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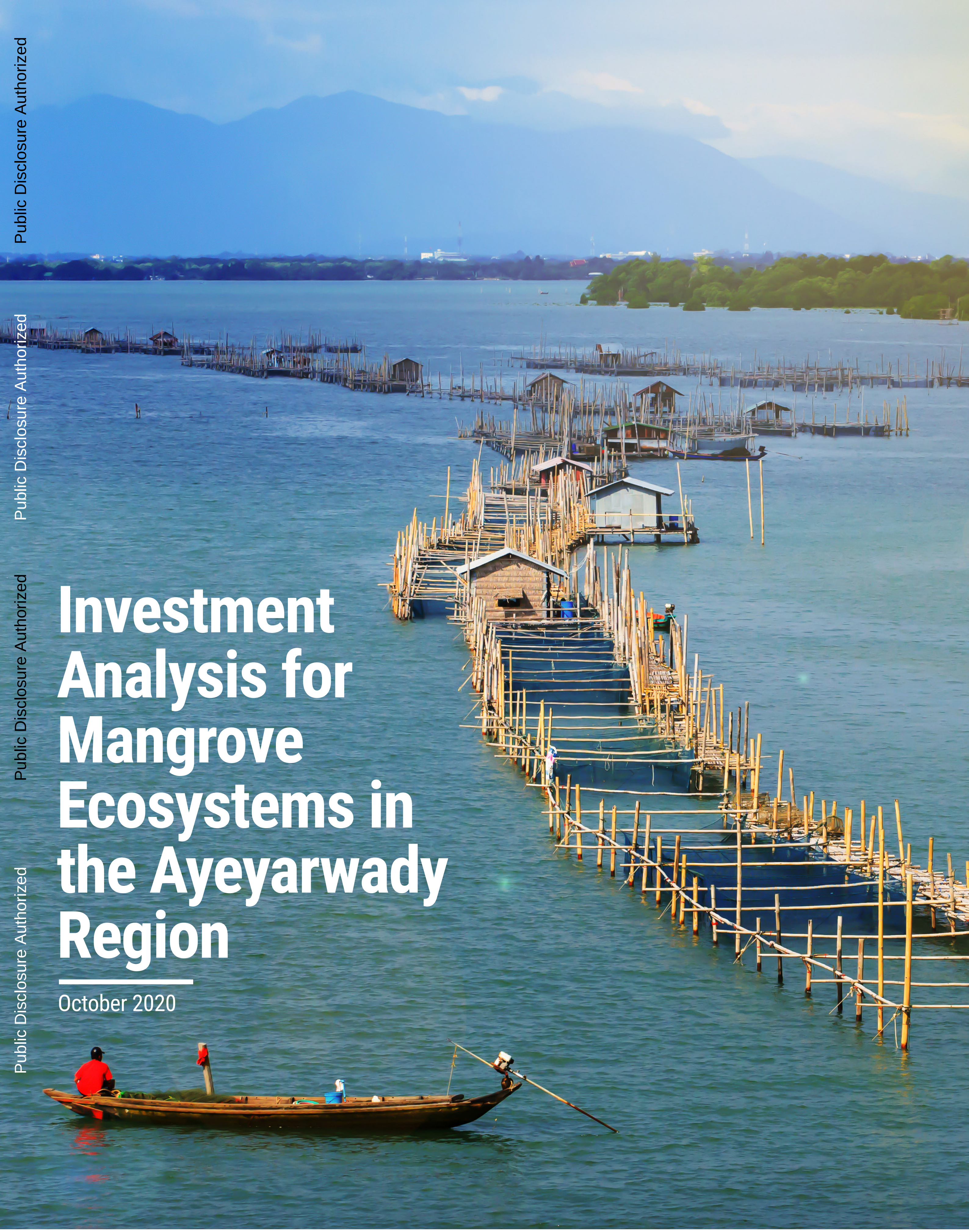

Investment Analysis for Mangrove Ecosystems in the Ayeyarwady Region

October 2020

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Investment Analysis for Mangrove Ecosystems in the Ayeyarwady Region

October 2020

Environment, Natural Resources and the Blue Economy Global Practice

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EXECUTIVE SUMMARY

Mangroves provide essential ecosystem functions and services that support coastal communities. Despite their importance they have been degraded and converted globally, resulting in loss of resilience of coastlines and their communities. Myanmar, in particular, has high levels of mangrove loss and has the highest current rate of mangrove loss among mangrove holding nations. With the aim to create impact through a shift from degraded forests to better quality forests and income improvement of local communities, the Government launched in 2016 the Myanmar Reforestation and Rehabilitation Program (MRRP 2017-2026). However, conservation and restoration require significant investment, and in order to stimulate investment, there is a need for levels of certainty of the returns on investment.

In order to underpin the development of investment strategies for mangrove conservation and restoration in Myanmar, the World Bank, the Global Green Growth Institute (GGGI), The University of Queensland (UQ), and the Ministry of Natural Resources and Environmental Conservation (MONREC) have collaborated on a study to assess the benefits that local communities obtain from conservation and restoration of mangroves in the Ayeyarwady Region. The study focusses on provisioning ecosystem services, as well as a range of regulating ecosystem services.

This study assesses the harvest of fuelwood, the harvest (catching) of mud crabs, polyculture aquaculture practices, the harvest of nipa palm leaves and sap, and rice production, which are the primary products obtained from mangrove lands in the Ayeyarwady Region. The study also assesses the potential benefits of carbon sequestration and coastal and riverbank protection, which are key regulating ecosystem services of mangroves in the region.

The valuation and investment analyses followed the goals of the Wealth Accounting and Valuation of Ecosystem Services (WAVES) global partnership and the Green Growth Knowledge Platform 3Returns Framework, both which aim to promote sustainable development by mainstreaming natural capital in the development of landscape planning and by supporting decision-making for sustainable coastal management.

The 3Returns Framework provides a method for assessing the effectiveness of sustainable landscape interventions. The 3Returns Framework accounts for 'green interventions' in a landscape as:

- **Investments in Natural Capital**: resources allocated to increase the stocks of natural assets;
- **Investments in Social & Human Capital**: resources allocated to increase cooperation within and among groups, individual and collective knowledge, skills, and competencies; while building/strengthening institutions for resource management, decision making, and social integration; and
- **Investment in Financial Capital**: resources allocated to acquire or increase the assets needed in order to provide goods or services.

Approach and Methodology

The 3Returns Framework contrasts a Business as Usual (BAU) scenario against green scenarios to understand changes in key capital indicators (natural, social & human, and financial capital) and the benefits derived from them. In this report, four green scenarios for mangrove conservation and restoration *within reserve forests (RFs) and national park (NP),* which are areas under government control, are considered, along with three improvement scenarios for management and investment of *mangrove land outside RFs and NP* (Figure 1). Improved management scenarios within reserve forests include allocation of mangrove lands to community forestry. Two types of community forestry are considered: 1) Community Forestry User Groups (CFUG), where only members have access to the mangrove resources, and 2) Village Fuelwood Plantations (VFP) where all community members, including landless people can access the mangrove resources. Green interventions considered enhanced mangrove restoration, improved infrastructure for aquaculture and aquaculture practices (i.e. concrete gates), improved thinning and wood collection practices and improved nipa palm production techniques. The analysis for different interventions and scenarios was done until 2026, which is the year that the MRRP finishes. Analyses of the different scenarios over longer time scales (until 2080) were also conducted, although uncertainties are high for such projections.

All products and services were estimated and valued by standard methods. Mangrove status and land-use were assessed using satellite image interpretation with extensive ground truthing. Carbon sequestration in mangrove biomass and soils, timber production, and fuelwood growth were estimated from inventories of mangrove sample plots and modeling. Income, job creation, and productivity of the harvesting of mud crabs, polyculture aquaculture, fuelwood, and nipa palm thatch and sap collection and utilization were assessed through socio-economic surveys of coastal villages in the region. Riverbank and coastal protection by mangroves were estimated from studies in the literature which have similar natural conditions.

Improved land use and resource use management within reserve forests and national park

The analysis revealed that improved and decentralized mangrove management interventions, in which more mangrove land was allocated to community management (Scenario 2-4), increased the total net present value (NPV) of resources in the landscape within reserve forests and national park in the region. For example, in the period 2020 to 2026, NPV increased by approximately 25%, from USD 368 million in the BAU scenario to USD 486 million for Scenario 4 (with a discount rate of 10%) (Figure 2).

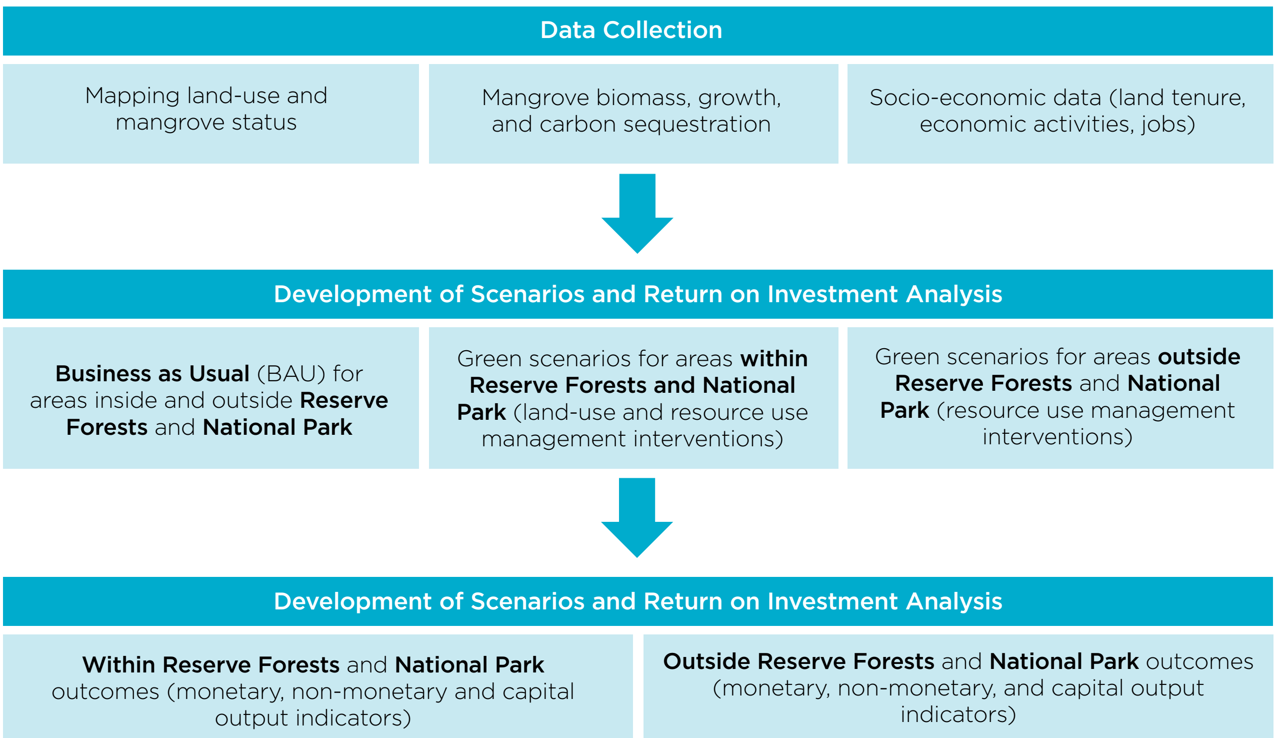
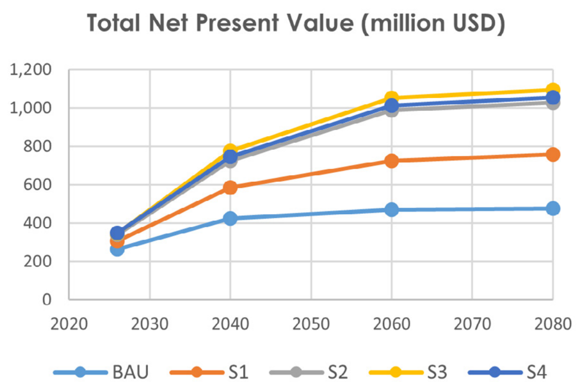
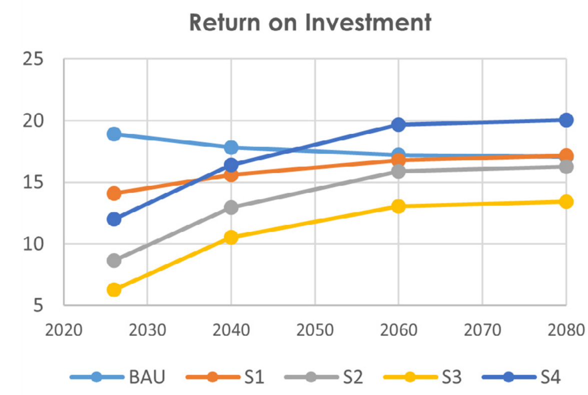


Figure 1. Major steps of the study.





	BAU	S1	S2	S3	S4
Land Use Direct Management Responsibility					
Reserve Forests and National Park	As current practice	• 84% Forest Department • 13% CFUG • 3% VFP	• 50% FD • 25% CFUG • 25% VFP	• 50% FD • 47% CFUG • 3% VFP	• 50% FD • 13% CFUG • 37% VFP
Forest Resource Use Management					
Forest Management	As current practice	Enforced	Improved	Improved	Improved
Law Enforcement	As current practice	Improved	Enforced for CF	Enforced for CF	Enforced for CF
Restoration	300 ha	1000 ha	1500 ha	1500 ha	1500 ha
Other Resource Use Management					
Aquaculture	Same condition	Same condition	Improved	Improved	Improved
Rice	Same condition	Same condition	Same condition	Same condition	Same condition
Nipa Palm	Same condition	Same condition	Improved	Improved	Improved

Figure 2. Net Present Values (NPV) and Return of Investment (ROI) of enhanced mangrove management, including a Business as Usual (BAU) and four improved management scenarios for mangrove within reserve forests and national park with a regular discount rate of 10%. Scenario 1 (S1) represents enforcement of the government's Mangrove Management Plan; Scenario 2 (S2) represents a balanced allocation to mangrove Community Forestry User Groups (CFUG) and Village Fuelwood Plantations (VFP); Scenario 3 (S3) represents higher allocation to CFUGs than VFPs; and Scenario 4 (S4) represents higher allocation to VFPs compared to CFUGs.

Allocation of larger areas of mangroves under CFUGs, as has been practiced in Myanmar for the last two decades, would contribute to improved livelihoods of families in the region. However, increases in the CFUGs areas come at the expense of jobs and livelihoods of many landless people who collect fuelwood and crabs from the mangrove. Yet, the most decentralized practice – through VFP (Scenario 4) – provides the highest returns and non-monetary benefits, as it creates an inclusive pathway for landless people to participate in the mangrove ecosystem. Therefore, a focus on CFUGs without consideration of the landless gives rise to the risk of undermining the improved mangrove management intended through community forestry.

The analysis also found that the mangroves within RFs and NP areas are providing jobs for several tens of thousands of landless people in the delta. It was estimated that the livelihoods of over 200,000 people significantly depend on mangrove resources. Currently, most of the jobs are from harvesting natural mangrove resources such as crabs and fuelwood collection. Many current jobs are not sustainable or environmentally friendly because they lead to over-exploitation of natural resources. The analysis shows that higher levels of investment in community forestry, especially through supporting VFP with associated capacity building, would result in a higher proportion of green jobs associated with mangrove resources. The areas of healthy mangroves and plantations (natural capital output indicator) increased from about 9,000 hectares (mainly plantations) in the BAU to over 27,500 hectares in the intervention Scenarios 2 to 4. Cumulative carbon sequestration in mangroves in 7 years (2020 – 2026), which accounts for half of the total biomass growth of mangroves in the delta, increased from over 515,000 Mg CO_2 in the BAU to over 1,709,000 Mg CO_2 in Scenario 4. Additionally, species biodiversity of community forestry mangroves, reported as the Shannon index, increases from 0.195 to 0.588, if CFUG pond owners and

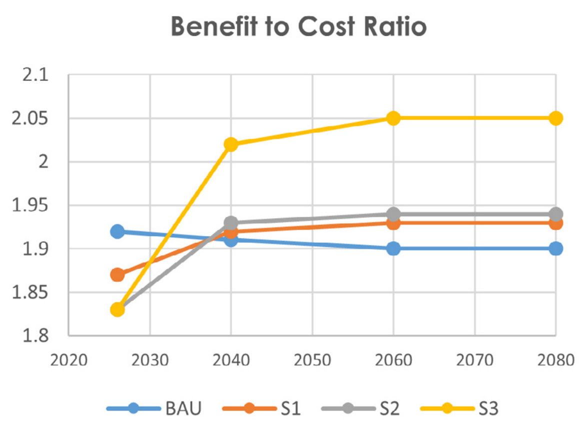
VFP managers keep at least 300 maternal trees of 3 different species on their land.

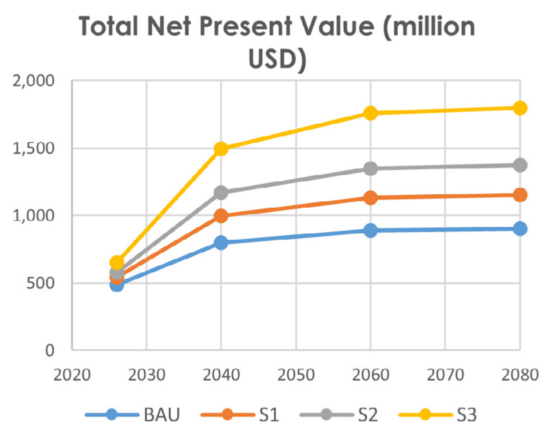
The study conducted analyses of the different scenarios over longer time scales, although uncertainties are high with such projections. The modeling results revealed that multiple capital investments have significantly higher impacts on the NPV, natural capital output indicators, social & human capital output indicators, cumulative biomass carbon sequestration, and the number of jobs and number of green jobs. In the longer term, the ROI of the green investment scenarios increases over time while the ROI in the BAU declines. This analysis suggests that conventional and current BAU practices are not sustainable and have negative impacts on mangrove resources within RFs and NP over time. Only after 20 years (by 2040), the ROI of all greener investment Scenarios exceeds the ROI of the BAU (with a 4% discount rate).

Improved resource use management outside reserve forests and national park

Analysis of the impacts of investment in a range of mangrove management scenarios outside RFs and NP, found that green investments can provide much higher monetary benefits compared to the BAU. Without capital investments, the BAU scenario is unsustainable and results in over-exploitation of natural resources, as observed in the decreasing BCR over the long term (Figure 3).

With a regular discount rate of 10%, the total NPV increases from USD 486 million in the BAU to USD 648 million in Scenario 3 by 2026. In the long term (2080), NPV increases to USD 912 million in the BAU and USD 1,798 million for Scenario 3, respectively. The increase in NPV for green scenarios with an impact discount rate of 4% was much higher that with 10% discount rate (Figure 3).





	BAU	S1	S2	S3
	Resource Use Management			
Mangroves	Same condition	Improved (25%)	Improved (50%)	Improved (75%)
Nipa Palm	Same condition	Improved (25%)	Improved (50%)	Improved (75%)
Aquaculture	Same condition	Improved (25%)	Improved (50%)	Improved (75%)

Figure 3. Benefit to Cost Ratio (BCR) and Net Present Value (NPV) of enhanced mangrove management, including a BAU and three improved management scenarios for mangrove outside reserve forests and national park with a regular discount rate of 10%. Scenario 1 (S1) represents a 25% improvement in resource management; Scenario 2 (S2) represents a 50% improvement in resource management and Scenario 3 (S3) represents a 75% improvement in resource management.

For mangrove land outside the RF and NP, the highest ROI was observed for the green Scenario 1, for which only 25% of mangrove forest rehabilitation (by enrichment planting), nipa palm, and aquaculture pond production systems are improved. The ROI for Scenario 1 (for both discount rates, 10% and 4%) was higher than that of Scenario 2 and Scenario 3. The reason for a decreasing ROI with greater interventions (Scenarios 2 and 3) is explained by the importance that fuelwood collection activities have on the ROI outcomes compared to other economic activities and the investment or interventions proposed in Scenario 2 and 3. In areas inside RFs and NP, fuelwood collection activities represent 23% of the total economic benefits, whereas in areas outside RFs and NP, fuelwood collection activities only represent 1% of the economic benefits. Therefore, because investment in mangrove rehabilitation by enrichment represents the greatest capital expenditure for scenarios in areas outside RFs and NP, an increase in the investment in mangrove rehabilitation in areas outside RFs and NP does not have the same impact as for areas inside RFs and NP. This suggests that to improve profitability and efficiency in a sustainable manner, interventions outside RFs and NP should consider improving the performance of fisheries and aquaculture, which represent the main economic activities in terms of monetary benefits. Interventions such as the investment in hatcheries or the sustainable intensification of aquaculture can support improvement not only in the profitability but also in the efficiency of interventions in areas outside RFs and NP.

Analysis of the impacts of different scenarios over the long term found that the NPV, BCR, and ROI of the green investment scenarios increased over time. Additionally, mangrove resources and capital investment in mangrove associated activities outside RFs and NP can provide over 100,000 full-time-equivalent jobs in the delta.

Improved management of mangrove resources outside RFs and NP could mitigate millions of tons of carbon dioxide. Cumulative carbon sequestration of mangroves by 2080 was around 2.5 million Mg CO_2 in the BAU, compared to 14.7 million Mg CO_2 in Scenario 3. Also, green investments in mangrove areas outside RFs and NP would bring multiple other benefits. For instance, they would contribute to increasing healthy mangrove cover to around 29,000 ha under Scenario 3 by 2026.

Finally, for all mangrove land, inside and outside the RFs and NPs, resources and investments could result in over 160,000 jobs. It is estimated that over 700,000 people can be provided with sustainable livelihoods with a range of appropriate investments.

Overall, the analysis reveals that the investments proposed through the different green scenarios improve the monetary and non-monetary benefits, as well as capital output indicators, when compared to the BAU. For areas inside RFs and NP, mangrove restoration and decentralization of mangrove management through community forestry is a key innovation for achieving sustainable outcomes, as fuelwood collection activities currently make up to 23% of the economic benefits derived from the mangroves in the RFs and NP. Meanwhile, for areas outside RFs and NP, improving fishing and aquaculture activities could be key innovations for achieving sustainable outcomes, as non-timber products are the main drivers of income generation outside the RFs and NP. Therefore, additional interventions or investments (e.g. development of hatcheries or sustainable intensification of aquaculture practices) could be considered further in areas outside the RFs and NP.

Conclusions

- Allocation of mangrove land to community forestry and green interventions such as mangrove restoration, improved aquaculture infrastructure and practices, improved thinning and wood collection practices, and nipa palm production techniques, brings greater benefits compared to current practices (represented in the BAU scenario).
- Green investments improved financial indicators as well as non-monetary and capital output indicators in both the short and the long term. Over longer time scales BAU practices are observed to be unsustainable in areas inside as well as outside the RFs and NP.
- For areas *inside RFs and NP*, decentralization and improved mangrove management are key innovations for achieving sustainable mangrove management. The most decentralized practice – through Village Fuelwood Plantations – provided the highest returns and non-monetary benefits, showing an inclusive pathway for landless people to participate in the benefits from the mangroves. Currently, for CFUGs there is no requirement for the involvement of all community members, including the landless. Therefore, consideration of appropriate safeguards for the landless in community forestry programs is a key potential opportunity to empower landless people, but this requires consultation within the community in order to secure their participation.
- For areas *outside RFs and NP*, improving crab catching and aquaculture activities in addition to mangrove rehabilitation could be innovations for achieving sustainable outcomes, as non-timber products provide the main income from the mangrove areas. While investments in mangrove rehabilitation by enrichment planting improves the NPV, the investment required should be carefully considered as the main production systems from these lands do not directly depend on mangrove fuelwood, and therefore, investments in the further development of non-timber economic activities should be considered.
- Land-use boundaries are not clear in mangrove landscapes in the Region, particularly those of reserve forests. Improving the mapping in the Region is fundamental to land-use planning which would support more effective and successful mangrove management.
- The inclusion of mangroves in mitigation as well as adaptation strategies in Myanmar can provide economic benefits for communities and important regulatory ecosystem services that contribute to Myanmar's Nationally Determined Contributions to the Paris Agreement.
- Finally, the interventions presented through this study aim to support and should be considered as a response to the efforts of the Myanmar government to create a more resilient economy expressed through the Myanmar Sustainable Development Plan 2018-2030 (MSDP), and more recently through the Myanmar Economic Recovery & Reform Plan (MERRP) developed as a response to COVID-19 impact.

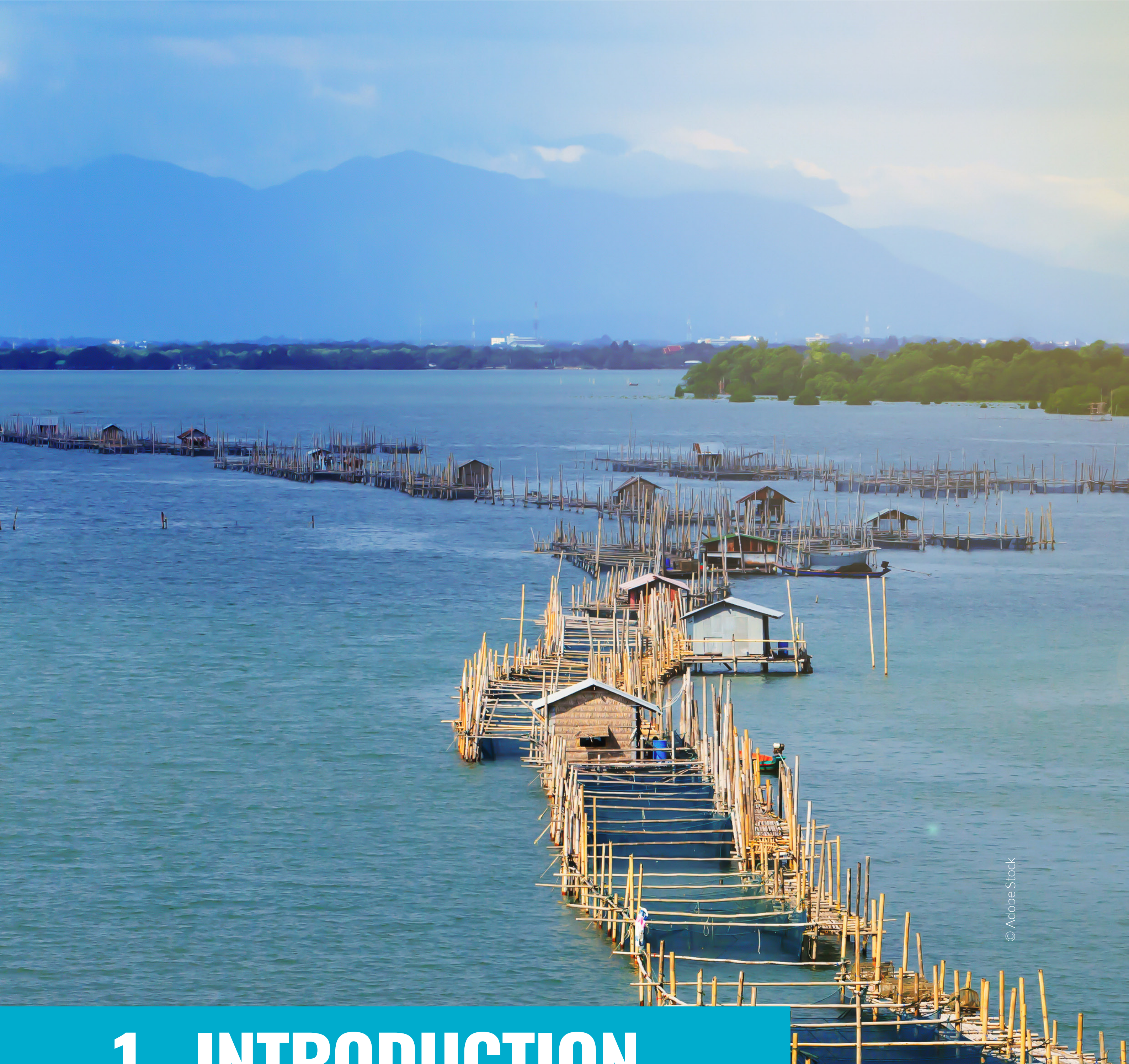
TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

BAU	Business as Usual
BCR	Benefit to Cost Ratio
CAPEX	Capital Expenditure
CBT	Community-Based Tourism
CF	Community Forestry
CFUG	Community Forestry User Group
CIFOR	Center for International Forestry Research
CIRAD	The French Agricultural Research Centre for International Development
DALMS	Department of Agricultural Land Management and Statistics
ES	Ecosystem Services
FAO	Food and Agriculture Organization
FREDA	Forest Resource Environment Development and Conservation Association, Myanmar
GAD	General Administration Department
GGGI	Global Green Growth Institute
GGKP	Green Growth Knowledge Platform
GIS	Geographic Information System
GPS	Global Positioning System
IFC	International Finance Corporation
IPCC	Intergovernmental Panel on Climate Change
JICA	Japan International Cooperation Agency
MAI	Mean Annual Increment
MEA	Millennium Ecosystem Assessment
MERRP	Myanmar Economic Recovery & Reform Plan
MIMU	Myanmar Information Management Unit
MONREC	Ministry of Natural Resources and Environmental Conservation
MMK	Myanmar Kyat
MRRP	Myanmar Reforestation and Rehabilitation Program
MSDP	Myanmar Sustainable Development Plan
NDC	Nationally Determined Contribution
NGO	Non-Governmental Organization
NP	National Park
NPV	Net Present Value
NTFP	Non-timber Forest Products
ODA	Overseas Development Aid
OPEX	Operational Expenditure
PFM II	Public Financial Managment II
RF	Reserve Forest
ROI	Return on Investment
SLR	Sea Level Rise
UQ	The University of Queensland
USD	United States Dollars
VCS	Verified Carbon Standards
VFP	Village Fuelwood Plantation
WAVES	Wealth Accounting and Valuation of Ecosystem Services
WB	The World Bank
WIF	Worldview International Foundation, Myanmar



1. INTRODUCTION

Mangroves provide essential ecosystem functions and services that support coastal communities (MEA 2005, Barbier, Hacker et al. 2011). Despite their importance, they have been degraded and removed globally (Valiela, Bowen et al. 2001, Hamilton and Casey 2016), resulting in loss of resilience of coastlines, their communities, and economies (Hochard, Hamilton et al. 2019). Myanmar in particular has suffered from high levels of mangrove loss (Webb, Jachowski et al. 2014) and has the highest current rate of mangrove loss among mangrove holding nations (Hamilton and Casey 2016). The role of mangroves in protecting coastlines and communities from storms and flooding, regulating carbon and nutrient cycles, and supporting fisheries has been well established (Barbier, Hacker et al. 2011, Duarte, Losada et al. 2013, Hochard, Hamilton et al. 2019). Yet, the effects of deforestation have resulted in lowering the capacity of mangrove forests to effectively act as a buffer against waves and storm surges (FAO 2017).

With the development goal of enhancing economic and environmental conditions, in 2016 the Government launched the Myanmar Reforestation and Rehabilitation Program (MRRP 2017- 2026). The MRRP aims to create impact through a shift from degraded forests to better quality forests and income improvement of local communities. This program looks to reinforce efforts of conservation and restoration, with the establishment of Community Forestry (CF) as a mechanism to provide communities the capacity to plan and manage their forest resources according to an agreed management plan (World Bank 2019).

Conservation and restoration of mangroves for their ecosystem functions and services, including those of climate change mitigation and adaptation, has therefore become a high priority in many nations, including Myanmar (Herr and Landis 2016). However, conservation and restoration require significant investment in order to improve the management of extraction and production activities of local key commodities for supporting mangrove recovery. In order to stimulate interventions through investment, there is a need for high levels of certainty of the returns on investment. While the benefits of ecosystem services such as storm and flood protection have been valued at regional scales (Hochard, Hamilton et al. 2019), knowledge of the benefits of mangrove conservation and restoration to the economies of local communities and individual households is less well established. For example, the value of mangrove products and value chain characteristics in terms of jobs created, income generated, as well as the influence on social wellbeing, is limited to a few locations. This limited knowledge of the value of mangrove products to local communities limits the development of investment strategies, which could support sustainable management of mangrove resources.

In order to underpin the development of investment strategies for mangrove conservation and restoration in Myanmar, the Global Green Growth Institute (GGGI), The University of Queensland (UQ), and the Ministry of Natural Resources and Environmental Conservation (MONREC) collaborated on a study to assess the benefits that local communities obtain from conservation and restoration of mangroves. The study was done in three townships in the south-eastern region of the Ayeyarwady Delta, which have some of the largest remaining mangrove areas in the delta. Following this analysis, **the current study further extends the analysis by 1) including additional mangrove products, those of cultivation of nipa palm and polyculture aquaculture, and 2) extending the scale of the analysis to the whole of the Ayeyarwady Region**. This study comprises intensive data collection, including mapping and on-ground assessment of mangrove resources, detailed household surveys on how community members use mangroves and what incomes they receive, accumulation of knowledge of costs for restoration, and management activities by governments and non-government organizations. Through consultation with government and non-government organizations, this assessment developed a range of plausible interventions to enhance conservation and restoration of mangroves, including evaluation of the costs of implementation and the returns on investment, where direct financial benefits were considered, as well as social and human benefits derived from the mangrove ecosystem.

