Public Disclosure Authorized

WORLD BANK GROUP

ISOP INDONESIA Indonesia Sustainable Oceans Program

GPS Global Program on Sustainability

The Economics of Large-scale Mangrove Conservation and Restoration in Indonesia

Pictures by Global Grasshopper, Geographical, Smithsonian

Internal Document

June 2021

Table of Contents

List of Figures

List of Tables

List of Boxes

Abbreviations

COVID-19	Coronavirus Disease 2019
FAO	United National Food and Agriculture Organization
GDP	Gross Domestic Product
GHG	Greenhouse Gases
GOI	Government of Indonesia
GPS	Global Program on Sustainability
IPCC	International Panel on Climate Change
ISOP	Indonesia Sustainable Oceans Program
LAUTRA	Lautan Sejahtera
MoEF	Ministry of Environment and Forestry
NCA	Natural Capital Accounting
NDC	Nationally Determined Contribution
NPV	Net Present Value
NTT	East Nusa Tenggara *(Nusa Tenggara Timur)*
PIPPIB	Indicative Moratorium Map
RPJMN	National Medium-Term Development Plan
RTRW-N	National Spatial Plan
SDG	Sustainable Development Goal
SEEA	System of Environmental-Economic Accounting
SISNERLING	Indonesian System of Environmental-Economic Accounts
SLMP	Sustainable Landscapes Management Program
SNA	System of National Accounts
tCO_2e	Tons of carbon dioxide equivalent
UN	United Nations
USD	United States Dollars
WAVES	Wealth Accounting and the Valuation of Ecosystem Services
KLHK	Ministry of Environment and Forestry
BRGM	Peatland and Mangrove Restoration Agency
KKP	Ministry of Marine Affairs and Fisheries

Acknowledgements

This work was developed by a team led by Juan Pablo Castaneda and Raffaello Cervigni. The report was prepared by Boris van Zanten, Luke Brander, Daniela Gutierrez, Paula Uyttendaele, Diego Herrera, Desta Patrama, and David Kaczan. We are also grateful for the continuous support from Ann Jeannette Glauber and Andre Rodrigues de Aquino, the latter providing the strategic and technical guidance to the overall project, which included several intermediate outputs that fed into this report.

This work will not have been possible without the valuable assistance to this project provided by WRI-Indonesia (Yayasan Institute Sumber Daya Dunia)'s team, including Willy Daeli, Indah Andesta, Aryo S. Sujiwo, Komariah Ervita, Khesyia A. Makhas, and Armyanda Tussadiah. Early support provided by Kim Reuter and Barakalla Robin is acknowledged.

We would like to acknowledge the invaluable contributions of Prof. Michael Beck, Benjamin Brown, Dr. Catalina Jakovac, Dr. Pelayo Menendez, Dr. Mark Spalding and Dr. Bernardo Strassburg, sharing datasets that are the foundation of the current assessment.

Executive Summary

Background

i. **Development in Indonesia has resulted in reduced poverty but has also been accompanied by significant pressure on natural capital, particularly its mangrove ecosystems, which are the most carbon-rich ecosystems on earth.** Representing an estimated 20 percent of global mangrove assets, Indonesia is home to the largest extent of mangrove ecosystems in the world. Current trends of mangrove degradation in Indonesia are severe (Figure 1), with the country facing the largest absolute losses of mangroves annually of any country (Goldberg, et al. 2020). Mangroves face several threats, including pollution, deforestation, and fragmentation (Giri et al., 2011). Expansion of urban areas and agricultural activities such as oil palm and aquaculture will continue to contribute further to these negative trends, which are exacerbated by climate change (Richards & Friess, 2016).

ii. **Mindful of the negative impacts associated with coastal ecosystems degradation, the Government of Indonesia has embarked on a "blue economy" strategy encompassing a range of initiatives, including tackling mangrove degradation and depletion.** A blue or sustainable ocean economy is one that generates economic and social benefits without compromising long-term environmental sustainability, thus estimating the net benefits of different interventions is at the core of the decision-making process to realize a blue economy. The Government recognizes that achieving a blue economy in Indonesia will require policy reforms in a range of areas, including marine and coastal management; strengthened data and monitoring systems, and new sources of financing and policy coordination.

iii. **Recently, the Government of Indonesia has set an ambitious target for mangrove restoration of 600,000 hectares by 2025** (World Bank, 2020b). How this target can be reached and the implications of the actions to be taken are subject to national debate. This study seeks to inform the ongoing policy dialogue, with a particular focus on the need to consider spatial variations when making investment allocations towards achieving the stated goal and more generally when making management decisions. The target set by Government is closely related to the total amount of mangrove lost since 1990, much of which can be explained by changes occurred in Sumatra and Kalimantan. The regional variations on these losses are shown in Figure 1a where Sumatra, Kalimantan, Java, and Sulawesi show the highest rates of degradation, well above the national average. Of these areas, the regions with the highest remaining mangrove cover in the country are Sumatra and Kalimantan (Figure 1b). The region with the highest mangrove cover and one of the lowest degradation rate is Papua with almost half of current mangrove cover of the whole country (Figure 1b).

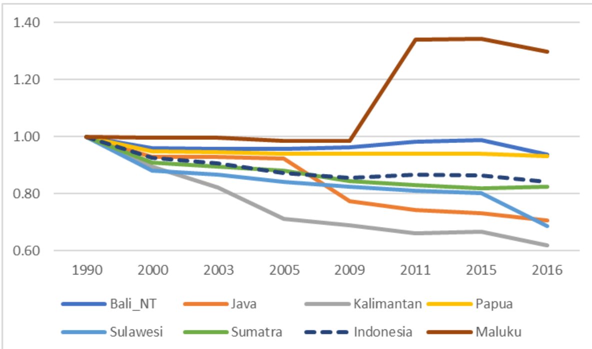
iv. **The objective of this report is to inform sustainable mangrove management policies in Indonesia through quantification of the values and spatial variations of the net benefits of mangrove conservation and restoration.** The report compares the costs and benefits of mangrove restoration and conservation using a nation-wide spatial cost-benefit analysis (CBA). [1] The analysis is spatially explicit, meaning that variation in costs and benefits by location are assessed, helping to identify cost-effective locations for large-scale mangrove restoration and conservation. The results of this assessment should help the Government, the private sector, and other stakeholders across Indonesia better understand the costs and benefits of mangrove management decisions.

---

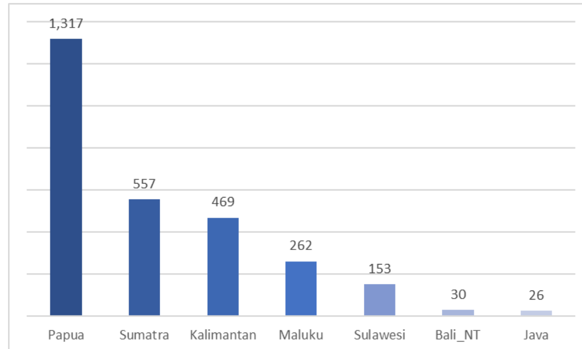
[1] **Spatial CBA includes:** the identification of the benefits (or ecosystem services), the identification of costs (including the opportunity costs of alternative uses of land) and the valuation of these costs and benefits. Valuation was conducted either using value transfer or market prices. For further details on the methods applied please refer to Annex 1, Methods Technical Report.

Figure 1. Trends of mangrove degradation and regional distribution of mangrove cover

(a) Index of mangrove cover change, 1990-2016 (Mangrove cover in 1990 equals one)



(b) Regional distribution of mangrove cover in 2016 (thousand hectares)



Source: Own elaboration based on KLHK maps.
Notes: Total mangrove cover for Indonesia equals 2.8 thousand hectares in 2016. Maluku is an outlier, however the figures here are changes, which in the case of Maluku represent only 60 thousand hectares since 1990. The big jump between 2009 and 2011 is probably due to the changes in methodologies. Years shown in the figure are based on the adjustments made. Figures adjusted as per standardization developed in the Indonesia pilot natural capital accounts (See Annex 2, Natural Capital Pilot Accounts Technical Reports)

v. **The main audience of the report comprises those stakeholders that participate in seeking sustainable mangrove management opportunities.** These include decision-makers and influencers that play an active role in the public debate on coastal and mangrove management. More specifically this work contributes to the development of a national-level implementation strategy for mangrove restoration and conservation in Indonesia providing new information that can inform decision-making. The main findings and related policy messages are particularly useful for Government officials from the Ministry of Marine Affairs and Fisheries (KKP), Ministry of Environment and Forestry (KLHK), Peat and Mangrove Restoration Agency (BRGM), Ministry of Finance (KEMENKEU), and other line ministries that are part of the decision-making process. In addition, the report's innovative methodological application is an important contribution to knowledge and decision-making and useful for future policymaking and research and thus relevant for think tanks, universities and NGOs working on coastal management.

vi. **Responding to an urgent request by the Government of Indonesia (GoI) to inform its mangrove restoration strategy, the study adds value through its novel rapid methodological approach.** The study brings new elements to the policy dialogue in Indonesia which are of general application for natural capital management decisions. The study uses a spatially explicit cost-benefit analysis approach, which allows to identify not only the net benefits of the interventions, but also the regional differences. This is of course informative for the decision-making process on the more suitable areas to invest. Furthermore the valuation approach used, amidst limitations outlined in the report, is a contribution to the broader discussion on the institutionalization of environmental valuation in policy, which is becoming an increasingly important part of environmental policy in Indonesia (Phelps et al, 2017).[2]

[2] The approach used in this report compares the costs and benefits of conservation and restoration (Figure 6). A spatial database was compiled with all cost and benefit components. Initially a set of relevant ecosystem services where identified and a selection of appropriate datasets and valuation methods was made. Information to be used had to fulfill a set of minimum criteria, including to: (1) be comprehensive enough to include the whole of Indonesia, (2) be susceptible to measurement at least at province level, and, (3) be publicly and readily available. As show in Figure 6, the values of costs and benefits had a different track, but the ultimate goal was to conduct a cost-benefit analysis and obtain the cost-benefit ratios for each district prone to mangrove management investments

Main Findings

vii. **Mangroves provide an important set of valuable ecosystem services that contribute to human wellbeing in Indonesia.** These services include provisioning (e.g., timber, fuel wood, and charcoal), regulating (e.g., climate regulation including carbon sequestration, flood, storm and erosion control; prevention of salt water intrusion), habitat (e.g., breeding, spawning and nursery habitat for commercial fish species; biodiversity), and cultural services (e.g., recreation, aesthetic, non-use) (Spaninks and Beukering, 1997, UNEP, 2006, TEEB, 2010). In this report not all services were well-captured within the proposed methods, but the most prominent were likely included. These services are grouped in five major groups as shown in Table 1, with coastal protection (i.e. flood control, storm attenuation, and erosion prevention) and climate regulation (i.e. carbon sequestration) with the highest present values per hectare, USD 6,760 and USD 2,798 respectively. As shown in Table 1, the estimations are highly sensitive to coastal protection values and as expected Bali and Java, which have a more developed coastal infrastructure, mangroves show the highest values. Beyond coastal protection, overall values are more equally distributed across Indonesia, but there are still regional differences as shown, with fisheries support services (i.e. habitat, biodiversity and provision of fish values) highly relevant for Sulawesi and less relevant for Papua possibly due to a higher coastal population with higher dependency on fish stocks.

