

Mangroves for Coastal Resilience in Bangladesh

Identification of Potential Locations, Assessment
of Triple Dividends, and Cost Estimation

Alejandra Gijón Mancheño

Luke Brander

Bramka Arga Jafino

Ignacio Urrutia

Swarna Kazi



WORLD BANK GROUP

Urban, Disaster Risk Management, Resilience and Land Global Department

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Abstract

Bangladesh is highly vulnerable to extreme weather events due to its frequent exposure to floods and extensive low-lying areas. Coastal flood risks are expected to increase due to climate change. Therefore, Bangladesh has been upgrading its coastal embankment system to enhance flood safety. This initiative includes not only hard flood defense infrastructure, but also nature-based solutions through planting mangroves on the seaside of embankments. Mangroves, serving as natural flood barriers, have been utilized in Bangladesh for coastal protection since the 1960s. However, their integration with embankment designs and their benefits in carbon sequestration remain underexplored. This paper consolidates current knowledge on the role of mangroves in coastal resilience in Bangladesh, incorporating recent studies and new analyses on their benefits on (i) flood risk reduction, (ii) livelihood enhancement, and (iii) carbon sequestration. The

estimated benefits are mapped along the country's coastal system. The study identifies some of the most beneficial mangrove sites to be combined with embankment designs, such as a belt south of polder 45 (Amtali) with an average width of 1.77 kilometers, and a belt around the Kukri-Mukri polder with an average width of 1.82 kilometers. These mangrove forests can reduce the required thickness for slope protection by up to 80 percent, offer carbon service benefits of US\$13,120 per hectare (over 2022–50, at a 6 percent discount rate), and provide livelihood benefits of more than US\$22,000 per hectare. Other wide mangrove belts are found in Sandwip and Mirersarai. The findings aim to guide future investments in integrating mangroves into coastal protection systems, highlighting their triple dividends for building resilience.

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Mangroves for Coastal Resilience in Bangladesh: Identification of Potential Locations, Assessment of Triple Dividends, and Cost Estimation

Alejandra Gijón Mancheño^{1,2,3}, Luke Brander^{4,5,2}, Bramka Arga Jafino², Ignacio Urrutia², Swarna Kazi²

¹*Delft University of Technology, Delft, The Netherlands*

²*The World Bank*

³*Invest International, The Netherlands*

⁴*Vrije Universiteit Amsterdam, Amsterdam, The Netherlands*

⁵*Leibniz University Hannover, Hannover, Germany*

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1. Introduction

Bangladesh is highly vulnerable to extreme weather events, since it is frequently exposed to flood hazards and hosts a large population in low-lying areas. In preparation for rising flood risks due to climate change, the Government of Bangladesh upgraded the country’s coastal embankment system to a higher flood safety standard, for instance through the Coastal Embankment Rehabilitation Project and the Coastal Embankment Improvement Project. As part of the improvement works, mangroves—a group of salt-tolerant trees and shrubs—are being implemented on the seaside of embankments to reduce coastal flooding. In Bangladesh, natural mangroves can be found in the southwest and southeast, while plantations are mostly located in the Meghna estuary (Figure 1), and, to a lesser extent, just to the east from the Sundarbans and in the Chittagong division.