2. OBJECTIVES

This study aims to analyze the benefits obtained from the products and services of mangrove ecosystems in the Ayeyarwady Region to support the World Bank Project: "Myanmar Forest Restoration, Development and Investment Project" (Project P168254) and, more broadly, support the implementation of community-managed regimes for mangroves in the Ayeyarwady Region. Under this overall goal, the specific objectives are:

a) To identify monetary and non-monetary benefits of mangrove restoration projects;

b) To evaluate the cost effectiveness of restoration projects over a range of enhanced government-led and community forestry scenarios;

c) To inform how management practices may help with mangrove restoration; and

d) To inform policy development options to support mangrove restoration in view of their importance for the provision of ecosystem products and services.

The valuation and investment analyses followed the goals of the Wealth Accounting and Valuation of Ecosystem Services (WAVES) global partnership and the Green Growth Knowledge Platform 3Returns Framework,[1] both which aim to promote sustainable development by mainstreaming natural capital in the development of landscape planning and by supporting decision-making for sustainable coastal management.

The 3Returns Framework provides a method for assessing the effectiveness of sustainable landscape interventions. The 3Returns Framework accounts for 'green interventions' in a landscape as:

- **Investments in Natural Capital**: resources allocated to increase the stocks of natural assets;
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- **Investment in Financial Capital**: resources allocated to acquire or increase the assets needed in order to provide goods or services.

1 The 3Returns Framework methodological description is publicly available and can be found in the Green Growth Knowledge Platform under the Expert Group on Natural Capital featured resources - https://www.greengrowthknowledge.org/working-group/natural-capital.

In order to quantify the benefits, understand gender roles, and identify opportunities from production systems that support mangrove restoration, this project assessed two key mangrove-associated products' value chains. These are presented in "insight briefs" titled: 'Mangrove Aquaculture: Polyculture Products in the Ayeyarwady Region'[2] and 'Nipa Palm Products in the Ayeyarwady Region'[3]. These analyses complement a previous study of 'Bio-based Value Chain Analysis for Sustainable Mangrove Restoration'[4] focused on mud-crab fattening and fishery solar-dome drying business models in the Ayeyarwady Region.

Box 1. Information on how this report can inform the World Bank portfolio in Myanmar.

Under preparation:

- Additional Financing to Agriculture Development Support Project - direct relation with the food and nutrition security.
- Myanmar Southeast Asia Disaster Risk Management Project Additional Financing - emphasis on the floods and storms in this area.
- Additional Financing - Ayeyarwady Integrated River Basin Management Project - identical focus area.
- Public Financial Management II (PFM II) Project and Enhancing Institutional Capacity of State and Region Governments Project – Both are looking at strengthening institutions by looking at human resources roles, organizational structure, and technology. Also ensuring that there is capacity to complete this operation, there are synergies both in terms of looking at the process to ensure efficiency and effectiveness and ensuring the right skills are available. Also, PFM II is looking at overall revenue generation and taxes.

Ongoing:

- Maternal and Child Cash Transfers for Improved Nutrition Project - looks at encouraging women to improve household nutrition.

Analytical activities:

- Myanmar Coastal and Delta Resilience Program - is looking at improving disaster and climate resilience of coastal and delta communities in the country, specifically it is looking at tools for early detection of disasters.
- Mekong Vision - the objective is to align the Mekong development and natural resources management activities more closely with long-term sustainability, in the context of the emerging challenges. Lessons from Ayeyarwady may help shape this analytical work.

IFC:

- Tourism Project to sustainably develop the tourism sector at the Inle Lake and Tanintharyi Region and at national-level destinations; interventions include strengthening destination planning and management to ensure sustainable and inclusive development.
- The aquaculture practices observed in the study site are mostly driven by the commercialization of crabs and shrimp; as well as on how would sea level rise impact rice land and livelihoods associated with rice production. Agribusiness - this project looks to improve operational efficiency and sustainability of agribusiness companies, including developing industry standards of key agriculture commodities, strengthening value chains, and supporting farmer engagement on good agricultural practices. How do the aquaculture practices observed in this study improve operational efficiency and sustain good agricultural practices.
- Environment and Social Sustainability Advisory Project aims to build responsible and sustainable private sector clients in Myanmar that can better access markets, and finance and reduce operational costs through improved environmental and social practices. IFC environment and social advisory team aims to take a holistic approach to create sustainable and transparent markets by supporting the private sector to adopt sound environmental and social practices.

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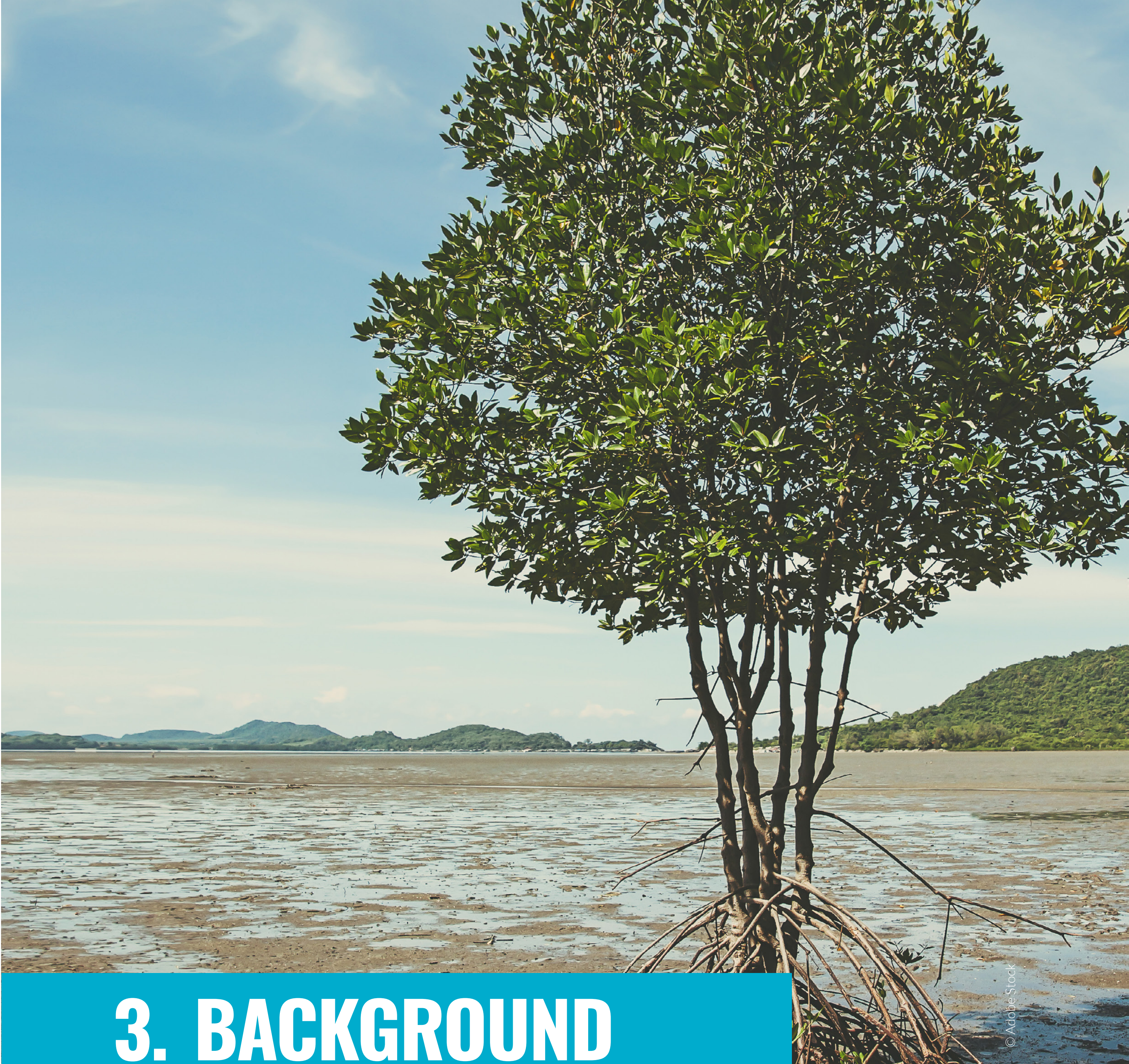
2 WB (2020). Mangrove Aquaculture: Polyculture Products in the Ayeyarwady Region – Insight Brief. Washington DC: The World Bank Group

3 WB (2020). Nipa Palm Products in the Ayeyarwady Region – Insight Brief. Washington DC: The World Bank Group

4 GGGI (2020). Bio-based Value Chain Analysis for Sustainable Mangrove Restoration, Ayeyarwady Delta, Myanmar. Link: https://gggi.org/report/bio-based-value-chain-analysis-for-sustainable-mangrove-restoration-ayeyarwady-delta-myanmar/



3. BACKGROUND AND SCOPING

3.1. MANGROVE ECOSYSTEMS IN THE AYEYARWADY REGION

In Myanmar, mangroves are distributed in three main regions: Rakine, Ayeyarwady, and the Tanintharyi regions (Figure 4). Mangrove vegetation is a dominant feature of the Ayeyarwady Delta, similar to other large tropical deltas of the world. The mangroves influence the evolution of tropical deltas, such as the Ayeyarwady, by trapping sediment and protecting coastlines against the impacts of large storm events. The mangroves of the Ayeyarwady are diverse ecosystems, comprising 21 true mangrove species and a wide range of other co-occurring plant species considered mangrove associates that thrive in the brackish conditions of the delta. The mangroves, rivers, and creeks support important faunal species linked to fisheries as well as species with high biodiversity value (e.g. Irrawaddy dolphin, crocodiles, and a range of bird species). The designation of the Meinmahala Kyun Wildlife Sanctuary as a Ramsar site in 2017 reflects the importance of the region for the biodiversity of Myanmar and for the emerging tourism industry.

Figure 4. Mangrove distribution in Myanmar (Updated from the mangrove map of Clark Lab 2018[5]).

The Ayeyarwady Delta comprises the main arms of Pathein, Pyapon, Bogale, and Toe Rivers. Unlike many of the other large deltas of South East Asia, the rivers that form the Ayeyarwady Delta are comparatively unmodified and thus sediment flows and other hydrological, biogeochemical, and biological processes are likely to contribute to ecosystem resilience in the face of climate change.

The mangroves in the Ayeyarwady Delta provide a range of functions and services that support local communities. These include provisioning services[6] (e.g. fuelwood, nipa leaves for thatching, crabs, and shrimp), regulating services[7] (e.g. flood mitigation, coastal protection, nutrient cycling, and carbon sequestration), cultural services[8], and supporting services[9]. The Ayeyarwady Delta is the key rice and fish producing area of Myanmar; responsible for about 35% of rice production of the country (Webb et al., 2014). To support development in the region, road

5 Data source: Clark Labs Sept 2020 (link: https://clarklabs.org/aquaculture/)

6 Provisioning services: products people obtain from ecosystems and which may include food, freshwater, timbers, fibers, and medicinal plants.

7 Regulating services: benefits people obtain from the regulation of ecosystem processes and which may include surface water purification, carbon storage and sequestration, climate regulation, and protection from natural hazards.

8 Cultural services: nonmaterial benefits people obtain from ecosystems and which may include natural areas that are sacred sites and areas of importance for recreational and aesthetic enjoyment.

9 Supporting services: natural processes that maintain the other services and which may include soil formation, nutrient cycling, and primary production.

transport infrastructure was greatly increased during the 1990s and 2000s, which may have also increased mangrove degradation as access to the forest was enhanced. Fishing is an important industry in the region (World Bank 2019), whose productivity can be directly and indirectly linked to mangrove cover, depending on the fish species. Fishers use fixed fishing traps as well as small boats in the rivers and mangrove creeks and use mangrove fuelwood to process their catch. Prawn fishery and the harvesting of sea turtle eggs are also major commercial activities, both which are now threatened by overexploitation and the loss of the mangrove forests.

Although mangrove loss in Myanmar is occurring in all three regions (Table 1), losses experienced in the Ayeyarwady have been the largest with >80% of the forest cover removed and degraded since the 1980s (Table 1). In 2019, satellite image interpretation combined with on-ground assessments found 34,650 ha of degraded mangrove of a total of 178,961 ha of what was mapped as mangrove land (including unvegetated land, regenerating mangrove, highly degraded mangroves, and nipa palm), suggesting further degradation since 2013 (Table 1). The mangroves in the Ayeyarwady Delta are currently at risk due to widespread deforestation and unsustainable management practices (Webb, Jachowski et al. 2014, De Alban, Jamaludin et al. 2020). This has reduced the resilience of the delta to intense storms. In 2008, the 5 meter storm surge and 2 meter high storm waves of the Category 4 Cyclone Nargis caused widespread loss of life and devastation in the delta (Fritz, Blount et al. 2009), including damage of the remaining mangrove (Aung, Mochida et al. 2013).

The impacts of Cyclone Nargis stimulated attempts to reduce losses of mangrove land and to restore the mangrove. Mangroves are included in the adaptation strategies described in Myanmar's Nationally Determined Contribution (NDC) to the Paris Agreement (Landis and Herr 2016). Degradation of mangroves in the Ayeyarwady Delta has been mainly associated with fuelwood collection, charcoal production, illegal logging, and paddy cultivation (Ling and Fodor 2019). The Ayeyarwady region is currently facing tremendous challenges in limiting mangrove loss (De Alban, Jamaludin et al. 2020), which is increasing vulnerability to extreme events and climate change, reducing the capacity for climate change mitigation, adaptation, and sustainable development. Despite the losses, the Ayeyarwady region has some of the largest remaining mangrove stands in Myanmar as well as significant opportunities for recovery.

In addition to human exploitation of the mangrove and intense storms, climate change, and particularly sea level rise, poses threats to the mangroves (Dasgupta, Laplante et al. 2011, Horton, De Mel et al. 2017). Sea level rise is anticipated to increase the impacts of storm surge (Horton, De Mel et al. 2017), with negative effects on communities of the region (Oo, Van Huylenbroeck et al. 2018). Climate change may change the frequency of intense storms, although there are high levels of uncertainty around projected changes in the frequency and intensity of intense storms and wind fields (Knutson, McBride et al. 2010, Reguero, Losada et al. 2019, Young and Ribal 2019). However, recent observations indicate that the deltas of Asia are already experiencing erosion associated with mangrove clearing in conjunction with intense storms, sea level rise, and changes in wind driven waves and tidal currents (IPCC 2019). For example, large areas of the Sundarbans and the Mekong Delta are projected to be submerged under even moderate climate change scenarios (Minderhoud, Coumou et al. 2019). The Ayeyarwady Delta, its mangroves, and associated human communities may have a moderate vulnerability to sea level rise and changes in storm frequency and intensity compared to other large deltas of Asia, because of their largely unmodified river systems that support natural deltaic processes (Lovelock, Cahoon et al. 2015). However, detailed studies of the vulnerability of the delta to climate change and the influence of climate change on deltaic processes (e.g. sediment delivery, erosion) are not yet available which prevents detailed spatial modeling of future impacts of sea level rise and other oceanic changes on mangroves. This represents a significant knowledge gap in the region, which contributes to the uncertainty associated with mangrove management strategies and their benefits.

Table 1. Mangrove extent in hectares (ha) by region at three time periods and the percentage loss between 1980-2013. The extent of closed-canopy mangrove in 2019 is also provided.

Division	No. of tree spp. (mangrove and mangrove associates)	Mangrove extent 1980 (ha)	Mangrove extent 2002 (ha)	Mangrove extent 2013 (ha)	Loss of mangrove forest cover in % (1980 – 2013)	Mangrove forest cover 2019 (ha) (this study)
Rakhine	32	167,730	no data	102,840	>30%	
Ayeyarwady	29	274,781	138,341	45,048	>80%	34,650*
Tanintharyi	43	262,063	250,00	151,001	>40%	

Data source: *(Zöckler and Aung 2019) and this study. *Total closed canopy mangrove area in the Ayeyarwady region in 2019 from this study. The total area of mangrove land 178,961 ha includes unvegetated land, regrowth mangroves, degraded mangroves, and nipa palm.*

3.2. STUDY AREA

The analysis presented in this report focused on the mangrove ecosystems of the Ayeyarwady Region (Figure 5). Two million people live in the region that are highly dependent on mangrove resources for their livelihoods. The population is spread over 2,277 villages and 622 village tracts (a village tract can have multiple villages). Among these village tracts, there are a limited number (59) of Community Forestry User Groups (CFUGs) in 2019, indicating that approximately 10% of village tracts have community forestry projects. In this context, it is urgent to determine which productive management options can facilitate protection and restoration of the mangrove forests in the Ayeyarwady Region.

Despite the Ayeyarwady Delta being the largest rice production area in Myanmar, over 70% of the population in the region are landless (Boutry, Allaverdian et al. 2017). The livelihoods of the landless in the delta largely depend on casual work employed by farm owners and harvesting natural resources, which is contributing to the over-exploitation of the natural resources, including the mangroves of the delta (Boutry, Allaverdian et al. 2017).

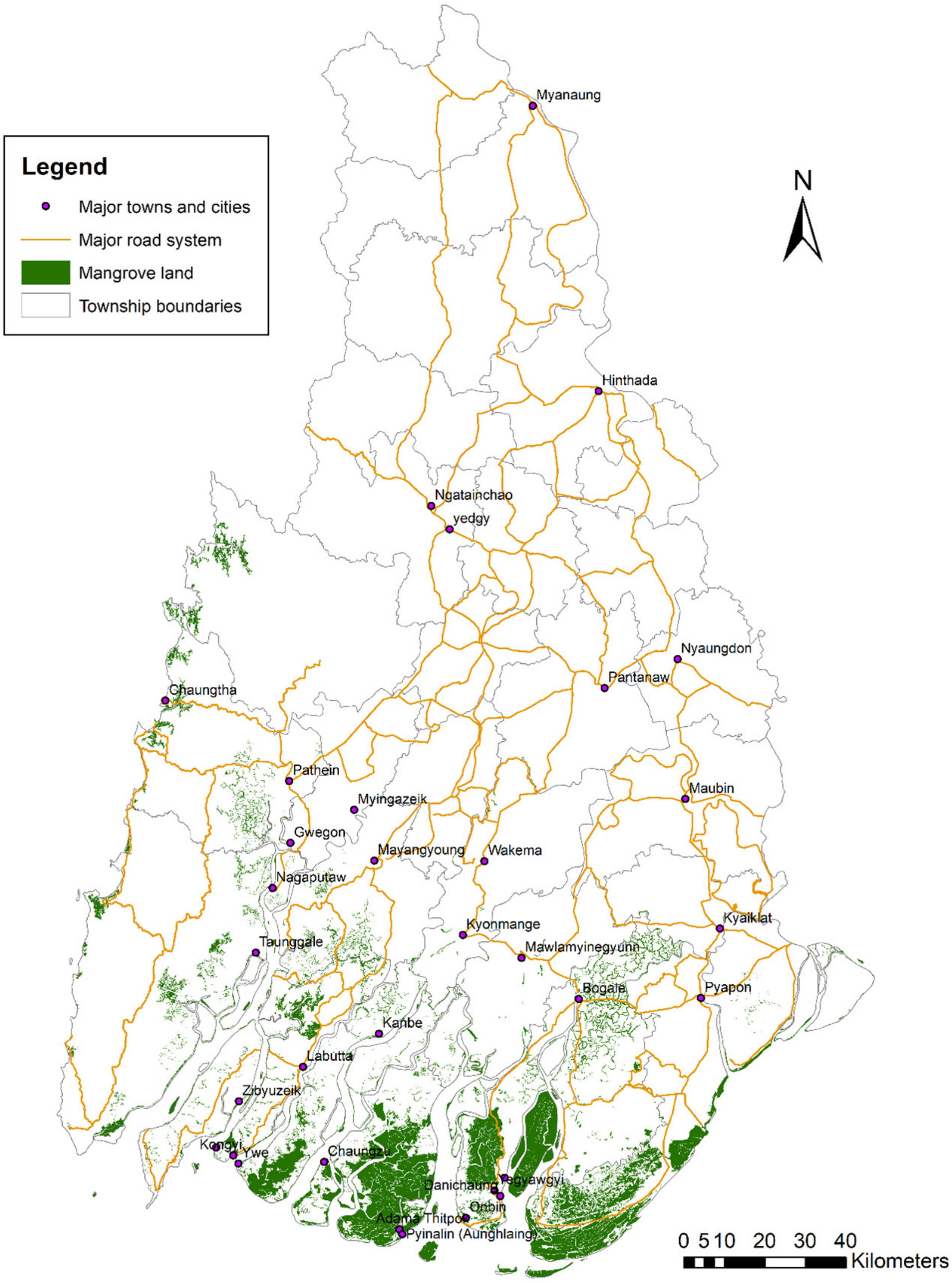


Figure 5. Mangrove land in the Ayeyarwady region. The map shows the distribution of the mangrove land that remains after the intense clearing and conversion of the mangroves since the 1980s.

3.3. IDENTIFICATION OF STAKEHOLDERS AND ECOSYSTEM SERVICES

Analyses of the management activities associated with mangroves in the Ayeyarwady identified a wide range of stakeholders that were associated with the mangrove or mangrove products in the study area. This analysis focused on acquiring knowledge of stakeholders involved in the direct-use of mangrove products (i.e. provisioning services), filling a critical knowledge gap in Myanmar. The analysis of stakeholders and direct-use values was restricted to five products: fuelwood, mud crabs, shrimp, nipa leaves, and rice (Box 3). These products were prioritized, as well as the activities associated with them, because they occur on mangrove land (e.g. rice farming, ponds for growing shrimp and crabs, nipa palm) or are extracted directly from mangrove lands (fuelwood, crabs, crab larvae). Wild caught fish can also be highly dependent on the mangrove land, either because species use mangrove land during their life cycle, or because they directly forage in mangroves or consume other organisms that feed in mangroves (Sheaves, Abrantes et al. 2020). However, because of limited information on the degree of habitat dependencies of fisheries in the delta and the potential indirect nature of this association, the following analysis did not include wild caught fisheries. Clearly, wild caught fisheries are important for livelihoods in the Ayeyarwady Delta and there is evidence of declining fish stocks (World Bank 2019). Further research is needed to understand the links between mangrove cover, fisheries, and the dependent livelihoods in the delta. Additionally, an examination of other products (e.g. honey) could also provide insights into products that may be developed in the future.

Box 2. Gender role in selected product's value chains

Fishery value chains. The fishery sub-sector in Myanmar is dominated by men; however, women play an important role in inland fisheries, aquaculture, and small-scale fisheries. While men mainly set the nets, women are more involved in retrieving the nets and sorting the catch into categories, determining what will be sold, eaten by the household, or processed. Women are involved in equipment preparation and repairs, and in selling fishery related products, including fish paste and bait.

Nipa palm value chain (thatching). The collection of nipa leaves is dominated by men. Whereas for the thatching process, family members, mostly women, are involved in the process of picking and stitching nipa leaves. As for intermediaries, mostly men are involved in the commercialization of nipa palm products.

In addition to the value of mangroves as fish habitat, mangroves provide a range of indirect-use regulating functions and services including coastal protection, protection of riverbanks from erosion, flood protection, carbon storage and sequestration, and nutrient cycling (Barbier et al. 2011). The communities of the delta, as well as the government that bears the costs of damage caused by extreme weather events, are key stakeholders that benefit from the regulating services that mangroves provide. Because of the devastating impacts of Cyclone Nargis, the study chose to include valuations of mangroves for coastal protection and for riverbank protection, which were estimated using studies from Myanmar (Estoque, Myint et al. 2018) and from neighboring countries where valuations were available for similar geomorphic settings (See Annex 1 for valuation details). Some communities in the delta, in collaboration with non-government organizations (e.g. WorldView International Foundation, Myanmar), have initiated pilot blue carbon projects. Thus, this study has also valued carbon storage and sequestration, which was estimated from field data as well as the pilot carbon project in the region (WIF 2018).

Mangroves also provide habitat for a wide range of biodiversity, including birds and other wildlife that are important for ecotourism activities (Spalding and Parrett 2019), as well as supporting ecological processes, including pollination (Barbier et al. 2011). Due to limited information available and the limitation to conduct surveys of the income generated by communities from mangrove-related ecotourism given COVID-19 restrictions, these functions and services were not included in this analysis. Further research is needed in the Region for understanding the provision of cultural and supporting services, as well as the importance of mangrove ecosystems as a habitat for different animal species that support ecotourism activities. This could strengthen current governmental efforts such as the promotion of the Community-Based Tourism (CBT) initiative.

Box 3. Brief description of the five mangrove products considered and the value chains associated with the products.

Fuelwood. Most of the families in the lower Delta use mangrove fuelwood for domestic cooking. Thus, households are the key stakeholders for this product. The fishers that use bamboo rafts (*kyar phaung*) for drying fish from the onshore fishing sector are the second largest consumer of fuelwood in the delta. Government authorities, particularly the Forest Department, are the key law enforcement for mangrove management and protection. Until another alternative cooking fuel becomes readily available, which is cheaper and/or local residents can afford, such as national electricity, gas, or fuel from agriculture by-products (e.g. rice husk briquettes), fuelwood collected from mangrove will remain the key domestic energy source. The collection of fuelwood is done by cutting trees, including branches and main stems. This may also be referred to as "logging", although the small size of the trees precludes the production of timber products.

Mud crabs. Juvenile crabs are collected from the mangrove and then "fattened", cultivated in small ponds within the mangrove before the sale. The major stakeholders involved are collectors of juvenile crabs, local mangrove landholders (who grow out crab larvae), middlemen in villages (who buy and transport the product), the Department of Fisheries, and consumers, including restaurants in the larger cities.

Shrimp. Juvenile shrimp (fry or larvae) are collected in the mangrove and then grown-out, cultivated in ponds constructed on mangrove land. The main actors involved include the collectors of wild shrimp fry (larvae), shrimp farmers, the Department of Fisheries, and local buyers who sell the product at the wholesale market to exporters and consumers.

Nipa palm. Nipa (scientific name *Nypa fruticans*) is a mangrove palm distributed throughout the Indo-Pacific region. Its leaves are used to produce thatch for roofing. The key stakeholders are nipa palm farmers, leaf collectors, and thatch production intermediaries, the Forest Department which manages nipa palm within reserve forests and national park, and the General Administration Department who manages nipa palm land outside the reserve forests and national park.

Rice. Rice is grown on converted mangrove land. In the agriculture sector, the major stakeholders related to rice are the owners of rice fields, rice farmers, and the Department of Agriculture, Livestock, and Irrigation. Large areas within the government managed mangrove reserve forests' boundaries were converted from natural mangroves to rice fields (Webb et al. 2014). These areas are managed by the Forest Department. In the region, rice farming faces high risks of soil acidification and saline water intrusion. Additionally, irrigation of rice is not highly developed in the study area, and therefore farmers usually grow only one rice crop per year with relatively low rates of productivity.

3.4. STUDY SCOPE

3.4.1 Mangrove Management

Understanding land tenure is critical to developing strategies to conserve and restore mangroves (Lee et al. 2019, Lovelock and Brown 2019). Government authorities in Myanmar manage forests and forestry land, including mangroves. The Forest Department has the authority to manage permanent forest estates and The General Administration Department (GAD) and Department of Agricultural Land Management and Statistics (DALMS) (former Settlement and Land Records Department) play major roles in managing all other lands (Shivakumar and Hlaing 2015). In the coastal areas of the Ayeyarwady Region, the Forest Department manages the mangrove reserve forests (RFs) and a mangrove national park (NP) – the Meinmahla Kyun Wildlife Sanctuary. Collection of fuelwood is illegal within the RFs and NP; however, it occurs and has contributed to the degradation of these mangrove assets.

There are several types of land uses within the boundaries of the mangrove RFs and NP (in addition to mangrove forest), including agriculture, cultivation of nipa palm, and ponds for aquaculture. Many of these land-uses, as well as degraded mangroves, provide opportunities for improved management for conservation and restoration. Agricultural land, mostly rice fields, are areas that are patches of non-mangrove land or land that was converted from mangroves to rice decades ago through alteration of hydrology (drainage and protection from tides through a system of walls and gates). Rice is a valuable commodity in the region and rehabilitation of mangroves in rice fields is a complex process with high uncertainty because of the unknown extent of hydrological modifications that have occurred, the unknown extent of salinized land and an unknown capacity for adaptation. Thus, for this analysis, rice fields are not considered as potential areas for restoration for the green investment scenarios. Surveys for this study revealed that most of nipa palm areas and mangrove aquaculture ponds within RFs are on land managed by farmers under Form 7[10] or through CFUGs, which are a type of community based forestry management (Figure 6 and Table 2; See Box 4 for CFUG definition); or the land continues to be used without any formal approval. Form 7 management has been implemented in RFs due to uncertainty in the mapped boundaries of RFs, which have varied over time.

10 Form 7: Land use certificate, farmer have rights for loan deposit, sale, inheritance of the land which has this certificate.

The Ayeyarwady Delta has a high population density, partially because of high levels of migration to the Ayeyarwady Delta in the last decades. Based on field observations, it is assumed that all mangroves and potential mangrove land that occurs outside the government RFs and NP are privately held lands. Figure 6 below, indicates the distribution of land tenure types of mangrove land in the delta.

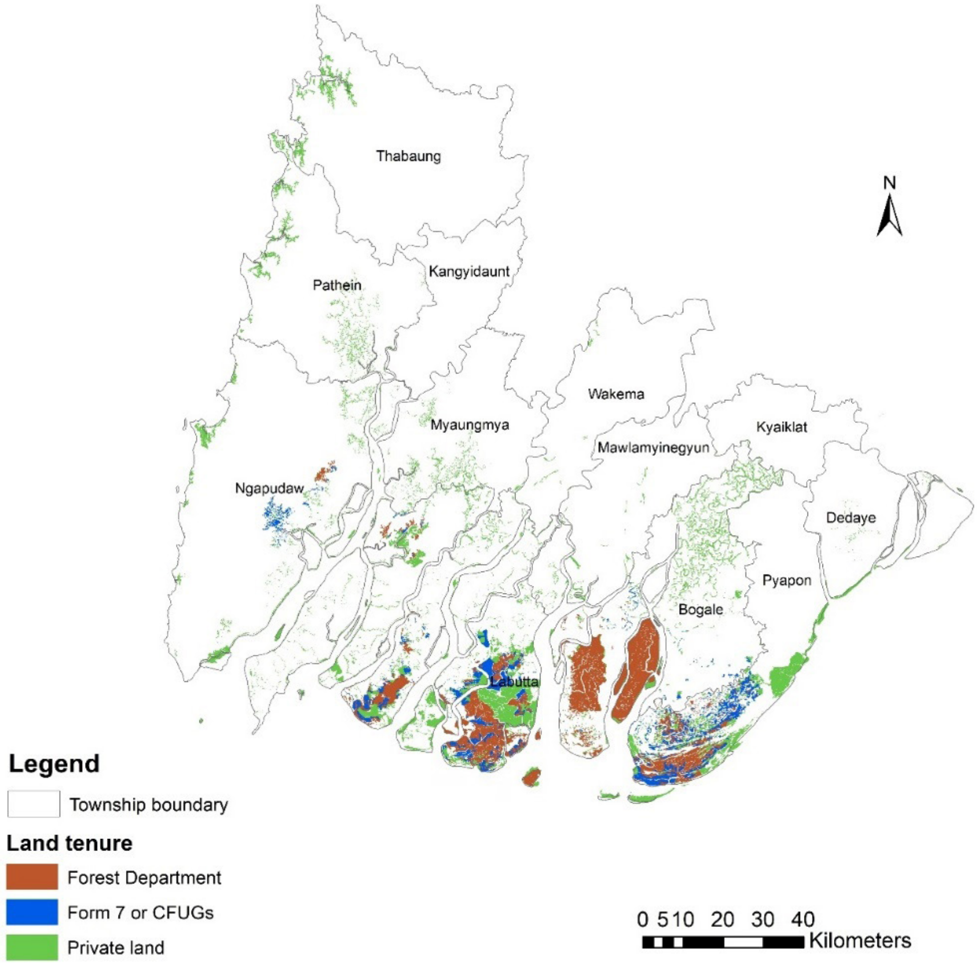


Figure 6. Land tenure of mangrove land in the Ayeyarwady Region.

Table 2. The extent of mangroves in hectares (ha) under different land tenure in the Ayeyarwady Region.

Land manager	Area (hectares)	Note
Forest Department	61,701	
Form 7 or Community Forest User Group (CFUG)	26,359 (18,464 as Form 7 and 7,895 by CFUGs)	CFUGs - Community Forest User Groups is a community-based system in Myanmar, see Box 4.
Private mangrove land	88,902	
Total	**178,961**	

3.4.2 Mangrove Forest Status

To support the development of mangrove management strategies, mangrove status maps were produced from satellite image interpretation combined with ground-truthing of land classifications. The mangrove land was classified into different categories (regrowth forests, degraded mangroves, nipa palm, unvegetated saline land, and ponds. See Table 5 for the description of each category). Large areas of the mangrove land of the delta have been hydrologically modified through conversion to aquaculture ponds. In these areas, particularly within RFs, ponds have mangroves in the shallow areas in the center of them, which is surrounded by a ditch that was dug to form the walls of the ponds. The mangroves within the ponds were classified in a similar way as mangroves that were not contained within ponds.

The analysis of benefits of mangrove management considered the benefits of rice cultivation where it occurred within the mangrove RFs. Given the complexity of the economic activity, the land use management framework and land-use change, rice farming, as well as coastal protection services, were not included in the analysis of mangrove areas outside the RFs and NP.