Table 1. Value of Mangroves' Provision of Ecosystem Services by Location

(Combined present value per hectare by region)

Ecosystem Services	Bali_NT	Java	Kalimantan	Maluku	Papua	Sulawesi	Sumatra	Average
(a) Coastal Protection	39,970	6,219	66	49	1	685	331	6,760
(b) Climate Regulation	2,798	2,798	2,798	2,798	2,798	2,798	2,798	2,798
(c) Fisheries support services	2,912	3,928	2,733	3,348	1,183	6,256	2,662	3,289
(d) Raw materials provision	1,138	1,535	1,068	1,309	462	2,445	1,040	1,286
(e) Cultural services	1,894	2,344	469	112	438	294	640	885
Total	**48,713**	**16,823**	**7,134**	**7,616**	**4,882**	**12,478**	**7,471**	**15,017**

Source: Own elaboration

Notes: The net present value of benefits is based on a 30-year project lifetime and assuming that mangroves are a 30-year coastal infrastructure asset. A discount rate of 5.5% is applied plus a sensitivity analysis with a 0% and 10% discount rate was used in the analysis. The discount rate was selected based on discussions with the Government of Indonesia.

viii. **Coastal protection** (Table 1 – item a)**.** Mangroves play an important role in reducing flood risk and erosion by attenuating storm surge and dissipating wave energy, thereby avoiding damages for coastal communities and assets. The coastal protection values for mangroves used in this report are based on avoided expected damages due to the presence of mangroves. High annual per hectare values of coastal protection are found in mangroves located in more developed and more populated areas, such as in Java and Bali. In these areas, there are more properties exposed to coastal flooding, and hence there is a higher coastal protection value of mangroves. In many of these areas, annual mangrove coastal protection benefits exceed 10,000 USD per hectare per year.

ix. **Climate regulation** (Table 1 – item b). Mangroves play an important role in regulating climate by sequestering carbon within soils and to a lesser extent in forest biomass, as well as exchanging carbon dioxide with and emitting methane to the atmosphere. Avoiding mangrove loss in Indonesia could potentially reduce carbon releases of about 0.19 Petagrams of CO2e/year to 0.96 Petagrams of CO2e/year

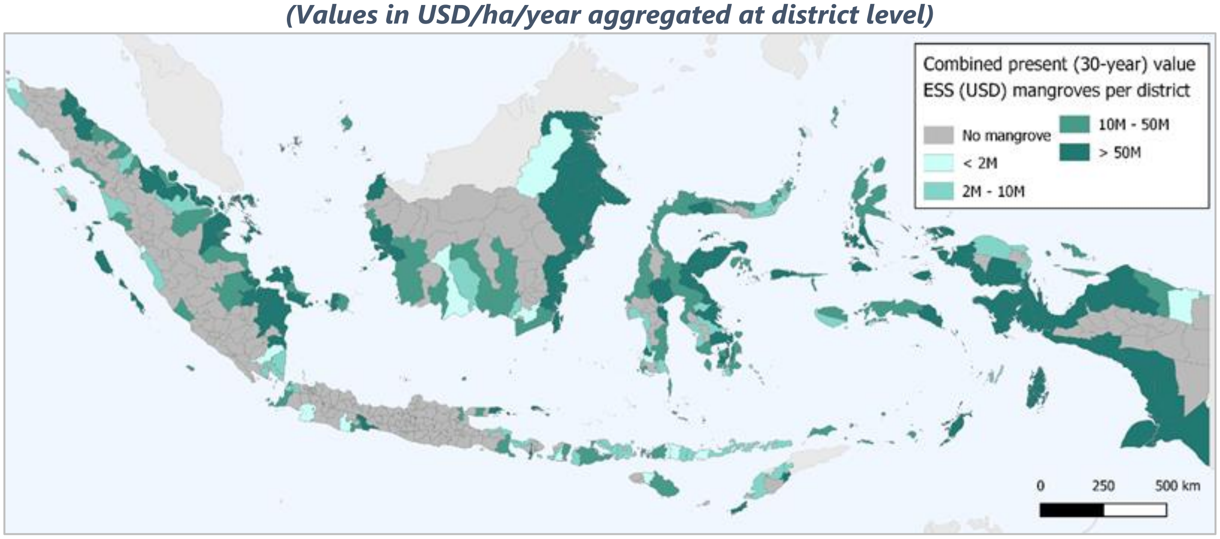
and obtain values per hectare. The steps were not necessarily sequential, and some feedback loops allowed to control for the quality of the data used.

(Mudyarso et al, 2015) with an average present value of 2,798 USD per hectare (Table 1).[3] This is equivalent to 20-25 percent of total carbon stored worldwide in on year (Hamilton and Friess, 2018).

x. **Fisheries support services and raw materials provision** (Table 1 – item c, and d). Mangroves harbor significant biodiversity and play a key role as a habitat and nursing ground for species that are commercially fished/harvested, and they provide firewood and timber to coastal communities. The United Nations Food and Agriculture Organization (FAO) estimated that in Indonesia, 55% of the total fish catch biomass consists of mangrove-dependent species with a total annual production value of 825M USD. In this study, the benefits of mangrove-dependent fisheries are assessed in a spatially explicit way with a value function using a meta-regression. Essentially, this approach predicts the value of provisioning services of a mangrove patch by refining and scaling the mean ecosystem services value estimate from a large database of pre-existing valuation studies based on the characteristics of the location (Brander et al., 2012). For Indonesia as a whole, the mean value of fisheries services per hectare of mangrove is estimated to be 220 USD/ha/year, while firewood and timber extraction is estimated to be 170 USD/ha/year.

xi. **Mangroves provide opportunities for wildlife viewing and support other tourist attractions such as coral reefs and sandy beaches** (Table 1 – item e). This study applied a unit value transfer method (i.e., extrapolation from other studies) to estimate the value of tourism services provided by mangrove tourism locations identified through geographic content from TripAdvisor. The median per hectare value of mangrove-related tourism in Southeast Asia is 553 USD per year. In total, 319 mangrove tourist sites were identified in Indonesia with a mangrove extent in its direct vicinity of 53,925 ha. The estimated value of tourism at these sites is just under USD 30 million per year.

Figure 2. Spatial distribution of ecosystem services provided by mangroves (Values in USD/ha/year aggregated at district level)



Source: Own elaboration (See Annex A1, Methods Report)

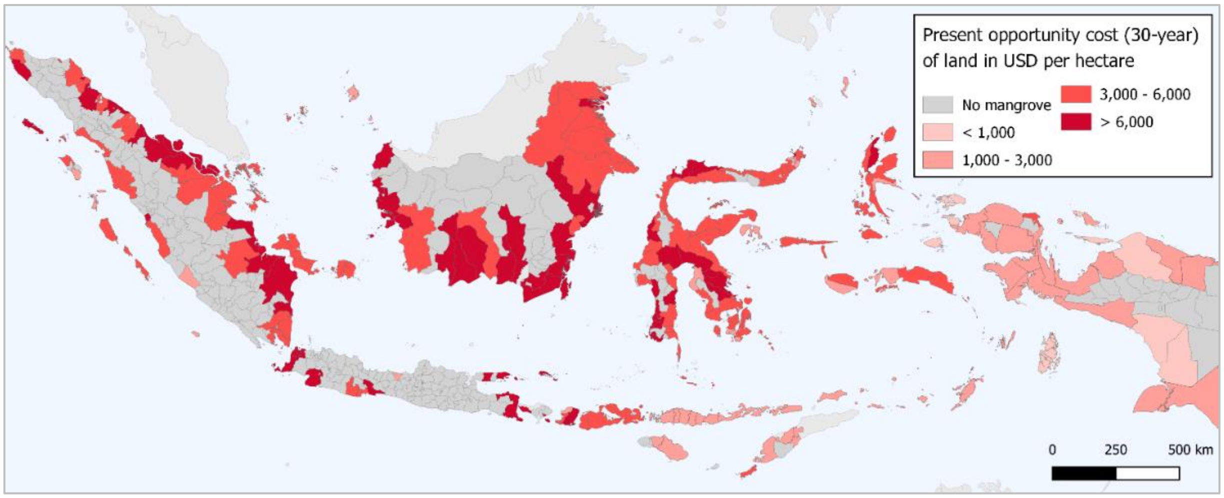
xii. **The costs to restore mangroves in Indonesia are similar to the median global cost estimates.** Median global costs of mangrove restoration ranges from USD 1,000 to USD 9,000 per hectare (Bayraktarov et al., 2016; Narayan et al., 2016). The cost is a function of the technique applied for mangrove restoration, for example, with low costs reflecting basic revegetation and higher costs reflecting degrees of habitat and/or hydrological restoration. The estimated costs[4] for one hectare of mangrove restoration in Indonesia is about

[3] Petagram of carbon (Pg), also known as a Gigaton (Gt), is equal to 10^15 grams or one billion tonnes. A tonne, also known as a metric ton, is equal to one thousand kilograms (1,000 kg).
[4] Costs were largely estimated using Government data.

US$ 3,900 including procurement of 10,000 mangrove seeds, planting facilities and infrastructure, and mangrove planting. These estimates are limited to the basic revegetation techniques and do not account for broader restoration activities, which are often associated with higher rates of mangrove survival.

xiii. **Given the importance of agriculture for mangrove conversion, opportunity costs of alternative land uses are important variables to consider in the cost assessment.** Given the limited availability of data on aquaculture productivity for most mangrove-supporting countries, opportunity costs were estimated based on agriculture and pasture commodities (adapted from Jakovac et al., 2020). On average, opportunity costs are 3,400 USD per hectare for a 30-year project lifetime assuming a 5.5% discount rate.[5]

Figure 3. Spatial distribution of opportunity cost of alternative land uses



Source: Own elaboration based on Strassburg (2020); Jakovac et al. (2020) (See Annex A1, Methods Report)

xiv. **Spatially explicit cost-benefit analysis provides insights as to where mangrove restoration and conservation could be expected to be economically viable in Indonesia**. Viability is defined as a cost-benefit ratio higher than 1, i.e. positive net benefits. Through a spatial overlay of cost and benefit information, cost-benefit indicators are calculated per district, including net present value (NPV) and benefit-to-cost ratios. Figure 4 shows the benefit-cost ratio of mangrove restoration and mangrove conservation at district level. Considering a discount rate of 5.5% over a 30-year period, the benefit-cost ratio of a hectare of mangrove restoration is >1 in most districts, indicating a positive net present value of the investment. A few highlights on the general results:

- In areas such as Eastern Sumatra and large parts of Kalimantan, where land opportunity costs are comparatively high and site-specific benefits such as coastal flood protection, fisheries and tourism are limited, the benefit-cost ratio of mangrove restoration is <1 indicating a negative net present value.
- In districts with low opportunity costs and high site-specific benefits, such as NTT and Western Papua, benefit-cost ratios of above 2 and in some districts above 5 are found. These results suggest that restoration has a stronger economic return in areas where land values/opportunity costs are low, or where values/opportunity costs are high, but are offset by the high benefits of mangrove protection to existing coastal assets .
- The main differences between the costs and benefits of restoration and conservation lie in the i) restoration cost of 3,900 USD per hectare, ii) an assumed 20-year time period for mangroves to be fully

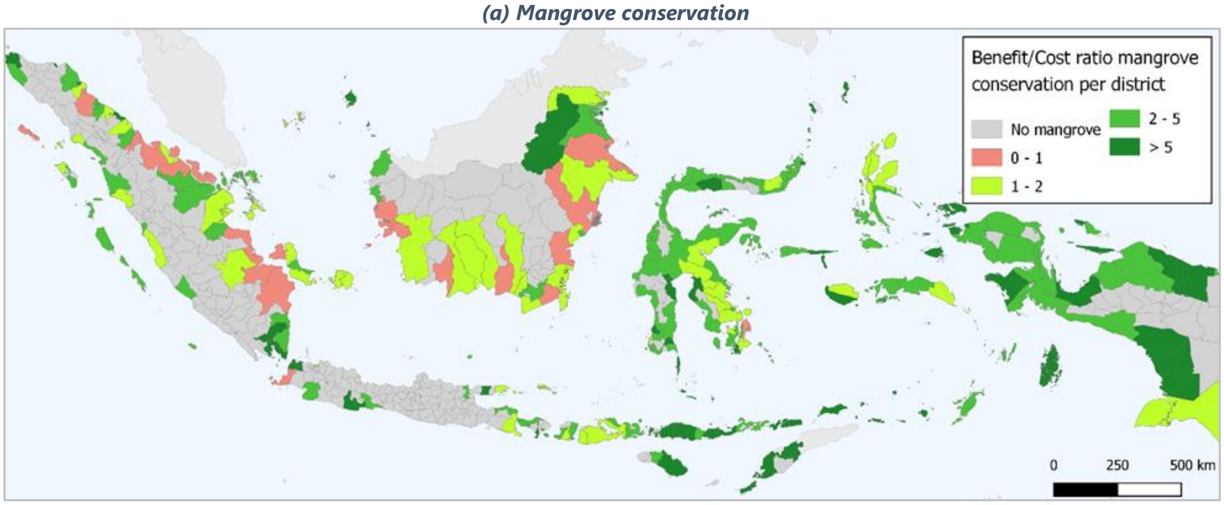
[5] The choice of discount rate is discussed in Annex 1, Methods Technical Report.

rehabilitated and providing benefits after initial restoration action, iii) and a higher potentially monetizable value of greenhouse gas reduction for restoration vs. conservation.

