain in the pond, thereby suppressing methane generation.
- In order for the separate and concurrent water management systems to function, it is necessary to ensure that the water channels, reservoirs, and water supply and discharge weirs are fully functional, and initial investment will be made to develop such aquaculture infrastructure.
- Mangrove trees are surveyed annually, either individually or via sampling. Trunk volume per hectare is estimated by measuring the diameter at breast height and tree height, and the amount of carbon absorbed is calculated. This monitoring is carried out annually.
- Conduct regular ecosystem service assessments.
- To support the consolidation of aquaculture ponds, secure local business partners, and provide technical and management know-how for the promotion of silvo-aquaculture business cluster development to increase market awareness and expand ESG investment.

In addition, when conducting a financial and economic analysis of the silvo-aquaculture business model, the following points should be taken into consideration:

- In the With-action scenario, in addition to offsetting opportunity costs and increasing profitability, disclose information on biodiversity improvement and ecosystem service evaluation to the market.
- The expected effect of introducing eco-feed is not only an improvement in the profitability of shrimp aquaculture but also an increased potential to obtain a premium price in the market.
- Based on the results of the financial and economic analysis of the With-action scenario, semi-intensive milkfish aquaculture can be considered as a technical specification of the silvo-aquaculture business model considering the technical difficulties of black tiger shrimp aquaculture.

It is evident that the validation of this business model relies on the market valuation of ecosystem services and recognition of biodiversity in addition to the improvement of profitability. For silvo-aquaculture to be popular in this country, it must be viable as a business and bring aquaculture operators profits equal to or greater than those of conventional aquaculture. While efforts are necessary to achieve this, it is also essential that the market recognizes the positive ecosystem service valuation and that a price premium can be recognized by the relevant markets. However, according to interviews with Japanese companies, there is a lack of recognition of ecosystem service value, and a price premium cannot be added at this stage. It is

believed that the priority is to create a social environment in which the market and consumers recognize ecosystem service value and price premiums.

As discussed in Section 8.2, semi-intensive milkfish aquaculture could contribute to an increase in the profitability of the silvo-aquaculture business. However, verification of silvo-aquaculture with semi-intensive milkfish production has not been conducted, and further empirical research is needed. In such cases, it is necessary to verify whether profitability can be sufficiently enhanced to satisfy fishermen and whether it can exceed the opportunity cost of the ponds. Furthermore, it is considered necessary to conduct further research on whether *Gracilaria* can be produced to improve profitability.

In this way, the verification of the silvo-aquaculture business model through this pilot activity has provided valuable knowledge. At the same time, it has clarified areas that need to be addressed and areas that require more detailed verification. To expand silvo-aquaculture to various regions, further technical verification is required along with closer collaboration between aquaculture and forestry stakeholders, the creation of a social environment in which ecosystem service assessments are recognized by the market and consumers, and the promotion of the use of information through information platforms.

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