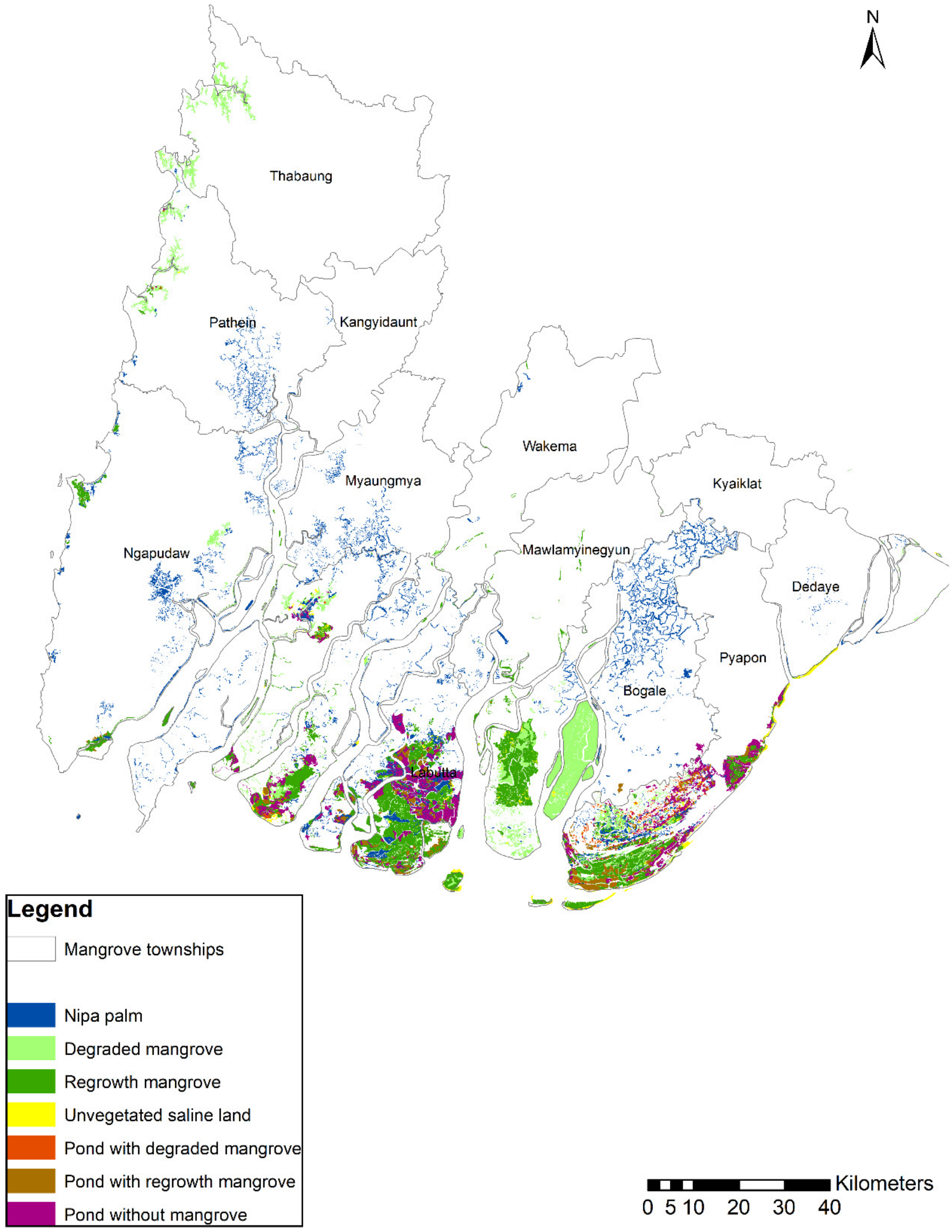


Figure 7. Mangrove status map for the Ayeyarwady Region

3.4.3 Targeted Mangrove Products and Stakeholders for the Analysis

In order to identify potential monetary and non-monetary benefits of mangrove restoration and improved management interventions, and considering the complex interaction between the mangrove, stakeholders, and economic activities, the scoping process for this study followed the recommendation of the 3Returns Framework (GGKP 2020). The framework recommends scoping the assessment of benefits considering the first two stages of the value chain (i.e. input and production) for extractive and productive commodity-based sectors. Consideration of the first stages of the value chains provides novel ways of visualizing the impact of interventions within the production and extraction systems connected with the related ecosystem services.

Fuelwood is the major energy source for domestic cooking in mangrove areas and designated buffer zones around mangrove areas (where it is assumed people can access mangrove resources) in the delta. Fuelwood is also the energy used for drying fish on bamboo racks on the shore in the Pyapon township (and other settlements). Harvesting timber for charcoal and fuelwood for cooking and drying was the main cause of mangrove deforestation and degradation in the delta (Giri et al. 2010 and Webb et al. 2014), but the high level of degradation likely limits current levels of charcoal production. Fuelwood is a significant income source for local people even though most of the fuelwood is illegally collected (or logged) from the reserve forests and national park in the delta.

The catching of crabs is a major activity and source of income for people in the delta. Compared to other fishing activities, which generally require significant investment (money to pay for a fishing permit, nets, boats, gasoline, and labor), crab collection can be done with few inputs. For example, crab traps can be made with little money and fishers can catch crabs in nearby mangroves, or on creek or riverbanks without the use of boats. As crab catching occurs mainly in mangrove forests, people doing this activity do not have to pay for fishing permits. Substantial demand from the export markets and domestic consumption has increased the price of crabs over the last 10 years. While fishers collect shrimp fry for sale to pond owners, shrimp fishing activity is not directly linked to the mangrove, as shrimp fry (fingerlings) occur in rivers or coastal waters. Thus, for this study crab catching is the only fishing activity considered.

In the delta, one of the highest incomes is derived from mangrove aquaculture ponds, which local farmers build in mangrove areas. Aquaculture is mostly extensive and characterized by polyculture practices.[11] The typical practice is that farmers build low earthen walls around their mangrove area. The walls are constructed in the processes of digging ditches in the mangroves, which make shallow ponds for aquaculture. The farmers tend to keep mangroves in the remaining central platform area within the pond walls, although often the mangroves are degraded or can die due to the altered hydrology. This occurs particularly if water levels are maintained at higher than normal levels for the mangrove trees, thereby imposing stress that reduces mangrove growth and can lead to mortality (Lewis et al. 2015). The ponds are periodically flushed with tidal water, which provides wild shrimp, crabs, and fish larvae into the pond. Many of the farmers also put additional shrimp fingerlings and juvenile crabs (which they catch or purchase) into ponds to increase productivity. The farmers do not feed fish within the ponds, and crabs, shrimp, and fish depend on natural food arriving from river water and from adjacent mangroves. The aquaculture practices observed in the study site are mostly driven by the commercialization of crabs and shrimp.

A large area of mangrove land is nipa palm,[12] which usually occupies areas of low elevation (inundated frequently) along the riverbanks. Nipa palm occurs in natural stands but can also be planted in some areas because of its usefulness to people. Although it is not a woody tree species, it provides similar riverbank and flood protection services as mangrove trees (Hossain and Islam 2015). In the Ayeyarwady region, large areas of nipa palm are distributed outside the RFs and NP. Nipa palm is an important income source of farmers in the region. It is harvested and sold for roof thatching, but it could be a much more important income source for local people if nipa palm sap is extracted and processed, as it is being done in the Tanintharyi region in Myanmar and neighboring countries such as Thailand, the Philippines, Indonesia, Vietnam, and Malaysia (Tamunaidu, Kakihira et al. 2011, Tamunaidu, Matsui et al. 2013). Thus, nipa palm thatch and sap are included in this analysis as key products from mangrove areas.

In addition to products obtained from the mangrove forests, mangrove areas have been historically converted to rice agriculture (Giri, Zhu et al. 2008, Webb, Jachowski et al. 2014). There are over 60,000 hectares of rice fields within the boundaries of the RFs. Rice provides important income for farmers. Significant rice areas occur in high elevation areas, which may not have originally been mangroves. However, these areas, particularly those at a lower elevation, are vulnerable to saline water intrusion and soil acidification. Considering the importance of rice farming for generating income, this analysis considered rice farming, but only within RFs. As mentioned before, the benefits of rice farming in areas outside the RFs

11 See the insight brief entitled: 'Mangrove Aquaculture: Polyculture Products in the Ayeyarwady Region'.

12 See the insight brief entitled: 'Nipa Palm Products in the Ayeyarwady Region'.

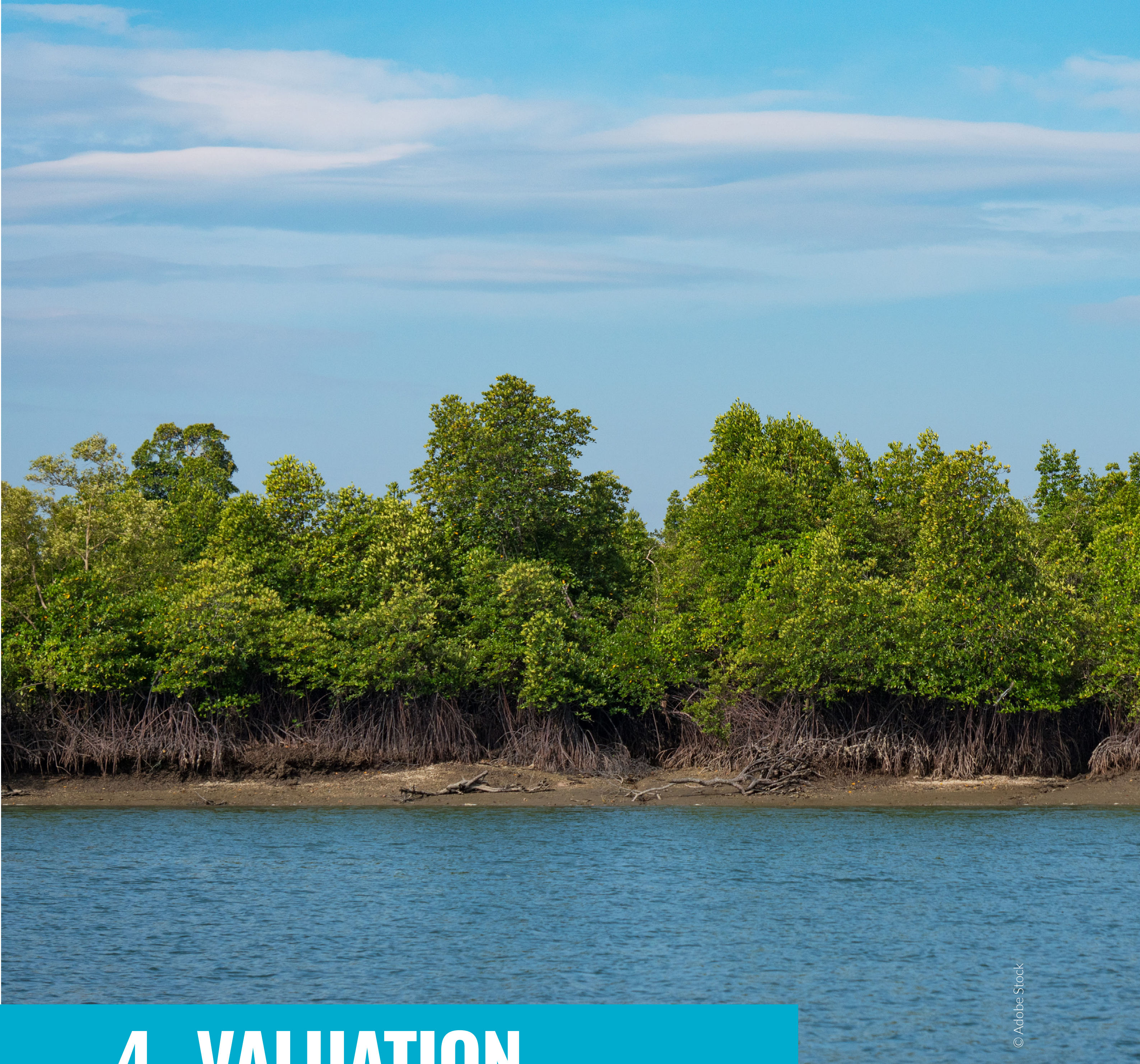
and NP were not considered because of the high level of additional complexity associated with this activity.

Finally, this analysis incorporated the likely impact of sea level rise on rice land and livelihoods associated with rice production in areas within RFs by assuming a constant reduction in productivity over time. This assumption was based on the prognosis for rice production in Bangladesh, which took into account potential management actions to reduce the impacts of SLR, including the introduction of salt tolerant rice varieties and modified planting and irrigation practices. The impacts of saltwater intrusion with sea level rise as well as possible changes in rainfall associated with the monsoon on agricultural production in the delta is a knowledge gap.

Table 3. Key stakeholders selected (colored in yellow) for the Valuation Stage, following the 3Returns Framework.

Product	Stakeholder	Activity
Fuelwood	Fuelwood Collectors	Extraction
	Middlemen	Commerce
	General Inhabitants	Consumption – Domestic Cooking
	Fishers	Consumption – Drying Fish
	Forest Department	Management, Control, and Protection
Mud Crab	Crab Collectors	Extraction
	Crab Farmers	Production
	Middlemen	Commerce
	General Inhabitants	Consumption
	Forest Department[13]	Mangrove Aquaculture Management
	Department of Fishery	Management
Shrimp	Shrimp Collectors	Extraction (not main activity)
	Shrimp Farmers	Production
	Middlemen	Commerce
	General Inhabitants	Consumption
	Forest Department[13]	Mangrove Aquaculture Management
	Department of Fishery	Management
Nipa palm	Nipa farmers	Production
	Middlemen	Commerce
	General Inhabitants	Consumption
	Forest Department[13]	Management in RFs
	Land department	Land Tenure for Nipa Palm Outside RFs and NPs
Rice (Agriculture – within reserve forests)	Rice Farmers	Production
	General Inhabitants	Consumption
	Middlemen	Commerce
	Department of Agriculture, Livestock, and Irrigation, Forest Department	Management

13 The Forest Department has the authority to manage mangrove aquaculture ponds within reserve forests. Mangrove aquaculture is not yet legalized. However, for the livelihoods of local communities, the Forest Department has provided the permission to CFUGs to conduct small-scale aquaculture practices in line with their CF management plan as part of the agroforestry act.



4. VALUATION

4.1. DEFINING A BASELINE

Field surveys and satellite image interpretation were used to establish a baseline of mangrove area (cover) and status to use in the economic analyses. The overall approach was to use the established links between mangrove area and status and ecosystem service provision (e.g. the relationship between mangrove area and status and value of fuelwood collection, or crabs caught) to underpin the economic analyses of the benefits derived from mangroves over the delta. The study found that 13 townships, out of 26 of the Ayeyarwady Region, have mangrove land (Table 4). The total area of mangrove land is approximately 178,000 ha (Table 2). Most of these mangroves are highly degraded reducing the ecosystem services they provide.

Data of existing mangrove area and status with land tenure arrangement, as well as data on land uses within and outside the mangrove land (Table 5 and 6) were used in the baseline assessment. In addition, data of the characteristics of villages and village tracts and their population were obtained from spatial analyses and from Myanmar government sources (Table 7).

Table 4. The extent of mangrove land in hectares (ha) in different townships and the area in different mangrove status categories in the Ayeyarwady Region. The data is for thirteen townships of a total of 26 townships that occure in the Ayeyarwady Region.

Mangrove status	Mangrove areas by township (ha)													
	Bogale	Dedaye	Kangyid-aunt	Kyaiklat	Labutta	Maubin	Mawlamy-inegyun	Myaungmya	Ngapudaw	Pathein	Pyapon	Thabaung	Wakema	Grand Total
Nipa palm	11,821	812	7	3	13,000		734	3,448	8,053	3,287	3,669		220	**45,055**
Degraded mangrove	18,726	224			3,862			39	749	3,096	4,077	3,878		**34,650**
Regrowth mangrove	10,408	138			27,216	6	1,139	74	2,715	157	11,782		314	**53,949**
Unvegetated saline land	600	619	1		1,408					27	2,354			**5,009**
Pond with degraded mangrove					353					19	2,323			**2,695**
Pond with regrowth mangrove	175				5,108				152	46	5,009			**10,489**
Pond with-out man-grove	289				15,604					30	9,189			**25,112**
Grand Total	**42,018**	**1,793**	**8**	**3**	**66,552**	**6**	**1,873**	**3,562**	**11,669**	**6,661**	**38,405**	**3,878**	**534**	**178,961**

Table 5. Mangrove status and land uses in the Ayeyarwady Region.

Mangrove status	Description	Area (ha)	% of mangrove land area
Nipa palm	Areas covered by *Nypa fruticans*, a mangrove palm species. Nipa palm is mainly distributed at low elevations along the edges of riverbanks.	45,055	25%
Degraded mangrove	Mangrove areas which have been continuously logged (cut) for fuelwood and timber. Species composition comprises few tree species with small stems or coppices, lianas, shrubs. Over a significant area, particularly in high elevation areas, *Phoenix* palm, a mangrove associate, has become the dominant species which limits the natural regeneration of mangrove tree species. These mangrove areas have a standing wood volume of 5 – 50 m^3 ha^{-1}	34,650	19%
Regrowth mangrove	Almost all mangroves in the delta have been severely degraded. The best quality mangroves in the region are mangrove plantations and some areas of natural regenerating mangroves which have been protected. These mangrove areas have standing wood volume of 50 – 200 m^3 ha^{-1}.	53,949	30%
Unvegetated saline land	This is potentially mangrove land but currently has no mangrove plants growing.	5,009	3%
Pond with degraded mangrove	Ponds are formed in mangrove land by digging ditches and creating earthen banks to limit water flows. Prawns and fish are cultivated in the deeper parts of the enclosed areas (the ditches), while mangroves can occupy the central shallower parts of the ponds. Flood gates, if present, can be used to manipulate water levels within the ponds. Ponds can have mangroves of varying states (regrowth, degraded), or can be without mangroves.	2,695	2%
Pond with regrowth mangrove		10,489	6%
Pond without mangrove		25,112	14%
Total mangrove land *(5% of the Grand Total)*		**178,961**	**100%**
Other land uses in the Ayeyarwady Region (agriculture, urban, etc.)		3,189,122	
Grand Total		**3,366,083**	

Table 6. Mangrove extent in different mangrove status categories *within* Reserve Forests and National Park and *outside* Reserve Forests and National Park.

Mangrove status	Total area (ha)	Within Reserve Forests and National Park (ha)	Outside Reserve Forests and National Park (ha)
Non-pond mangroves			
Nipa palm	45,055	8,876	36,179
Degraded mangrove	34,650	23,402	11,248
Regrowth mangrove	53,949	36,571	17,379
Unvegetated saline land	5,009	1,664	3,345
Sum of non-pond mangrove land	**138,664**	**70,513**	**68,151**
Ponds within mangrove areas			
Pond with degraded mangrove	2,695	1,992	704
Pond with regrowth mangrove	10,489	6,769	3,720
Pond without mangrove	25,112	8,784	16,327
Sum of pond areas within mangrove land	**38,296**	**17,545**	**20,751**
Total mangrove area	**178,961**	**88,059**	**88,902**

Table 7. Data describing the villages and their population associated with mangroves.

Social Data	Number	Source
Number of **village tracts** in mangrove lands and their 2km buffer zone	622 village tracts*	Extracted from Forest Department maps, Myanmar Information Management Unit (MIMU) data, and GIS analysis ** Village tracts within 2 km buffer zone but have less than 10 hectares of land within the buffer zone are excluded*
Number of **villages** in mangrove land and their 2km buffer zone	2,277 villages	Extracted from Forest Department maps, MIMU data, and GIS analysis
Population of villages within mangrove land and 2 km buffer zone	1,826,359 people	Extracted from Forest Department maps, MIMU data, and GIS analysis
Community Forestry User Group (CFUG) mangrove areas	7,895 ha	Forest Department data (2020)
Total Community Forestry User Groups (CFUG) in mangrove areas	59 CFUGs	Forest Department data (2020)

4.1.1 Economic Value

Fuelwood collection, crab catching, and "fattening" (cultivation of juveniles) of crabs, shrimp farming, harvesting and making of nipa thatch, and rice farming are the major economic activities identified and considered in the scope of this assessment. Following the objectives of this report, these activities were valued in order to determine how different management interventions may impact or affect their financial performance.

The spatial extent of mangrove production activities is shown in a series of maps (Figures 8 to 14). Figures 8 and 9 present the fuelwood collection areas in the delta over different land tenure arrangements and mangrove status. Figure 10 and 11 present accessible mud crab catching areas within mangrove land. Figure 12 and 13 show aquaculture ponds within mangrove land. Figure 14 shows the existing nipa palm areas in the delta.

The number of people involved in these activities, the incomes generated, and costs incurred (from survey data) are presented below; for fuelwood collection (Table 8), crab catching (Table 9), mangrove aquaculture (Table 10), and nipa palm farming (Table 11).

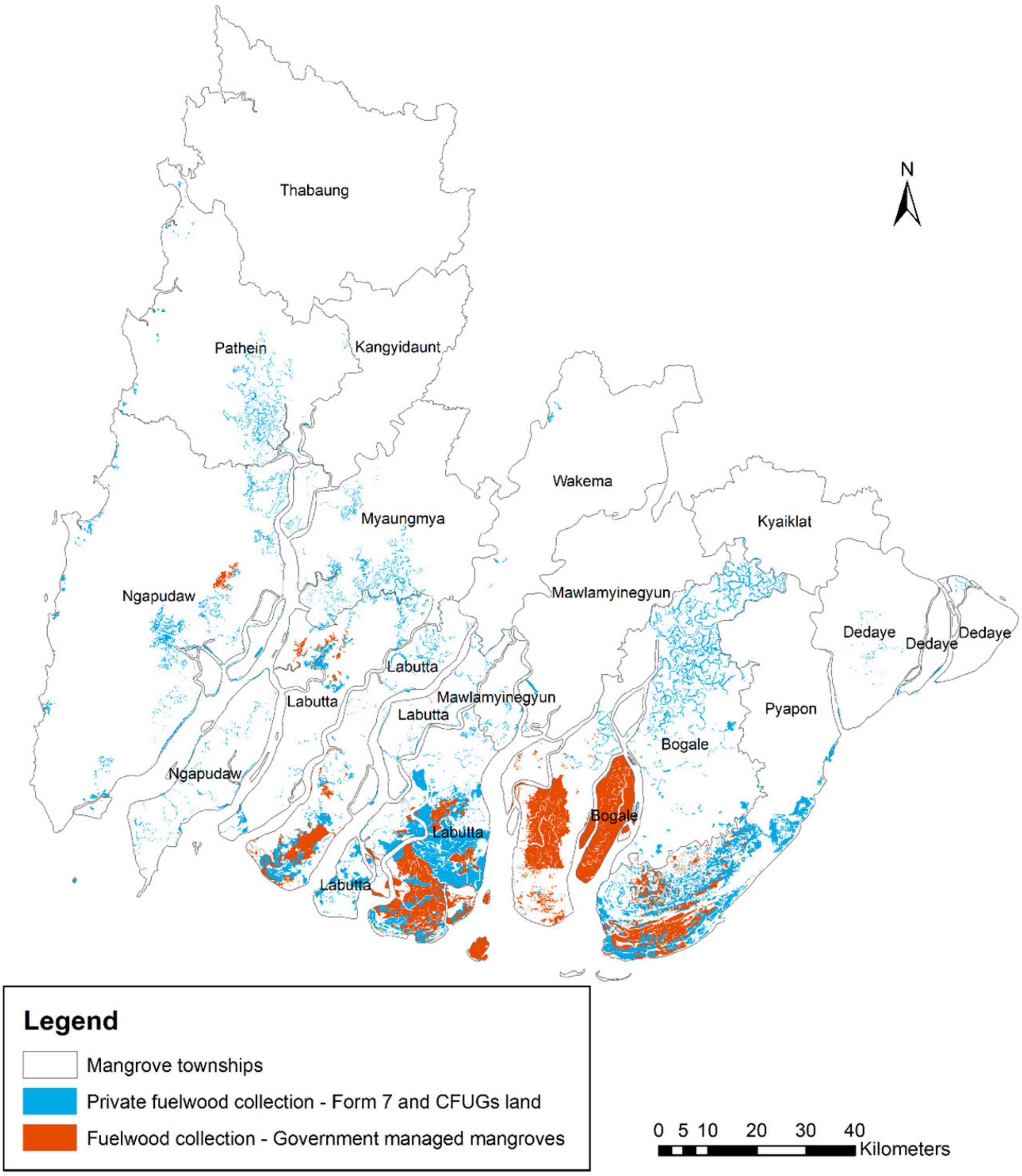


Figure 8. Mangrove fuelwood collection areas for different land tenure types

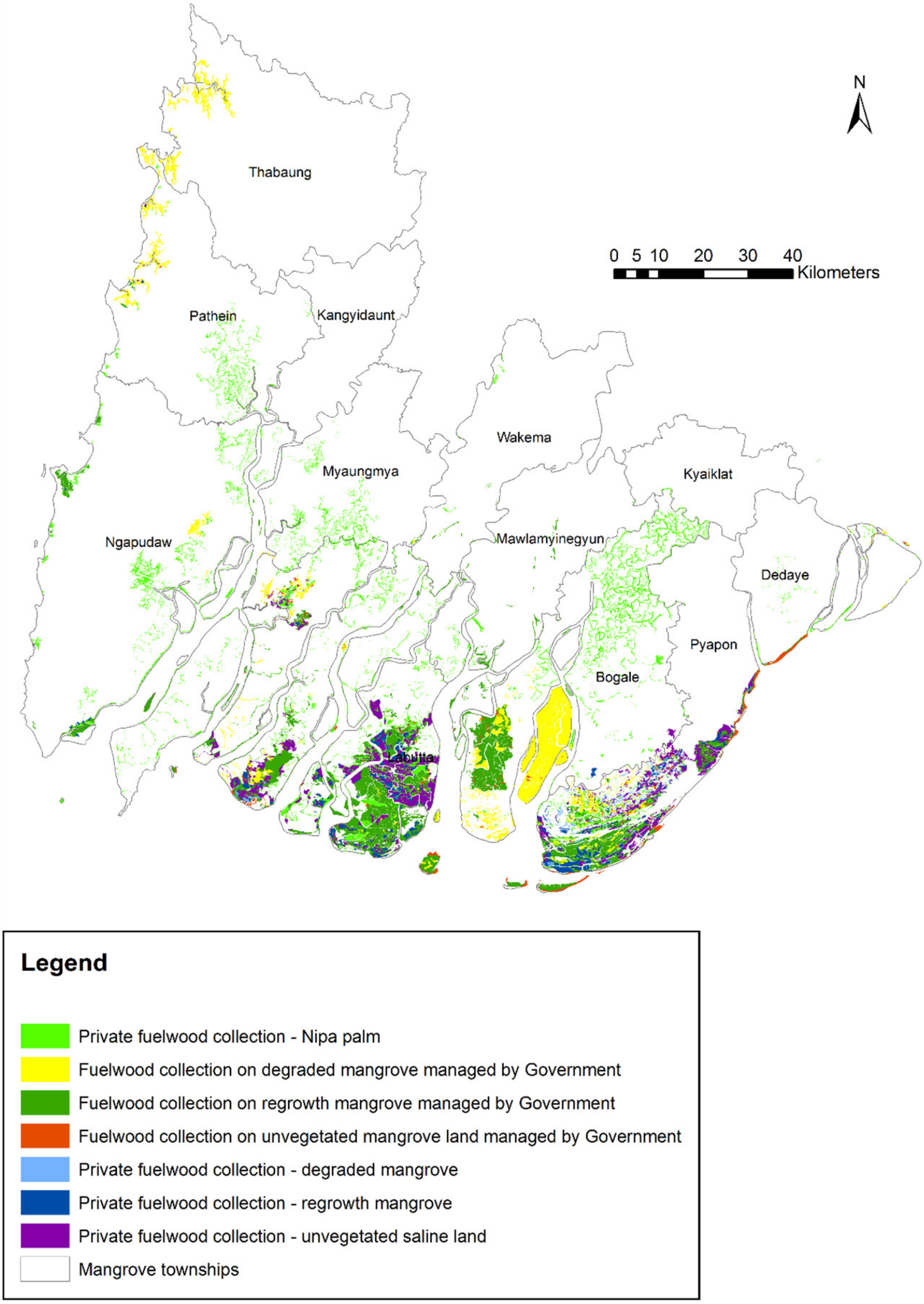


Figure 9. Fuelwood collection by mangrove status.

Table 8. Fuelwood collection from mangroves within reserve forests and national park in the Ayeyarwady Region.

	Unit	Average amount	St Dev
Number of households per village	household	252	225
Number of fuelwood logger working as full-time per village	logger	17	15
Number of fuelwood logger working as part-time per village	logger	26	21
Income earned per month for full-time logger	MMK	221,000	28,000
Income earned per month for part-time logger	MMK	145,000	42,000
Expenditure for fuelwood collecting per month (excluding labor cost) for full-time logger	MMK	32,000	12,000
+ rent-seeking payment (normally each time 1,000 MMK)	MMK	5,000	3,000
	Value (Millions MMK) (2019 – annual – estimate)		
Income from fuelwood collection on mangroves managed by Government	33,140		
Income from fuelwood collection from village fuelwood plantations	1,459		
Income from fuelwood collection in mangrove aquaculture ponds	5,234		
Mangrove fuelwood collection operational costs	20,451		
Fuelwood collection operational costs for village fuelwood plantations	871		
Fuelwood collection operational cost for mangrove ponds	3,126		
Jobs from fuelwood collection in mangroves (unregulated) (number of jobs[14])	15,745		
Jobs from sustainable fuelwood collection from village fuel-wood plantations (number of jobs[14]).	550		
Jobs from fuelwood collection from mangrove aquaculture ponds (number of jobs[14])	1,974		

14 Full-time and full-time equivalent jobs.

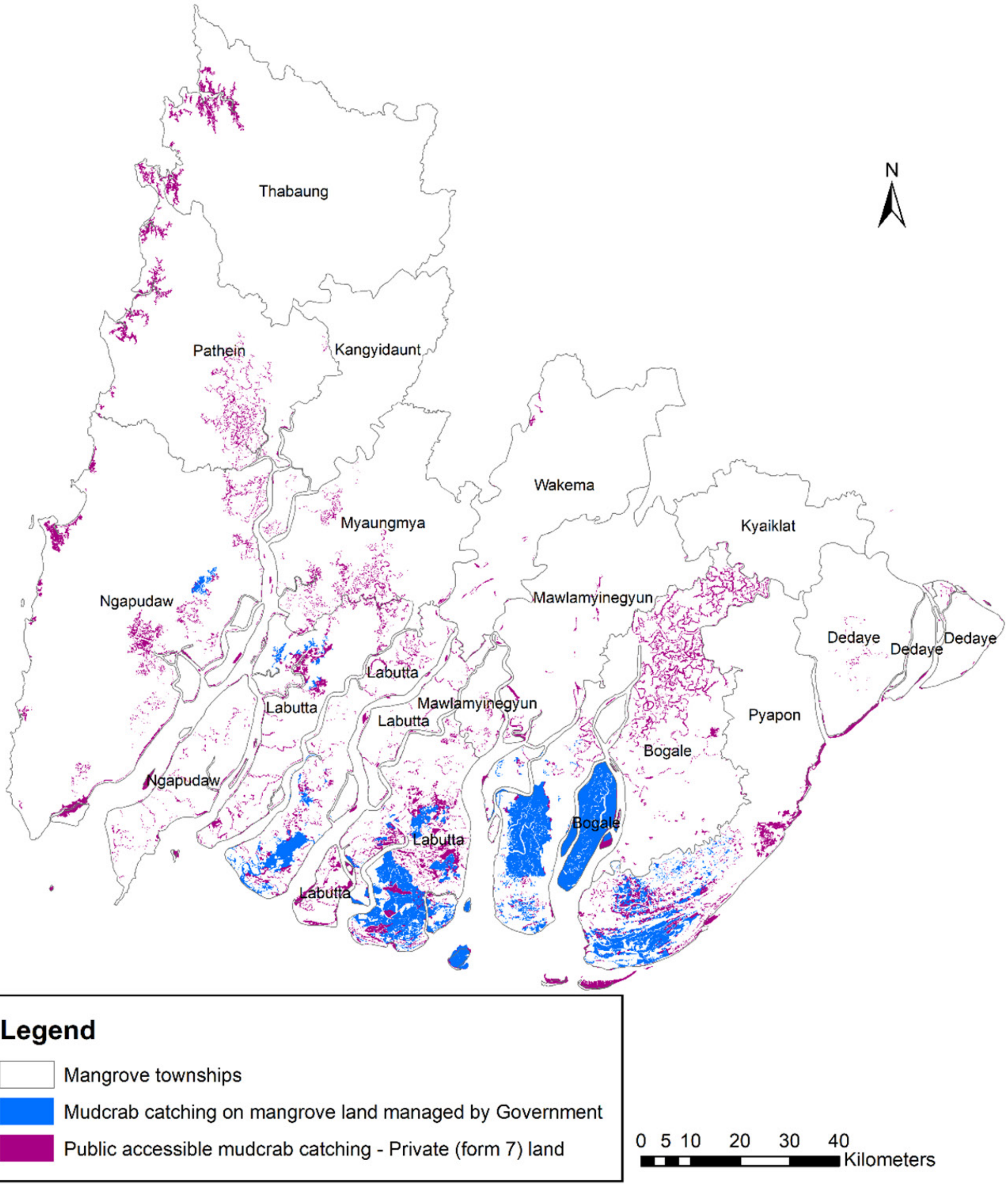


Figure 10. Mud crab catching in different and tenure types.