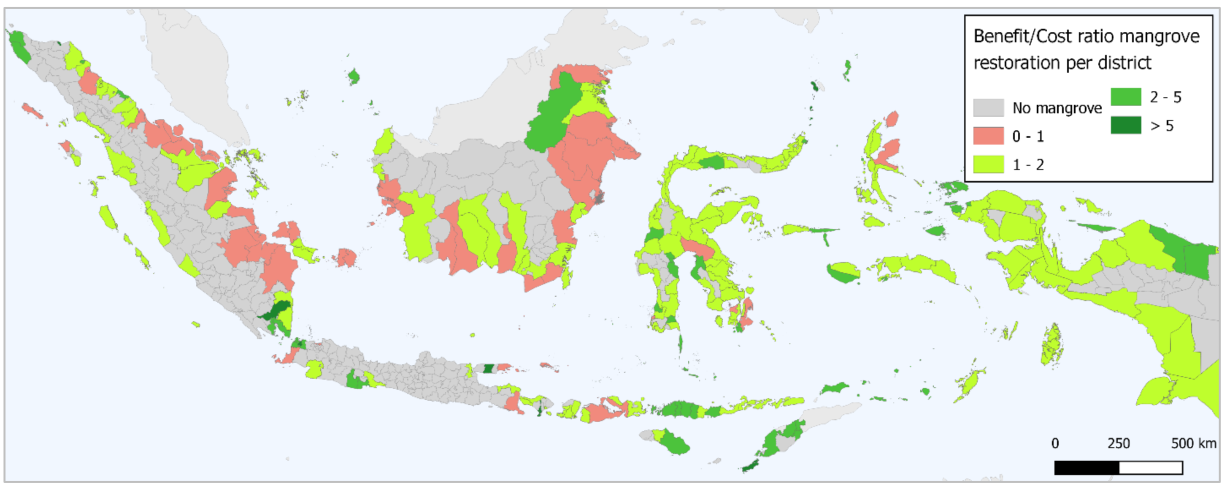
- Tourism benefits of mangroves are among the highest. These, however, only apply for mangroves identified as having feasible tourism activity, i.e. those activities that are close to tourism spots in which mangrove are part of the landscapes (Spalding & Parret, 2019).

Figure 4. Spatial distribution of benefit-cost ratios for mangrove conservation and restoration

(a) Mangrove conservation



(b) Mangrove restoration



Source: Own elaboration based on Strassburg (2020); Jakovac et al. (2020)

xv. **Importantly, mangrove conservation is the cheapest and most effective mechanism to ensure long-term environmental service provision**. It is significantly more cost-effective in economic and environmental terms to conserve existing mangroves than it is to restore them. Mangrove conservation has a higher benefit-cost ratio due to the steep initial costs for restoration and the time it takes restored mangroves to deliver ecosystem services. Also, the rate of success of restoration projects is highly dependent on the quality of monitoring, maintenance, and enforcement. Especially in areas with low opportunity cost, such as Maluku, Papua and NTT and some districts in Sulawesi. A few highlights of the results include:

- Parts of Kalimantan and Eastern Sumatra have benefit-cost ratios <1 for conservation, indicating a negative NPV on average across those districts, meaning that in those areas in particular restoration is a good alternative.
- The combined quantified present value of mangrove benefits from under 2M USD to over 50M USD per district in Indonesia. This value represents the combined per hectare conservation value of coastal flood protection, reduced greenhouse gas emissions, tourism, fisheries, and firewood/timber multiplied by the mangrove extent per district.
- While the combined present benefits of mangrove that are considered in this assessment reach up to more than 50,000 USD per hectare in some areas, high land opportunity cost, with a present value of over 6,000 USD per hectare, is found in Southern Kalimantan, Eastern Sumatra and parts of Java and Sulawesi, suggesting that there is a strong rationale for prioritizing conservation efforts in these areas. Given opportunity costs are so high, there is a need to put in place effective incentive/disincentive as alternatives to land conversion, for example in the form of subsidies, taxes, or conversion moratoria.

Key Findings and Messages

xvi. **There is a need to consider mangrove restoration within the broader policy context of the Government of Indonesia's blue economy strategy, seen in the targets under the medium-term development plan (RPJMN) for 2020-24, and the Indonesia Oceans Policy.** This broader suite of actions include: (i) improved fisheries governance through operationalization of the Fishery Management Area (WPP) system, (ii) development, integration, and implementation of spatial plans, (iii) expansion of marine protected areas, (iv) a national action plan for marine debris, and (v) an integrated and sustainable tourism development program. Sustainable mangrove management however requires actions on the ground that could potentially mobilize high investments at high returns. Mangrove conservation and restoration activities offer an opportunity for that. The main findings of this study (outlined succinctly in Box 1) could help guide the Government of Indonesia in designing an efficient set of investments for sustainable mangrove management.

Box 1. Findings from the study relevant for the policy dialogue in Indonesia

A. The value of ecosystem services provided by mangroves varies substantially across regions, suggesting the need to better target restoration and conservation investments:

- The highest combined values of ecosystem services are found in Papua, Kalimantan, Sumatra, and Sulawesi
- Coastal protection services are particularly high in Java, Northern Sumatra, Bali, Lombok, and parts Nusa Tenggara Timur
- High values of supporting fisheries services are found in Java, Nusa Tenggara Timur, Sulawesi and Southern Sumatra
- Mangrove climate regulation services present an opportunity to contribute to national emissions reductions targets and generate income through carbon markets in almost all districts with mangrove patches in 2018

B. Costs of restoration in Indonesia are close to the median global estimates and thus lessons from global implementation experiences can be useful to inform investment decisions

C. Opportunity costs of land vary across regions with implications on the policy tools to be used for sustainable management

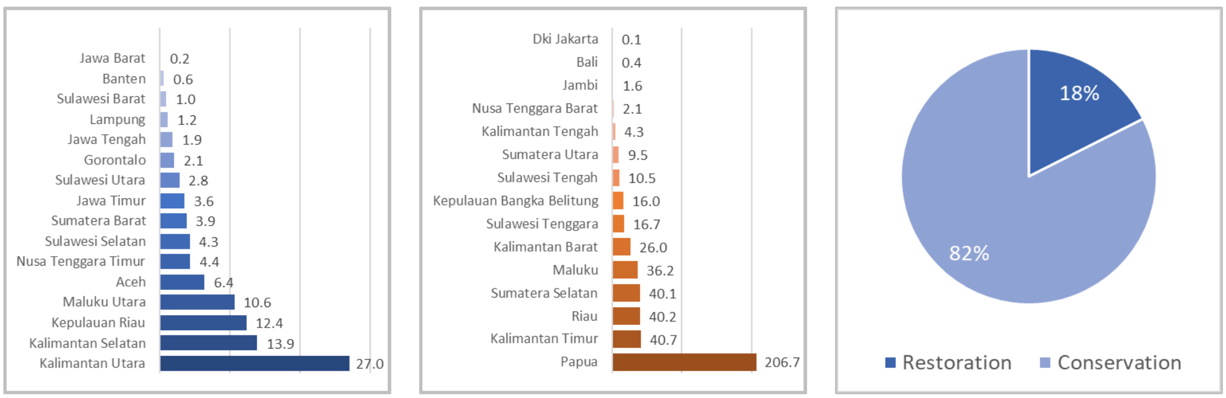
D. Conservation in general is a significantly more efficient than restoration, but regional differences need to be considered when making investment decisions.

E. An optimal mix of conservation and restoration activities could potentially lead to better mangrove management, as opposed to an isolated restoration target. Based on the study, a 20/80 investment ratio of restoration/conservation activities will be an economically efficient way to reach the 600 thousand hectares Government target. These figures should guide future policy dialogue and should be considered a first estimate of many that could potentially be derived from the methodologies applied.

xvii. **Stemming from the findings of the study the key policy message is that an efficient mix of mangrove restoration and conservation activities could help inform decisions of the Government of Indonesia's goal to restore 600,000 ha of mangroves or more importantly, manage mangroves sustainably**. The spatial cost-benefit analysis helps determine the appropriate areas where these activities will have higher returns. The possible scenario presented Figure 5, includes almost 20% of restoration activities and the rest of investments, more than 80%, intended to conservation actions. This scenario is one of the many that could be constructed using the tool available that was created for the purpose of this study. The tool itself could be an instrument for dialogue and the definition of other plausible scenarios is possible. In this case an expert judgement provides a baseline where the benefit-cost ratio is the single indicator of reference, however as described before, the rates of degradation and the contribution to total cover play a role when defining future scenarios. In general, any scenario will probably usually produce a higher allocation for conservation activities.[6]

Figure 5. Location and distribution of investments on mangrove sustainable management

(a) Restoration (100,000 ha) *(b) Conservation (500,000 ha)* *(c) National distribution of investments*



Source: Own elaboration

xviii. **This possible mix of investments** (as provided in Figure 5) **will require a combination of policy approaches or enabling actions that will make the investments have the expected results, including**:

a) **Ensure restoration practices and financing includes adequate provisions for long-term management and monitoring.** Data show that the success of restoration activities depends on the adequacy of the habitat to be restored (e.g. appropriate hydrology), the materials used (quality of seedlings), the medium-term management (e.g. tending, protection), and long-term operational

[6] **It is important for the reader to understand that the study has certain limitations and thus these numbers are informative of policy dialogue but should be analyzed in the context of the methods and data used.** In principle, methods are available but the lack of data and quantitative knowledge regarding some key ecological relationships affirm the need for further inquiry, however by using standardized approaches such as natural capital accounting, this study manages to overcome some of these limitations. The basic steps outlined above are conceptually straightforward, but many complications invariably arise in practice. First, it is often difficult to confirm the internal validity of value estimates that are reported in existing nonmarket valuation studies and might be used for benefit transfers. Another potential threat to the validity of primary valuation estimates that might be used for benefit transfers is publication bias, which occurs when the outcome of a study influences the researchers' choice of whether to submit the report for publication or the editors' choice of whether to accept it. Determining the suitability of candidate study cases for transfer to the policy cases is also subject to discussion and here expert judgement plays a big role. Incomplete reporting or lack of access to primary information could deviate the results of the study. The team did a good effort to consult with experts and follow best practices. None of these observations are meant to diminish the importance of this or other meta-analyses of nonmarket valuation studies. The team strongly support making the best possible use of the relevant information that happens to be available, whether it was collected in an experimental or an observational setting, but caveat in their policy use should be considered up front.

oversight. Efforts focused on replanting alone do not show high rates of long-term success. This will probably require prioritizing adequately areas for restoration (e.g. those that provide the highest benefit in terms of net benefits). Restoration can provide significant environmental and economic benefits but should be done in areas where it provides maximum value in terms of benefit-cost ratios. These areas are tentatively outlined in Figure 5.

b) **Promote restoration methodologies that maximize labor utilization, especially as part of the COVID recovery stimulus investments.** Expand labor-intensive coastal and marine restoration activities, including mangrove restoration and coastal cleanups, to provide short-term employment during the post-COVID recession while providing long-term and resilient rehabilitation of mangrove benefits. This is consistent with the findings of this study and aligned with the findings of the High-Level Panel on Oceans which recommended coastal ecosystems restoration as a top-five blue economic stimulus for the post-COVID recovery.

c) **Strengthening the evidence base for improved enforcement and mangrove management**. This could include finalizing the Mangrove OneMap to ensure an accepted and consistent whole-of-Government understanding of the extent, quality and trends in mangroves and adjacent coastal ecosystems. Development of a credible and reliable valuation and accounting system could potentially also offer opportunities to better bridge improved data and policy decision making. Building on improved data, natural capital accounting supports marine and coastal policies by providing standardized data on the status and economic values of natural assets and how these assets are affected by human activity. Indonesia began building NCA through the Indonesian System of Environmental-Economic Accounts (SISNERLING) and could continue to include marine and coastal assets including mangroves.

d) **Inclusion of mangroves in the national REDD+ framework and nationally determined contribution (NDC).** Indonesia would need to develop blue carbon readiness to ensure Indonesia can benefit from international blue carbon financing, including carbon accounting, monitoring and verification tools. Likewise, inclusion of mangroves as nature-based solutions of coastal adaptation and resilience in NDCs, Indonesia could come up with targets for coastal adaptation and resilience using nature-based and hybrid solutions through protecting, managing, or enhancing mangroves.

e) **Complementary policies should be explored, including for example implementing a mangrove moratorium**. Indonesia has a moratorium on land conversion for Indonesia's primary forests and peatlands. Despite their immense value, including higher carbon sequestration value per hectare, there is no equivalent protection for mangroves. Indonesia could expand the scope of the license issuance moratorium in primary forest and peatlands to include mangroves. Such an achievement could be done through issuance of legislation, thereby demonstrating Indonesia's commitment to achieving climate targets and realization of a blue economy.

1. Background

1.1. Introduction

1. **Development in Indonesia in the 21st Century has resulted in reduced poverty, largely driven by a natural capital-intensive productive structure**.[7] For instance, Indonesia's ocean resources, including coastal and marine ecosystems, contribute to over US$280 billion annually to economic activities, or the equivalent to more than a quarter of GDP (World Bank, 2021). This substantial contribution to the economy comes from "blue sectors", including (among others) capture fisheries and aquaculture, coastal tourism, marine construction, and transportation. In the context of a blue economy (i.e. one that generates economic and social benefits while ensuring ocean's long-term environmental sustainability), blue sectors are recognized by Government, private sector, and the public as an opportunity for development in Indonesia. However, inadequate management and underinvestment, with the resulting degradation of ocean resources, particularly mangroves,[8] threaten the prospects of future economic growth.