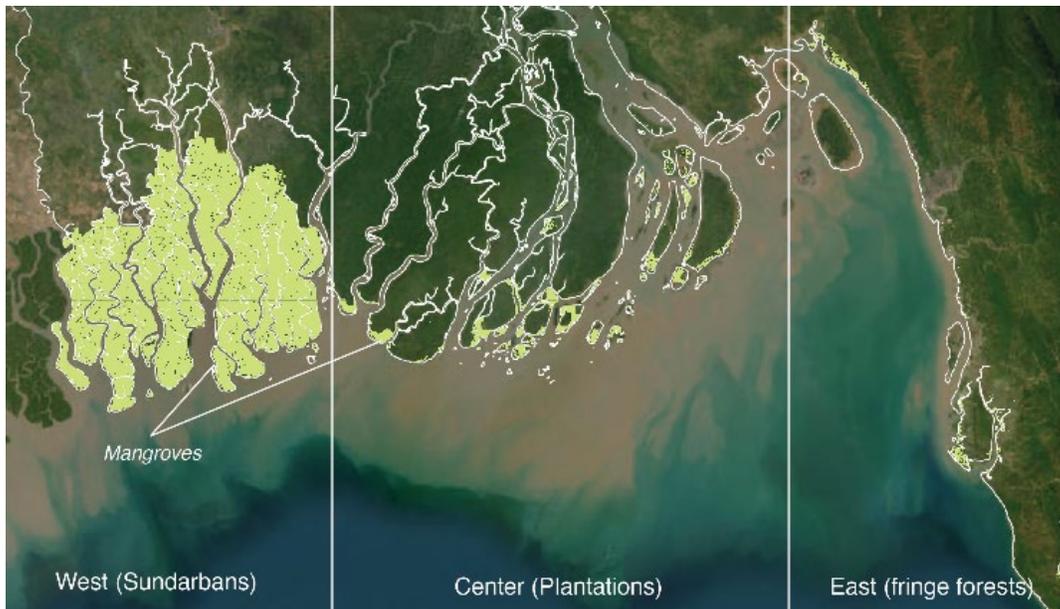


Figure 1 Location of existing mangroves in Bangladesh (in light green, from the Global Mangrove Watch, 2023)

Although mangrove trees have been planted in Bangladesh for coastal protection purposes since the 1960s, existing mangrove fringes, natural or planted, are not currently considered in embankment designs. This implies that in some instances, embankments could be lower or have a lighter wave-protection revetment due to the protective effect of existing vegetation. Moreover, mangroves are one of the disaster risk reduction strategies that can provide triple dividends of resilience (Tanner, et al., 2015). First, they can reduce disaster risk, especially potential losses from storm surges and coastal floods, as they decelerate waves and dampen storm-surge heights (Dasgupta, et al., 2021; Gijón Mancheño, et al., 2022; Van Hespén, et al., 2023). Second, they provide livelihood gains as they can be sources of fuelwood, honey and timber as well as provide tourism opportunities (Hussain & Badola, 2010; Feurer, Gritten, & Than, 2018). Third, mangrove soils and biomass can store large quantities of carbon (Alongi, 2012; Ray, et al., 2011).

Mangrove areas provide coastal protection in several ways. During extreme events, the dense structure of mangrove forests exerts resistance to incoming currents and surge flows, which lose their energy as they travel through the trees (Figure 2). Modeling scenarios in Bangladesh suggest that mangrove afforestation patches with a width of 500 m (in the direction of flow propagation) can mitigate current velocities up to 90% but would have a relatively modest effect on surge levels (Dasgupta, et al., 2021). A much wider forest could have a stronger impact on surge heights, reducing them up to 0.2 m per km (Krauss, Doyle, Doyle, Swarzenski, & From, 2019; Montgomery, Bryan, Mullarney, & Horstman, 2019), depending on the local hydrology. Mangroves also attenuate wave heights between 5% and 100% over 100 m of forest (Bao, 2011), which in turn decreases wave-driven water levels in coastal communities and wave loads on coastal structures (Vuik, Jonkman, Borsje, & Suzuki, 2016). Reducing wave loads can lead to a decrease in the amount of material needed for slope protection on embankments, or to lower required embankment heights. *Sonneratia apetala* plantations on the seaside of embankments with lengths between 100-1000 m in coastal Bangladesh could reduce waves in 7%-55% and decrease the size of the required slope protection blocks of embankments by 13%-46% at Galachipa, Bhola, Hatiya South, Khangona, and Boro Moheshkhali (Gijón Mancheño, et al., 2022). At other sites, the rate of wave reduction and its effect on slope protection designs could differ depending on the local mangrove characteristics and wave exposure.

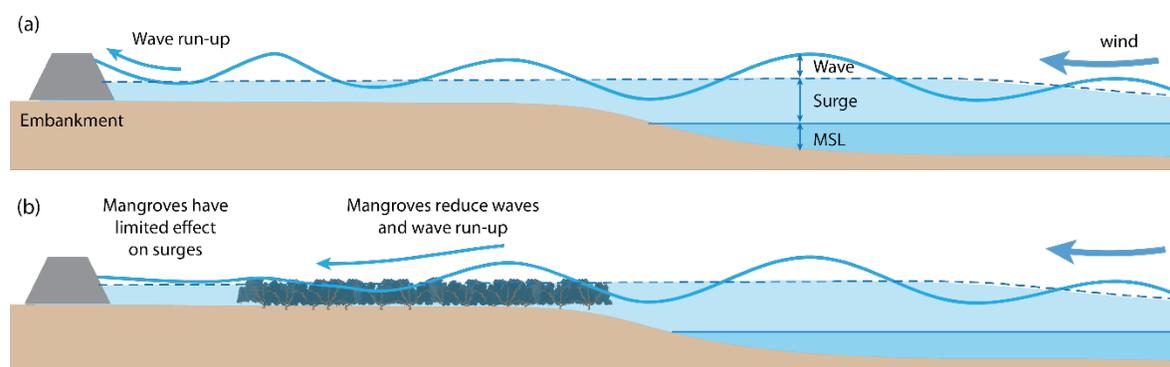


Figure 2 Effect of mangroves on coastal embankments, from (Gijón Mancheño, et al., 2022). (a) Without mangroves, coastal embankments are exposed to the effect of surges and tides, and wave run-up. (b) Mangroves have a limited effect on surges but can significantly reduce wave loads and wave run-up, potentially decreasing the costs of coastal infrastructure.