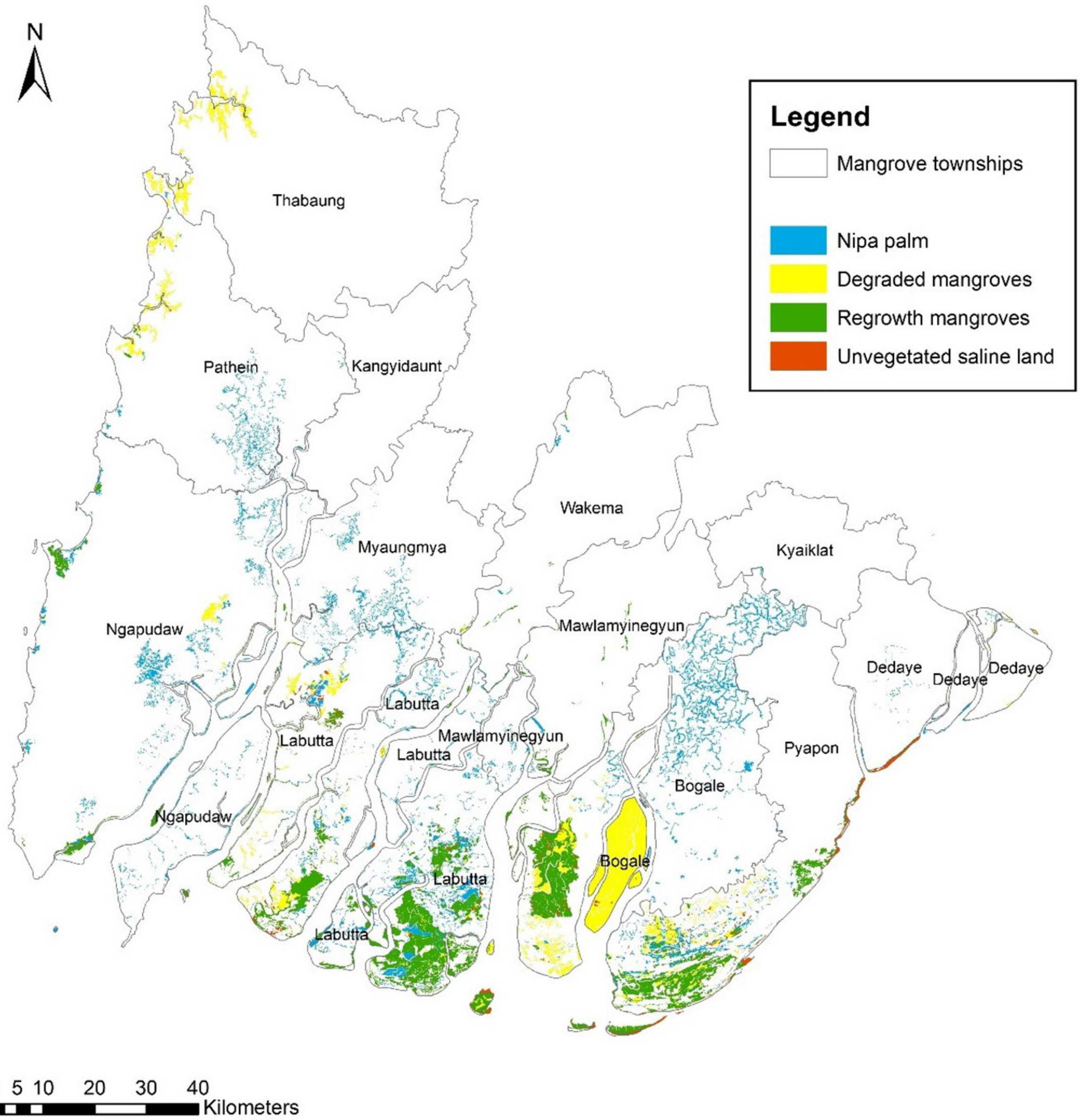


Figure 11. Mud crab catching on different mangrove status categories.

Table 9. The characteristics of crab catching activities from mangroves managed by the Government within reserve forests and national park areas.

	Unit	Average amount	St Dev*
Number of households per village	Households	231	199
Number of full-time crab catchers per village	Person	43	32
Number of part-time crab catchers per village	Person	26	18
Average number of crabs caught per day by crab catchers	Crabs	20	4
Average weight of crabs caught per day by crab catchers	Kg	2.1	0.9
Average income of full-time crab catcher per month	MMK	237,000	62,000
Average income of part-time crab catcher per month	MMK	164,000	60,000
	Value (2019 – annual estimate)		
Income from crab catching in mangroves managed by the Government	MMK 84,392 million		
Crab catching labor costs	MMK 47,128 million		
Number of jobs from crab catching in mangroves (number of full-time and full-time equivalent jobs)	32,695 jobs		

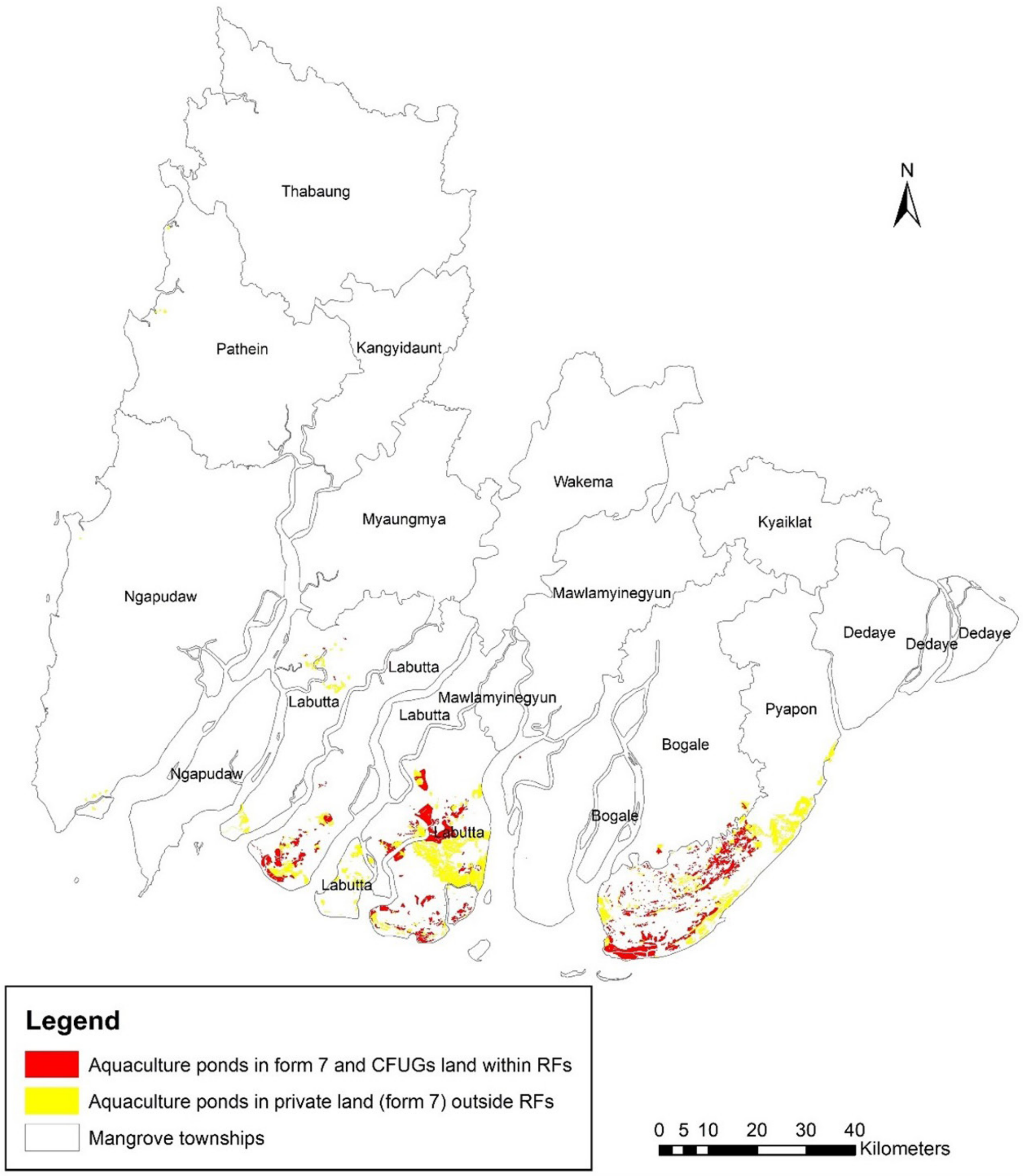


Figure 12. Aquaculture ponds in mangrove lands for different land tenure types.

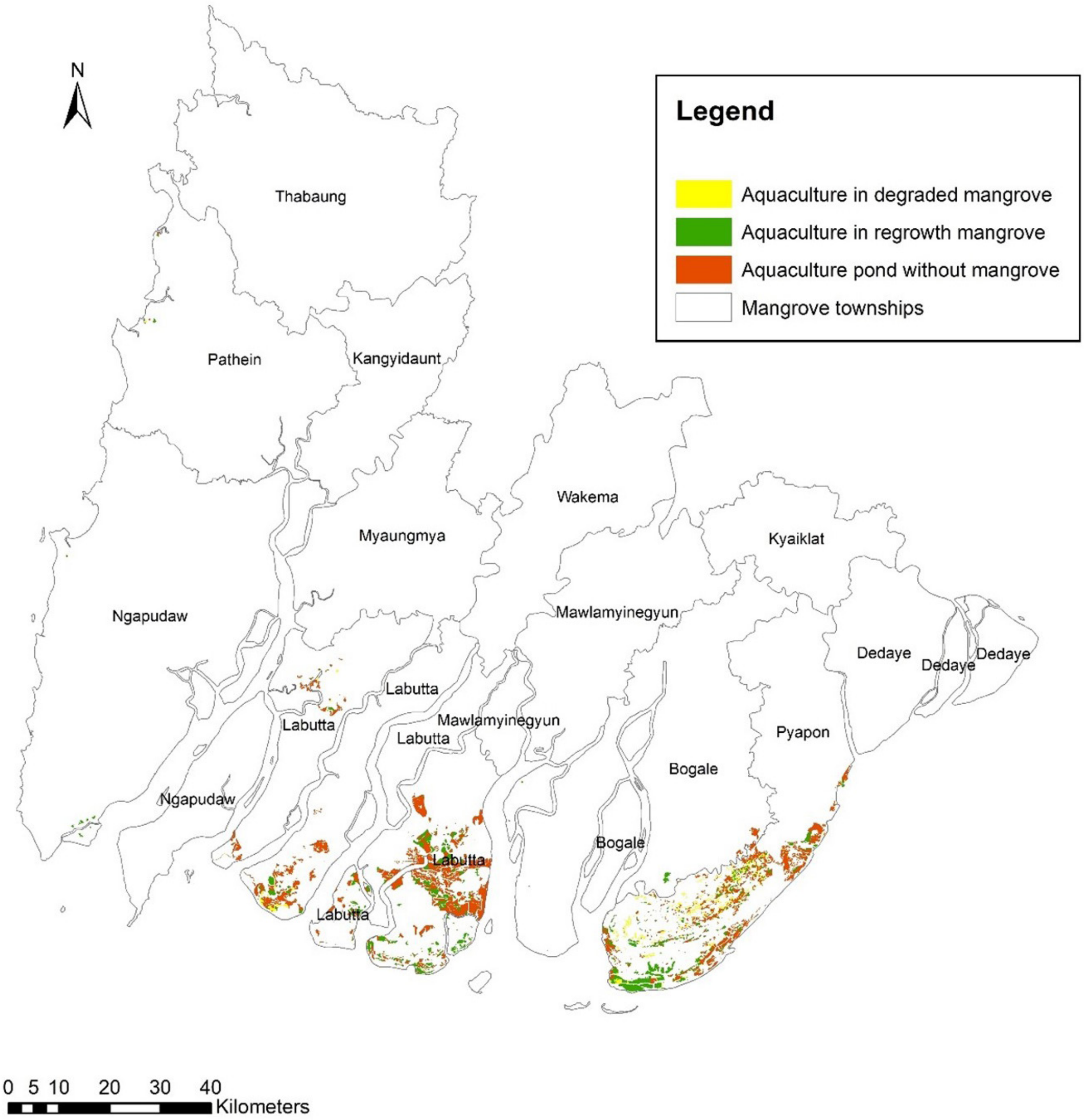


Figure 13. Aquaculture ponds within different mangrove status categories.

Table 10. The characteristics of mangrove aquaculture pond operations within reserve forests and national park areas.

Operation data	Value (2019)	Note
Income from mangrove ponds	MMK 14,787 million	Annual estimation from mangrove areas (survey)
Pond operational costs	MMK 9,169 million	Estimation from survey data
Number of jobs[15] from mangrove aquaculture farming	1,951 jobs	Estimation from survey data

15 Full-time and full-time equivalent jobs.

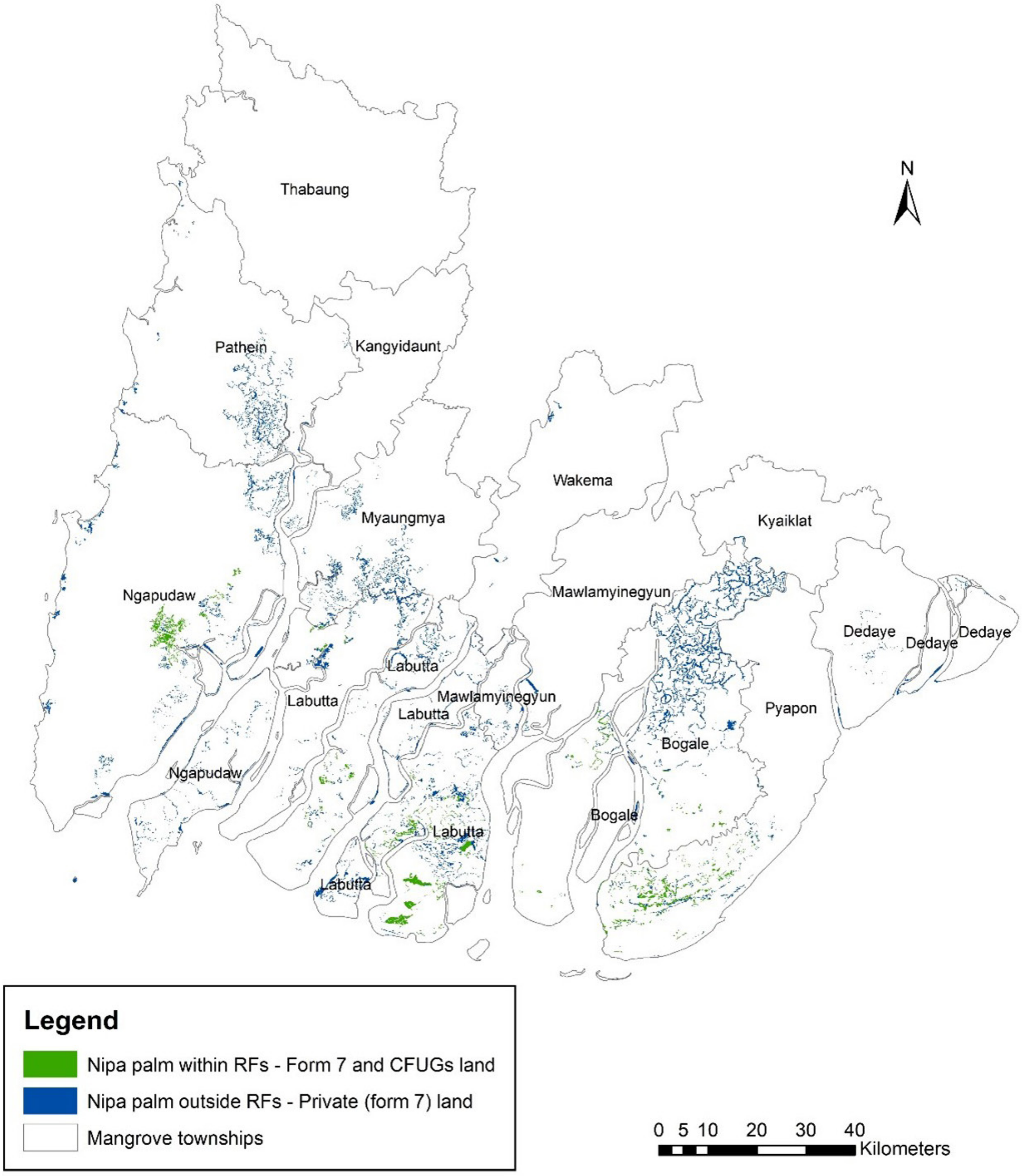


Figure 14. The distribution of Nipa palm over different land tenure types.

Table 11. The characteristics of nipa palm farm operations within reserve forests and national park areas.

Operation data	Value (2019)	Note
Income from nipa palm farms	MMK 8,929 million	Annual estimation from survey data
Nipa palm farm operational costs	MMK 5,437 million	Estimation from survey data
Number of jobs[16] from nipa palm farming	1,512 jobs	Estimation from survey data

16 Full-time and full-time equivalent jobs.

Almost all agriculture lands within RFs are rice fields. Over 60 rice farmers who have rice fields which were converted from mangroves in the delta were surveyed. The income, costs, and historical land use[17] were recorded. The average income, costs, and labor needs per hectare of rice field (Table 12) were used to estimate the economic activity based on agriculture (rice fields) within the government RFs.

For land outside RFs and NP (assumed private land) the study also estimated the income and costs associated with aquaculture (Table 13) and nipa palm activities (Table 14).

Table 12. The characteristics of rice production operations within reserve forest areas[18].

Operation data	Value (2019 – annual)	Note
Average rice income per hectare per year	MMK 0.432 million	Estimated from surveys
Income from agriculture (rice production)	MMK 30,311 million	Assumption: all are rice – one crop per year
Rice cultivation operational costs	MMK 16,208	Estimated from surveys
Jobs from agriculture (rice cultivation)	17,541	Estimated from surveys

Table 13. The characteristics of mangrove aquaculture pond operations in mangrove land outside reserve forests and national park in the Ayeyarwady Region.

Operation data	Value (2019)	Note
Income from mangrove land ponds	MMK 38,867 million	Annual estimation from mangrove areas (survey)
Pond operational costs	MMK 24,100 million	Estimation from survey data
Number of jobs[19] from mangrove aquaculture farming	10,376 jobs	Estimation from survey data

Table 14. The characteristics of nipa palm farm operations outside reserve forests and national park in the Ayeyarwady Region.

Operation data	Value (2019)	Note
Income from nipa palm farms	MMK 56,512 million	Annual estimation from survey data
Nipa palm farm operational costs	MMK 28,364 million	Estimation from survey data
Number of jobs[19] from nipa palm farming	6,476 jobs	Estimation from survey data

17 Based on information collected, most rice fields were converted from mangroves before 1995.
18 Assumption – 1 crop – rice.
19 Full-time and full-time equivalent jobs.

4.1.2 The Value of Regulatory Ecosystem Services and Social Values

Valuing ecosystem services reveals the importance of ecosystem functions and is an essential component for devising management activities. Ecosystem services do not just generate products and raw materials, but also provide vital life support services that are critical to human well-being and the functioning of economies. The valuation of direct-use ecosystem services (refer to Economic Value Section) was followed by the valuation of indirect-use ecosystem services that affected the overall population of the study area. Through literature review, expert consultation, and baseline surveys in the study area, the value of mangrove carbon sequestration, coastal protection, and riverbank protection services were quantified and monetized. As mentioned before, the benefits of coastal protection in areas outside the RFs and NP were not considered because of the high level of complexity and uncertainties.

Mangroves have high carbon stocks (called blue carbon) and rates of carbon sequestration in their soils and biomass (Mcleod et al. 2011). Carbon sequestration through the restoration of mangroves can be used to generate carbon credits which can be sold to generate income for communities. In the Ayeyarwady Delta there is a pilot blue carbon project that has been registered with the Verified Carbon Standard (VCS) through a project supported by WorldView International Foundation. This pilot project has indicated that carbon farming through mangrove restoration may be an income stream for communities, adding to the adaptation benefits already articulated in Myanmar's NDC. In this study, the potential of carbon gains from the restoration of aboveground biomass was quantified. Further laboratory analyses will enable the incorporation of carbon sequestered in soils.

To estimate carbon sequestered in mangrove biomass, the study modelled mangrove growth using simulation models. In this report, a simple approach was used by applying an average growth rate for each plantation species estimated from the surveyed data.

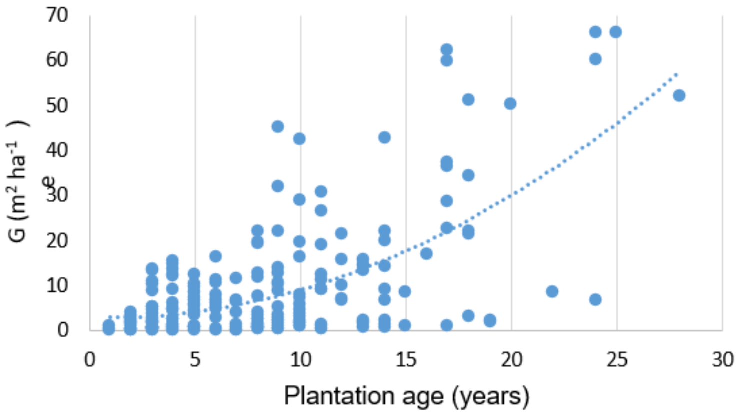


Figure 15. Basal area growth of different aged mangrove plantations in the Ayeyarwady Delta.

The equation is of the form $G = b_1 (1 - e^{-b_2 A})^{b_3}$ (G stands for basal area, A is the age of plantation, b1, b2, b3 are equation parameters). Variation about the relationship is high due to variation in environmental factors and management, including levels of tidal inundation, fertility, rates of thinning and other factors, which were not assessed or where data was not available. The dashed line illustrates the growth trend over time.

The average basal area growth rate for each species was estimated. These growth rates were used to estimate growth rates of mangrove plantation in the delta. The detailed basal area growth rates of mangrove tree species are presented in Table 15.

Table 15. Average tree basal area growth rate of different mangrove plantation species in the Ayeyarwady Delta, Myanmar. Units are area of mangrove stems (m^2) per hectare per year.

Species	Botanical name	Average basal area growth rate (m^2 ha^{-1} $year^{-1}$)	StDev*
Aa	*Avicennia alba*	0.42	0.25
Ac	*Aegiceras corniculatum*	0.13	0.04
Am	*Avicennia marina*	1.09	0.99
Ao	*Avicennia officinalis*	1.05	1.17
Bc	*Bruguiera cylindrical*	0.21	0.11
Bg	*Bruguiera gymnorrhiza*	0.50	0.34
Bs	*Bruguiera sexangula*	0.94	0.71
Cd	*Ceriops decandra*	0.17	0.01
Ct	*Ceriops targal*	0.11	0.0003
Ea	*Excoecaria agallocha*	1.74	0.98
Hf	*Heritiera formes*	1.18	0.92
Ll	*Lumnitzera littorea*	0.81	0.46
Lr	*Lumnitzera racemosa*	0.95	0.26
Pp	*Pongamia pinnata*	0.29	0.14
Ra	*Rhizophora apiculata*	0.15	0.01
Rm	*Rhizophora mucronata*	0.75	1.45
Sg	*Sonneratia griffithii*	0.38	0.34
Xm	*Xylocarpus mekongensis*	1.39	0.23

**Stdev: standard deviation of the mean*

A universal equation relating tree biomass and basal area was developed using surveyed data and other data available in the literature for mangroves in the Ayeyarwady Delta in Myanmar. The equation is:

$$\text{Biomass} = 2.6453 * G^{1.1255} \quad (R^2 = 0.9894) \qquad (1)$$

In which Biomass[20] (Mg ha^{-1}) is biomass of mangrove vegetation per hectare (fully dried); G is total tree basal area (m^2 ha^{-1})

From equation (1) it is straightforward to estimate biomass of different species from their basal area growth rate (G). Biomass increments were then converted to carbon sequestration using conversion factor from the IPCC Wetland Supplement (2014).

To estimate growth rates of natural mangroves the study assumed that growth rates were similar to mangrove plantations that had similar tree basal area per hectare. Based on the 215 survey plots within mangrove plantations in the delta, growth rates of different mangrove stands in different status categories were estimated as below:

- Degraded secondary and regenerating mangrove. These have growth rates similar to poor performing plantations (low levels of tree stocking). These types of mangroves have growth rates of 2 Mg biomass per hectare per year.
- Mangrove plantations and natural mangroves in good condition. Growth rates were assumed similar to plantations with a tree density of greater than 1,500 trees per hectare and have mean growth rates of 5 Mg biomass per hectare per year.
- Regenerating mangroves. These have basal area and growth rates similar to new mangrove plantations (1-3 years old) and have growth rates of 2 Mg biomass per hectare per year.

20 Mg = Megagram, which is equivalent to a metric tonne.

Table 16. Mangrove tree growth rates analyzed from surveyed plantations.

Mangrove status	Mean tree basal area (m^2 ha^{-1})	Mean tree biomass increment of similar stocking plantation (Mg ha^{-1} $year^{-1}$)	N (number of plots)	Stdev*
Degraded secondary and regenerating mangrove	16.3	2.6	24	0.59
Mangrove plantations and natural mangroves in good condition	52.1	6.2	31	1.14
Regenerating mangroves	9.0	1.9	98	0.34

**Stdev: standard deviation of the mean*

Table 17. Biomass sequestration services for mangroves inside and outside reserve forests and national park[21].

Data	Value (2019 – annual)	Note
Average annual tree biomass growth of natural mangrove and plantations	6.2 Mg/ha/year	An equation relating tree biomass and basal area was developed using survey data and secondary data available in the Ayeyarwady Delta.
Average tree biomass growth of degraded mangrove	2.6 Mg/ha/year	
Average tree biomass growth of young regenerating mangrove	1.9 Mg/ha/year	Eq. Biomass = $2.6453 \ast G^{1.1255}$ (R^2 = 0.9894) From the equation, biomass was estimated for different species from their basal area growth rate (G).
Within reserve forests and national park		
Healthy natural mangrove	1,100 ha	
Mangrove plantations	5,470 ha	
Degraded mangrove	43,910 ha	
Young regenerating mangrove	4,609 ha	
Carbon sequestration from mangroves annually[22]	58,477 Mg of CO_2 equivalents	Estimated from survey and modeling (total in the study area)
Carbon price	USD 10 per Mg	Estimation from ongoing carbon sequestration projects
Income from biomass carbon sequestration	MMK 819 million	Conversion rate USD 1 = MMK 1,400
Carbon marketing and relevant costs	MMK 41 million	Estimation from ongoing carbon sequestration projects (5% of carbon value)
Outside reserve forests and national park		
Natural mangrove	0 ha	
Regrowth mangroves	21,099 ha	
Degraded mangrove	11,952 ha	
Young regenerating mangrove	0 ha	
Carbon sequestration from mangroves annually[23]	41,273 Mg of CO_2 equivalents	
Carbon price	USD 10 per Mg	

21 For Myanmar Revised NDC, outside RF and NP carbon sequestration would support the Agroforestry targets.

22 Total biomass was converted to carbon sequestration using a conversion factor from the IPCC Wetland Supplement (2013) - *Total biomass x 20% x 0.5 C x 3.67 CO_2* - Only 20% biomass stored on the mangrove stands, other biomass is continuously collected for fuelwood, mainly from existing natural and plantation mangroves. 1 Mg of biomass is 0.5 Mg organic carbon (IPCC 2013) or 1.84 Mg CO_2 equivalents (x 3.67).

23 Total biomass was converted to carbon sequestration using a conversion factor from the IPCC Wetland Supplement (2013) - *Total biomass x 20% x 0.5* C x 3.67 CO_2 - Only 20% biomass stored on the mangrove stands, other biomass is continuously collected for fuelwood, mainly from existing natural and plantation mangroves.

Income from biomass carbon sequestration	MMK 578 million	
Carbon marketing and relevant costs	MMK 29 million	

The coastal and riverbank protection valuation of mangroves is based on the methods presented in the methodology section. Only well-developed mangroves adjacent to open water (coastal) were considered to have coastal protection value (including both mangroves in ponds and outside ponds). For nipa palm, which is mainly for thatching and is extensively utilized, a protection value was estimated at 150 USD ha^{-1} $year^{-1}$. Nipa palm used for both, thatch and sap, was considered to have higher protection value (300 USD $year^{-1}$) given that they are not over-exploited for thatching.

Table 18. Coastal and riverbank protection ecosystem services derived from mangroves.

Data	Value (2019 – annual)	Note
Within reserve forests and national park		
Healthy natural mangrove	1,100 ha	Assumption: stocking >2,000 trees/ha and tree volume >50m^3/ha
Mangrove plantation	5,470 ha	Assumption: stocking >2,000 trees/ha and tree volume >50m^3/ha
Nipa palm	8,876 ha	Assumption: Nipa palm for thatching has ½ the river back protection value (150 USD ha^{-1} $year^{-1}$)
Coastal protection value	USD 1,369 ha^{-1} $year^{-1}$	For healthy mangrove and nipa palm
Value of coastal protection service	MMK 13,491 million	Estimated
Nipa palm river protection value	MMK 1,864 million	
Outside reserve forests and national park		
Nipa palm	36,179 ha	
Nipa palm river protection value	MMK 7,598 million	Assumption: Nipa palm for thatching have ½ river protection value (150 USD ha^{-1} $year^{-1}$)

Given the important role that the Forest Department has in managing and controlling RFs and NP areas, data was collected regarding government operational expenditure for field management and control. Additional jobs related to mangrove restoration and protection activities were quantified (Table 19). Finally, based on data collected from the study area, species biodiversity only for community forestry mangrove areas was estimated using the Shannon Diversity Index, which was 0.195 in 2019.

Table 19. Government operational expenditure for control and protection of reserve forests and national park areas in the Ayeyarwady Region.

Operation data	Value (2019)	Note
Current government forestry staff	65	Estimated from 4 townships for RF and NP management
Government costs for 1 staff – on average per month	MMK 500,000	Estimated from staff salary and other costs, survey 2019
Forest Department staff operational expenses (annual)	MMK 390 million	Estimated from salaries and other operational costs
Jobs related to mangrove restoration and protection	900 jobs	Estimated and equivalent to full time job (including nursery, planting, tending, monitoring)

Table 20 and 21 summarize the valuation process and baseline assessment in order to model the impacts of potential interventions and management options in areas within and outside RFs and NP following the Return on Investment Analysis structure described in the 3Returns Framework (GGKP, 2020). The study estimated the number of 'green jobs[24]', defined as jobs created in an environmentally sustainable, and legal activity, as a measurement and indicator of job quality, complementing the indicator 'total jobs' that quantifies the amount of direct jobs. The study also estimated the number of people involved in community-based land management (Community Forestry User Group and Village Fuelwood Plantations) and those involved in capacity building (or under technical assistance) as an indicator of social & human capital[25] (See Box 4).

Box 4. Community-based mangrove management and capacity building in the Ayeyarwady Delta

Community Forestry User Groups (CFUG) represents a group of community members (the minimum is 5) that are allocated a certain amount of mangrove land area that the CFUG is collectively responsible for managing. Depending on community leadership or supporting extension actions by the government or NGOs, some CFUGs can claim a collective mandate. However, most of the times the responsibilities for land management and rights to access the resources are divided among the members of the group. A CFUG member has rights and responsibilities for his/her own plot. The current forest management plan for CFUG is 30 years and renewable.

Village Fuelwood Plantations (VFP) are usually rehabilitated mangrove plantations which are established within existing reserve forest by the regional forestry department officials. They are established for fuelwood purposes and allocated to the most nearby villages. All the members of the villages which are granted with VFPs have equal rights and responsibilities on their village's fuelwood plantations. Therefore, village fuelwood plantations are a community forestry scheme. The current forest management plan for village fuelwood plantation is 30 years and renewable.

In the Ayeyarwady Delta, **capacity building activities** are mainly conducted by NGOs and international development projects. Capacity building activities are mostly focused on managing and improving production techniques related to aquaculture, agriculture, and forestry systems, and are often for both the community as well as for government staff.

4.1.3 Summary of Baseline Costs and Benefit

For 2019, the total monetary benefits from areas within RFs and NP add up to MMK 128,722 million, while operational expenses add up to MMK 80,438 million. Among non-monetary benefits, for 2019 total carbon sequestration equals 58,477 Mg of CO2e, green jobs comprise 22,491 jobs, and species diversity (Shannon Index) of the trees is 0.195. **Output indicators of the status of different capitals (natural, financial, social & human) found that natural capital is comprised of 6,570 ha of healthy mangrove and 8,876 ha of nipa palm. The number of people, involved in community forestry and capacity building as an output indicator for social & human capital, were 8,038.**

24 A job is classified as a 'green job' if it meets one or more of the following criteria: (a) adequate monthly wage, (b) work stability and security, (c) occupational hazard level involved, (d) decent working hours, and (e) availability of social protection scheme (e.g. social security). Work that uses child labor and bounded labor did not qualify as 'green job'. Additionally, employment characteristics related to *sustainable forestry activities* (tree plantation, forest certification, national voluntary certification), and sustainable production practices (climate smart agricultural practices) were also considered as part of the 'green job' criteria.

25 Social capital defined as the shared norms and values, networks and organizations that enable the coordination and mobilization of individuals' contributions; and human capital defined or related as the individual's capacity for work, such as knowledge, skills, and health.