2. **Representing an estimated 20 percent of the world's mangroves, Indonesia is home to the largest extent of mangrove ecosystems in the world, contributing to at least USD 1.5 billion annually to the national economy** (World Bank, 2020). With more than 17,500 islands, 108,000 kilometers of coastline, and three-quarters of its territory at sea, mangrove ecosystems, are central to Indonesia's prosperity (Ministry of Maritime Affairs and Investment, 2021). Mangroves serve as nursery grounds for species that are essential for Indonesia's commercial fish catch and food security. In addition, mangroves provide livelihood for coastal communities and shoreline protection from climate-related and other disasters such as storms and tsunamis and reduce risks from flood and erosion. At the same time mangroves store significant amounts of carbon.

3. **Current trends of ecosystem degradation are likely to threatens their economic and ecological value, including the livelihoods of Indonesia's coastal communities who are dependent on them.** Ecosystems are showing substantial losses due to land conversion mainly caused by clearing for aquaculture and palm oil, and coastal development for urban expansion (World Bank, 2020). About 52 thousand hectares are lost every year and in addition, 1.8 million of the country's 3.5 million hectares of mangrove are already in a degraded condition (MMAF and MoEF, 2019). In Java, Sulawesi and part of Kalimantan mangroves conversion were mostly triggered by fisheries and aquaculture. In the Western part of Indonesia, covering Sumatra and some part of Kalimantan islands, mangroves are largely converted into oil palm and pulp wood plantations.

1.2. Objective and Audience

4. **The objective of this report is to inform sustainable mangrove management policies in Indonesia through quantification of the values and spatial variations of the net benefits of mangrove conservation and restoration.** The report compares the costs and benefits of mangrove restoration and

[7] Indonesia is the world's largest exporter of steam coal, refined tin and, until recently, nickel ore. It is also a leading exporter of gold, bauxite, lead, zinc, and copper. Its potential in renewable resources is also huge. It has become the world's number one palm oil producer and exporter. In addition, it is the second-largest producer of rubber, Robusta coffee and fisheries products, and holds 40% of the world's geothermal energy reserves. Indonesia's top five exports are all commodities. Refer to Dutu (2015) for additional information on natural resource dependency and the economic structure of Indonesia.

[8] The term mangrove is loosely used to describe a wide variety of trees and shrubs (around 80 species), that share characteristics of being adapted to conditions of high salinity, low oxygen and changing water levels (Saenger et al., 1983). The mangrove biome dominates tropical and sub-tropical coastlines between latitudes 32°N and 38°S and covers approximately 22 million hectares. Around 28% of global mangroves are located in Southeast Asia with Indonesia alone accounting for 25%.

conservation using a nation-wide spatial cost-benefit analysis (CBA). [9] The analysis is spatially explicit, meaning that variation in costs and benefits by location are assessed, helping to identify cost-effective locations for large-scale mangrove restoration and conservation. The results of this assessment should help the Government, the private sector, and other stakeholders across Indonesia better understand the costs and benefits of mangrove management decisions.

5. **The main audience of the report comprises those stakeholders that participate in seeking sustainable mangrove management opportunities.** These include decision-makers and influencers that play an active role in the public debate on coastal and mangrove management. More specifically this work contributes to the development of a national-level implementation strategy for mangrove restoration and conservation in Indonesia by bringing new information to the table. The main findings and related policy messages are particularly useful for Government officials from the Ministry of Marine Affairs and Fisheries (KKP), Ministry of Environment and Forestry (KLHK), Peat and Mangrove Restoration Agency (BRGM), Ministry of Finance (KEMENKEU), and other line ministries that are part of the decision-making process. In addition, the report's innovative methodological application is an important contribution to knowledge and decision-making and useful for future policymaking and research and thus relevant for think tanks, universities and NGOs working on coastal management.

    1. **Responding to an urgent request by the Government of Indonesia (GoI) to inform its mangrove restoration strategy, the study adds value through its novel rapid methodological approach.** The study brings new elements to the policy dialogue in Indonesia which are of general application for natural capital management decisions. The study uses a spatially explicit cost-benefit analysis approach, which allows to identify not only the net benefits of the interventions, but also the regional differences. This is of course informative for the decision-making process on the more suitable areas to invest. Furthermore the valuation approach used, amidst limitations outlined in the report, is a contribution to the broader discussion on the institutionalization of environmental valuation in policy, which is becoming an increasingly important part of environmental policy in Indonesia (Phelps et al, 2017).[10]

    6. **The next three sections that follow this one describes: the methodology applied (Section 2), the key findings (Section 3) and the main policy messages (Section 4).**

[9] **Spatial CBA includes:** the identification of the benefits (or ecosystem services), the identification of costs (including the opportunity costs of alternative uses of land) and the valuation of these costs and benefits. Valuation was conducted either using value transfer or market prices. For further details on the methods applied please refer to Annex 1, Methods Technical Report.

[10] The approach used in this report compares the costs and benefits of conservation and restoration (Figure 6). A spatial database was compiled with all cost and benefit components. Initially a set of relevant ecosystem services where identified and a selection of appropriate datasets and valuation methods was made. Information to be used had to fulfill a set of minimum criteria, including to: (1) be comprehensive enough to include the whole of Indonesia, (2) be susceptible to measurement at least at province level, and, (3) be publicly and readily available. As show in Figure 6, the values of costs and benefits had a different track, but the ultimate goal was to conduct a cost-benefit analysis and obtain the cost-benefit ratios for each district prone to mangrove management investments and obtain values per hectare. The steps were not necessarily sequential, and some feedback loops allowed to control for the quality of the data used.

2. Methods and data

2.1. Overview of the Analytical Framework

7. **This study uses a national-level spatial cost-benefit analysis (CBA) to measure the net benefits of alternative sustainable mangrove management policies.** CBA, also called benefit-cost analysis (BCA) was created as a technique for evaluating investments in the private sector and then spread to the field of public decision making as a tool to support the economic and financial feasibility analysis of a single project, a program or even an economic policy instrument (Koopmans and Oosterhaven, 2010). It is an investment evaluation technique, based on the assumption that all the benefits and costs related to a project can be evaluated in monetary terms and based on the principle of the "intertemporal discount of values".

8. **The spatial dimension was added to the CBA used in this study, providing an innovative application seldom see in these types of analysis**. With the introduction of Geographic Information Systems (GIS) in the late 20th Century and with that, spatial CBA started to be widely used due to the ability of these new technologies to process and correlate spatial data with monetary information on costs and benefits. Analysis has mostly been concerned with the application of Spatial CBA as an ex post evaluation to assess damages after disasters strike and the costs of remediation. Ex-post studies conducted in recent years are in the field of flood risk mitigation from but there are still gaps to fill in Ex-ante evaluation of ecosystems' sustainable management options (Torrieri and Rossitti, 2021).

9. **The policies analyzed are mainly conservation and restoration activities as these are the two main areas in which the Government of Indonesia is focusing**. The Government has a higher interest in restoration due to its apparent higher returns in the short term, including rapid mobilization of employment opportunities, however, as shown in the results this is report, restoration is seldom the best bet in terms of mangrove sustainable management. By comparing the costs and benefits of both restoration and conservation activities, the report shows the need for seeking an appropriate mix of activities which is highly dependent on the location of the intervention and thus the spatial dimension is critical in the analysis.

10. **The approach used in this report compares the costs and benefits of conservation and restoration** (Figure 6). A spatial database was compiled with all cost and benefit components. Initially a set of relevant ecosystem services where identified and a selection of appropriate datasets and valuation methods was made. Information to be used had to fulfill a set of minimum criteria, including to: (1) be comprehensive enough to include the whole of Indonesia, (2) be susceptible to measurement at least at province level, and, (3) be publicly and readily available. As show in Figure 6, the values of costs and benefits had a different track, but the ultimate goal was to conduct a cost-benefit analysis and obtain the cost-benefit ratios for each district prone to mangrove management investments and obtain values per hectare. The steps were not necessarily sequential, and some feedback loops allowed to control for the quality of the data used.

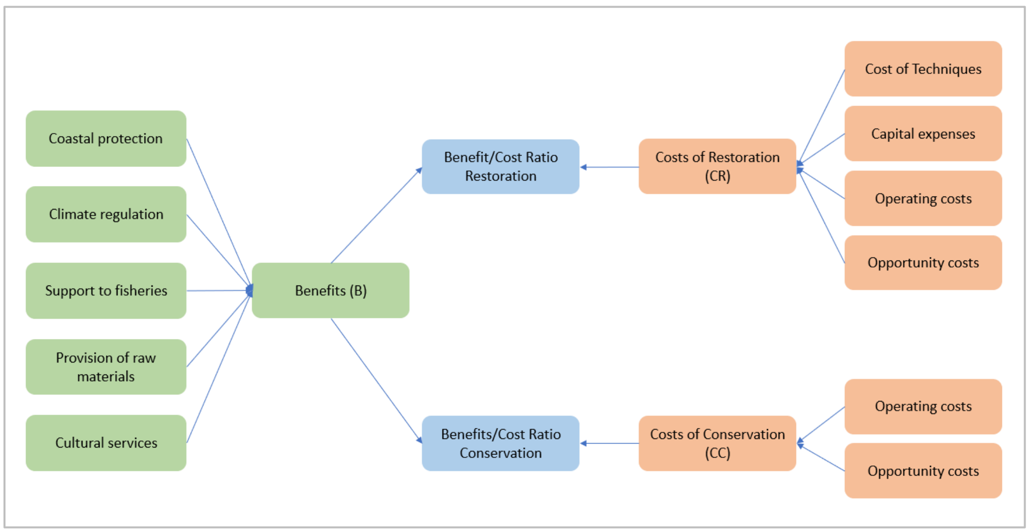
11. **The benefit components were measured as the value of key ecosystem services (broadly defined as the benefits to society).** The benefit components included with information obtained from state-of-the-art academic valuation studies of ecosystem services such the coastal flood protection value (Menendez et al., 2020), nature-based tourism (Spalding & Parret, 2019), and blue carbon (Jakovac et al., 2020; Strassburg et al., 2020). For the valuation of provisioning ecosystem services provided by mangroves, such as the catch of mangrove dependent fish species and the extraction of raw materials, regression-based value transfer was conducted by the study team utilizing and summarizing the findings of the numerous site-specific valuation studies of mangrove ecosystem services that have been conducted in the region. The approach is described in Brander et al. (2012). **The cost components considered are the expected costs of mangrove**

restoration and conservation, and the opportunity cost of land. These costs include the actual cost of implementing the techniques to be used, the capital expenses and the operating costs.

12. **Benefit-cost ratios of mangrove restoration and mangrove conservation are calculated at district level.** The net present value of costs and benefits of mangrove restoration and conservation is based on a 30-year project lifetime and assuming that mangroves are a 30-year coastal infrastructure asset. A discount rate of 5.5% is applied plus a sensitivity analysis with a 0% and 10% discount rate in the scenario analysis. The discount rate was selected based on discussions with the Government of Indonesia. A benefit-cost ratio of a hectare of mangrove restoration or conservation higher than 1 indicates a positive net present value of the investment.

13. **The values of costs and benefits represent the weighted mean values per hectare for the whole country**. The main differences between the costs and benefits of restoration and conservation lie in the i) restoration cost per hectare, ii) an assumed 20-year time period for mangroves to be fully rehabilitated and providing benefits after restoration, iii) and a higher potentially monetizable value of greenhouse gas reduction for restoration vs. conservation. Tourism benefits of mangroves are among the highest. These, however, only apply for mangrove tourism sites as identified by Spalding & Parret (2019). Additional information on the cost-benefit analysis are provided in Section 3 of the Methods Annex.

Figure 6. Framework for the spatial economic analysis of mangrove restoration and conservation



Source: own elaboration

2.2. Benefits Assessment

14. **Mangroves provide a number valuable ecosystem services that contribute to human wellbeing.** These benefits to different populations include provisioning (e.g., timber, fuel wood, and charcoal), regulating (e.g., flood, storm and erosion control; prevention of salt water intrusion), habitat (e.g., breeding, spawning and nursery habitat for commercial fish species; biodiversity), and cultural services (e.g., recreation, aesthetic, non-use) (Spaninks and Beukering, 1997, UNEP, 2006, TEEB, 2010).

15. **Mangrove ecosystem services are many, but those susceptible to measurement are coastal protection, climate regulation support services to fisheries, provision of raw materials and cultural services.** Data sources are described in Table 2 with an indication in which section of the Methods Annex for the reader to get additional details on the specific methods and estimations that were made. It is important to point out that not all ecosystem services where included, only those that were susceptible to monetary valuation within the framework and criteria previously described.