Since the 1960s, 28,000 ha of plantations east of the Sundarbans have accumulated 114,149 Mg C per year (Uddin, Aziz, & Lovelock, 2023). If plantations continue to expand at the same rate as they have over the past few decades, they could trap 664,850 Mg C by 2030 (Uddin, Aziz, & Lovelock, 2023). Livelihood benefits due to mangroves include enhancing fisheries, being a source of timber and their recreational value (Islam & Hossain, 2017), among other benefits. For instance, 90% of commercial fish species in Bangladesh breed in the mangrove forest of the Sundarbans (Kamal, 1999), corresponding with a fishing revenue of 158,360 USD in 2014-2015 (DoF, 2015). Timber harvesting is limited due to excessive exploitation until the 1980s, but it is still a source of income due to the harvest of fallen trees during cyclones (DoF, 2015). The Sundarbans also attracts

thousands of tourists that join cruises, go on wildlife observation tours, and hike through the forest. In 2014-2015, 96,949 domestic tourists and 3,868 international tourists visited the Sundarbans, creating a revenue of 144,832 USD (Islam & Hossain, 2017).

The assessment of mangroves' potentials and their benefits in Bangladesh has so far been done in an ad-hoc, polder-specific, or qualitative basis. For instance, the effects of mangroves on wave reduction were investigated only for selected polders by Gijón Mancheño, et al. (Gijón Mancheño, et al., 2022). Islam & Hossain investigated the ecosystem services benefits of mangroves in the Sundarbans but only in a qualitative manner, without quantitatively investigating the benefits across different parts of the coastal zone (Islam & Hossain, 2017). There is an absence of comprehensive coastal zone-wide assessments on how mangroves can influence embankment designs in Bangladesh and how their integration can provide triple dividends of resilience. This study therefore assesses the potentials and impacts of mangrove fringes across the coastal embankment system. First, we adopt a remote sensing approach to identify potential sites for mangroves along Bangladesh's coastal zone. Second, we quantify how mangrove presence can potentially reduce the required height and slope protection of coastal embankments, as well as mitigate erosive processes at the toe of these structures. Third, we estimate the carbon sequestration potential and livelihood benefits of individual mangrove belts, as well as potential costs of mangroves restoration. This end-to-end assessment is critical to give a complete overview of mangroves' potential to support the government's strategic planning in the coastal zone. The findings are intended to inform future investment decisions and identify key research gaps for effectively integrating mangroves into Bangladesh's coastal protection strategy.

2. Methodology

2.1. Potential locations for mangroves

The identification of potential mangrove sites follows the methodology as laid out in (Gijón Mancheño, et al., 2021; World Bank, 2024). In particular, mangrove sites are identified by taking into account:

- Existing presence of mangroves on the foreshore. We consider sites within 10 km of existing mangroves as potentially suitable for colonization. Data from the Global Forest Watch¹ are used to map out existing mangrove patches.
- Areas located on the water side of coastal embankments, since mangroves afforestation within the embankments will not provide significant flood risk reduction benefits.
- Intertidal areas (Murray, et al., 2019) and tidal range (Bricheno, Wolf, & Islam, 2016), as mangroves can grow naturally in sheltered intertidal locations with relatively low wave and with freshwater input (Alongi D. M., 2002).
- Local dynamics of the foreshore, i.e., whether the coasts are accreting or eroding (Luijendijk, et al., 2018), as it influences the techniques needed to vegetate a site.

¹ <https://www.globalforestwatch.org/>

- Areas where there are no active agriculture, aquaculture, or residential settlements, to avoid land acquisition.

Some of the sites have low mangrove cover due to past human activities—for example, remnants of abandoned shrimp ponds visible in aerial imagery—and may require restoration efforts. This study estimates the maximum potential co-benefits under the assumption of optimal mangrove conditions across the coastal system, highlighting locations where protection and restoration efforts could be particularly valuable. However, local feasibility studies are essential to assess the practicality of implementing such interventions.