Table 20. Baseline results for mangroves within reserve forests and national park.

	2019
Benefits (monetary)	**millions MMK**
Value of fuelwood collection in government managed mangrove	*26,337*
Value of fuelwood collection from village fuelwood plantations	*1,459*
Value of aquaculture	*14,787*
Value of fuelwood collection in mangrove aquaculture ponds	*5,234*
Value of fishing in government managed mangroves (crab-catching)	*51,828*
Value of agriculture (rice production)	*30,311*
Value of biomass carbon sequestration	*819*
Value of coastal protection	*13,491*
Value of nipa palm thatch only	*8,929*
Value of nipa palm riverbank protection	*1,864*
Operational expenditure (OPEX)	**millions MMK**
Forest Department staff (millions MMK)	*390*
Mangrove aquaculture pond operational costs	*9,169*
Rice cultivation costs annually	*16,208*
Mangrove fuelwood collection labor costs	*16,253*
Fuelwood collection labor costs for village fuelwood plantations	*871*
Fuelwood collection cost for mangrove ponds	*3,126*
Fishing labor costs	*28,943*
Other operational expenditures (related to carbon marketing)	*41*
Nipa palm thatch collecting and producing costs	*5,437*
Non-Monetary Benefits	**Unit**
Total carbon sequestration (Mg of CO2 equivalent)	*58,477*
Number of 'green jobs' maintained annually (number of jobs)	*22,491*
Species diversity (Shannon index for CF mangroves)	*0.195*
Status of Capitals (Output Indicators)	**Unit**
Natural Capital - healthy mangrove areas (natural mangroves and plantations which have stocking > 2,000 trees/ha and tree volume > 50m^3/ha) (ha)	*6,570*
Social & Human Capital - people involved in community forestry and capacity building (number of people)	*8,038*
Natural Capital - nipa palm (ha)	*8,876*

Following the study scope, for 2019 the total monetary benefits from areas **outside RFs and NP** add up to MMK 190,805 million, while operational expenses add up to MMK 99,197 million. Among non-monetary benefits, for 2019 total carbon sequestration equals 41,273 Mg of CO2e, and green jobs are 47,048 jobs. The output indicator of natural capital was 0 ha of healthy mangrove and 36,179 ha of nipa palm. There are no people involved in community forestry and capacity building in areas outside RFs and NP.

Table 21. Baseline results for areas outside reserve forests and national park.

	2019
Benefits (monetary)	**millions MMK**
Value of aquaculture	*38,867*
Value of fuelwood collection in mangroves (inside and outside ponds)	*2,642*
Value of fishing in mangroves managed by the Government (crab-catching)	*104,724*
Value of biomass carbon sequestration	*578*
Value of nipa palm thatch only	*36,396*
Value of nipa palm riverbank protection	*7,598*
Operational expenditure (OPEX)	**millions MMK**
Law enforcement and extension staff	*120*
Mangrove aquaculture pond operational costs	*24,100*
Mangrove fuelwood collection labor costs	*423*
Fishing labor costs in mangroves	*52,362*
Other operational expenditures (related to carbon marketing)	*29*
Operational costs for nipa palm for thatch only	*22,163*
Non-Monetary Benefits	**Unit**
Total carbon sequestration (Mg of CO_2 equivalent)	*41,273*
Number of 'green jobs' maintained annually (number of jobs)	*47,048*
Status of Capitals (Output Indicators)	**Unit**
Natural Capital - healthy mangrove areas (natural mangroves and plantations which have stocking > 2,000 trees/ha and tree volume > 50 m^3/ha) (ha)	*0*
Social & Human Capital - people involved in capacity building (number of people)	*0*
Natural Capital - nipa palm (ha)	*36,179*

Considering the importance to reveal how natural capital does not just provide products and raw materials, but also provide vital life support services that are critical to human well-being and the functioning of economies, the economic value of ecosystem services from mangrove land in the Ayeyarwady Region is presented in Table 22. It is worth mentioning that the economic value presented for ecosystem services is limited by the scope of this analysis and follows specific assumptions explained in detail in the methodology section.

Table 22. Ecosystem service supply from mangrove land (inside and outside RFs and NP) in the Ayeyarwady Region for 2019*.

Resource Rent	Unit	Nipa palm	Other mangroves & mangrove land	Aquaculture	Agriculture
Area	hectares	45,055	133,906	17,545	62,785
Fuelwood & timber	Millions MMK	210	15,422		
Aquaculture products	Millions MMK			20,385	
Fishing (mud crab catching)	Millions MMK	24,079	51,168		
Rice production (within Reserve forests and National park only)	Millions MMK				14,103
Nipa palm thatch	Millions MMK	17,725			
Nipa palm riverbank protection	Millions MMK	9,462			
Biomass carbon sequestration	Millions MMK	60	1,397		
Coastal protection	Millions MMK		13,491		

**Value indicated in the table is the resource rent (total value deducted operational costs).*

4.2. SCENARIO MODELING

The study developed a range of mangrove management scenarios in order to assess and compare the potential outcomes of different management strategies. The scenarios are based on varying investments in activities such as mangrove restoration, improved infrastructure (concrete gates for aquaculture ponds), capacity building (improved thinning and wood collection, aquaculture practices, and nipa palm production techniques), and allocation of lands to community forestry. Additionally, in areas inside RFs and NP different community-based mangrove management associated with its respective government enforcement has been analyzed. The analysis for different scenarios was done until 2026, which is the year that the MRRP finishes. Analyses of the different scenarios over longer time scales (until 2080) were also conducted, although uncertainties are high for such projections.

4.2.1 Scenarios for Areas Within Reserve Forests and National Park

The study developed a range of mangrove management scenarios in order to assess and compare the potential outcomes of different management strategies. The scenarios include:

A Business as Usual (BAU); a scenario where the current government mangrove management plan (MRRP) is fully enforced (MRRP+), and a range of scenarios that assess the increased allocation of mangroves to community forestry (CF), either through increasing the area allocated to CFUGs or through an increase in the area of VFP. These two community forestry arrangements differ in the access that they provide for landless people in the study area for fishing (i.e. crab catching) and collecting wood within the mangroves. A range of other improvements for forest management and aquaculture were also included. The different scenarios are described below (Table 23). Annex 2 describes in detail the impact drivers, the expected impacts, and the consequences and dependencies for each scenario.

Table 23. Scenarios (see text) for mangrove and associated land use within reserve forests and national park.

	BAU	Scenario 1 (MRRP+)	Scenario 2 (CFUG 25%)	Scenario 3 (CFUG 47%)	Scenario 4 (VFP 38%)
Land Use Direct Management Responsibility					
Reserve Forests and National Park managed by Forest Department (FD)	Rate as current practice	84% under FD direct responsibility	50% under FD direct responsibility	50% under FD direct responsibility	50% under FD direct responsibility
Mangrove Community Forest User Group (CFUG)	Rate as current practice	Allocate 13% of total RF by 2026 (as in current MRRP)	Allocate 25% of total RF by 2026	Allocate 47% to 2026	Allocate 13% of total RF by 2026 (as in current MRRP)
Mangrove Village Fuelwood Plantations (VFP)	Rate as current practice	3% of total RF by 2026 (as in current MRRP)	25% of total RF by 2026	3% to 2026 (as in current MRRP)	37% to 2026 of total RF by 2026 (as in current MRRP)
Forest Resource Use Management					
Forest Management Activities (Community Forest Management Plan)	Thinning 2 years and clear collection	Thinning 3-5 years, no clear collection	Thinning 5 years, no clear collection, and keeping (300) maternal trees[26]	Thinning 5 years, no clear collection, and keeping (300) maternal trees	Thinning 5 years, no clear collection, and keeping (300) maternal trees

26 Maternal trees are mature trees which can produce propagules and seeds which facilitate natural regeneration in mangroves.

Law Enforcement	Law enforcement remains the same	Improved enforcement for reducing illegal fuelwood collection and logging	Forest management is enforced for increasing the area of CF	Forest management is enforced for increasing the area of CF	Forest management is enforced for increasing the area of CF
Restoration effort	300 hectares of successful mangrove plantations annually	1000 ha of successful mangrove rehabilitation under implementation target (under MRRP plan)	1500 ha of successful mangrove rehabilitation under implementation target	1500 ha of successful mangrove rehabilitation under implementation target	1500 ha of successful mangrove rehabilitation under implementation target
Other Resource Use Management					
Aquaculture	Remain in the same condition	Remain in the same condition	Production techniques improved (concrete gate build, improved aquaculture techniques)	Production techniques improved (concrete gate build, improved aquaculture techniques)	Production techniques improved (concrete gate build, improved aquaculture techniques)
Rice	Remain in the same condition	Remain in the same condition	Remain in the same condition	Remain in the same condition	Remain in the same condition
Nipa palm	Remain in the same condition	Remain in the same condition	Production techniques improved (improved culture for multiple products)	Production techniques improved (improved culture for multiple products)	Production techniques improved (improved culture for multiple products)

4.2.2 Scenarios for Areas Outside Reserve Forests and National Park

The study developed a range of mangrove management scenarios in order to assess and compare the potential outcomes of different management strategies in mangrove land outside the RFs and NP. The different scenarios are described below. Annex 2 describes in detail the impact drivers, the expected impacts, and the consequences and dependencies for each scenario.

Table 24. Scenarios for mangroves and associated land use outside reserve forests and national park.

Resource Use Management	BAU	Scenario 1 (25% improvement)	Scenario 2 (50% improvement)	Scenario 3 (75% improvement)	Note
Degraded mangroves	Mangroves under BAU conditions	Improved felling and enrichment planting (or new planting for unvegetated saline land) 25% of the area, 75% of the area remains under BAU practices	Improved felling and enrichment planting (or new planting for unvegetated saline land) 50% of the area, 50% of the area remains under BAU practices	Improved felling and enrichment planting (or new planting for unvegetated saline land) 75% of the area, 25% of the area remains under BAU practices	Mangrove management, enriched for fuelwood production (economic activity)
Nipa palm	Nipa palm under BAU conditions	Improved culture for multiple products 25% of the area, 75% of the area remains under BAU practices	Improved culture for multiple products 50% of the area, 50% of the area remains under BAU practices	Improved culture for multiple products 75% of the area, 25% of the area remains under BAU practices	Individual use and management for economic activity impact assessment
Aquaculture in brackish water ponds with and without mangroves	Aquaculture ponds under BAU conditions	Mangrove rehabilitation of 25% of the area, 75% of the area remains under BAU practices 25% of the ponds will be improved (concrete gate build, improved aquaculture techniques)	Mangrove rehabilitation of 50% of the area, 50% of the area remains under BAU practices. 50% of the ponds will be improved (concrete gate build, improved aquaculture techniques)	Mangrove rehabilitation of 75% of the area, 25% of the area remains under BAU practices. 75% of the ponds will be improved (concrete gate build, improved aquaculture techniques)	Mangrove friendly aquaculture practices introduced and promoted

4.2.3 Climate Change, Including Sea Level Rise in Scenario Modeling

Following the 3Returns Framework, which strongly emphasizes the importance and necessity to identify, analyze, and model changes in capitals associated with external factors, the study incorporated increases in sea level, as they are expected with a high level of confidence (IPCC 2019) even though impacts in Myanmar have not yet been assessed adequately. Sea level rise (SLR) is a global risk to nations with low elevation coastal land due to impacts from increased inundation, storm surge, erosion, and saltwater intrusion (Nicholls and Cazenave 2010). In addition, the effects of SLR are predicted to be particularly negative for developing nations (Dasgupta, Laplante et al. 2011), with negative economic consequences especially for rice production[27] (Chen, McCarl et al. 2012). SLR is also expected to increase the damage caused by storm surges (Fritz, Blount et al. 2009). Mangroves provide coastal protection from storms and other waves (Hochard, Hamilton et al. 2019), yet they are also at risk from SLR if increases in tidal inundation and erosion exceed rates of accretion of shores, which can result in mangrove losses (Lovelock, Cahoon et al. 2015). Estimates of change in mangroves with SLR was based on the global model of Schuerch et al. (2019), which included impacts with and without coastal squeeze (Table 25). Thus, the impacts of SLR on mangroves were either positive, where coastal squeeze was avoided (+43% to 2100), or negative where not (-24% in cover to 2100). The amount of mangrove land lost or gained each year was incorporated into the modeling assuming a linear change to 2100.

27 As rice farming was excluded for the analysis in areas outside RFs and NP, SLR impact over rice production is only considered in areas inside RFs and NP.

Table 25. Scenarios of mangrove cover change with sea level rise within reserve forests and national park areas[28]

	Coastal Squeeze Scenarios	
	High coastal squeeze – low adaptation (P5)	Low coastal squeeze – high adaptation (P300)
Initial cover (km^2)	5,100	5,100
Cover 2100 (km^2)	3,900	7,300
Change in mangrove cover (km^2)	-1,200	2,200
% Change	-24%	43%

28 The model of Schuerch et al. (2019) was used to estimate changes in mangrove area with sea level rise. This model considered two scenarios, one with high coastal squeeze when landward migration of mangroves is prevented at population densities of 5-20 persons/km^2; and low coastal squeeze – high adaptation, where landward migration of mangroves is prevented at 300 persons/km^2).

5. RETURN ON INVESTMENT ANALYSIS

Following the 3Returns Framework, the scenarios were modeled according to the impact drivers, expected impacts, and consequences and dependencies described in Annex 2. Interventions such as mangrove restoration, improved infrastructure (concrete gates for aquaculture ponds), capacity building (improved thinning and wood collection, aquaculture practices, and nipa palm production techniques), and allocation of lands to community forestry were analyzed as an investment of capitals given their impact over the benefits and costs considered. The analysis and results of this process are presented in Sub-section 5.1 for areas within RFs and NP and in Sub-section 5.2 for areas outside RFs and NP considering the different scenarios analyzed, accordingly.

For the analysis, two discount rates were used, a regular discount rate (10%) and an impact investment discount rate (4%). Both discount rates, explained in Box 5, were applied for the investment analysis for areas within and outside RFs and NP. Following a conservative economic modeling approach, the results observed from using different discount rates reflected the same impact tendency regarding the interventions proposed.

Overall, the analysis reveals that investment in mangrove rehabilitation, capacity building, improved infrastructure, and community development brings more benefits compared to current practices. Green investments improve financial indicators as well as non-monetary and capital output indicators in the short and the long term. Over longer time scales, and considering the relationship between benefits and costs, conventional BAU practices are observed to be unsustainable in areas inside as well as outside RFs and NP. However, differences in the scenarios, land management, and interventions inside and outside RFs and NP proposed in this analysis have different impacts which are explained and presented in the sections below.

Box 5. Discount Rates for the Return on Investment Analysis

At each modeling scenario, two discount rates were applied.

Regular Discount Rate or market discount rate (10%): The discount rate is estimated based on interest and inflation rates of the economy. Currently, the commercial discount rate is about 12% for Myanmar. Considering the outlook for the economic development of the country it is expected that the capital market will be stable with lower inflation and interest rates over time. Therefore, a 10% discount rate is one of the discount rates applied for this analysis.

Impact Investment Discount Rate: The investment scenarios proposed in this study are for long-term ecosystem services and livelihood for the poor. These investments can be considered as Impact Investment. Therefore, lower discount rates are applied for these kinds of investments, for instance, 2% - 6%. In this study, an impact discount rate of 4% has also being applied for all investment scenarios and for the BAU.

5.1. RETURN ON INVESTMENT ANALYSIS FOR AREAS WITHIN RESERVE FORESTS AND NATIONAL PARK

Table 26, 27 and Figure 16 are the results of the Return on Investment Analyses for activities in mangroves and other land uses within RFs and NP using two different discount rates, the regular discount rate of 10% and the impact investment discount rate of 4%.

Table 26. Results of different scenarios over years for activities in mangroves within reserve forests and national park (discount rate 10%).

Financial Analysis	Results in 2026					Results in 2040					Results in 2060					Results in 2080				
	BAU	S1	S2	S3	S4	BAU	S1	S2	S3	S4	BAU	S1	S2	S3	S4	BAU	S1	S2	S3	S4
BCR	1.82	1.96	1.91	1.81	1.98	1.78	2.08	2.13	2.05	2.17	1.75	2.17	2.35	2.24	2.39	1.74	2.20	2.38	2.27	2.41
ROI	18.90	14.07	8.63	6.28	12.00	17.84	15.61	12.96	10.53	16.42	17.22	16.80	15.88	13.06	19.65	17.05	17.15	16.26	13.41	20.04
NPV Total Benefits (million USD)	585	620	709	767	702	969	1,124	1,361	1,515	1,380	1,090	1,341	1,714	1,896	1,740	1,109	1,388	1,770	1,957	1,798
NPV Operational Expenditures (million USD)	307.3	292.8	327.1	357.3	323.5	520.1	499.4	577.6	658.5	586.3	593	572	662	759	674	606.1	584.5	676.5	775.8	689.2
NPV Capital Expenditures (million USD)	14.7	23.2	44.3	65.2	31.6	25.1	40.0	60.5	81.3	48.3	29	46	66	87	54	29.5	46.9	67.3	88.1	55.3
Total NPV (million USD)	262.7	303.7	337.9	344.0	347.4	423.3	584.9	723.0	774.8	745.7	468	724	986	1,051	1,012	473.4	757.0	1,026.5	1,093.5	1,053.4
Other outputs																				
Social & Human Capital (number of people)	11,818	15,958	38,656	23,987	48,618	19,378	29,958	38,656	23,987	49,738	24,658	31,558	38,656	23,987	51,338	26,258	33,158	38,656	23,987	52,938
Natural capital - Good mangrove (ha)	8,670	20,570	27,570	27,570	27,570	12,870	48,570	69,570	69,570	69,570	18,870	78,000	78,000	78,000	77,683	24,870	78,000	78,000	78,000	77,683
Cumulative biomass carbon sequestration (thousand Mg)	515	1,552	1,752	1,559	1,709	1,545	6,189	7,349	7,163	7,303	3,287	17,388	19,528	19,343	19,383	5,308	32,296	34,435	34,248	34,161
Green jobs (number of jobs)	21,061	30,372	38,124	40,187	43,117	18,515	33,447	38,124	40,187	44,245	15,270	43,447	53,124	55,187	59,245	12,802	43,447	53,124	55,187	59,245
Total number of jobs	53,092	50,016	57,768	59,830	62,761	51,570	51,691	56,368	58,430	62,489	49,484	60,988	70,665	72,728	76,786	47,447	60,988	70,665	72,728	76,786

Table 27. Results for different scenarios over years for activities in mangroves within reserve forests and national park (discount rate 4%).

Financial Analysis	Results in 2026					Results in 2040					Results in 2060					Results in 2080				
	BAU	S1	S2	S3	S4	BAU	S1	S2	S3	S4	BAU	S1	S2	S3	S4	BAU	S1	S2	S3	S4
BCR	1.81	1.97	1.93	1.83	2.00	1.76	2.14	2.24	2.15	2.27	1.70	2.39	2.79	2.63	2.79	1.65	2.54	2.90	2.73	2.90
ROI	18.81	14.17	9.04	6.54	12.79	17.33	16.40	15.57	13.24	19.01	15.79	19.78	23.81	20.99	27.35	14.79	21.65	25.78	23.14	29.03
NPV Total Benefits (million USD)	738	786	910	990	902	1,602	1,942	2,402	2,699	2,453	2,271	3,206	4,386	4,843	4,477	2,591	3,995	5,339	5,869	5,448
NPV Operational Expenditures (million USD)	388.3	369.2	416.6	459.1	412.5	869.8	838.0	982.2	1,138.8	1,005.8	1,277	1,240	1,450	1,694	1,493	1,492.6	1,457.9	1,700.2	1,985.3	1,750.5
NPV Capital Expenditures (million USD)	18.6	29.4	54.5	81.2	38.3	42.3	67.3	91.2	117.9	76.1	63	99	123	150	109	74.2	117.2	141.2	167.9	127.4
Total NPV (million USD)	331.0	387.3	438.5	449.7	451.2	689.9	1,036.3	1,328.9	1,442.7	1,371.6	931	1,866	2,812	2,999	2,875	1,023.8	2,419.8	3,497.3	3,716.0	3,570.3
Other outputs																				
Social & Human Capital (number of people)	11,818	15,958	38,656	23,987	48,618	19,378	29,958	38,656	23,987	49,738	24,658	31,558	38,656	23,987	51,338	26,258	33,158	38,656	23,987	52,938
Natural capital - Good mangrove (ha)	8,670	20,570	27,570	27,570	27,570	12,870	48,570	69,570	69,570	69,570	18,870	78,000	78,000	78,000	77,683	24,870	78,000	78,000	78,000	77,683
Cumulative biomass carbon sequestration (thousand Mg)	515	1,552	1,752	1,559	1,709	1,545	6,189	7,349	7,163	7,303	3,287	17,388	19,528	19,343	19,383	5,308	32,296	34,435	34,248	34,161
Green jobs (number of jobs)	21,061	30,372	38,124	40,187	43,117	18,515	33,447	38,124	40,187	44,245	15,270	43,447	53,124	55,187	59,245	12,802	43,447	53,124	55,187	59,245
Total number of jobs	53,092	50,016	57,768	59,830	62,761	51,570	51,691	56,368	58,430	62,489	49,484	60,988	70,665	72,728	76,786	47,447	60,988	70,665	72,728	76,786

Regular discount rate 10 %	Impact investment discount rate 4 %

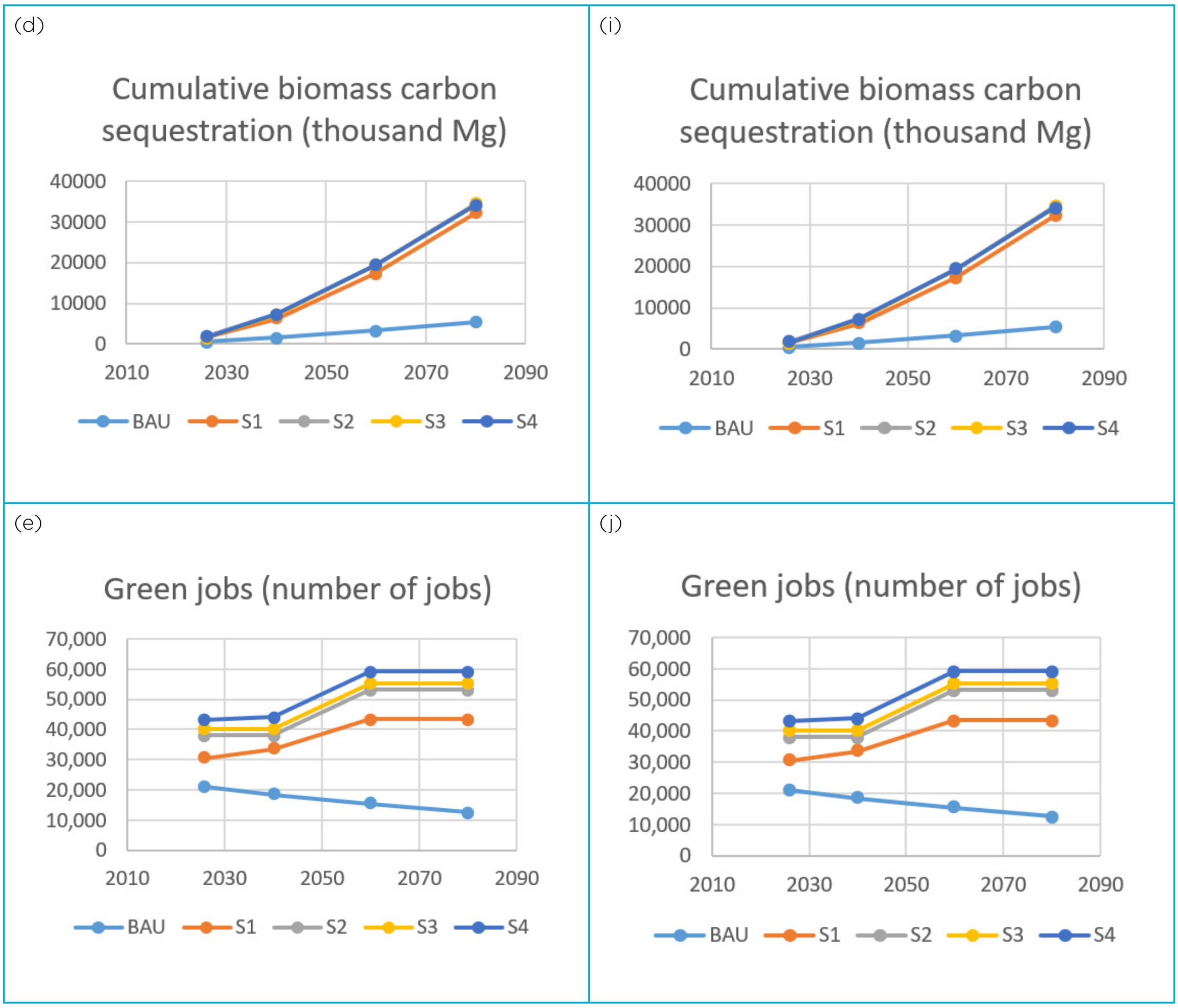


Figure 16. Return on Investment Analysis for enhanced mangrove management, including a BAU and four improved management scenarios (see Table 26 and 27) for mangrove within reserve forests and national park. Figures (a), (b), (c), (d), and (e) on the left side, are results of modeled scenarios with a regular discount rate of 10%. Figures (f), (g), (h), (i), and (j) on the right side, are modeled scenario results with a discount rate of 4%.

Improved and decentralized mangrove management interventions, in which more mangrove land was allocated to community forestry increased the total net present value (NPV) of resources in the landscape within RFs and NP in the delta (Tables 26 and 27, Figure 16). For example, NPV increased by approximately 25% between 2020 to 2026, from USD 368 million in the BAU scenario to USD 486 million for Scenario 4 (with a discount rate of 10%) (Figure 16c). Scenario 4 allocated most of the community forestry mangrove areas to villages as Village Fuelwood Plantations and included an enhanced community forestry management and improved production techniques. With an impact investment discount rate of 4%, the NPV of the BAU and Scenario 4 by 2026 are further increased to USD 351 million and USD 451 million, respectively.

Allocation of larger areas of mangroves under CFUGs, as has been practiced in Myanmar for the last two decades, would contribute to improved livelihoods of families in the region. However, increases in the CFUGs areas come at the expense of jobs and livelihoods of many landless people who collect fuelwood and crabs from the mangrove. Therefore, it is suggested that the Myanmar Government and investors should support community forestry in VFP, where all community members are permitted to catch crabs and collect fuelwood under the current fishery regulations.

The analysis also found that the mangroves within RFs and NP areas are providing jobs for several tens of thousands of landless people in the delta (Figure 16e and 16j). It was estimated that over 200,000 people's livelihoods depend significantly on mangrove resources. Currently, most of the jobs are from harvesting natural mangrove resources such as crab catching and fuelwood collection. Under the BAU the number of jobs associated with mangrove declined, while it was high and sustained for all green scenarios, although highest for Scenario 4. Many current jobs are not sustainable or environmentally friendly because they lead to overexploitation of natural resources. Intensive and frequent unplanned logging and fuelwood collection and crab catching under weak law enforcement have resulted in deforestation and degradation of natural resources in mangrove areas in the delta. The analysis shows that investment in community forestry, especially through supporting VFP and capacity building, would result in a higher proportion of green jobs associated with mangrove resources. Green jobs from sustainable crab catching, fuelwood collection from VFP, and mangrove restoration, increased from about 21,000 in the BAU scenario to about 43,000 jobs in Scenario 4 by 2026.

Other essential indicators of green growth show improvement under green investment scenarios (Scenarios 2 – 4). The areas of healthy mangroves and plantations (natural capital output indicator), increased from about 9,000 hectares (mainly plantations) in the BAU to over 27,500 hectares in the intervention Scenarios 2, 3, and 4. Cumulative carbon sequestration in mangroves in 7 years (2020 – 2026), which accounts for half of the total biomass growth of mangroves in the delta, increases from over 515,000 Mg CO_2 in the BAU to over 1,709,000 Mg CO_2 in Scenario 4. Additionally, species biodiversity of CF mangroves, reported as the Shannon index, increases from 0.195 to 0.588, if CFUG pond owners and VFP managers keep at least 300 maternal trees of 3 different species on their land.

The study also conducted analyses of the different scenarios over longer time scales, although uncertainties are high with such projections (Tables 26 and 27). The modeling results reveal that multiple capital investments have significantly higher impacts on the NPV, natural capital output indicators, social & human capital output indicators, cumulative biomass carbon sequestration, and number of jobs and number of green jobs. In the longer term, the return on investment (ROI) of green investment scenarios increases over time while the BAU's ROI declines. This analysis suggests that conventional and current BAU practices are not sustainable and have negative impacts on mangrove resources within RFs and NP over time (Figure 16). Only after 20 years (by 2040), the ROI of all greener investment Scenarios exceeds the ROI of the BAU (with a 4% discount rate).

5.2. RETURN ON INVESTMENT ANALYSIS FOR AREAS OUTSIDE RESERVE FORESTS AND NATIONAL PARK

Table 28, 29 and Figure 17 are the results of the Return on Investment Analyses for activities in mangroves and other land uses outside RFs and NP using two discount rates, the regular discount rate of 10% and the impact investment discount rate of 4%.

Table 28. Results of different scenarios by years for mangroves outside reserve forests and national park (discount rate 10%).

	Results in 2026				Results in 2040				Results in 2060				Results in 2080			
Financial Analysis	BAU	S1	S2	S3	BAU	S1	S2	S3	BAU	S1	S2	S3	BAU	S1	S2	S3
BCR	1.92	1.87	1.83	1.83	1.91	1.92	1.93	2.02	1.90	1.93	1.94	2.05	1.90	1.93	1.94	2.05
ROI	- [29]	25.91	14.97	13.74	-	37.65	23.51	20.17	-	39.83	25.13	21.28	-	40.07	25.31	21.39
NPV Total Benefits (million USD)	1,017	1,165	1,267	1,431	1,673	2,074	2,424	2,959	1,873	2,351	2,779	3,433	1,902	2,393	2,832	3,503
NPV Operational Expenditures (million USD)	531	600	650	731	877	1,051	1,204	1,386	984	1,190	1,375	1,586	1,001	1,211	1,401	1,617
NPV Capital Expenditures (million USD)	0	21.8	41.2	50.9	0	27.1	51.9	77.9	0	29.1	55.8	86.7	0	29.5	56.5	88.2
Total NPV (million USD)	486	543	575	648	796	996	1,168	1,495	888	1,132	1,348	1,759	901	1,152	1,374	1,798
Other outputs																
Social & Human Capital (number of people)	0	750	1,500	2,250	0	750	1,500	2,250	0	750	1,500	2,250	0	750	1,500	2,250
Natural capital - Good mangrove (ha)	0	13,181	26,362	28,998	0	12,181	24,362	35,000	0	12,181	24,362	35,000	0	12,181	24,362	35,000
Cumulative biomass carbon sequestration (thousand Mg)	330	1,039	1,199	1,450	908	3,156	3,989	4,916	1,733	6,173	7,958	9,857	2,559	9,189	11,928	14,797
Green jobs (number of jobs)	47,048	61,208	77,125	91,490	47,048	61,326	75,604	90,065	47,048	61,326	75,604	90,065	47,048	61,326	75,604	90,065
Total number of jobs	58,892	73,956	90,777	105,619	58,892	73,978	89,064	104,347	58,892	73,978	89,064	104,347	58,892	73,978	89,064	104,347

29 As no investment in areas outside RFs and NP (following the interventions considered in this analysis) were identified, the ROI for the BAU is not reported.

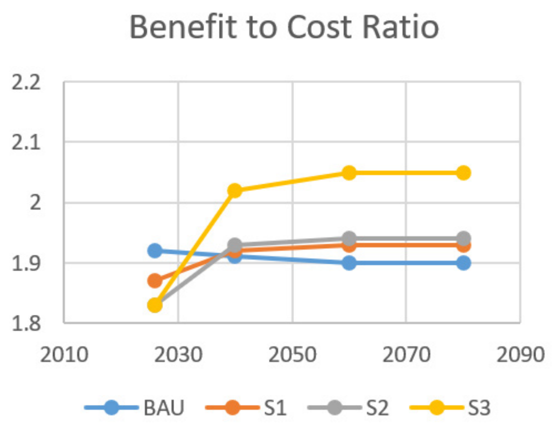
Table 29. Results of different scenarios by years for activities in mangroves outside reserve forests and national park (discount rate 4%).