- **Coastal protection.** Mangroves protect coastal communities and assets against storm surges, coastal erosion, and rising seas. By building a living seawall they can slow or halt erosion, diminish wave energy, and temper the flooding driven by storm surges. The case for mangrove restoration is straightforward regarding coastal protection: beside offering protection from rising seas and storms surges, the cost of restoration is two to five times cheaper than building engineered structures like underwater breakers (Beck et al, 2019).
- **Climate regulation.** Mangroves are one of the most effective ecosystems at capturing and storing carbon dioxide from the atmosphere, carbon sequestration and storage. They capture carbon dioxide from the atmosphere (known as blue carbon) and store it in their biomass and in rich organic soils, where it remains stable (Worthington et al., 2019).
- **Support to fisheries.** Mangroves support capture fisheries by re-generating fish stocks, by providing nursing grounds, and habitat. A significant proportion of commercial fish species and other marine fauna found in Indonesian coastal waters depend on or are associated with mangroves and for some or all their life cycle. About 55% of the total biomass of fish landings in Indonesia consists of mangrove dependent species (FAO, 2014).
- **Provision of raw materials.** Mangroves provide raw materials that can be used by surrounding communities. Villagers can extract timber using sustainable practices which in the long-term ensure the availability of the ecosystems. Also, wood extracted from mangroves can be used as fuel for cooking in the coastal communities. Non-timber forest products, fodder, food, fish and meat can also be provided by mangrove ecosystems
- **Cultural services.** Mangroves provide opportunities for wildlife viewing and grow close to other tourist attractions such as coral reefs and sandy beaches (IUCN, 2017).

16. **The use of value transfer to provide information for decision making has several advantages over conducting primary research to estimate ecosystem values.** As shown in Table 2, the preferred methodology in most cases is to apply a value transfer. Value transfer is the procedure of estimating the value of an ecosystem (or goods and services from an ecosystem) by applying an existing valuation estimate for a similar ecosystem (Navrud and Ready, 2007). This procedure is also known as benefit transfer but since the values being transferred may also be estimates of costs or damages, the term value transfer is arguably more appropriate (Brouwer, 2000). From a practical point of view, it is generally less expensive and time consuming than conducting primary research. Value transfer can also be applied on a scale that would be unfeasible for primary research in terms of valuing large numbers of sites across multiple countries. Value transfer also has the methodological attraction of providing consistency in the estimation of values across policy sites (Rosenberger and Stanley, 2006).

Table 2. Mangrove benefits, valuation methods and data sources

Mangrove benefit	Valuation method	Source	Section in the Methods Annex
(a) Coastal protection	Avoided damage costs	Menendez et al., 2020	Section 3.1
(b) Climate regulation	Carbon sequestration and avoided emissions. Voluntary market price estimate for avoided emissions and carbon sequestration	Estimations based on Mudiyarso et al. (2015); Jakovac et al. (2020); Cameron et al (2018); Cameron et al (2019).	Section 3.2
(c) Support to fisheries	Value transfer using meta-analytic value function. Primary studies applied production function approach.	Estimations based on methodology presented in Brander et al. (2012)	Section 3.3
(d) Raw materials provision	Value transfer using meta-analytic value function. Primary studies applied production function approach.	Estimations based on methodology presented in Brander et al. (2012)	Section 3.3
(e) Cultural services	Value transfer in areas where mangroves are used for tourism activities.	Estimations using the median of meta-dataset of mangrove tourism estimates in SE Asia (Data from ESVD). Mangrove tourism use areas are depicted by Spalding et al. (2019).	Section 3.4

Source: Own elaboration

2.3. Costs Assessment

17. **Costs of restoring and conserving mangroves, including opportunity costs of land that were susceptible to measurement are briefly described below.** Data sources for the estimations are described in Table 3 with an indication of the Methods Annex section where the reader can find additional details on the specific methods used and estimations made. It is important to point out that not all costs where included, only those that were susceptible to monetary valuation within the framework and criteria previously described.

18. **Costs of restoring.** Costs of active mangrove restoration projects depend on the techniques applied, and their capital and operating expenses. Active mangrove restoration projects create job opportunities, renew degraded ecosystems, improve the quality of ecosystems, trap the sediment that passes through the mangrove restoration areas, improve coastal resilience, prevent coastal erosion, and mitigate coastal hazards. In Southeast Asia mangrove restoration management strategies involve planting seeds and seedlings, transplanting, or the construction of artificial habitats such as detached breakwaters. Capital expenditures include costs for planning, purchasing, land acquisition, materials, and equipment (such as pumps, vehicles, computers, fencing) and financing. Operating costs encompass maintenance, monitoring, and equipment repair and replacement.

19. **Costs of conserving.** Mangrove conservation projects involve the protection and sustainable use and management of mangrove forests. Mangrove protection activities include formal and informal education programs, sale of carbon credits, monitoring of forest growth, measurements of carbon deposited below ground by different mangrove species, fundraising activities, mapping and marking of agreed protected areas, and perimeter patrols and policing of illegal mangrove harvesting. Costs of mangrove protection projects can be classified into project development expenses and operational costs. Mangrove conservation projects require long-term incentives which can be provided through the sale of mangrove-related goods and services, such as certified organic shrimp or sustainably harvested crab. In general, these kinds of projects require 50 percent of the budget for the first year, 30 percent of the budget for the second year, and 20 percent for the third year (Flint et al. 2018).

20. **Opportunity costs of land.** Land opportunity costs of alternative land uses potentially replacing mangroves were included in the cost assessment. Agriculture and aquaculture have been the main drivers of mangrove loss and degradation over the last decades (Jakovac et al. 2020). In Southeast Asia, 38 percent of the converted mangrove areas was designated to rice and oil palm agriculture, while 30 percent supported aquaculture during the period between 2000 and 2012 (Richards and Friess, 2015). Given the importance of agriculture for mangroves conversion and the unavailability of data on aquaculture productivity for most mangrove-holding countries, opportunity costs were estimated at a 5 km resolution based on the average productivity of agriculture and pastures for all mangrove-holding countries.

Table 3. Cost estimates and data sources

Cost category	Valuation method	Source	Section in the Methods Annex
(a) Restoration costs	Based on secondary data of costs for techniques applied, capital expenditures and operating costs.	Estimations of cost of techniques based on Motamedi et al (2014); Primavera and Esteban (2008); Narayan et al (2016); Hashim et. al (2010); Ministry of Marine Affairs and Fisheries, 2020). Estimations of capital expenditures based on Bayraktarov et al. (2016); Flint et al. (2018). Operating costs based on Bayraktarov et al. (2016).	Section 4.1
(b) Conservation costs	Based on secondary data of maintenance costs.	Estimations base on Flint et al. (2018) and consultations with Government.	Section 4.2
(c) Opportunity costs of land	Opportunity costs were estimated at a 5 km resolution based on the average productivity of agriculture and pastures for all mangrove-holding countries	Estimations based on Jakovac et al (2020); Strassburg et al (2019); Richards and Friess (2015).	Section 4.3

Source: Own elaboration

21. **For agriculture, the opportunity costs for 31 commodities were estimated based on the net present value of one ton of produce for 40 years considering a 5 percent discount rate.** The 31 commodities were chosen based on the data availability for their current and potential productivity (Jakovac et al 2020).

The net present value of each commodity was used to convert the value of produced quantity per area to production value per area in a spatially explicit model (Jakovac et al 2020). For pastures, the opportunity costs were estimated based on stocking rates, which were converted from heads per hectare to tons of produce per hectare using the values of animal yield per country and then converted into production value per area based on beef net present value (Jakovac et al 2020). The opportunity costs for both agriculture and pasture were calculated assuming a 20 percent margin of profit (Strassburg et al 2019).

2.4. Limitations

22. **It is important for the reader to understand that the study has certain limitations and thus these numbers are informative of policy dialogue but should be analyzed in the context of the methods and data used.** In principle, methods are available but the lack of data and quantitative knowledge regarding some key ecological relationships affirm the need for further inquiry, however by using standardized approaches such as natural capital accounting, this study manages to overcome some of these limitations. The basic steps outlined above are conceptually straightforward, but many complications invariably arise in practice.

23. **It is often difficult to confirm the internal validity of value estimates that are reported in existing nonmarket valuation studies and might be used for benefit transfers**. Another potential threat to the validity of primary valuation estimates that might be used for benefit transfers is publication bias, which occurs when the outcome of a study influences the researchers' choice of whether to submit the report for publication or the editors' choice of whether to accept it. Determining the suitability of candidate study cases for transfer to the policy cases is also subject to discussion and here expert judgement plays a big role. Incomplete reporting or lack of access to primary information could deviate the results of the study. The team did a good effort to consult with experts and follow best practices. None of these observations are meant to diminish the importance of this or other meta-analyses of nonmarket valuation studies. The team strongly support making the best possible use of the relevant information that happens to be available, whether it was collected in an experimental or an observational setting, but caveat in their policy use should be considered up front.

3. Main findings

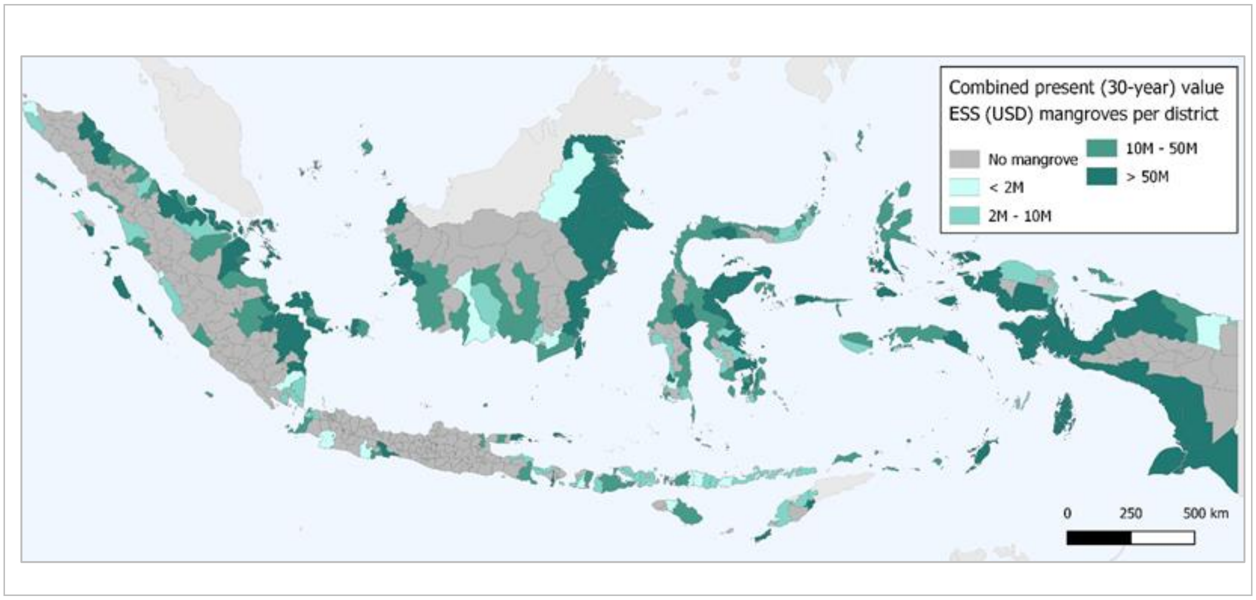
3.1. The value of mangrove related ecosystem services varies substantially across regions which is indicative of the need to better target investments

(a) The highest combined values of ecosystem services are found in Papua, Kalimantan, Sumatra, and Sulawesi

24. **The combined quantified present value of mangrove benefits over a 30-year time ranges from under 2M USD to over 50M USD per district.** This value represents the combined per hectare conservation value of coastal flood protection, avoided greenhouse gas emissions, tourism, fisheries, and firewood/timber multiplied by the mangrove extent per district. While high values > 50M USD are found in districts with large mangrove extents on Papua, Kalimantan, and Sumatra. Likely due to high per hectare values, several districts in Sulawesi, Bali, Lombok, and Java are also in the top bracket even though they are home to a smaller mangrove extent.