Financial Analysis	Results in 2026				Results in 2040				Results in 2060				Results in 2080			
	BAU	S1	S2	S3	BAU	S1	S2	S3	BAU	S1	S2	S3	BAU	S1	S2	S3
BCR	1.92	1.87	1.83	1.82	1.90	1.94	1.96	2.08	1.89	1.95	1.98	2.14	1.88	1.95	1.98	2.15
ROI	- [30]	25.28	14.27	13.00	-	42.65	26.66	22.08	-	48.18	30.75	24.45	-	49.39	31.71	24.81
NPV Total Benefits (million USD)	1,284,641	1,492,386	1,638,781	1,865,831	2,757,345	3,534,601	4,243,819	5,315,141	3,851,518	5,056,803	6,189,079	7,914,858	4,350,885	5,751,516	7,076,870	9,101,335
NPV Operational Expenditures (million USD)	670,566	768,122	839,907	952,909	1,449,237	1,780,583	2,085,824	2,422,862	2,039,199	2,543,855	3,022,157	3,525,141	2,314,851	2,898,627	3,455,935	4,034,654
NPV Capital Expenditures (million USD)	0	28,653	55,984	70,202	0	41,130	80,937	130,986	0	52,154	102,986	179,572	0	57,764	114,206	204,225
Total NPV (million USD)	614,075	695,611	742,891	842,720	1,308,108	1,712,888	2,077,057	2,761,293	1,812,319	2,460,794	3,063,936	4,210,146	2,036,033	2,795,125	3,506,730	4,862,456
Other outputs																
Social & Human Capital (number of people)	0	750	1,500	2,250	0	750	1,500	2,250	0	750	1,500	2,250	0	750	1,500	2,250
Natural capital - Good mangrove (ha)	0	13,181	26,362	28,998	0	12,181	24,362	35,000	0	12,181	24,362	35,000	0	12,181	24,362	35,000
Cumulative biomass carbon sequestration (thousand Mg)	330	1,039	1,199	1,450	908	3,156	3,989	4,916	1,733	6,173	7,958	9,857	2,559	9,189	11,928	14,797
Green jobs (number of jobs)	47,048	61,208	77,125	91,490	47,048	61,326	75,604	90,065	47,048	61,326	75,604	90,065	47,048	61,326	75,604	90,065
Total number of jobs	58,892	73,956	90,777	105,619	58,892	73,978	89,064	104,347	58,892	73,978	89,064	104,347	58,892	73,978	89,064	104,347

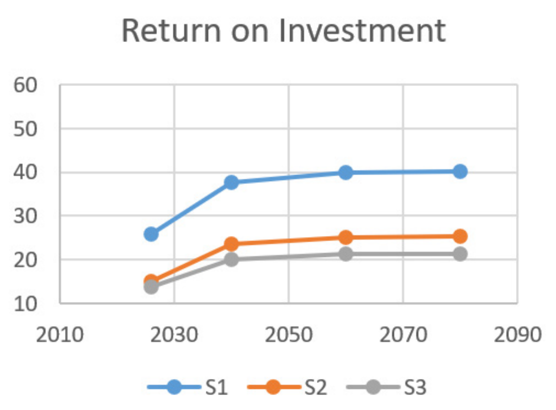
30 As no investment in areas outside RFs and NP (following the interventions considered in this analysis) were identified, the ROI for the BAU is not reported.

Regular discount rate 10%

a)



b)



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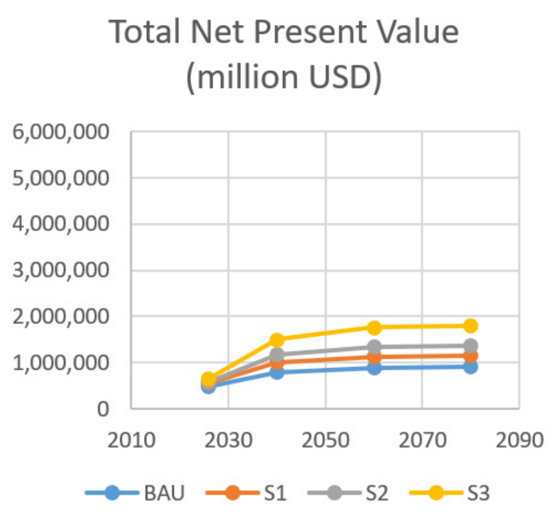
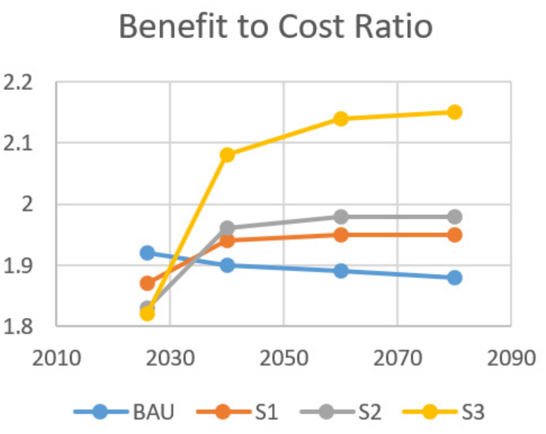
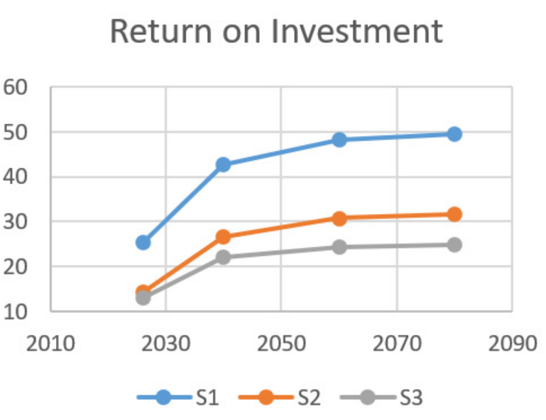


Impact investment discount rate 4%

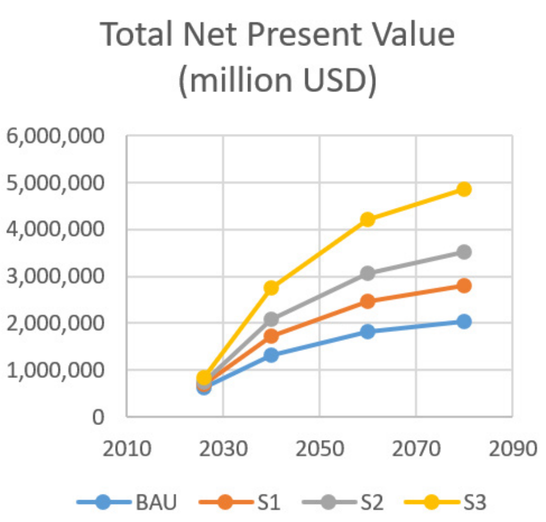
f)



g)



h)



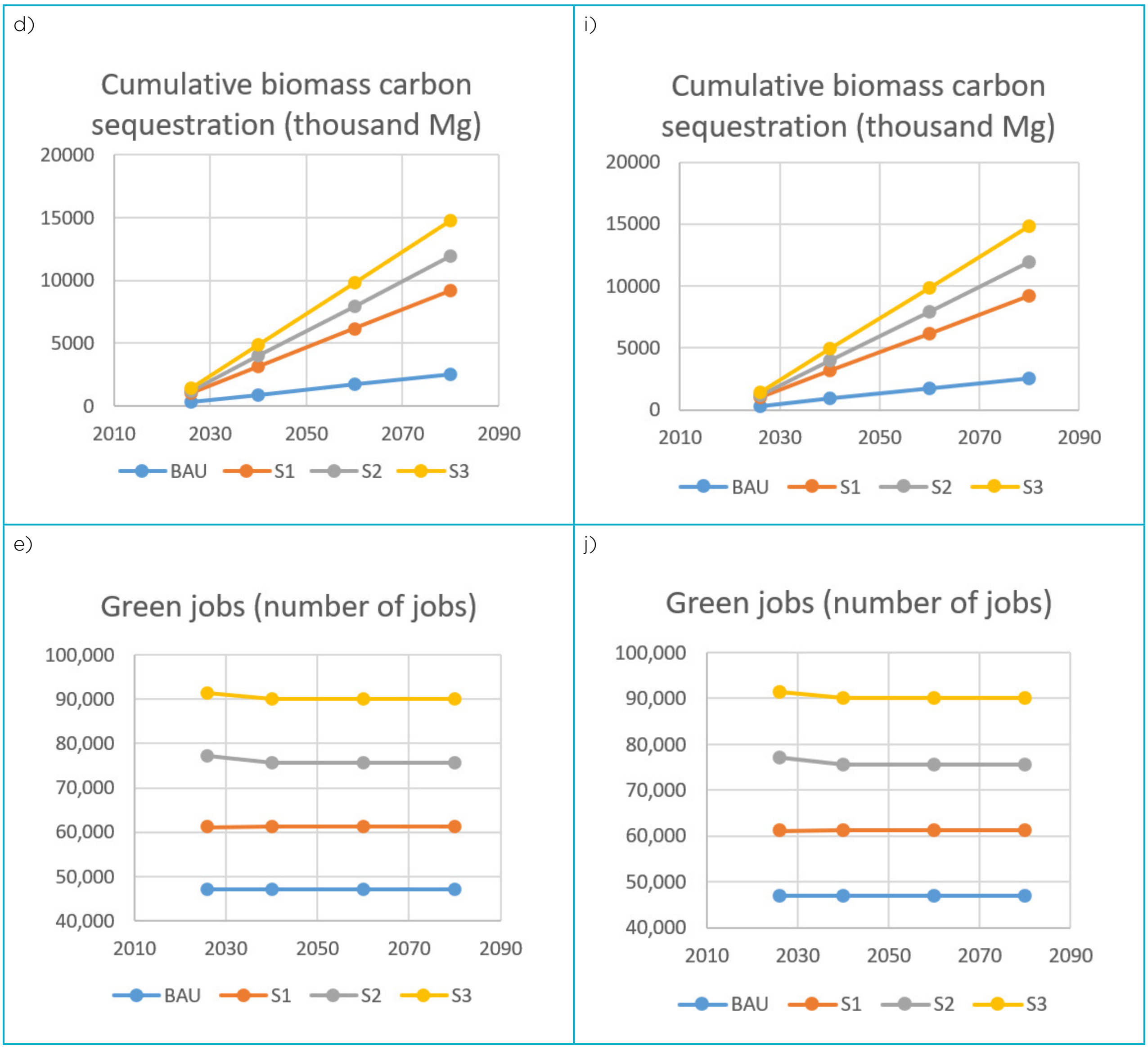


Figure 17. Return on Investment Analysis for enhanced mangrove management, including a BAU and three improved management scenarios (see Table 28 and 29) for mangrove land outside reserve forests and national park. Figures (a), (b), (c), (d), and (e) on the left side, are results of modeling with a regular discount rate of 10%. Figures (f), (g), (h), (i), and (j) on the right side, are modeling results with a discount rate of 4%.

Analyzing the impacts of investment in a range of mangrove management scenarios outside RFs and NP, green investments can provide much higher monetary benefits compared to the BAU. Without multiple capital investments, the BAU scenario results in unstainable benefits from exploiting natural resources as observed in the decreasing benefit to cost ratio over the long term (Figure 17a and b).

With a regular discount rate of 10%, the total NPV increases by 2026 from USD 486 million in the BAU to USD 648 million in Scenario 3. Over the long term (2080), these figures represent USD 912 million in the BAU and USD 1,798 million for Scenario 3, respectively. The increase in NPV in green scenarios with a discount rate of 4% (Table 29) is much higher than with a 10% discount rate (Table 28).

The highest ROI was observed for the green Scenario 1, for which only 25% of mangrove forests, nipa palm, and aquaculture ponds production systems were improved. The ROI of Scenario 1 (for both discount rates 10% and 4%) is over 44 times of Scenario 2 and over 24 times of Scenario 3. The reason for a decreasing ROI with greater interventions reflected in Scenarios 2 and 3 is explained by the importance that fuelwood collection activities have on the ROI outcomes, compared to other economic activities and the investment or interventions proposed. In areas inside RFs and NP, fuelwood collection activities represent 23% of the total benefits from the economic benefits under analysis, whereas in areas outside RFs and NP, fuelwood collection activities only represent 1%. Considering that investment in mangrove rehabilitation by enrichment represents the greatest capital expenditure under this analysis for areas outside RFs and NP, an increase in the investment in mangrove rehabilitation in areas outside RFs and NP does not have the same impact as in areas inside RFs and NP. This suggests that in order to improve the profitability and efficiency of investments in a sustainable manner, interventions outside RFs and NP should consider improving the performance of the main economic activities analyzed which are fisheries and aquaculture. Interventions such as the investment in hatcheries or the sustainable intensification of aquaculture could support improving not only the profitability but also the efficiency of interventions in areas outside RFs and NP.

Analysis of the impacts of different scenarios over the long term found that the NPV, BCR, and ROI of green investment scenarios increases over time. Additionally, mangrove resources and capital investment on mangroves outside RFs and NP can provide over 100,000 equivalent full-time jobs in the delta. For all mangroves, outside and inside RFs and NPs, resources and investments bring over 160,000 jobs. It is estimated that over 700,000 people can be provided with sustainable livelihoods with appropriate investments.

Improved management of mangrove resources outside RFs and NP could mitigate millions of tons of carbon dioxide. Cumulative carbon sequestration of mangroves by 2080 was only around 2.5 million Mg CO_2 in the BAU, compared to 14.7 million Mg CO_2 in Scenario 3.

Finally, green investments in mangrove areas outside RFs and NP would bring multiple other benefits. They would contribute to increasing mangrove areas by 2026 to around 29,000 ha of healthy mangroves in Scenario 3. The social & human capital output indicator was also strengthened with green scenarios. According to the results, under the Scenario 1, around 750 people would receive training from different programs and projects, while over 2,250 people by 2026 will be educated under green Scenario 3.

Overall, the analysis reveals that the investments proposed through the different green scenarios improve the monetary and non-monetary benefits, as well as capital output indicators, when comparing to the BAU. However, for areas inside RFs and NP, mangrove restoration and decentralization of mangrove management through VFP is a key innovation in achieving sustainable outcomes, as fuelwood collection activities currently make up to 23% of the economic benefits. Meanwhile, for areas outside RFs and NP, improving fishing and aquaculture activities could be effective activities to achieving sustainable outcomes, as non-timber products are the main drivers of income generation. Therefore, additional interventions or investments (e.g. development of hatcheries or sustainable intensification of aquaculture practices) should be considered and analyzed for areas outside RFs and NP.

5.3. SENSITIVITY ANALYSIS

The study analyzed different land and resource use management scenarios and its impact reflected through changes in reported products' and services' related outputs and selected indicators. For these analyses, the discount rate, as well as the commodities' prices, played a vital role at the moment of analyzing the monetary impact. Therefore, a sensitivity analysis was conducted running the models through different discount rates with a minimum discount rate of 2% and a maximum discount rate of 14%. Additionally, a sensitivity analysis was conducted for changes in the price of the nipa palm sap, as the price for products such as mud crab, shrimp, mangrove fuelwood, and nipa palm leaves has an already established and less volatile market, whereas for nipa palm sap, there is no such market yet in the Ayeyarwady Region.

When testing different discount rates within the specified range in the models within and outside RFs and NP, higher discount rates penalized the positive results as investment costs accrue earlier while benefits mostly arise in the long run. On the other hand, lower discount rates favored the positive impact of the proposed interventions. Yet, the sensitivity analysis from using different discount rates reflected the same impact tendency regarding the activities under analysis in areas within and outside RFs and NP, which supported to robustness of the results' interpretation based on the interventions proposed.

Regarding the nipa palm sap, the estimation of its price was based on a conservative value based on neighboring Myanmar regions and countries (i.e. Thailand and Indonesia). However, the price could be negatively affected if there is a limited market for this product in the Region. Following an assumption that the value of nipa palm sap could face a reduction of 50% and 75% of its value, the sensitivity analysis showed that the conversion of production practices for nipa palm for sap and thatch still have positive investment outcomes despite lower prices.

5.4. SEA LEVEL RISE SCENARIOS AND IMPACTS

In areas inside RFs and NP[31], the impact of climate change on rice productivity (due to saline water intrusion and climate events) was applied as an annual decline in productivity of 0.4%. Further, SLR scenarios that considered the impact of coastal squeeze were analyzed which included a high coastal squeeze (low adaptation) scenario where a loss of -0.29% mangrove area per year was used, and low coastal squeeze (high adaptation) scenario where the mangrove area increased by 0.54% per year.

Table 30 shows that coastal squeeze scenarios with SLR have significant impacts on rice cultivation jobs due to a reduction in the productivity and area of rice fields. Over 4,000 jobs are gained in the low coastal squeeze scenario while over 10,000 jobs are lost in the highest coastal squeeze scenario. However, the loss of agricultural jobs was compensated by jobs created from increase mangrove land, associated with fishing and fuelwood collection in mangroves managed by the Government. The impacts of a coastal squeeze as a consequence of SLR are likely to be more complex and interact with other factors (climate, storms, land-use) than modelled here. SLR with low coastal squeeze may increase mangrove extent, but the acceleration of coastal erosion could also occur which could result in a decrease of coastal land. Further analyses should be conducted to estimate SLR's impacts on mangroves and associated land uses and communities in the delta.

31 Due to the high uncertainty of land use and land use change in mangrove area **outside** RFs and NP, the impact of sea level rises was not analyzed for this area.

Table 30. Sea level rise impacts on investment analyses of activities in mangroves and mangrove land-use (only for areas within RFs and NP).

	Results in 2080 - no SLR					Results in 2080 - SLR 1, -0.29 %					Results in 2080 - SLR 2, 0.54 %				
Financial analysis	BAU	Sc1	Sc2	Sc3	Sc4	BAU	Sc1	Sc2	Sc3	Sc4	BAU	Sc1	Sc2	Sc3	Sc4
BCR	1.65	2.55	2.88	3.17	4.19	1.62	2.52	3.00	4.27	4.89	1.66	2.56	3.42	3.11	3.83
ROI	14.79	21.82	25.57	28.89	48.00	14.70	21.31	26.89	42.63	57.92	16.30	22.37	33.09	28.40	43.43
NPV Total Benefits (million USD)	2,591	4,015	5,310	6,834	7,865	2,666	3,941	5,481	9,126	9,115	2,845	4,107	6,400	6,782	7,311
NPV Operational Expenditures (million USD)	1,493	1,458	1,700	1,985	1,750	1,575	1,444	1,685	1,969	1,737	1,635	1,487	1,729	2,015	1,779
NPV Capital Expendi-tures (million USD)	74	117	141	168	127	74	117	141	168	127	74	117	141	168	127
Total NPV (million USD)	1,024	2,440	3,469	4,681	5,987	1,017	2,380	3,654	6,988	7,250	1,136	2,503	4,530	4,600	5,405
Other outputs						0	0	0	0	0					
Social & Human Capital	26,258	33,158	38,656	23,987	52,938	26,258	33,158	38,656	23,987	52,938	26,258	33,158	38,656	23,987	52,938
Natural capital - Good mangrove	24,870	77,000	77,000	76,500	78,500	24,870	78,000	58,000	55,000	55,000	24,870	78,000	91,500	93,000	95,000
Cumulative biomass carbon sequestration (thousand Mg)	5,308	31,952	33,860	33,177	33,317	5,053	31,126	28,797	27,302	27,442	5,347	34,544	40,045	40,266	40,290
Green jobs	12,802	33,504	38,209	40,357	44,529	17,843	29,883	34,548	36,661	40,856	30,113	41,922	46,832	48,581	52,940
Total number of jobs	47,447	51,045	55,750	57,898	62,070	55,240	50,998	55,663	57,776	61,971	57,336	50,901	55,811	57,560	61,920
Agriculture job	17,541	17,541	17,541	17,541	17,541	21,591	21,591	21,591	21,591	21,591	7,461	7,461	7,461	7,461	7,461

6. CONCLUSIONS AND RECOMMENDATIONS

6.1. CONCLUSIONS

Mangroves in the delta provide essential ecosystem services. Livelihoods derived from the natural resources of the mangroves reach hundreds of thousands of people in the Ayeyarwady Region. The analysis of green scenarios and capital investment reveals that interventions in mangrove rehabilitation, capacity building, improved infrastructure, and community development brings substantial and multiple monetary benefits, non-monetary benefits, and enhancement of natural, social, human, and economic capital. Green scenarios, considering an investment in natural, social & human, and financial capital improved financial indicators such as the NPV, the BCR, the ROI, as well as non-monetary and capital output indicators such as the amount of carbon sequestration, number of green jobs, and hectares of healthy mangrove. The trade-off, which is common to green investments, is that these sustainable practices require a higher capital investment than the BAU scenario, with the expectation that greater future benefits will offset the additional cost. While improved environmental, social, human, and economic outcomes are realized in the short term, there is a risk in fully realizing the monetary and non-monetary benefits, as these typically take longer to accrue and require strategic long-term planning and commitment. Therefore, the role of the Government as a planner and strategic designer for the sustainable development in the Ayeyarwady Region is crucial. The investment in mangrove ecosystems requires a careful understanding of the complex interaction between stakeholders, economic activities, ecosystem services, and the importance of different land management schemes.

For areas inside RFs and NP, decentralization and improved mangrove management are key innovations in achieving sustainable outcomes, as fuelwood collection activities currently make up to 23% of the economic benefits (2019). The most decentralized practice – through VFP – provides the highest returns and non-monetary benefits, as it creates an inclusive pathway for landless people to participate in the mangrove ecosystem. Currently, there is no requirement for the involvement of all community members, including the landless. Promotion of community forestry with due respect of equal rights of all within local communities will help mitigate a potential risk of undermining the improved mangrove management intended through community forestry. Consideration of appropriate safeguards for the landless in community forestry programs is a key potential opportunity to empower landless people, but this requires consultation within the community in order to secure their participation.

For areas outside RFs and NP, improving fishing and aquaculture activities in addition to mangrove rehabilitation could be activities to achieve sustainable outcomes, as non-timber products provide the main income from the mangrove ecosystems. Improving mud crab catching and aquaculture practices could yield the most efficient outcomes. While investments in mangrove rehabilitation by enrichment improves the NPV, the investment required should be carefully considered as the main production systems from these land areas do not directly depend on mangrove fuelwood, and therefore, investments in the further development of non-timber economic activities should be considered.

Box 6. Investment risks in mangrove ecosystems in the Ayeyarwady Region

Strengthening community forestry to support long term and sustainable mangrove rehabilitation and management requires full participation of local communities. Low participation is the highest risk to the success of community-based investments. The Forest Department and the Government could reduce this risk by establishing clear institutional and legal frameworks to support community forestry, including those that enable community's access to capital and extension services for mangrove-based livelihood activities.

Infrastructure is required for the successful implementation and support of the economic activities discussed. Unstable electricity supply threatens the success of aquaculture hatcheries and aquaculture production. Similarly, poor road systems negatively impact market access and commerce in the Region.

Strong consumer demand is essential for the effective development of mangrove products. Events such as COVID-19 or the lack of a stable market for commercializing nipa palm sap jeopardize the implementation of the recommended interventions that support sustainable production practices.

Overall, climate change and sea level rise pose a high risk to economies and social structures of low-lying landscapes like that in the Ayeyarwady Region.

6.2. RECOMMENDATIONS

To support successful economic activities on mangrove land, livelihood improvement, and strengthened ecosystem services it is recommended:

- For areas inside RFs and NP, community forestry in mangroves could be developed further by the Myanmar Government which, according to the analysis, would enhance community incomes, mangrove extent, and the number of green jobs. Support may include the establishment of legal frameworks that allow communities holding mangroves to borrow capital for investment in management activities. Establishing VFPs could be increased to provide fuelwood for villagers and access for landless mud crab catchers, thereby increasing benefits for all community members. Developing safeguards for the landless is important to be considered in any decentralized community forestry intervention.
- Land-use boundaries are not clear in mangrove landscapes in the Region, particularly those of reserve forests. In many mangrove areas, for instance, nipa palm has been allocated to local farmers under Form 7 user rights but are still included in the reserve forest areas. Investments in land-use planning and land delineation for different land use types and users would provide increased clarity in land-tenure arrangements and land management processes. Improving the mapping in the Region is fundamental to land-use planning which would support more effective and successful mangrove management. Improved mapping could be provided in easily accessible digital platforms.
- Investment in nipa palm culture for sap and sustainable mangrove friendly aquaculture could enhance economic benefits for landholders inside and outside RFs and NP. Investment in extension activities to introduce improved culture systems for both, nipa palm sap and mangrove friendly aquaculture, is required to accelerate the development of these activities. Establishment of nipa palm sap processing facilities through the introduction and development of innovative technology, as well as market research, are vital for the success of a new nipa palm sap industry. For mangrove aquaculture, techniques for small-scale hatcheries for crabs and shrimp, as well as improved mangrove aquaculture techniques, could have a positive and significant impact in yields and income.
- In areas outside RFs and NP, interventions such as the development of hatcheries or the sustainable intensification of aquaculture practices could be considered as mechanisms to further improve the benefits of people in these areas. Outside the

RFs and NP investments will need to be tailored for each area, weighing the costs, benefits, and efficient use of capital.

- The inclusion of mangroves in mitigation as well as adaptation strategies in Myanmar could provide economic benefits for communities and important regulatory ecosystem services that contribute to Myanmar's Nationally Determined Contributions to the Paris Agreement. Further investment in the development of blue carbon projects could increase benefits to communities. Benefits would include enhanced incomes but could also create a new industry that would comprise a range of different kinds of jobs that could promote education and capacity building within communities. Developing innovative ways to aggregate small community forestry projects into carbon sequestration projects that take advantage of economies of scale should be explored.

- Finally, the interventions presented through this study aim to support and should be considered as a response to the efforts of the Myanmar government to create a more resilient economy expressed through the Myanmar Sustainable Development Plan 2018-2030 (MSDP), and more recently through the Myanmar Economic Recovery & Reform Plan (MERRP, draft document currently under review by the Ministry of Planning and Finance) developed as a response to COVID-19 impact. Central to the MERRP is the recognition of the private sector for an accelerated economic growth and inclusive development, for which several strategies aim to assist the country's firms, sole-traders, farmers, and investors. For example, policies to improve the business climate in Myanmar include a number of initiatives related to making easier permission arrangements, appropriate and lawful access to land, information exchange, among others. Aquaculture practices can benefit from these initiatives, as the current study has identified policy and regulatory frameworks as an important barrier for the sub-sector's development. Additionally, nipa palm recommended interventions assessed through this study can directly benefit from the MERRP promotion of inclusive growth through agricultural development. Foundational to the MSDP was the strengthening of Myanmar's agricultural economy, which is a central goal to the MERRP too. Strategies aim to promote a greater diversification and include, among others, increased investment in rural infrastructure and logistics, improved formal access to land, and the encouragement of greater value-adding in food processing and rural enterprise broadly.

Box 7. Importance and opportunity for gender inclusion in selected value chains.

Importance. Encouraging the participation of women in the aquaculture sub-sector is considered a direct method for improving household nutrition. Rural Myanmar women are traditionally responsible for buying food that will be prepared and consumed at household meals. Additionally, their involvement also provides them with the ability to obtain greater financial independence leading to greater female involvement in household decision making.

Opportunity. As mentioned in Box 2, under the current nipa palm products' value chain, women's role is limited to the processing of sheets of nipa thatch. The extraction and commercialization of nipa palm sap opens the opportunity for the integration of women into the production and processing stage, through the collection of nipa palm sap and primary and/or secondary processing depending on the final product.

Box 8. Investment implications for economic development and livelihood improvement in coastal landscapes in the Ayeyarwady Region.

Due to the limited scope of this research, several production systems which could contribute significantly to economic development and livelihood improvement in the delta have not been addressed.

Nipa palm farming for nipa palm sap is a sustainable and high value in livelihoods improvement for the people in the coastal areas in the delta. To improve nipa palm farming, it is essential to convert the current 'nipa for thatch system' to nipa for both, sap and thatch. However, nipa palm sap would be a high value product only if there is a local market for the product. Bioethanol production from nipa sap is a feasible approach which can consume all nipa sap harvested in the delta. The Government and donors could further assess this production system for introduction to the delta.

Intensive brackish water aquaculture could bring significantly higher production than the existing extensive mangrove aquaculture system. Where it is suitable (e.g. outside reserve forests and national park and with the availability of suitable infrastructure and extension services), sustainable intensive aquaculture could be an option to meet the increasing demanding of both domestic and export markets. Higher productivity from an intensive system would contribute to reducing land use change and mangrove deforestation if it is properly developed and regulated.

Long term aquaculture development requires abundant and stable seed (larvae) sources. Existing brackish water aquaculture in the delta is dependent on wild caught fingerlings and juvenile fish stocks. This causes the depletion of natural resources. An improved system of hatcheries for shrimp, mud crab, and fish in the delta is needed to support long term and sustainable development of brackish water aquaculture.

ANNEXES

ANNEX 1. METHODOLOGY

a. Valuation and Investment Analysis

The valuation and investment analysis in this report follows the goals of the Wealth Accounting and Valuation of Ecosystem Services (WAVES) global partnership and the 3Returns Framework, which aim to promote sustainable development by mainstreaming natural capital in development planning while supporting decision-making for sustainable coastal management.

The valuation of ecosystem services reveals the importance of ecosystem functions and is an essential component for devising management activities. The valuation of ecosystem services in this report follows the Millennium Ecosystem Assessment Framework methodological approach (MEA 2003), as well as the recommendations from the WAVES Technical Report: Guidelines for Measuring and Valuing the Coastal Protection Services of Mangroves and Coral Reefs. Based on the scope of the analysis and the specific objectives of this report, the valuation of ecosystem services focuses on valuing a subset of the direct use (fuelwood, crabs) and indirect use (carbon sequestration and coastal and riverbank protection) of ecosystem services provided by mangrove land in the Ayeyarwady Region.

- For the investment analysis, this study follows the 3Returns Framework[32], which presents a method for assessing sustainable landscape interventions. The 3Returns Framework accounts for 'green interventions' in a landscape as:
- Investments in Natural Capital: resources allocated to increase the stocks of natural assets;
- Investments in Social & Human Capital: resources allocated to increase cooperation within and among groups, individual and collective knowledge, skills, and competencies; while building/strengthening institutions for resource management, decision making, and social integration; and

Investment in Financial Capital[33]: resources allocated to acquire or increase the assets needed in order to provide goods or services.

The 3Returns Framework contrasts a Business as Usual (BAU) scenario against green growth scenarios to understand changes in key capital indicators (natural, social & human, and financial capital) and the benefits derived from them. In this report, the development of a range of green growth scenarios was based on literature review, expert consultation, and baseline survey in the study sites. The BAU scenario assumes continued mangrove degradation with limited mangrove restoration projects. The green growth scenarios are based on a range of investments in restoration and improved management approaches with varying intensity and altering management arrangements of government and private-managed mangroves.

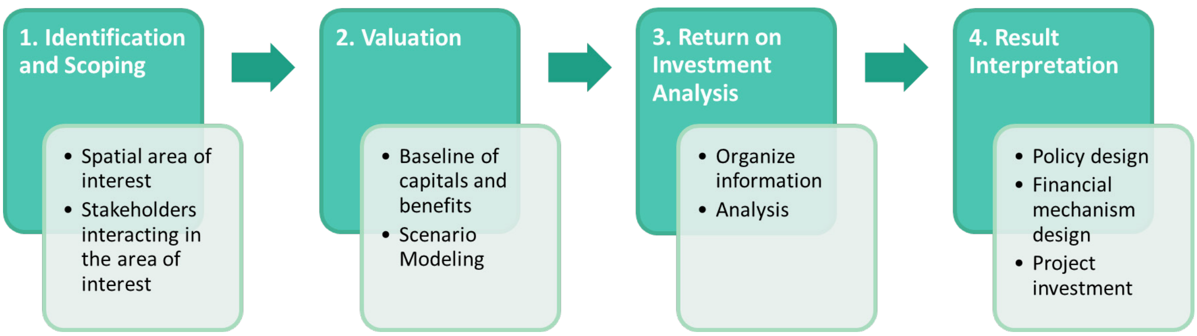


Figure 18. 3Returns Framework Stages

32 The 3Returns Framework methodological description is publicly available and can be found in the Green Growth Knowledge Platform under the Expert Group on Natural Capital featured resources - https://www.greengrowthknowledge.org/working-group/natural-capital

33 Financial capital is part of the economic capital.

b. Satellite Image Interpretation and Mapping

The objective of the satellite image interpretation was to produce mangrove status and land use maps for mangrove lands in the Ayeyarwady Region. Planet Earth images were analyzed for producing maps (Planet team 2017). The results were validated by Google Earth and Spot 5 images. A semi-supervised image classification approach was used.

The nature of land uses in areas of high-density population and agriculture and aquaculture production, like the coastal region of the Ayeyarwady Region, is complex. Thus, only semi-automatic classification was used for analyzing satellite images. Manual digitalizing was used for most of the ponds given that it was not possible to auto-classify pond walls as they are also used for agricultural land and/or other purposes.

c. Mangrove Data Collection

Several field campaigns to collect data from the mangroves in the Ayeyarwady Region were conducted. Overall, more than 670 plots were established on mangroves and adjacent land uses to evaluate mangrove status, biomass, and soil carbon. Plots were located inside and outside mangrove aquaculture ponds and in natural and planted mangroves. Data collection identified characteristics such as tree species, tree diameter, height, biomass, understory vegetation, and regeneration. Plot coordinates were recorded with a hand-held GPS, and 4 photos were taken from the center of the plot at cardinal directions. Soil core samples were collected from over 300 plots in mangroves and alternative land uses for analyses of soil carbon to determine the impacts of land use change on soil carbon and other soil properties. The plot level data were also used for satellite image interpretation and for producing mangrove forest status and land use maps for the study area.

d. Mangrove Forest Growth and Carbon Sequestration

The mangrove forest growth data from permanent sample plots in mangroves in Myanmar are not available. Due to several limitations, tree ring analyses were also not possible. Thus, the growth and dynamics of mangroves were based on measured plantations where information on the date of planting and other silviculture practices were known. Basal area, biomass, mean annual increment of basal area (MAI), were calculated from surveyed plantations.