Figure 7. Spatial distribution of ecosystem services provided by mangroves

(Values in USD/ha/year aggregated at district level)



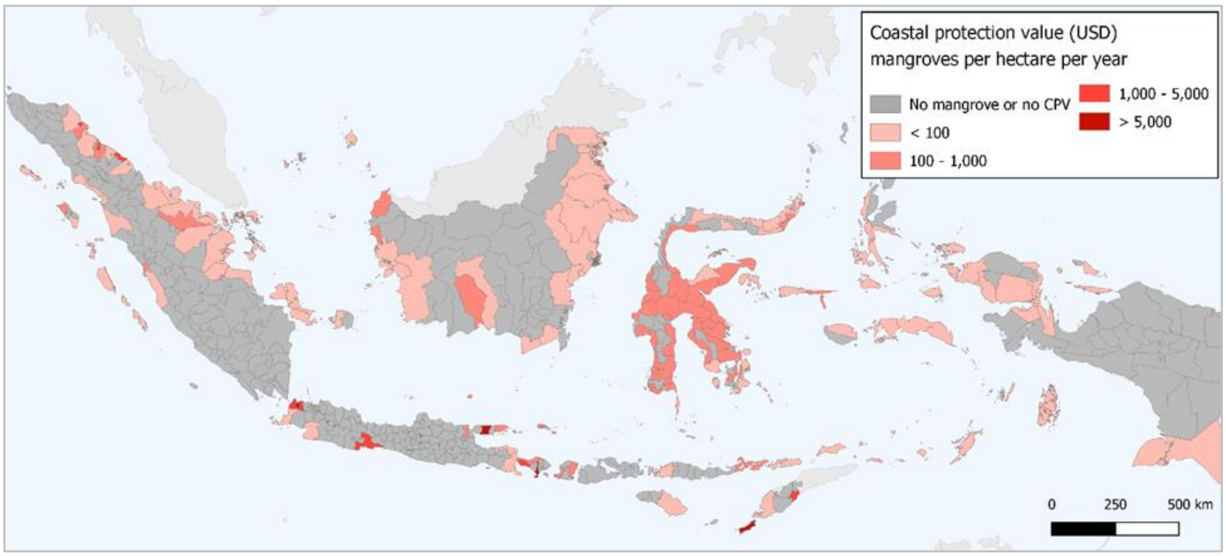
Source: Own elaboration (See Annex A1, Methods Report)

(b) Coastal protection services are particularly high in Java, Northern Sumatra, Bali, Lombok, and parts Nusa Tenggara Timur

25. **High annual per hectare values of coastal protection are found in mangroves located in more developed and more populated areas, such as in Java, Bali and Lombok** (Figure 5). In these areas, there are more properties exposed to coastal flooding, and hence, there is a higher coastal protection value of mangroves. In many of these high value areas, annual mangrove coastal protection benefits exceed 10,000 US$ per hectare per year and in some cases are modeled up to 100,000 US$ per hectare per year.

Figure 8. Spatial distribution of coastal protection benefits

(Values in USD/ha/year aggregated at district level)



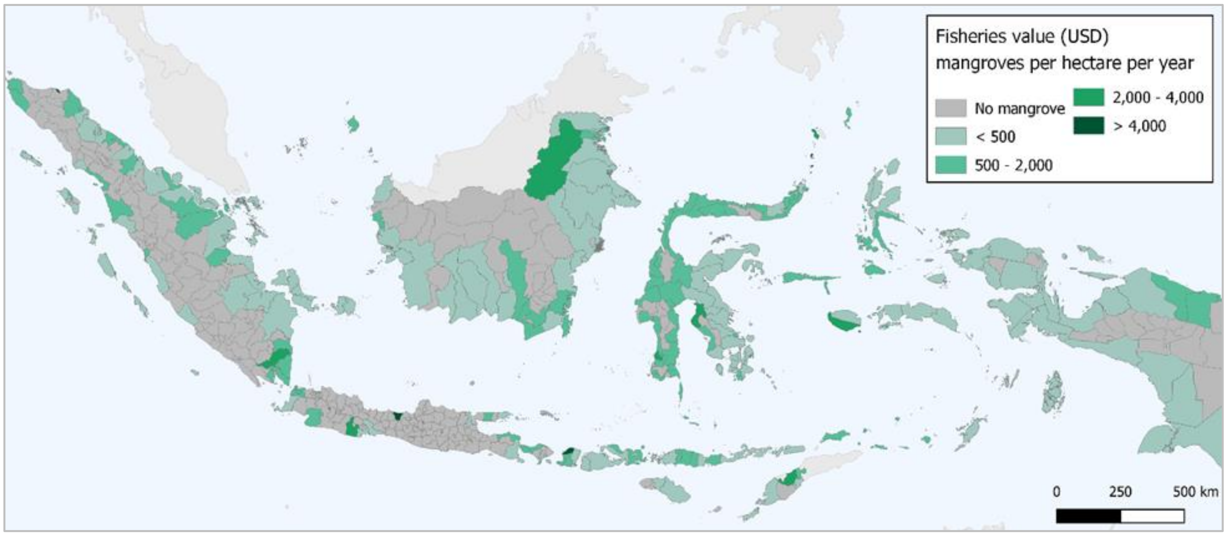
Source: Own elaboration based on Menendez et al. (2020) (See Annex A1, Methods Report)

(c) High values of supporting fisheries services are found in Java, Nusa Tenggara Timu, Sulawesi and Southern Sumatra

26. **The per hectare fisheries value of mangroves is expected to be higher in areas where there is a relatively low abundance of mangroves in the neighborhood, smaller patches and close to the main road network** (Figure 7). High values are found around Java, NTT, Sulawesi, and Southern Sumatra among other areas.

Figure 9. Spatial distribution of fisheries related ecosystem services

(Values in USD/ha/year aggregated at district level)



Source: Own elaboration (See Annex A1, Methods Report)

(d) Mangrove climate regulation services present an opportunity to generate income through carbon markets in almost all districts with mangrove patches in 2018

27. **Mangroves are highly productive habitats and, like other habitats under the blue carbon umbrella such as seagrass beds and tidal saltmarshes.** They can play an important role in climate change mitigation and adaptation through counterbalancing anthropogenic CO2 emissions. In this assessment, carbon storage and sequestration in Indonesian mangroves is valued in two ways: i) reduced greenhouse gas (GHG) in the atmosphere as a result of mangrove restoration and ii) avoided GHG emissions because of conservation of existing mangrove habitat (Table 2). The reduction of GHGs because of restoration is attributed to biomass sequestration and soil carbon burial – as a result of the regrowing mangrove habitat – but is also attributed to reducing baseline GHG emissions. That is, if a restored mangrove habitat was a fishpond or mudflat before its restoration, the averted annual GHG emission of such land uses is part of the blue carbon value of mangrove restoration (Table 1).

28. **In existing mangrove areas, blue carbon in mangroves represents one of highest values of carbon stocks per hectare**. Mangroves allocate 50–90% of their carbon pool below ground and the remaining is stored in aboveground biomass. There is uncertainty about the share of stored carbon that will be released into the atmosphere in case of mangrove deforestation. To value carbon storage in mangrove conservation areas, this assessment quantifies the avoided emissions from preventing mangrove deforestation – assuming a conservative averted loss of 25% of the carbon stock (carbon density in tCO2e ha) (Jakovac et al., 2020). Considering a mean carbon density per hectare in mangroves of 1,083 tCO2e (Mudiyarso et al., 2015), avoided GHG emissions per hectare are estimated to amount to 271 tCO2e (Table 2).

Table 4. Physical quantification approach for GHG reduction due to mangrove restoration (left) and avoided emissions due to mangrove conservation (right)

Mangrove restoration		Mangrove conservation	
GHG reduction components per ha		*Avoided emissions from deforestation per ha*	
GHG baseline reductions*	17 ± 5.6 tCO_2e per year	Avoided GHG emissions preventing mangrove deforestation, equaling 25% of the carbon density per hectare, estimated at 1,083 tCO_2e ha(Murdiyarso et al., 2015), over a 30-year time span(Jakovac et al., 2020)	
Biomass sequestration developing mangrove forest (average 35 years)**	-15 ± 5 tCO_2e per year		
Soil carbon burial (average for established mangrove forests)^	-6.5 ± 2.1 tCO_2e per year		
Total	-38.5 ± 12.7 tCO_2e year	Total	25% * 1,083 tCO_2e = 271 tCO_2e

** Based on GHG flux (sum CO2, CH4, N2O) from partially inundated aquaculture ponds in Indonesia with no mangrove coverage reported in Cameron et al. (2019). Use this number as it's likely to be in the same ball park as non-vegetated mudflats and degraded mangroves with sparse coverage, and .33% covers the potential range here.*

*** Sourced from Cameron et al. (2018), median values for coastal fringing and estuarine mangroves.*

^ Sourced from Alongi (2014). This is the average carbon burial rate for an established forest, and rates of soil carbon capture / burial generally increase as forests develop over time but- as you note- this can also be really rapid initially in some instances e.g. when you knock pond walls down and soil accumulates and infills quickly. Again a .33% provides a decent and defensible buffer for the numbers you need in this proposal to cover a range of baseline scenarios.

***Note**: negative numbers = net sequestration (CO2 captured from the atmosphere), positive numbers = net GHG emissions to the atmosphere, which is consistent with the global literature, so the total = (biomass + soil) minus GHG baseline*

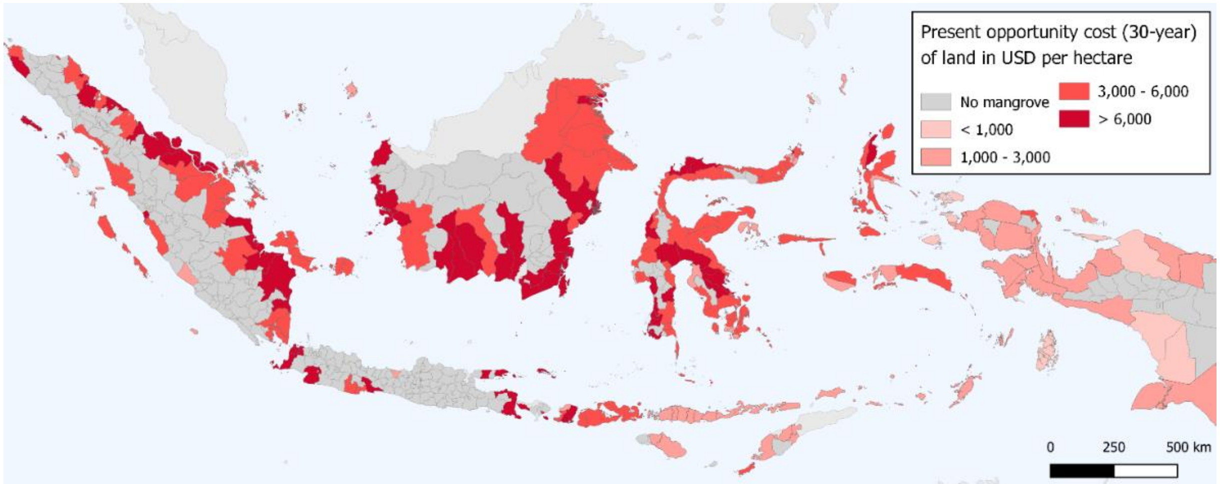
3.2. Costs of restoration in Indonesia are close to the median global estimates and thus lessons from global implementation experiences can be useful to inform investment decisions

29. **Cost estimates of mangrove restoration projects from the Government of Indonesia are close to the median global cost estimates**. The total cost for one hectare of mangrove restoration (planting 10,000 seeds) is about US$ 3,550 including procurement of mangrove seeds, planting facilities and infrastructure, and mangrove planting work (Ministry of Marine Affairs and Fisheries). On top of this amount, 330 USD is factored into account for additional investments in a mangrove center of excellence, community training, semi-permeable dams, and mangrove tourism infrastructure. In this assessment, a combined restoration cost per hectare of 3,863 USD is used following costs estimates of the Government of Indonesia.

3.3. Opportunity costs of land vary across regions with implications on the policy tools to be used for sustainable management

30. **High land opportunity cost, with a net present value of over USD 6,000 per hectare, are found in Southern Kalimantan, Eastern Sumatra and parts of Java and Sulawesi** (Figure 10). In these areas, that have seen significant mangrove deforestation over the past decades, mangroves are under pressure due to the high profitability of oil palm plantations, aquaculture, and agriculture. Although opportunity costs are

Figure 10. Spatial distribution of opportunity cost of alternative land uses



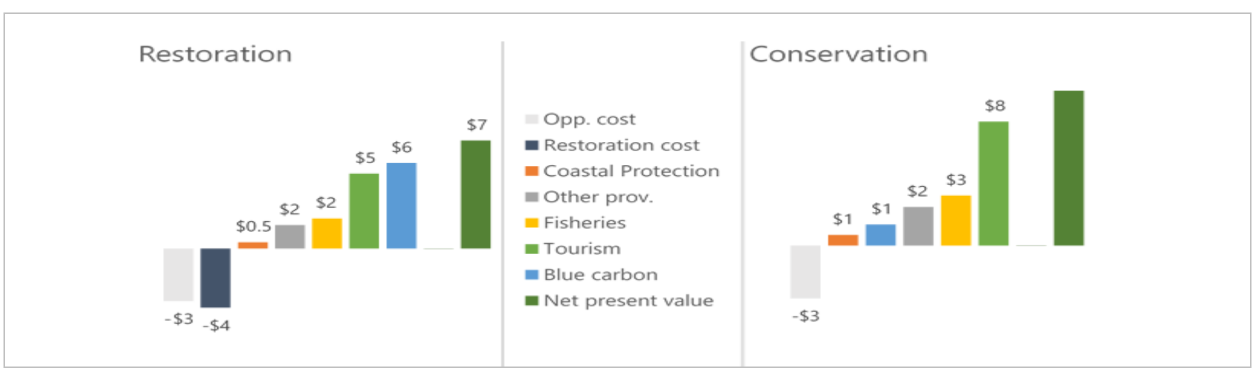
Source: Own elaboration based on Strassburg (2020); Jakovac et al. (2020) (See Annex A1, Methods Report)

3.4. Conservation in general is a more efficient investment than restoration, but regional differences need to be considered when making investment decisions

31. **Cost-benefit indicators can be calculated per district, such as net present value (NPV) and benefit to cost ratios.** Figure 11 illustrates the cost and benefit components considered for a hectare of mangrove restoration and conservation over a 30-year project lifetime. The values of costs and benefits in Figure 11 represent the weighted mean values per hectare for the whole country. Regional differences in costs and benefits need to be considered when making investment decisions Spatially explicit cost-benefit analysis provide insights in where in Indonesia mangrove restoration and conservation is expected to be economically viable. Through a spatial overlay of cost and benefit information

Figure 11. Costs and benefits of conservation and restoration across Indonesia

(Weighted mean estimates in thousand US dollars per hectare)

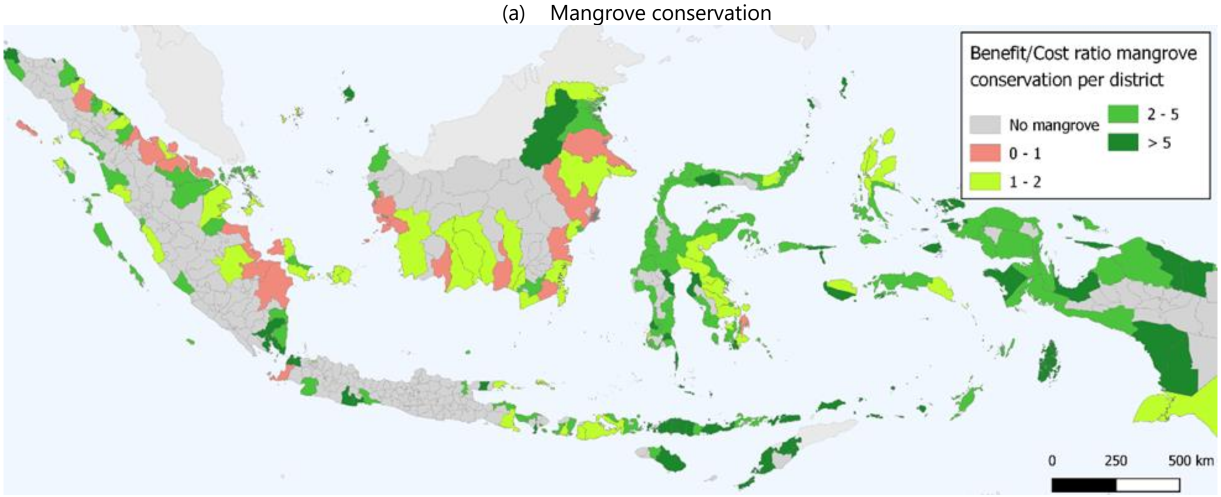


Source: Own elaboration based on overall estimations (See Annex A1, Methods Report)

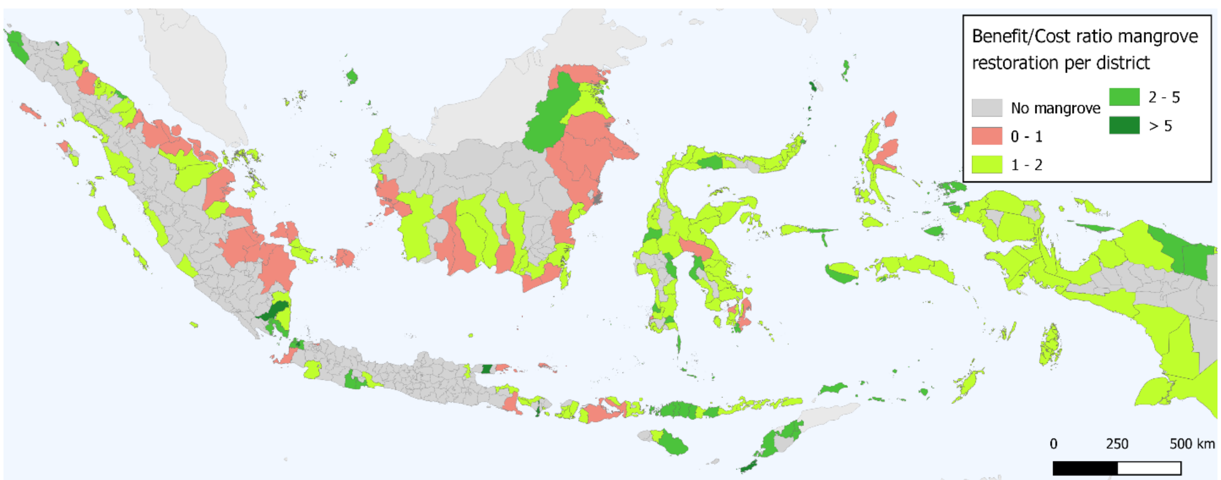
32. **The benefit-cost ratio of a hectare of mangrove restoration is >1 in most districts indicating a positive net present value of the investment.** Figure 12 shows the benefit-cost ratio of (a) mangrove conservation and (b) mangrove restoration at district level. Considering a discount rate of 5.5% and a 30-year project lifetime, In areas such as Eastern Sumatra and large parts of Kalimantan, where land opportunity cost area comparatively high and site-specific benefits such as coastal flood protection, fisheries and tourism are limited, the benefit-cost ratio of mangrove restoration is <1 indicating a negative net present value. In districts with low opportunity costs and high site-specific benefits, such as NTT and Western Papua, benefit-cost ratios of above 2 and in some districts above 5 are found.

Figure 12. Spatial distribution of benefit-cost ratios for mangrove conservation and restoration

(a) Mangrove conservation



(a) Mangrove restoration



Source: Own elaboration based on Strassburg (2020); Jakovac et al. (2020)

3.5. An optimal mix of conservation and restauration activities could potentially lead to better mangrove management, as opposed to an isolated restoration target

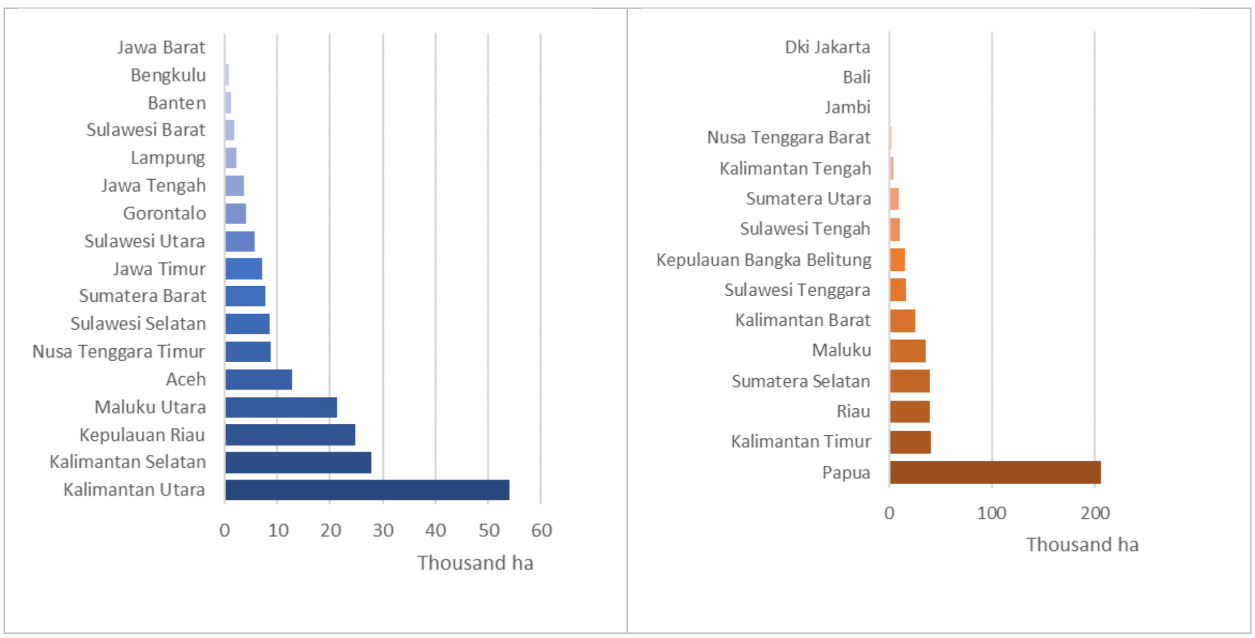
33. **The spatially explicit framework of district-level costs and benefits can be applied to assess mangrove restoration and conservation investment scenarios and support optimizing the location of such investments across Indonesia**. Strategically locating of conservation and restoration options can potentially significantly reduce the public investment costs in mangrove management and improve overall benefits received. For example, in areas with lower opportunity cost for mangrove conservation and restoration, large scale conservation co-financed by carbon offsets is likely economically viable, while in areas with high site-specific benefits (e.g., flood protection, fisheries and tourism), large scale restoration is economically viable.

34. **The scenario analysis indicated an expert-supervised optimization of the target of 600,000 hectares of mangrove restoration**. For the scenario analysis, benefits and costs are aggregated to province level. To accurately reflect land opportunity cost, the scenario analysis considers a distribution of previous land uses of restored areas consisting of classes: I) plantations and agriculture, ii) aquaculture/fishponds and iii) degraded mangrove area. These land use classes also inform the type of mangrove restoration technique to be applied and hence refine the restoration cost estimates.

Figure 13. Investment allocations to reach a target of 600,000 ha of sustainable mangrove management based on B/C ratios

(a) 100,000 ha of restoration. Includes all those provinces with B/C ratios higher than 1

(b) 500,000 ha of conservation. Includes all those provinces with B/C ratios higher than restoration



Source: Own elaboration

35. **To finance conservation and restoration activities Government will have to disburse an estimated value of USD 500 million**. This investment should be done in the course of five years and the benefits, in

which time the benefits will still greatly surpass the costs. These investments are measured against the optimal allocation of 20/80 as previously discussed and shown in detail in the Table below. In case the Government decides to invest only on restoration the total amount to invest will increase to almost USD 750 million, knowingly that these investments show a benefit/cost ratio which is lower than conservation.

Table 5. Investments needed for the optimal allocation for conservation and restoration activities

Region	Province	Conservation	Restoration	Total
Bali_NT	Bali	115,633		115,633
	Nusa Tenggara Barat	575,699		575,699
	Nusa Tenggara Timur		16,969,851	16,969,851
	Bali_NT Total	**691,332**	**16,969,851**	**17,661,183**
Java	Banten		2,240,585	2,240,585
	Dki Jakarta	22,140		22,140
	Jawa Barat		652,125	652,125
	Jawa Tengah		7,209,388	7,209,388
	Jawa Timur		13,844,517	13,844,517
	Java Total	**22,140**	**23,946,615**	**23,968,755**
Kalimantan	Kalimantan Barat	7,135,059		7,135,059
	Kalimantan Selatan		54,147,791	54,147,791
	Kalimantan Tengah	1,175,525		1,175,525
	Kalimantan Timur	11,166,185		11,166,185
	Kalimantan Utara		105,292,887	105,292,887
	Kalimantan Total	**19,476,769**	**159,440,679**	**178,917,448**
Maluku	Maluku	9,913,959		9,913,959
	Maluku Utara		41,457,633	41,457,633
	Maluku Total	**9,913,959**	**41,457,633**	**51,371,592**
Papua	Papua	56,677,439		56,677,439
	Papua Total	**56,677,439**		**56,677,439**
Sulawesi	Gorontalo		8,017,245	8,017,245
	Sulawesi Barat		3,742,419	3,742,419
	Sulawesi Selatan		16,672,015	16,672,015
	Sulawesi Tengah	2,870,269		2,870,269
	Sulawesi Tenggara	4,586,741		4,586,741
	Sulawesi Utara		11,048,166	11,048,166
	Sulawesi Total	**7,457,009**	**39,479,844**	**46,936,854**
Sumatra	Aceh		24,907,283	24,907,283
	Jambi	431,894		431,894
	Kepulauan Bangka Belitung	4,384,537		4,384,537
	Kepulauan Riau		48,270,879	48,270,879
	Lampung		4,526,916	4,526,916
	Riau	11,011,893		11,011,893
	Sumatera Barat		15,021,262	15,021,262
	Sumatera Selatan	10,987,834		10,987,834
	Sumatera Utara	2,605,690		2,605,690
	Sumatra Total	**29,421,847**	**92,726,341**	**122,148,188**
Indonesia total		**123,660,496**	**374,020,963**	**497,681,458**