To estimate growth rates of natural mangroves, the analysis assumed that natural mangrove stands have a similar growth rate as plantations if they have a similar basal area (which is a common assumption demonstrated in terrestrial forests).

e. Socio-Economic, Fuelwood, Crab Catching, Mangrove Aquaculture, Nipa Palm, and Rice Farming

Surveys were used to collect data related to livelihoods, land tenure, jobs[34], and rights over ecosystem-based land. Interviews with stakeholders in the study area followed the guidance from 'The practical guidelines for socio-economic surveys' by CIFOR – CIRAD (Liswanti, Shantiko et al. 2013). Detailed questions regarding fuelwood harvesting, crab catching, mangrove aquaculture activities, nipa palm, and rice farming were also developed. This socio-economic research was approved by the Australian Human Research Ethics Committee at The University of Queensland (No. 2018000480).

For modeling the economic dynamics from extractive and productive systems of the selected products (fuelwood, mud crabs, shrimp, nipa palm, and rice), the study followed the principles and methodology of a cost benefit analysis to establish a baseline. From the baseline, improvement in production yields considering the interventions proposed were applied based on observations and project practices monitored by The University of Queensland in Myanmar. Conservative assumptions were applied for modeling operational and capital cost growth rates (e.g. 1% increase per year due to inflation) as well as for the income growth rate (i.e. no increase or decrease on income prices, increase based only on yield improvement).

34 Considering limitations of the study, only direct jobs were assessed. Indirect and induced jobs were not part of the scope of this study.

f. Mangrove Accessibility to Communities – an Approach to Scaling-up

The mangrove lands of reserve forests and national park are under the direct management of the Forest Department, but people can access these areas for crab catching freely and they also collect fuelwood, although this is not officially permitted. Individuals from thirty-six villages in Pyapon, Bogale, and Labutta were surveyed to investigate fuelwood collection effort from mangroves, and 20 villages were assessed to gather data on crab catching activities from mangrove land. Most of these villages were within the village tracts where government managed mangroves were highly accessible, which was designated as where the ratio of government managed mangrove land area to the village tract area was more than 30% (i.e. parts of village tract are within the 2 km buffer zone[35] of mangrove land around reserve forests or national park). The livelihood surveys from these village tracts were considered as villages where people receive the maximum (100%) of benefits from mangrove lands. The study used this estimate of people's access to government managed mangrove land as an approach to scale up data from surveyed villages to all villages in the delta. Different levels of benefits (defined below) as a function of the accessibility of government managed mangrove land were estimated.

The benefits for fuelwood and crab catching from mangrove land were defined as below as a function of accessibility to government managed mangrove.

i. Values of Fuelwood and Mud Crab Catching in Mangroves and Mangrove Land in the Delta

The benefits assumed for villages with different ratios of accessible mangrove land managed by the Government were estimated as follows:

- 1% - 10% ratio of mangrove land to village tract area assumed to receive 25% of the maximum benefit from mangrove for fuelwood and crab catching
- 10% - 20% ratio of mangrove land to village tract area assumed to receive 50% benefit from mangrove for fuelwood and crab catching
- 20% - 30% ratio of mangrove land to village tract area assumed to receive 75% benefit from mangrove for fuelwood and crab catching
- More than 30% ratio of mangrove land to village tract area assumed to receive 100% benefit from mangrove for fuelwood and crab catching

35 Based on observation and data collection, villagers, on average, traveled on foot or in small boats a distance of 2 kilometers in order to catch crabs and collect fuelwood. Therefore, a 2 km buffer zone was used to estimate people's access to resources.

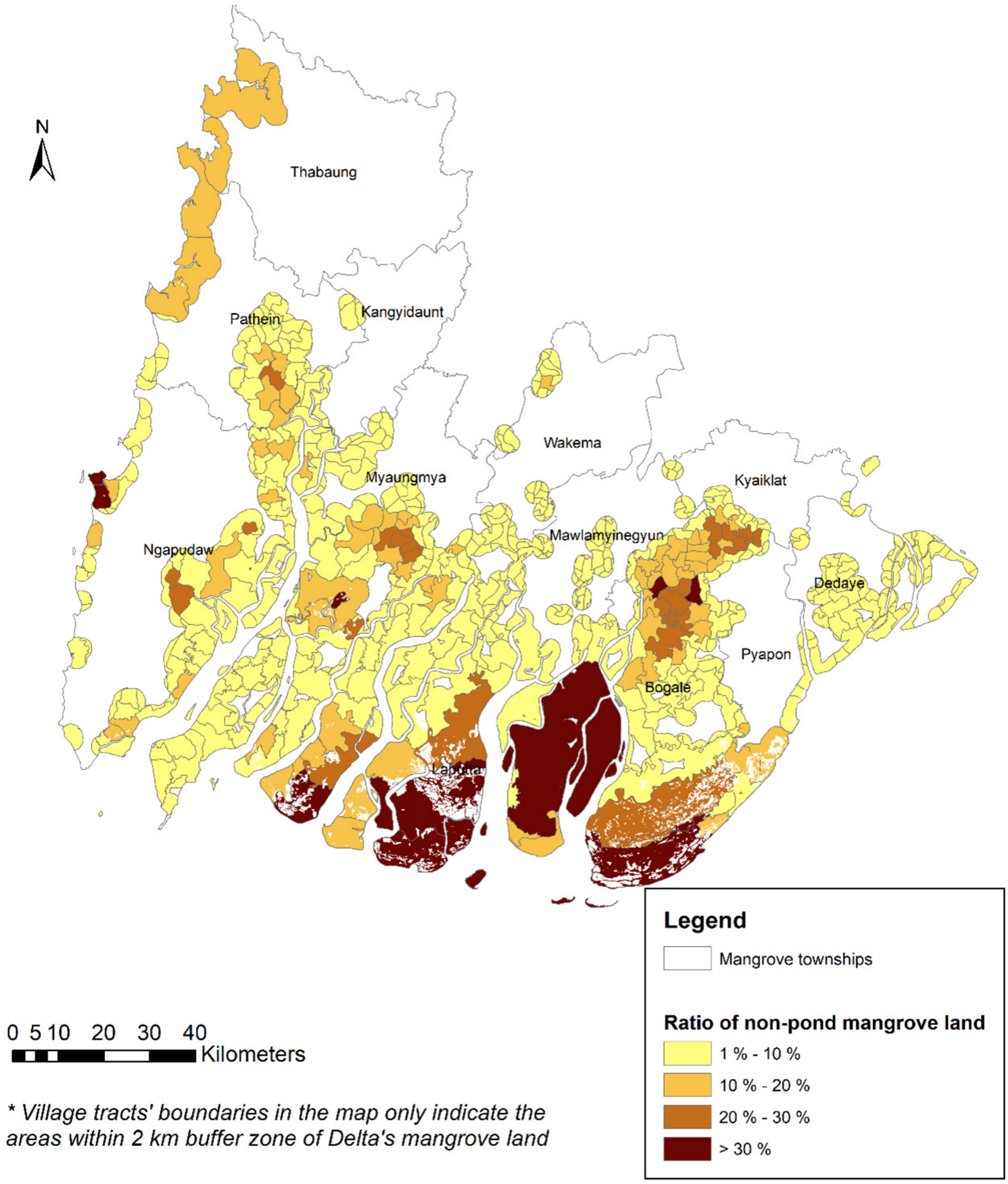


Figure 19. Variation in the ratio of mangrove land area for crab catching to village tract area over the delta.

The number of villages with different levels of access to government managed mangrove land was calculated over the delta and results are presented in Table 30.

Table 31. Number of villages in each category of access to accessible mangrove land for mud crab catching (i.e. reserve forests and national park)[36].

Village location with respect to government managed mangrove land	Number of villages in each category of access to government managed mangrove land				
	0 - 10 %	10 % - 20 %	20 % - 30 %	> 30 %	Sum
Total number of villages within the 2km buffer zone around mangrove land in the Delta	1,535	400	184	158	2,277
Number of villages within the national park, reserve forests, and their 2 km buffer zone. These villages are directly benefited from mangrove resources of reserve forests and national park	128 (Crabs and Fuelwood 25%)	80 (Crabs and Fuelwood 50%)	122 (Crabs and Fuelwood 75%)	128 (Crabs and Fuelwood 100%)	459
Remaining villages (villages within the 2km buffer zone of mangrove land in the Delta but outside the reserve forests, national park, and their 2 km buffer zone)	1407 (Crabs 25%)	320 (Crabs 50%)	61 (Crabs 75%)	30 (Crabs 100%)	1,818

ii. Values of Fuelwood Collection in Government Managed Mangroves Habitat in the Delta

The benefits assumed for villages with different levels of accessibility to mangrove land within **government managed forests** were estimated as follows:

- 1% - 10% ratio of mangrove land to village tract area assumed to receive 25% of the maximum benefit from mangrove for fuelwood
- 10% - 20% ratio of mangrove land to village tract area assumed to receive 50% benefit from mangrove for fuelwood
- 20% - 30% ratio of mangrove land to village tract area assumed to receive 75% benefit from mangrove for fuelwood
- More than 30% ration of mangrove land to village tract area assumed to receive 100% benefit from mangrove for fuelwood

36 Access to government managed mangrove is defined by the area of government managed mangrove to the area of the village tract. Assumed benefit for crab catching and fuelwood collection for each category of village is presented in parentheses.

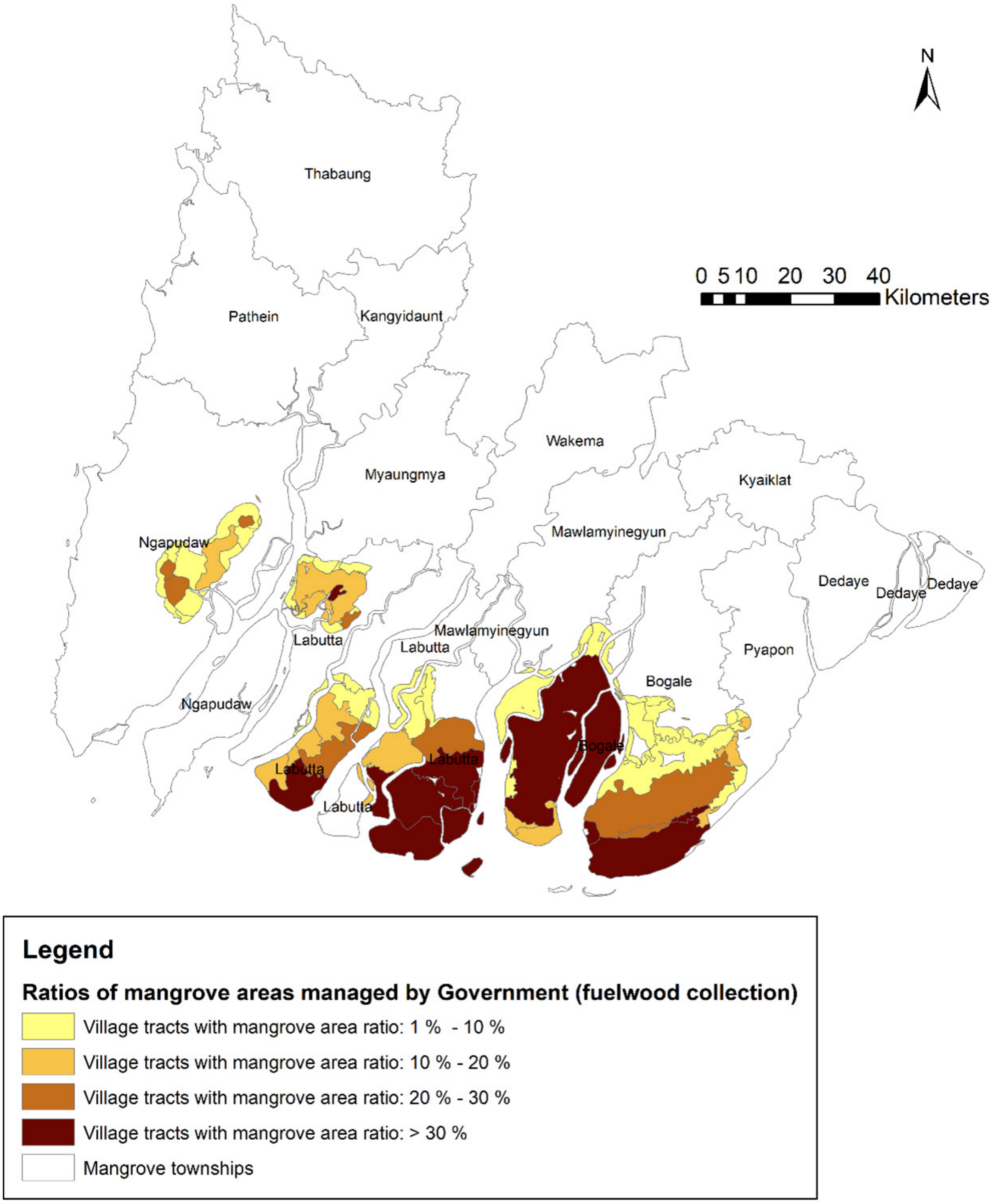


Figure 20. Variation in the ratio of government managed mangrove land area to village tract area over the delta

Table 30 has detailed number of villages which have access to fuelwood collection in government managed mangroves within RFs and NP.

iii. Areas Outside Government Managed Mangroves and their 2 km Buffer Zones

Mangrove land outside reserve forests and national park and the 2 km buffer zones are likely owned by individual households and other economic entities. Thus, the study assumed that people cannot freely enter into these areas for fuelwood collection, but they may still be allowed to catch crabs. Therefore, it was assumed no benefits for fuelwood collection from these areas, but benefits from crab catching:

- 1% - 10% ratio of mangrove land to village tract area assumed to receive 25% benefit from mangrove for crab catching
- 10% - 20% ratio of mangrove land to village tract area assumed to receive 50% benefit from mangrove crab catching
- 20% - 30% ratio of mangrove land to village tract area assumed to receive 75% benefit from mangrove crab catching
- More than 30% ratio of mangrove land to village tract area assumed to receive 100% benefit from mangrove crab catching

g. Coastal and Riverbank Protection

The assessment of coastal protection was not spatially explicit, as sufficient data was not available to derive models with confidence. Therefore, coastal protection service at the landscape level was determined based on secondary data and literature from studies in Myanmar and nearby countries following the recommendations from the WAVES guidelines for measuring and valuing coastal protection services. The storm protection value estimated ranged between US$ 1,120 – 1,369 $ha^{-1}year^{-1}$ based on the results of Barbier (2007) and Estoque et al. (2018), which used an avoided expenditure on physical reclamation and replenishment approach. Considering the high population density in the study area, full values for storm protection were applied throughout.

There is limited information about the value of mangroves for the protection of riverbanks or the role of nipa palm in protecting riverbanks from erosion. Therefore, the riverbank protection value of nipa palm was estimated by remedial costs for riverbank re-vegetation. Bartley et al. (2015) reviewed the impact of riverbank remediation on bank erosion in the United States, Australia, Canada, United Kingdom, and Denmark and found major re-vegetation efforts have reduced the impacts of riverbank erosion (Bartley, Henderson et al. 2015). The cost for active revegetation is 2,790 AUD (2,610 USD – conversion rate in 2013) per hectare, or 3,000 USD per hectare if considering accumulative 15% inflation between 2013 - 2019. This analysis followed the assumption that nipa palm plantations would take 10 years to grow and achieve their full capacity for riverbank protection, which is likely due to the high density of their frond foliage. Thus, the average cost for remediation per hectare per year is 300 USD for nipa palm. Existing nipa palm in the Delta is for thatch harvesting only and not for the extraction of nipa sap and production of sugar or biofuels. The current over-exploitation of nipa fronds (S. Phan, pers. com.) reduces the canopy cover and should have a negative impact on riverbank protection values. Therefore, the study estimated that nipa palm stands used for harvesting thatch would have half of riverbank protection value (i.e. USD 150 per hectare per year).

h. Climate Change and Sea Level Rise (SLR)

Detailed modeling of the impacts of SLR requires accurate digital elevation models as well as knowledge of sediment supply, wave exposure, and vertical and horizontal accretion of shorelines (Minderhoud et al., 2019). Without detailed site level data and modeling, projections of the impact of SLR are likely to have large errors. Therefore, in order to estimate the effects of SLR on the mangroves of the Ayeyarwady Region, the study used recent analyses from global models. The availability of data to parameterize regional spatially explicit models of the impacts of sea level rise limits research on the impacts of climate change on the delta and its mangroves and requires further investment in research.

The model of Schuerch et al. (2018), based on the DIVA model, assessed the impacts of SLR on segments of the global coastline that are 30-50 km in length. DIVA model coastal segments are assigned parameters describing local rates of SLR, the geomorphology, and human population density. This study follows this model, using a SLR scenario of Representative Concentration Pathway 8.5 (0.6 – 0.8 m by 2100, IPCC 2018) and two coastal squeeze scenarios (High coastal squeeze – low adaptation, where landward migration of mangroves is prevented at population densities of 5-20 persons/km^2; and Low coastal squeeze – high adaptation, where landward migration of mangroves is prevented at 300 persons/km^2). Potential proportional annual losses and gains of mangrove land over the delta were used to make first order estimates of the changes in the potential value of mangroves over time with SLR.

ANNEX 2. DESCRIPTION OF IMPACT DRIVERS, IMPACTS, AND IMPACT CONSEQUENCES AND DEPENDENCIES

a. In the BAU Scenario in Areas Within RFs and NP.

Impact Drivers	Expected impact on the study area	Impact consequences and dependencies
Law enforcement on mangrove management	Weak law enforcement; continuous and repeatedly illegal logging of fuelwood and timber from mangroves; and mangrove resources are degraded	• Mangrove forest structure and dynamics are degraded. Dominance of unwanted species which limits recovery of mangroves • Mangrove biomass carbon and timber loss. Mangrove biomass productivity significantly reduced
		• Reduce habitat for wildlife, especially birds and mammals
		• Conflict between meeting the needs of local landless people and the Government's target to maintain and improve mangrove forests • Limited outcome for Government mangrove rehabilitation program because of illegal logging and unregulated management activities
Community Forestry and mangrove aquaculture practices	Intensive fuelwood harvesting for cash and more intensive farming is likely preferred	• Simple forest structure comprised of pioneer, fast growing species. Only young trees remain in the mangrove stands • Extensive aquaculture productivity directly linked to the pond surface area; thus, CF farmers tend to keep less trees and dig more ponds if possible, reducing mangrove area
		• Water levels are kept high most of the time in the ponds resulting in unsuitable hydrological regimes for mangroves
		• Rapid cash return for mangrove aquaculture pond owners from fuelwood and aquaculture contributions to livelihoods
Nipa palm farming practices	Intensive thatch collection for cash	• Reduce riverbank protection capacity • Increase nipa palm mortality • Reduce flowering and sap • Unsustainable nipa palm utilization
Mangrove restoration	Limited mangrove restoration given limited government budget; some unsuitable plantation establishment techniques	• Mangrove restoration achieves only about 2/3 of the target set by the MRRP program • Unsuitable plantation establishment techniques have negative ecological impacts (e.g., burning vegetation before planting)
		• Low investment in capacity building within local Forest Department staff
		• Healthy seedlings from nursery contribute to the higher survival rate of planted trees
Management of village fuelwood plantations (VFP)	Ineffective management due to insufficient capacity building and low investment	• Micro institutional village frameworks are not sufficiently strengthened through capacity building and investment • Illegal logging still occurs in the VFP areas
		• People have free access to mangroves for catching crabs
Sea level rise	Soil acidification and saline water intrusion	• Soil which was previously mangrove land has been acidified and become toxic resulting in low or very low rice productivity • Saline water intrusion in low elevation rice fields. Farmers have no, or little, rice harvest in about 10 % of the rice area. On average, rice yields reduced by 0.4 % per year.

Negative impacts | Mild positive/negative impact | Positive impact expected

b. For Scenario 1 in Areas Within RFs and NP.

Impact Drivers	Expected impact on the study area	Impact consequences and dependencies
Law enforcement	Law enforcement improved for RFs, NP and CFUGs; Less illegal logging of mangroves and reduced thinning time of CF mangroves	• Decreased illegal logging of mangroves helps to recover mangrove areas and their quality • Increased forest quality in mangroves of CFUGs • Increased habitat for fish, crabs, and additional wildlife
		• Reduced illegal logging, at the expense of livelihood losses for fuelwood collectors • Increased disputes between local landless people and Forest Department authorities over mangrove protection
CF mangrove aquaculture practices	Higher compliance with approved CF management plans	• Increased quality of mangroves within the CFUG ponds • Increased value of ecosystem services and timber production of CF mangroves • Increased resilience and sustainability of extensive mangrove aquaculture • Increased income for CF pond owners
		• Decreased crab and shrimp productivity due to increases in the forest canopy resulting in declines of open water surface area
		• Decreased cash return for CF farmers in the first few years when they need income to cover capital and operational investment for the ponds (extreme cash shortage is a major problem for the poor in Myanmar)
Nipa palm farming practices	Higher contribution of Nipa palm on local livelihood and ecosystem services	• Increased riverbank protection of the nipa palm for both sap & thatch (improved management area) • Increased income from nipa palm on the improved management area
		• Increased contribution of nipa palm on local livelihoods (number of local labors needed for sap & thatch) • The remaining nipa palm area for thatch only still have negative impacts as mentioned above
Mangrove restoration	Investment meets MRRP targets	• Achieve mangrove restoration targets set by the MRRP program
		• Unsuitable plantation establishment techniques have negative ecological impacts (e.g. burning vegetation prior to planting)
		• Healthy seedlings from nurseries contribute to the higher survival rate of planted trees
Management of village fuelwood plantations	Higher law enforcement in VFP. Increased area and quality of access to Government managed mangroves	• Micro institutional village frameworks are not sufficiently strengthened through capacity building and investment
		• Illegal logging continues, but less occurs in the VFP areas
		• All people have free access to mangroves for crab catching • Income from crab catching and fuelwood collection in mangroves and VFPs is increased
Sea level rise	Soil acidification and saltwater intrusion	• Soils in areas that were previously mangroves are affected by acidification and become toxic. This results in low or very low rice productivity • Saline water intrusion in low elevation rice field. Farmers have no or little rice harvest from about 10 % of rice area. On average, rice yields reduced by 0.4 % per year.

Negative impacts   Mild positive/negative impact   Positive impact expected

c. For Scenarios 2, 3, and 4 in Areas Within RFs and NP.

Impact Drivers	Expected impact on the study area	Impact consequences and dependencies
Law enforcement	Law enforcement improved for RF, NP, and CFUGs. Less illegal logging from mangroves and reduce thinning time of CF mangroves	• Decreased illegal logging of mangroves leads to recovery of mangrove areas and increased quality • Increased forest quality in CFUGs and VFPs mangroves • Increased habitat for fish, crabs, and additional wildlife, particularly in public RFs and NP mangroves
		• Reduced illegal logging at the expense of livelihoods of fuel-wood collectors, particularly in Scenario 3 • Increased disputes between local landless people and Forest Department authorities over mangrove protection, particularly in Scenario 3.
CF mangrove aqua-culture practices	Forest management plan changed towards more sustainable actions	• Increased quality of mangroves within the CFUGs ponds • Value of ecosystem services and timber production of CF mangroves are improved • Large maternal trees are protected and provide essential habitat for wildlife • Maternal trees provide seeds for natural regeneration • Increased resilience and sustainability of extensive mangrove aquaculture
		• Higher economic return from larger timber size classes to meet the future high demand for logs in the Delta • Decreased crab and shrimp productivity due to the increase in the forest canopy and declines in open water surface area
		• Lower cash return for CF farmers in the first few years when they are in need of income to cover capital and operational investment for the ponds (extreme cash shortage is a major problem for the poor in Myanmar)
Nipa palm farming practices	Higher contribution of Nipa palm on local livelihood and ecosystem services	• Increased riverbank protection of the nipa palm for both sap & thatch (improved management area) • Increased income from nipa palm on the improved management area • Increased contribution of nipa palm on local livelihoods (number of local labors needed for sap & thatch)
		• The remaining nipa palm area for thatch only still have negative impacts as indicated above
Mangrove restoration	Investment meets MRRP targets Potential additional `ditional investors	• Mangrove restoration achieves targets set by the MRRP program • Increased mangrove restoration rate due to increased investment
		• Unsuitable plantation establishment techniques have negative ecological impacts (e.g. burning vegetation prior to planting) in government mangrove rehabilitation projects
		• Healthy seedlings from nurseries contribute to the higher survival rate of planted trees
Micro-institutional strengthen for VFPs	Significant new areas allocated to villages as fuelwood plantations, many new VFPs established Increase area and quality of Government managed mangroves	• Micro institutional village frameworks strengthened through capacity building and investment
		• Illegal logging reduced in the VFP areas
		• People have free access to VFP for crab catching, particularly in Scenario 2 • Creation of additional income for crab catching and fuelwood collection in mangroves and VFPs

Impact Drivers	Expected impact on the study area	Impact consequences and dependencies
Rehabilitation of ponds without mangrove	50% of ponds without mangrove will be restored	• Increased mangrove area for ecosystem services • Increased resilience and sustainability of extensive aquaculture ponds
		• Investment from the government, donors, and pond owners is required
Capacity building	Decreased vulnerability to climate and socioeconomic shocks Aquaculture practices improved	• Resilient ecosystems are more sustainable and provide less volatile income • Decreased impacts of climate and socioeconomic perturbations on ecosystems and communities • Increased income for CF pond owners
Sea level rise	Soil acidification and saline water intrusion	• Soils which were previously mangroves are affected by acidification and become toxic, resulting in low or very low rice productivity • Saline water intrusion in low elevation rice fields. Farmers have no or little rice harvest in about 10% of rice area. On average, rice yields reduced by 0.4% per year.

Negative impacts | Mild positive/negative impact | Positive impact expected

d. In the BAU Scenario in Mangrove land Outside RFs and NP

Impact Drivers	Expected impact on study area	Impact consequences and dependencies
Mangrove management	Intensive fuelwood harvesting for cash. Mangrove resources are degraded	• Mangrove forest structure and dynamics are degraded. Dominance of unwanted species which limits recovery of mangroves • Mangrove biomass carbon and timber loss. Mangrove biomass productivity significantly reduced
		• Reduce habitat for wildlife, especially birds and mammals
		• Reduce habitat/food chain for mud crab
Mangrove aquaculture practices	Intensive fuelwood harvesting in ponds for cash and more intensive farming is likely preferred	• Extensive aquaculture productivity directly linked to the pond surface area; thus, farmers tend to keep less trees and dig more ponds if possible, reducing mangrove area
		• Water levels are kept high most of the time in the ponds resulting in unsuitable hydrological regimes for mangroves
		• Rapid cash return for mangrove aquaculture pond owners from fuelwood and aquaculture contributions to livelihoods
Nipa palm farming practices	Intensive thatch collection for cash	• Reduce riverbank protection capacity • Increase nipa palm mortality • Reduce flowering and sap • Unsustainable nipa palm utilization

Negative impacts | Mild positive/negative impact | Positive impact expected

e. For Scenarios 1, 2, and 3 in Mangrove land Outside RFs and NP.

Impact Drivers	Expected impact on the study area	Impact consequences and dependencies
Mangrove management	Mangrove resources improved by enrichment planting	• Improved mangrove productivity & structure and increased areas • Increased contribution of mangroves on livelihoods of the owners and mud crab catchers
		• Value of ecosystem services and timber production of mangroves are improved
		• Higher economic return from larger timber size classes to meet the future high demand for logs in the Delta
Mangrove aquaculture practices	Ponds and mangroves within ponds are improved	• Increased quality of mangroves within the ponds • Increased value of ecosystem services and timber production of mangroves in ponds • Increased resilience and sustainability of extensive mangrove aquaculture • Increased income for pond owners
		• Increased mud crab productivity due to improving crab habitat and food chain
		• Increased area of extensive aquaculture might impact on the available areas for intensive aquaculture
Nipa palm farming practices	Multiple products silviculture practice	• Increased nipa palm economic values • Increased livelihoods contribution to local communities (create jobs) • Increased riverbank projection value due to nipa palm structure improved
		• More biodiversity because nipa palm is more suitable for flowering and sap
		• Sustainable nipa palm utilization

Negative impacts   Mild positive/negative impact   Positive impact expected

ANNEX 3. RETURN ON INVESTMENT ANALYSIS FOR AREAS WITHIN RESERVE FORESTS AND NATIONAL PARK WITH A DISCOUNT RATE 10%

a. ROI Analysis for Areas Within RFs and NP by 2026 (10% discount rate)

Relevant Actions	BAU	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Aquaculture	Remain in the same condition	Remain in the same condition	Production techniques improved	Production techniques improved	Production techniques improved
Rice	Remain in the same condition	Remain in the same condition	Remain in the same condition	Remain in the same condition	Remain in the same condition
Community Forest User Group (CFUG)	Rate as current practice	Rate as planned by national MRRP plan	25% to 2026	47% to 2026	12.3% to 2026
Village Fuelwood Plantation (VFP)	Rate as current practice	Rate as planned by national MRRP plan	25% to 2026	3% to 2026	37.7% to 2026
Community Forest Management Plan	Thinning 2 years and clear cutting	Thinning 3-5 years, no clear cutting	Thinning 5 years, no clear cutting, and keeping (300) maternal trees	Thinning 5 years, no clear cutting, and keeping (300) maternal trees	Thinning 5 years, no clear cutting, and keeping (300) maternal trees
Law Enforcement	Law enforcement remains the same	Improved enforcement for reducing illegal logging	Forest management is enforced for increasing the area of CF	Forest management is enforced for increasing the area of CF	Forest management is enforced for increasing the area of CF
Restoration effort	300 hectares of successful mangrove plantations annually	1000 ha of successful mangrove rehabilitation under implementation target (under MRRP plan)	1500 ha of successful mangrove rehabilitation under implementation target	1500 ha of successful mangrove rehabilitation under implementation target	1500 ha of successful mangrove rehabilitation under implementation target
Nipa palm farming	100% Nipa palm areas are still for thatch only	10% Nipa palm area for both sap & thatch	25% Nipa palm area for both sap & thatch	50% Nipa palm area for both sap & thatch	75% Nipa palm area for both sap & thatch

Financial Analysis	BAU	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Benefit (monetary)					
Value of fuelwood cutting in Government managed mangrove	124,240	57,945	57,945	57,945	57,945
Value of fuelwood cutting from village fuelwood plantations	10,970	15,241	32,243	7,846	47,774
Value of aquaculture	82,907	97,695	144,611	225,023	93,840
Value of fuelwood cut in mangrove aquaculture ponds	29,347	29,593	43,827	68,224	28,423
Value of clear cutting surplus plantation area annually	0	0	0	0	0
Value of fishing in Government managed mangroves	267,116	275,236	262,725	241,282	276,264
Value of agriculture (rice production)	159,763	159,763	159,763	159,763	159,763
Value of biomass carbon sequestration	4,764	15,077	16,791	15,138	16,360
Value of coastal protection	81,851	137,806	170,721	170,721	170,721
Value of nipa palm area for thatch only	47,637	44,054	39,904	36,154	35,300
Value of nipa palm area for sap & thatch	0	24,561	53,010	78,712	84,566
Value of nipa palm riverbank protection	9,944	10,692	11,558	12,341	12,519

Operational expenditure (OPEX)					
Forest Department staff	2,144	5,398	2,970	2,970	2,970
Mangrove aquaculture pond operational costs	52,208	52,208	77,482	120,800	50,129
Rice cultivation costs annually	89,114	89,114	89,114	89,114	89,114
Mangrove fuelwood collection labor costs	78,936	36,333	36,333	36,333	36,333
Fuelwood collection labor costs for village fuel-wood plantations	6,786	9,459	20,102	4,830	29,824
Fuelwood collection cost for mangrove ponds	18,080	18,232	27,143	42,415	17,498
Fishing labor costs	153,643	158,394	151,072	138,522	158,997
Other operational expenditures (carbon market-ing)	238	754	840	757	818
Operational costs for nipa palm area for thatch only	29,008	26,826	24,299	22,016	21,496
Operational costs for nipa palm area for sap & thatch	0	13,266	28,632	42,515	45,677
Capital expenditure (CAPEX)					
Mangrove restoration by planting *NC*	18,639	30,020	30,020	30,020	30,020
Capacity building (CF & forestry staff) *S&HC*	907	907	1,814	1,814	1,814
Mangrove pond establishment costs *FC*	1,006	686	7,490	19,151	0
Concrete gates for improving aquaculture *FC*	0	906	22,668	40,228	12,401
Financial Analysis for regular discount rate					
NPV Total Benefits	818,538	867,663	993,098	1,073,148	983,476
NPV Operational Expenditures	430,158	409,986	457,988	500,272	452,858
NPV Capital Expenditures	20,552	32,520	61,993	91,213	44,235
Total NPV	*367,828*	*425,157*	*473,117*	*481,663*	*486,383*
BCR	*1.82*	*1.96*	*1.91*	*1.81*	*1.98*
ROI	*18.90*	*14.07*	*8.63*	*6.28*	*12.00*

NPV in million USD					
NPV Total Benefits	585	620	709	767	702
NPV Operational Expenditures	307	293	327	357	323
NPV Capital Expenditures	15	23	44	65	32
Total NPV	*263*	*304*	*338*	*344*	*347*
Other outputs by 2026	**BAU**	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
Social & Human Capital (people involved in community forestry and capacity building)	11,818	15,958	38,656	23,987	48,618
Natural Capital - Good mangrove areas (natural mangroves and plantations which have stocking > 2,000 trees per hectare and tree volume > 50 m^3 per hectare)	8,670	20,570	27,570	27,570	27,570
Cumulative biomass carbon sequestration in Mg (after deduction of fuelwood cutting)	514,730	1,551,682	1,751,711	1,559,072	1,708,755
Green jobs maintained	21,061	30,372	38,124	40,187	43,117
Total number of jobs from livelihoods and restoration activities within RFs and NP maintained	53,092	50,016	57,768	59,830	62,761
CF tree species diversity (Shannon index)	0.195	0.588	0.588	0.588	0.588

b. ROI Analysis for Areas Within Reserve Forests and National Park by 2080 (10% discount rate)

Relevant Actions	BAU	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Aquaculture	Remain in the same condition	Remain in the same condition	Production techniques improved	Production techniques improved	Production techniques improved
Rice	Remain in the same condition	Remain in the same condition	Remain in the same condition	Remain in the same condition	Remain in the same condition
Community Forest User Group (CFUG)	Rate as current practice	Rate as planned by national MRRP plan	25% to 2026	47% to 2026	12.3% to 2026
Village Fuelwood Plantations (VFP)	Rate as current practice	Rate as planned by national MRRP plan	25% to 2026	3% to 2026	37.7% to 2026
Community Forest Management Plan	Thinning 2 years and clear cutting	Thinning 3-5 years, no clear cutting	Thinning 5 years, no clear cutting, and keeping (300) maternal trees	Thinning 5 years, no clear cutting, and keeping (300) maternal trees	Thinning 5 years, no clear cutting, and keeping (300) maternal trees
Law Enforcement	Law enforcement remains the same	Improved enforcement for reducing illegal logging	Forest management is enforced for increasing the area of CF	Forest management is enforced for increasing the area of CF	Forest management is enforced for increasing the area of CF
Restoration effort	300 hectares of successful mangrove plantations annually	1000 ha of successful mangrove rehabilitation under implementation target (under MRRP plan)	1500 ha of successful mangrove rehabilitation under implementation target	1500 ha of successful mangrove rehabilitation under implementation target	1500 ha of successful mangrove rehabilitation under implementation target
Nipa palm farming	100% Nipa palm areas are still for thatch only	10% Nipa palm area for both sap & thatch	25% Nipa palm area for both sap & thatch	50% Nipa palm area for both sap & thatch	75% Nipa palm area for both sap & thatch
Financial Analysis	**BAU**	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
Benefit (monetary)					
Value of fuelwood cutting in Government managed mangrove	220,506	69,060	69,060	69,060	69,060
Value of fuelwood cutting from village fuelwood plantations	33,029	53,034	88,490	14,679	135,479

Value of aquaculture	171,983	198,330	330,043	573,326	175,578
Value of fuelwood cut in mangrove aquaculture ponds	60,878	60,125	100,087	173,899	53,222
Value of clear cutting surplus plantation area annually	0	39,444	177,860	177,528	177,528
Value of fishing in Government managed mangroves	463,517	510,325	475,202	410,326	516,392
Value of agriculture (rice production)	290,398	290,398	290,398	290,398	290,398
Value of biomass carbon sequestration	9,703	40,971	47,092	45,477	46,560
Value of coastal protection	194,950	527,573	682,879	682,879	682,131
Value of nipa palm area for thatch only	89,050	81,326	70,964	56,861	45,654
Value of nipa palm area for sap & thatch	0	52,950	123,982	220,656	297,481
Value of nipa palm riverbank protection	18,589	20,201	22,364	25,308	27,648
Operational expenditure (OPEX)					
Forest Department staff	4,312	11,900	6,138	6,138	6,138
Mangrove aquaculture pond operational costs	112,973	110,239	184,179	321,212	97,160
Rice cultivation costs annually	179,182	179,182	179,182	179,182	179,182
Mangrove fuelwood collection labor costs	149,747	44,075	44,075	44,075	44,075
Fuelwood collection labor costs for village fuelwood plantations	23,009	37,001	60,355	9,720	92,590
Fuelwood collection cost for mangrove ponds	40,930	40,179	67,405	118,041	35,246
Fishing labor costs	283,621	315,614	293,240	251,630	319,668

Other operational expenditures (carbon marketing)	485	2,049	2,355	2,274	2,328
Operational costs for nipa palm area for thatch only	54,227	49,523	43,213	34,625	27,801
Operational costs for nipa palm area for sap & thatch	0	28,600	66,966	119,183	160,679
Capital expenditure (CAPEX)					
Mangrove restoration by planting *NC*	37,477	60,362	60,362	60,362	60,362
Capacity building (CF & forestry staff) *S&HC*	1,824	1,824	3,648	3,648	3,648
Mangrove pond establishment costs *FC*	2,006	1,344	7,490	19,151	0
Concrete gates for improving aquaculture *FC*	0	2,073	22,668	40,228	13,462
Financial Analysis for the regular discount rate					
NPV Total Benefits	1,552,603	1,943,738	2,478,422	2,740,397	2,517,131
NPV Operational Expenditures	848,485	818,361	947,108	1,086,079	964,866
NPV Capital Expenditures	41,307	65,603	94,168	123,389	77,472
Total NPV	*662,810*	*1,059,774*	*1,437,146*	*1,530,929*	*1,474,794*
BCR	*1.74*	*2.20*	*2.38*	*2.27*	*2.41*
ROI	*17.05*	*17.15*	*16.26*	*13.41*	*20.04*

NPV in million USD					
NPV Total Benefits	1,109	1,388	1,770	1,957	1,798
NPV Operational Expenditures	606	585	677	776	689
NPV Capital Expenditures	30	47	67	88	55
Total NPV	*473*	*757*	*1,027*	*1,094*	*1,053*
Other outputs by 2026	**BAU**	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
Social & Human Capital (people involved in community forestry and capacity building)	26,258	33,158	38,656	23,987	52,938
Natural Capital - Good mangrove areas (natural mangroves and plantations which have stocking > 2,000 trees per hectare and tree volume > 50 m^3 per hectare)	24,870	78,000	78,000	78,000	77,683
Cumulative biomass carbon sequestration in Mg (after deduction of fuelwood cutting)	5,308,275	32,295,812	34,435,492	34,248,037	34,161,216
Green jobs maintained	12,802	43,447	53,124	55,187	59,245
Total number of jobs from livelihoods and restoration activities within RFs and NP maintained	47,447	60,988	70,665	72,728	76,786
CF tree species diversity (Shannon index)	0.195	0.588	0.588	0.588	0.588

ANNEX 4. RETURN ON INVESTMENT ANALYSIS FOR AREAS WITHIN RESERVE FORESTS AND NATIONAL PARK WITH A DISCOUNT RATE OF 4%

a. ROI Analysis for Areas Within RFs and NP by 2026 (4% discount rate)

Relevant Actions	BAU	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Aquaculture	Remain in the same condition	Remain in the same condition	Production techniques improved	Production techniques improved	Production techniques improved
Rice	Remain in the same condition	Remain in the same condition	Remain in the same condition	Remain in the same condition	Remain in the same condition
Community Forest User Group (CFUG)	Rate as current practice	Rate as planned by national MRRP plan	25% to 2026	47% to 2026	12.3% to 2026
Village Fuelwood Plantations (VFP)	Rate as current practice	Rate as planned by national MRRP plan	25% to 2026	3% to 2026	37.7% to 2026
Community forest management plan	Thinning 2 years and clear cutting	Thinning 3-5 years, no clear cutting	Thinning 5 years, no clear cutting, and keeping (300) maternal trees	Thinning 5 years, no clear cutting, and keeping (300) maternal trees	Thinning 5 years, no clear cutting, and keeping (300) maternal trees
Law enforcement	Law enforcement remains the same	Improved enforcement for reducing illegal logging	Forest management is enforced for increasing the area of CF	Forest management is enforced for increasing the area of CF	Forest management is enforced for increasing the area of CF
Restoration effort	300 hectares of successful mangrove plantations annually	1000 ha of successful mangrove rehabilitation under implementation target (under MRRP plan)	1500 ha of successful mangrove rehabilitation under implementation target	1500 ha of successful mangrove rehabilitation under implementation target	1500 ha of successful mangrove rehabilitation under implementation target
Nipa Palm Farming	100% Nipa palm areas are still for thatch only	10% Nipa palm area for both sap & thatch	25% Nipa palm area for both sap & thatch	50% Nipa palm area for both sap & thatch	75% Nipa palm area for both sap & thatch

Financial Analysis	BAU	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Benefit (monetary)					
Value of fuelwood cutting in Government managed mangrove	155,925	67,422	67,422	67,422	67,422
Value of fuelwood cutting from village fuelwood plantations	14,232	20,138	43,665	9,905	65,157
Value of aquaculture	105,120	123,869	188,792	300,066	118,465
Value of fuelwood cut in mangrove. Aquaculture ponds	37,210	37,531	57,229	90,989	35,892
Value of clear cutting surplus plantation area annually	0	0	0	0	0
Value of fishing in Government managed mangroves	335,972	347,197	329,884	300,211	348,638
Value of agriculture (rice production)	201,386	201,386	201,386	201,386	201,386
Value of biomass carbon sequestration	6,043	19,355	21,730	19,442	21,187
Value of coastal protection	104,499	181,930	227,478	227,478	227,478
Value of nipa palm area for thatch only	60,118	55,378	49,680	44,207	42,889
Value of nipa palm area for sap & thatch	0	32,496	71,554	109,070	118,104
Value of nipa palm riverbank protection	12,550	13,539	14,729	15,871	16,146
Operational expenditure (OPEX)					
Forest Department staff	2,714	7,028	3,794	3,794	3,794
Mangrove aquaculture pond operational costs	66,292	66,292	101,297	161,294	63,374

Rice cultivation costs annually	112,789	112,789	112,789	112,789	112,789
Mangrove fuelwood collection labor costs	99,359	42,378	42,378	42,378	42,378
Fuelwood collection labor costs for village fuel-wood plantations	8,829	12,532	27,286	6,115	40,764
Fuelwood collection cost for mangrove ponds	22,990	23,190	35,543	56,714	22,160
Fishing labor costs	193,805	200,385	190,234	172,837	201,232
Other operational expenditures (carbon marketing)	302	968	1,087	972	1,059
Operational costs for nipa palm area for thatch only	36,609	33,722	30,253	26,920	26,117
Operational costs for nipa palm area for sap & thatch	0	17,552	38,648	58,912	63,792
Capital expenditure (CAPEX)					
Mangrove restoration by planting *NC*	23,591	37,996	37,996	37,996	37,996
Capacity building (CF & forestry staff) *S&HC*	1,148	1,148	2,296	2,296	2,296
Mangrove pond establishment costs *FC*	1,273	926	10,102	25,829	0
Concrete gates for improving aquaculture *FC*	0	1,090	25,951	47,600	13,293
Financial Analysis for regular discount rate					
NPV Total Benefits	1,033,055	1,100,243	1,273,550	1,386,048	1,262,765
NPV Operational Expenditures	543,690	516,836	583,308	642,724	577,459
NPV Capital Expenditures	26,012	41,160	76,345	113,721	53,585

Total NPV	*463,354*	*542,246*	*613,896*	*629,602*	*631,721*
BCR	*1.81*	*1.97*	*1.93*	*1.83*	*2.00*
ROI	*18.81*	*14.17*	*9.04*	*6.54*	*12.79*
NPV in million USD					
NPV Total Benefits	738	786	910	990	902
NPV Operational Expenditures	388	369	417	459	412
NPV Capital Expenditures	19	29	55	81	38
Total NPV	*331*	*387*	*438*	*450*	*451*
Other outputs by 2026	**BAU**	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
Social & Human Capital (people involved in community forestry and capacity building)	11,818	15,958	38,656	23,987	48,618
Natural Capital - Good mangrove areas (natural mangroves and plantations which have stocking > 2,000 trees per hectare and tree volume > 50 m^3 per hectare)	8,670	20,570	27,570	27,570	27,570
Cumulative biomass carbon sequestration in Mg (after deduction of fuelwood cutting)	514,730	1,551,682	1,751,711	1,559,072	1,708,755
Green jobs maintained	21,061	30,372	38,124	40,187	43,117
Total number of jobs from livelihoods and restoration activities within RFs and NP maintained	53,092	50,016	57,768	59,830	62,761
CF tree species diversity (Shannon index)	0.195	0.588	0.588	0.588	0.588

b. ROI Analysis for Areas Within RFs and NP by 2080 (4% discount rate)

Relevant Actions	BAU	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Aquaculture	Remain in the same condition	Remain in the same condition	Production techniques improved	Production techniques improved	Production techniques improved
Rice	Remain in the same condition	Remain in the same condition	Remain in the same condition	Remain in the same condition	Remain in the same condition
Community Forest User Group (CFUG)	Rate as current practice	Rate as planned by national MRRP plan	25% to 2026	47% to 2026	12.3% to 2026
Village Fuelwood Plantations (VFP)	Rate as current practice	Rate as planned by national MRRP plan	25% to 2026	3% to 2026	37.7% to 2026
Community forest management plan	Thinning 2 years and clear cutting	Thinning 3-5 years, no clear cutting	Thinning 5 years, no clear cutting, and keeping (300) maternal trees	Thinning 5 years, no clear cutting, and keeping (300) maternal trees	Thinning 5 years, no clear cutting, and keeping (300) maternal trees
Law enforcement	Law enforcement remains the same	Improved enforcement for reducing illegal logging	Forest management is enforced for increasing the area of CF	Forest management is enforced for increasing the area of CF	Forest management is enforced for increasing the area of CF
Restoration effort	300 hectares of successful mangrove plantations annually	1000 ha of successful mangrove rehabilitation under implementation target (under MRRP plan)	1500 ha of successful mangrove rehabilitation under implementation target	1500 ha of successful mangrove rehabilitation under implementation target	1500 ha of successful mangrove rehabilitation under implementation target
Nipa palm farming	100% Nipa palm areas are still for thatch only	10% Nipa palm area for both sap & thatch	25% Nipa palm area for both sap & thatch	50% Nipa palm area for both sap & thatch	75% Nipa palm area for both sap & thatch
Financial Analysis	**BAU**	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
Benefit (monetary)					
Value of fuelwood cutting in Government managed mangrove	477,102	90,934	90,934	90,934	90,934
Value of fuelwood cutting from village fuelwood plantations	105,083	165,809	238,557	33,579	369,047
Value of aquaculture	444,265	481,984	831,297	1,506,905	401,678
Value of fuelwood cut in mangrove aquaculture ponds	157,258	146,183	252,164	457,142	121,818

Value of clear cutting surplus plantation area annually	0	496,580	1,360,048	1,358,697	1,358,697
Value of fishing in Government managed mangroves	959,003	1,159,249	1,066,099	885,937	1,180,664
Value of agriculture (rice production)	638,571	638,571	638,571	638,571	638,571
Value of biomass carbon sequestration	24,532	132,274	147,375	145,153	146,143
Value of coastal protection	574,912	1,919,389	2,322,136	2,322,136	2,316,792
Value of nipa palm area for thatch only	203,612	184,522	157,300	115,954	78,763
Value of nipa palm area for sap & thatch	0	130,860	317,465	600,891	855,837
Value of nipa palm riverbank protection	42,503	46,488	52,171	60,802	68,565
Operational expenditure (OPEX)					
Forest Department staff	10,883	31,534	15,732	15,732	15,732
Mangrove aquaculture pond operational costs	308,497	281,469	486,415	884,674	233,132
Rice cultivation costs annually	452,267	452,267	452,267	452,267	452,267
Mangrove fuelwood collection labor costs	355,431	58,816	58,816	58,816	58,816
Fuelwood collection labor costs for village fuelwood plantations	81,920	128,040	179,006	24,545	277,337
Fuelwood collection cost for mangrove ponds	118,560	108,182	187,297	341,758	89,052
Fishing labor costs	636,816	791,102	726,089	599,158	806,823
Other operational expenditures (carbon marketing)	1,227	6,614	7,369	7,258	7,307
Operational costs for nipa palm area for thatch only	123,989	112,364	95,787	70,610	47,962
Operational costs for nipa palm area for sap & thatch	0	70,682	171,473	324,560	462,264
Capital expenditure (CAPEX)					
Mangrove restoration by planting *NC*	94,595	152,356	152,356	152,356	152,356
Capacity building (CF & forestry staff) *S&HC*	4,604	4,604	9,208	9,208	9,208
Mangrove pond establishment costs *FC*	4,725	2,354	10,102	25,829	0
Concrete gates for improving aquaculture *FC*	0	4,706	25,951	47,600	16,770

Financial Analysis for regular discount rate					
NPV Total Benefits	3,626,842	5,592,845	7,474,118	8,216,702	7,627,509
NPV Operational Expenditures	2,089,588	2,041,069	2,380,250	2,779,377	2,450,693
NPV Capital Expenditures	103,925	164,021	197,618	234,994	178,335
Total NPV	*1,433,329*	*3,387,755*	*4,896,249*	*5,202,331*	*4,998,481*
BCR	*1.65*	*2.54*	*2.90*	*2.73*	*2.90*
ROI	*14.79*	*21.65*	*25.78*	*23.14*	*29.03*
NPV in million USD					
NPV Total Benefits	2,591	3,995	5,339	5,869	5,448
NPV Operational Expenditures	1,493	1,458	1,700	1,985	1,750
NPV Capital Expenditures	74	117	141	168	127
Total NPV	*1,024*	*2,420*	*3,497*	*3,716*	*3,570*
Other outputs by 2026	**BAU**	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
Social & Human Capital (people involved in community forestry and capacity building)	26,258	33,158	38,656	23,987	52,938
Natural Capital - Good mangrove areas (natural mangroves and plantations which have stocking > 2,000 trees per hectare and tree volume > 50 m^3 per hectare)	24,870	78,000	78,000	78,000	77,683
Cumulative biomass carbon sequestration in Mg (after deduction of fuelwood cutting)	5,308,275	32,295,812	34,435,492	34,248,037	34,161,216
Green jobs maintained	12,802	43,447	53,124	55,187	59,245
Total number of jobs from livelihoods and restoration activities within RFs and NP maintained	47,447	60,988	70,665	72,728	76,786
CF tree species diversity (Shannon index)	0.195	0.588	0.588	0.588	0.588

ANNEX 5. RETURN ON INVESTMENT ANALYSIS FOR AREAS OUTSIDE RESERVE FORESTS AND NATIONAL PARK WITH A DISCOUNT RATE OF 10%

a. ROI Analysis for Areas Outside RFs and NP by 2026 (10% discount rate)

Relevant Actions	BAU	Scenario 1	Scenario 2	Scenario 3
Aquaculture	Remain in the same condition	Production techniques improved	Production techniques improved	Production techniques improved
Law enforcement	Law enforcement remains the same	Improved enforcement for sustainable aquaculture	Improved enforcement for sustainable aquaculture	Improved enforcement for sustainable aquaculture
Restoration effort	0 hectare of successful mangrove plantations annually	Annually 5% of mangroves will be improved by enrichment planting and rehabilitation to reach 25% of existing mangrove land outside RFs and NP	Annually 10% of mangroves will be improved by enrichment planting and rehabilitation to reach 50% of existing mangrove land outside RFs and NP	Annually 10% of mangroves will be improved by enrichment planting and rehabilitation to reach 75% of existing mangrove land outside RFs and NP
Nipa palm	Remain in the same condition. Nipa palm for thatch only	Annually 5% of nipa palm will be cultured for both sap & thatch to reach 25% of existing nipa palm areas	Annually 10% of nipa palm will be cultured for both sap & thatch to reach 50% of existing nipa palm areas	Annually 10% of nipa palm will be cultured for both sap & thatch to reach 75% of existing nipa palm areas
Financial Analysis	**BAU**	**Scenario 1**	**Scenario 2**	**Scenario 3**
Benefit (monetary)				
Value of aquaculture	207,351	216,007	220,377	224,747
Value of fuelwood cutting in mangroves (inside and outside ponds)	14,097	17,722	20,328	25,625
Value of fishing in Government managed mangroves (crab-catching)	558,697	569,853	577,871	578,338
Value of biomass carbon sequestration	3,083	9,370	10,565	12,995
Value of timber and fuelwood cutting from surplus plantations	0	0	0	0
Value of nipa palm thatch only	194,170	173,904	159,340	133,373
Value for nipa palm thatch and sap	0	134,347	230,900	403,042
Value of nipa palm riverbank protection	40,533	44,763	47,803	53,224
Operational expenditure (OPEX)				

Law enforcement staff	660	825	990	990
Mangrove aquaculture pond operational costs	130,501	130,501	130,501	130,501
Mangrove fuelwood collection labor costs	2,256	2,836	3,252	4,100
Fishing labor costs in mangroves	279,349	284,927	288,935	289,169
Other operational expenditures	154	468	528	650
Operational costs for nipa palm for thatch only	118,239	105,898	97,029	81,217
Operational costs for nipa palm for sap & thatch	0	75,036	128,963	225,109
Capital expenditure (CAPEX)		**Scenario 1**	**Scenario 2**	**Scenario 3**
Mangrove rehabilitation by enrichment *NC*	0	12,689	24,282	26,202
Capacity building *S&HC*	0	687	1,375	2,062
Pond improvement cost *FC*	0	8,451	15,550	22,649
Financial Analysis for a regular discount rate				
NPV Total Benefits	1,017,931	1,165,967	1,267,184	1,431,344
NPV Operational Expenditures	531,158	600,491	650,199	731,735
NPV Capital Expenditures	0	21,828	41,207	50,913
Total NPV	*486,772*	*543,648*	*575,777*	*648,695*
BCR	*1.92*	*1.87*	*1.83*	*1.83*
ROI	-	*25.91*	*14.97*	*13.74*
NPV in million USD				
NPV Total Benefits	727	833	905	1,022
NPV Operational Expenditures	379	429	464	523
NPV Capital Expenditures	0	16	29	36
Total NPV	*348*	*388*	*411*	*463*
Other outputs by 2026	**BAU**	**Scenario 1**	**Scenario 2**	**Scenario 3**
Social & Human Capital (people involved in capacity building)	0	750	1,500	2,250
Natural Capital - Good mangrove areas	0	13,181	26,362	28,998
Cumulative biomass carbon sequestration in Mg (after deduction of fuelwood cutting)	330,188	1,038,803	1,198,803	1,449,513
Green jobs maintained	47,048	61,208	77,125	91,490
Total number of jobs from livelihoods and restoration activities outside RFs and NP maintained	58,892	73,956	90,777	105,619

b. ROI Analysis for Areas Outside RFs and NP by 2080 (10% discount rate)

Financial Analysis	BAU	Scenario 1	Scenario 2	Scenario 3
Benefit (monetary)				
Value of aquaculture	387,611	414,294	436,690	459,086
Value of fuelwood cutting in mangroves (inside and outside ponds)	26,352	36,795	46,217	58,347
Value of fishing in Government managed mangroves (crab-catching)	1,044,402	1,072,205	1,096,870	1,102,978
Value of biomass carbon sequestration	5,763	19,197	23,520	29,084
Value of timber and fuelwood cutting from surplus plantations	0	47,195	94,390	321,610
Value of nipa palm thatch only	362,973	300,506	243,741	175,573
Value for nipa palm thatch and sap	0	414,105	790,415	1,242,314
Value of nipa palm riverbank protection	75,770	88,809	100,659	114,889
Operational expenditure (OPEX)				
Law enforcement staff	1,327	1,658	1,990	1,990
Mangrove aquaculture pond operational costs	252,156	252,156	252,156	252,156
Mangrove fuelwood collection labor costs	4,216	5,887	7,395	9,336
Fishing labor costs in mangroves	522,201	536,103	548,435	551,489
Other operational expenditures	288	960	1,176	1,454
Operational costs for nipa palm for thatch only	221,031	182,992	148,425	106,915
Operational costs for nipa palm for sap & thatch	0	231,288	441,466	693,863
Capital expenditure (CAPEX)				
Mangrove rehabilitation by enrichment *NC*	0	19,669	38,242	61,420
Capacity building *S&HC*	0	1,382	2,764	4,146
Pond improvement cost *FC*	0	8,451	15,550	22,649
Financial Analysis for regular discount rate				
NPV Total Benefits	1,902,871	2,393,107	2,832,502	3,503,881
NPV Operational Expenditures	1,001,219	1,211,044	1,401,043	1,617,202
NPV Capital Expenditures	0	29,502	56,556	88,215
Total NPV	*901,652*	*1,152,560*	*1,374,903*	*1,798,464*
BCR	*1.90*	*1.93*	*1.94*	*2.05*

ROI	-	*40.07*	*25.31*	*21.39*
NPV in million USD				
NPV Total Benefits	1,359	1,709	2,023	2,503
NPV Operational Expenditures	715	865	1,001	1,155
NPV Capital Expenditures	0	21	40	63
Total NPV	*644*	*823*	*982*	*1,285*
Other outputs by 2026	**BAU**	**Scenario 1**	**Scenario 2**	**Scenario 3**
Social & Human Capital (people involved in community forestry and capacity building)	0	750	1,500	2,250
Natural Capital - Good mangrove areas	0	12,181	24,362	35,000
Cumulative biomass carbon sequestration in Mg (after deduction of fuelwood cutting)	2,558,954	9,189,236	11,927,755	14,796,996
Green jobs maintained	47,048	61,326	75,604	90,065
Total number of jobs from livelihoods and restoration activities outside RFs and NP maintained	58,892	73,978	89,064	104,347

ANNEX 6. RETURN ON INVESTMENT ANALYSIS FOR AREAS OUTSIDE RESERVE FORESTS AND NATIONAL PARK FOR A DISCOUNT RATE OF 4%

a. ROI Analysis for Areas Outside RFs and NP by 2026 (4% discount rate)

Relevant Actions	BAU	Scenario 1	Scenario 2	Scenario 3
Aquaculture	Remain in the same condition	Production techniques improved	Production techniques improved	Production techniques improved
Law enforcement	Law enforcement remains the same	Improved enforcement for sustainable aquaculture	Improved enforcement for sustainable aquaculture	Improved enforcement for sustainable aquaculture
Restoration effort	0 hectares of successful mangrove plantations annually	Annually 5% of mangroves will be improved by enrichment planting and rehabilitation to reach 25% of existing mangrove land outside RFs and NP	Annually 10% of mangroves will be improved by enrichment planting and rehabilitation to reach 50% of existing mangrove land outside RFs and NP	Annually 10% of mangroves will be improved by enrichment planting and rehabilitation to reach 75% of existing mangrove land outside RFs and NP
Nipa palm	Remain in the same condition. Nipa palm for thatch only	Annually 5% of nipa palm will be cultured for both sap & thatch to reach 25% of existing nipa palm areas	Annually 10% of nipa palm will be cultured for both sap & thatch to reach 50% of existing nipa palm areas	Annually 10% of nipa palm will be cultured for both sap & thatch to reach 75% of existing nipa palm areas
Financial Analysis	**BAU**	**Scenario 1**	**Scenario 2**	**Scenario 3**
Benefit (monetary)				
Value of aquaculture	261,679	273,867	280,346	286,826
Value of fuelwood cutting in mangroves (inside and outside ponds)	17,791	22,895	26,658	33,199
Value of fishing in Government managed mangroves (crab-catching)	705,083	720,789	732,372	733,104
Value of biomass carbon sequestration	3,890	12,067	13,794	16,794
Value of timber and fuelwood cutting from surplus plantations	0	0	0	0
Value of nipa palm thatch only	245,045	216,513	195,471	159,449
Value for nipa palm thatch and sap	0	189,146	328,637	567,438
Value of nipa palm riverbank protection	51,153	57,109	61,501	69,021
Operational expenditure (OPEX)				
Law enforcement staff	835	1,044	1,253	1,253
Mangrove aquaculture pond operational costs	164,929	164,929	164,929	164,929

Mangrove fuelwood collection labor costs	2,847	3,663	4,265	5,312
Fishing labor costs in mangroves	352,541	360,395	366,186	366,552
Other operational expenditures	195	603	690	840
Operational costs for nipa palm for thatch only	149,220	131,845	119,032	97,096
Operational costs for nipa palm for sap & thatch	0	105,643	183,552	316,928
Capital expenditure (CAPEX)		**Scenario 1**	**Scenario 2**	**Scenario 3**
Mangrove rehabilitation by enrichment *NC*	0	16,680	32,799	35,806
Capacity building *S&HC*	0	870	1,740	2,610
Pond improvement cost *FC*	0	11,103	21,445	31,786
Financial Analysis for regular discount rate				
NPV Total Benefits	1,284,641	1,492,386	1,638,781	1,865,831
NPV Operational Expenditures	670,566	768,122	839,907	952,909
NPV Capital Expenditures	0	28,653	55,984	70,202
Total NPV	*614,075*	*695,611*	*742,891*	*842,720*
BCR	*1.92*	*1.87*	*1.83*	*1.82*
ROI	-	*25.28*	*14.27*	*13.00*
NPV in million USD				
NPV Total Benefits	918	1,066	1,171	1,333
NPV Operational Expenditures	479	549	600	681
NPV Capital Expenditures	0	20	40	50
Total NPV	*439*	*497*	*531*	*602*
Other outputs by 2026	**BAU**	**Scenario 1**	**Scenario 2**	**Scenario 3**
Social & Human Capital (people involved in community forestry and capacity building)	0	750	1,500	2,250
Natural Capital - Good mangrove areas	0	13,181	26,362	28,998
Cumulative biomass carbon sequestration in Mg (after deduction of fuelwood cutting)	330,188	1,038,803	1,198,803	1,449,513
Green jobs maintained	47,048	61,208	77,125	91,490
Total number of jobs from livelihoods and restoration activities outside RFs and NP maintained	58,892	73,956	90,777	105,619

b. ROI Analysis for Areas Outside RFs and NP by 2080 (4% discount rate)

Relevant Actions	BAU	Scenario 1	Scenario 2	Scenario 3
Aquaculture	Remain in the same condition	Production techniques improved	Production techniques improved	Production techniques improved
Law enforcement	Law enforcement remains the same	Improved enforcement for sustainable aquaculture	Improved enforcement for sustainable aquaculture	Improved enforcement for sustainable aquaculture
Restoration effort	0 hectares of successful mangrove plantations annually	Annually 5% of mangroves will be improved by enrichment planting and rehabilitation to reach 25% of existing mangrove land outside RFs and NP	Annually 10% of mangroves will be improved by enrichment planting and rehabilitation to reach 50% of existing mangrove land outside RFs and NP	Annually 10% of mangroves will be improved by enrichment planting and rehabilitation to reach 75% of existing mangrove land outside RFs and NP
Nipa palm	Remain in the same condition. Nipa palm for thatch only	Annually 5% of nipa palm will be cultured for both sap & thatch to reach 25% of existing nipa palm areas	Annually 10% of nipa palm will be cultured for both sap & thatch to reach 50% of existing nipa palm areas	Annually 10% of nipa palm will be cultured for both sap & thatch to reach 75% of existing nipa palm areas
Financial Analysis	**BAU**	**Scenario 1**	**Scenario 2**	**Scenario 3**
Benefit (monetary)				
Value of aquaculture	886,267	960,914	1,029,852	1,098,790
Value of fuelwood cutting in mangroves (inside and outside ponds)	60,255	88,846	116,098	146,383
Value of fishing in Government managed mangroves (crab-catching)	2,388,009	2,460,199	2,528,266	2,547,030
Value of biomass carbon sequestration	13,176	46,057	58,559	72,452
Value of timber and fuelwood cutting from surplus plantations	0	172,115	344,231	1,172,881
Value of nipa palm thatch only	829,932	655,178	487,915	305,671
Value for nipa palm thatch and sap	0	1,158,482	2,267,309	3,475,445
Value of nipa palm riverbank protection	173,246	209,726	244,641	282,684
Operational expenditure (OPEX)				
Law enforcement staff	3,348	4,186	5,023	5,023
Mangrove aquaculture pond operational costs	601,815	601,815	601,815	601,815
Mangrove fuelwood collection labor costs	9,641	14,215	18,576	23,421
Fishing labor costs in mangroves	1,194,004	1,230,099	1,264,133	1,273,515
Other operational expenditures	659	2,303	2,928	3,623

Operational costs for nipa palm for thatch only	505,384	398,968	297,114	186,137
Operational costs for nipa palm for sap & thatch	0	647,040	1,266,347	1,941,121
Capital expenditure (CAPEX)				
Mangrove rehabilitation by enrichment *NC*	0	43,173	85,785	161,974
Capacity building *S&HC*	0	3,488	6,976	10,464
Pond improvement cost *FC*	0	11,103	21,445	31,786
Financial Analysis for a regular discount rate				
NPV Total Benefits	4,350,885	5,751,516	7,076,870	9,101,335
NPV Operational Expenditures	2,314,851	2,898,627	3,455,935	4,034,654
NPV Capital Expenditures	0	57,764	114,206	204,225
Total NPV	*2,036,033*	*2,795,125*	*3,506,730*	*4,862,456*
BCR	*1.88*	*1.95*	*1.98*	*2.15*
ROI	-	*49.39*	*31.71*	*24.81*
NPV in million USD				
NPV Total Benefits	3,108	4,108	5,055	6,501
NPV Operational Expenditures	1,653	2,070	2,469	2,882
NPV Capital Expenditures	0	41	82	146
Total NPV	*1,454*	*1,997*	*2,505*	*3,473*
Other outputs by 2026	**BAU**	**Scenario 1**	**Scenario 2**	**Scenario 3**
Social & Human Capital (people involved in community forestry and capacity building)	0	750	1,500	2,250
Natural Capital - Good mangrove areas	0	12,181	24,362	35,000
Cumulative biomass carbon sequestration in Mg (after deduction of fuelwood cutting)	2,558,954	9,189,236	11,927,755	14,796,996
Green jobs maintained	47,048	61,326	75,604	90,065
Total number of jobs from livelihoods and restoration activities outside RFs and NP maintained	58,892	73,978	89,064	104,347

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