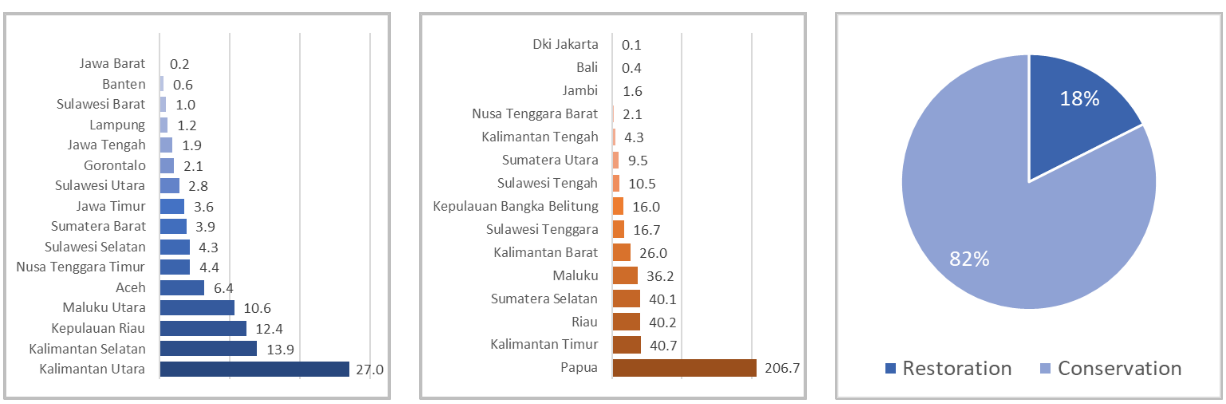
4. Recommendations for improved mangrove management

36. **There is a need to consider mangrove restoration within the broader policy context of the Government of Indonesia's blue economy strategy, seen in the targets under the medium-term development plan (RPJMN) for 2020-24, and the Indonesia Oceans Policy.** This broader suite of actions include: (i) improved fisheries governance through operationalization of the Fishery Management Area (WPP) system, (ii) development, integration, and implementation of spatial plans, (iii) expansion of marine protected areas, (iv) a national action plan for marine debris, and (v) an integrated and sustainable tourism development program. Sustainable mangrove management however requires actions on the ground that could potentially mobilize high investments at high returns. Mangrove conservation and restoration activities offer an opportunity for that. The main findings of this study (outlined succinctly in Box 1) could help guide the Government of Indonesia in designing an efficient set of investments for sustainable mangrove management.

37. **Stemming from the findings of the study the key policy message is that an efficient mix of mangrove restoration and conservation activities could help inform decisions of the Government of Indonesia's goal to restore 600,000 ha of mangroves or more importantly, manage mangroves sustainably.** The spatial cost-benefit analysis helps determine the appropriate areas where these activities will have higher returns. The possible scenario presented Figure 5, includes almost 20% of restoration activities and the rest of investments, more than 80%, intended to conservation actions. This scenario is one of the many that could be constructed using the tool available that was created for the purpose of this study. The tool itself could be an instrument for dialogue and the definition of other plausible scenarios is possible. In this case an expert judgement provides a baseline where the benefit-cost ratio is the single indicator of reference, however as described before, the rates of degradation and the contribution to total cover play a role when defining future scenarios. In general, any scenario will probably usually produce a higher allocation for conservation activities.

Figure 14. Location and distribution of investments on mangrove sustainable management

(a) Restoration (100,000 ha) *(b) Conservation (500,000 ha)* *(c) National distribution of investments*



Source: Own elaboration

38. **This possible mix of investments** (provided in Figure 5) **will require a combination of policy approaches or enabling actions that will make the investments produced the expected results, including:**

f) **Ensure restoration practices and financing includes adequate provisions for long-term management and monitoring.** Data show that the success of restoration activities depends on the adequacy of the habitat to be restored (e.g. appropriate hydrology), the materials used (quality of seedlings), the medium-term management (e.g. tending, protection), and long-term operational oversight. Efforts focused on replanting alone do not show high rates of long-term success. This will probably require prioritizing adequately areas for restoration (e.g. those that provide the highest benefit in terms of net benefits). Restoration can provide significant environmental and economic benefits but should be done in areas where it provides maximum value in terms of benefit-cost ratios. These areas are tentatively outlined **Error! Reference source not found.**.

g) **Promote restoration methodologies that maximize labor utilization, especially as part of the COVID recovery stimulus investments.** Expand labor-intensive coastal and marine restoration activities, including mangrove restoration and coastal cleanups, to provide short-term employment during the post-COVID recession while providing long-term and resilient rehabilitation of mangrove benefits. This is consistent with the findings of this study and aligned with the findings of the High-Level Panel on Oceans which recommended coastal ecosystems restoration as a top-five blue economic stimulus for the post-COVID recovery.

h) **Strengthening the evidence base for improved enforcement and mangrove management**. This could include finalizing the Mangrove OneMap to ensure an accepted and consistent whole-of-Government understanding of the extent, quality and trends in mangroves and adjacent coastal ecosystems. Development of a credible and reliable valuation and accounting system could potentially offer also opportunities to better bridge improved data and policy decision making. Building on improved data, natural capital accounting supports marine and coastal policies by providing standardized data on the status and economic values of natural assets and how these assets are affected by human activity. Indonesia began building NCA through the Indonesian System of Environmental-Economic Accounts (SISNERLING) and could continue to include marine and coastal assets including mangroves.

i) **Inclusion of mangroves in the national REDD+ framework and nationally determined contribution (NDC).** Indonesia would need to develop blue carbon readiness to ensure Indonesia can benefit from international blue carbon financing, including carbon accounting, monitoring and verification tools. Likewise, inclusion of mangroves as nature-based solutions of coastal adaptation and resilience in NDCs, Indonesia could come up with targets for coastal adaptation and resilience using nature-based and hybrid solutions through protecting, managing, or enhancing mangroves.

j) **Complementary policies should be explored, including for example implementing a mangrove moratorium**. Indonesia has a moratorium on land conversion for Indonesia's primary forests and peatlands. Despite their immense value, including higher carbon sequestration value per hectare, there is no equivalent protection for mangroves. Indonesia could expand the scope of the license issuance moratorium in primary forest and peatlands to include mangroves. Such an achievement could be done through issuance of legislation, thereby demonstrating Indonesia's commitment to achieving climate targets and realization of a blue economy.

References

Bayraktarov, E., Saunders, M. I., Abdullah, S., Mills, M., Beher, J., Possingham, H. P., Mumby, P. J., & Lovelock, C. E. (2016). The cost and feasibility of marine coastal restoration. Ecological Applications, 26(4), 1055–1074. https://doi.org/https://doi.org/10.1890/15-1077

Brander L.M, Alfred J. Wagtendonk, Salman S. Hussain, Alistair McVittie, Peter H. Verburg, Rudolf S. de Groot, Sander van der Ploeg. Ecosystem service values for mangroves in Southeast Asia: A meta-analysis and value transfer application, Ecosystem Services, Volume 1, Issue 1, (2012). Pages 62-69, https://doi.org/10.1016/j.ecoser.2012.06.003.

Ecoshape. (2021). Building with nature Indonesia. https://www.ecoshape.org/en/pilots/building-with-nature-indonesia/

Global Commission on Adaptation. (2019). ADAPT NOW: A GLOBAL CALL FOR LEADERSHIP ON CLIMATE RESILIENCE #AdaptOurWorld.

IUCN. (2017). What are mangroves worth? There's no easy answer. https://www.iucn.org/news/forests/201704/what-are-mangroves-worth-there's-no-easy-answer

Jakovac, C. C., Latawiec, A. E., Lacerda, E., Leite Lucas, I., Korys, K. A., Iribarrem, A., Malaguti, G. A., Turner, R. K., Luisetti, T., & Baeta Neves Strassburg, B. (2020). Costs and Carbon Benefits of Mangrove Conservation and Restoration: A Global Analysis. Ecological Economics, 176. https://doi.org/10.1016/j.ecolecon.2020.106758

Menéndez, P., Losada, I.J., Torres-Ortega, S. et al. The Global Flood Protection Benefits of Mangroves. Sci Rep 10, 4404 (2020). https://doi.org/10.1038/s41598-020-61136-6

Ministry of Maritime Affairs and Investment. (n.d.). Statistics from reference data by the Coordinating .

MMAF and MoEF. (2019). Based on 2015 data.

Murdiyarso, D., Purbopuspito, J., Kauffman, J. B., Warren, M. W., Sasmito, S. D., Donato, D. C., Manuri, S., Krisnawati, H., Taberima, S., & Kurnianto, S. (2015). The potential of Indonesian mangrove forests for global climate change mitigation. Nature Climate Change, 5(12), 1089–1092. https://doi.org/10.1038/nclimate2734

Narayan, S., Beck, M. W., Reguero, B. G., Losada, I. J., van Wesenbeeck, B., Pontee, N., Sanchirico, J. N., Ingram, J. C., Lange, G.-M., & Burks-Copes, K. A. (2016). The Effectiveness, Costs and Coastal Protection Benefits of Natural and Nature-Based Defences. PLOS ONE, 11(5), e0154735-. https://doi.org/10.1371/journal.pone.0154735

Rare Indonesia. (n.d.). Based on early survey data.

Richards, D. R., & Friess, D. A. (2016). Rates and drivers of mangrove deforestation in Southeast Asia, 2000-2012. Proceedings of the National Academy of Sciences of the United States of America, 113(2), 344–349. https://doi.org/10.1073/pnas.1510272113

Spalding, M. & Parrett, C. Global patterns in mangrove recreation and tourism, Marine Policy, Volume 110, (2019), 103540, https://doi.org/10.1016/j.marpol.2019.103540.

Strassburg, B. B. N., Iribarrem, A., Beyer, H. L., Cordeiro, C. L., Crouzeilles, R., Jakovac, C. C., Braga Junqueira, A., Lacerda, E., Latawiec, A. E., Balmford, A., Brooks, T. M., Butchart, S. H. M., Chazdon, R. L., Erb, K.-H., Brancalion, P., Buchanan, G., Cooper, D., Díaz, S., Donald, P. F., … Visconti, P.

(2020). Global priority areas for ecosystem restoration. Nature, 586(7831), 724–729. https://doi.org/10.1038/s41586-020-2784-9

Word Bank. (2021). Indonesia Sustainable Oceans Program.

World Bank Group. (2016). Managing Coasts with Natural Solutions: Guidelines for Measuring and Valuing the Coastal Protection Services of Mangroves and Coral Reefs. http://hdl.handle.net/10986/23775

World Bank. (2017). THE POTENTIAL OF THE BLUE ECONOMY Increasing Long-term Benefits of the Sustainable Use of Marine Resources for Small Island Developing States and Coastal Least Developed Countries. www.worldbank.org

World Bank. (2020a). Indonesia's mangroves for prosperous communities and a healthy planet-Factsheet.

World Bank. (2020b). Oceans for Prosperity: Reforms for a Blue Economy in Indonesia.

World Bank. (2021). Indonesia Sustainable Oceans Program - News.

World Bank. (n.d.). Staff calculations based on BPS data.

World Bank. 2019. "Forces of Nature: Assessment and Economic Valuation of Coastal Protection Services Provided by Mangroves in Jamaica".

Worthington, T., Spalding, M., Herr, D., Hingorani, S., & Landis, E. (n.d.). Mangrove Restoration Potential A global map highlighting a critical opportunity. In Geological Survey. USDA Forest Service. www.globalmangrovewatch.org

World Bank (2021) Oceans for Prosperity: Reforms for a Blue Economy in Indonesia.

Spaninks, F., Beukering, P.V., 1997. Economic Valuation of Mangrove Ecosystems: Potential and Limitations. CREED Working Paper 14.

UNEP (2006) Marine and Coastal Ecosystems and Human Well-Being: A Synthesis Report Based on the Findings of the Millennium Ecosystem Assessment. United Nations Environment Programme, Nairobi

TEEB (2010) The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations. Pushpam Kumar (Ed.), Earthscan, London and Washington

Annexes

A1. Methods Technical Report

Link to methods report:

https://worldbankgroup-my.sharepoint.com/:f:/g/personal/jpcastaneda_worldbank_org/EgI-sHaV5mZHvU5H_RR-8BoBIlqmkFG1o74X-FjROCNCmg?e=FBw7IQ

A2. Coastal Ecosystem Accounts Technical Reports

Link to technical reports:

https://worldbankgroup-my.sharepoint.com/:f:/g/personal/jpcastaneda_worldbank_org/EgI-sHaV5mZHvU5H_RR-8BoBIlqmkFG1o74X-FjROCNCmg?e=FBw7IQ