2.2. Triple dividends estimation

2.2.1. Flood protection benefits

Since we are considering mangrove sites that extend up to several kilometers perpendicularly to the shoreline, mangroves would cause only a small reduction of surge levels (between 0-0.2 m per km). We therefore focus on the effect of mangroves on short wave reduction and on the design requirements of coastal embankments. For this, we apply the approach of Gijón Mancheño et al. (Gijón Mancheño, et al., 2022) to estimate wave attenuation by mangrove fringes, and how these fringes could reduce the embankment crest height, the size of the slope protection (revetment) blocks, and the bed erodibility of the toe of the structure. The equations of this method are summarized in the Appendix.

The study of Gijón Mancheño et al. (Gijón Mancheño, et al., 2022) evaluated the effect of mangroves for selected polders at the center of Bangladesh, whereas this study considers the variation in hydrodynamic conditions across the coastal zones. For each region (west, center, east – see Figure 1), the hydrodynamic design conditions are obtained from IWM (IWM, 2018) for a return period of 25 years (Table 1). Wave heights and surges are smallest on the west and central regions, and largest at the east coast of Bangladesh. Water levels include + 1 m of sea level rise by 2050, corresponding with the worst-case scenario due to climate change (Gijón Mancheño, et al., 2022).

Table 1 Hydrodynamic design conditions of embankments at the locations of Figure 4. For each region, the maximum and minimum value of the surge level (25-year return period, including + 1 m due to sea level rise by 2050) and wave height (25-year return period) are calculated from the data of IWM (IWM, 2018).

Location	Surge_min [m]	Surge_max [m]	H_min [m]	H_max [m]
West	3,8	4,2	1,0	1,0
Center	3,6	4,4	0,9	3,2
East	4,5	5,2	2,2	3,9

The vegetation properties are obtained combining the model for the vegetation surface area of Gijón Mancheño et al. (Gijón Mancheño, et al., 2022) with mangrove geometrical properties measured in Bangladeshi plantations by Uddin et al. (Uddin, Rahman, Hossain, & Akter, 2014), at Domkhali, Moghadia, and Bamonsundar (north of Chittagong). Vegetation characteristics likely differ at other

sites, especially in the west, but we lack data to include such spatial variations. We use vegetation properties of plantations that are 20-29 years old to simulate vegetation growth by 2050 (Table 2).

Within the model, we assume a constant water depth through the vegetation, equal to the surge levels from IWM (IWM, 2018). We consider mangrove plantation widths varying between 10 and 2,000 m. Attenuated wave heights are used to calculate the embankment properties. The crest height is calculated using the formula of van der Meer (Van der Meer, et al., 2018) to reach an overtopping rate of 5 l/m/s with slopes of 1:8, armor layers (corresponding with $\gamma_f = 0.55$), and a berm (with $\gamma_b = 0.89$), perpendicular wave incidence (so $\gamma_\beta = 1$), and no vertical walls ($\gamma_v = 1$). The size of the slope protection is calculated using the expression of van der Meer (Van der Meer J. , 1988), with a permeability of $P = 0.1$, relative density of concrete blocks of $\Delta = 1.7$, acceptable level of damage of $S = 2$ and a number of waves of $N = 500$. The shear stresses at the toe of an embankment are calculated assuming a grain size of $D_{n50} = 7\mu\text{m}$ in Equations 10-11 of the Appendix.

Table 2 Vegetation properties from plantations with ages between 20-29 years old at Domkhali, Moghadia, and Bamonsundar from Uddin et al. (Uddin, Rahman, Hossain, & Akter, 2014)

Variable	Minimum value	Maximum value
Density [tree/m ²]	0,07	0,15
dBH [m]	0,23	0,25
hv [m]	10,5	11,8

2.2.2. Livelihood benefits

The proposed method used to estimate the value of provisioning services (livelihood benefits and opportunities) supplied by mangroves is meta-analytic value function transfer (World Bank, 2024). This value function is estimated from the results of multiple primary studies representing multiple study sites in conjunction with information on parameter values for the policy sites to calculate the values of ecosystem services at the policy sites (Brander, 2013). The approach is represented in Figure 3.

A value function is an equation that relates the value of an ecosystem service to the characteristics of the ecosystem and the beneficiaries of the ecosystem service. Since a meta-analytic value function is estimated from the results of multiple studies, it can represent and control for greater variation in the characteristics of ecosystems, beneficiaries, and other contextual characteristics (Stanley, 2001).

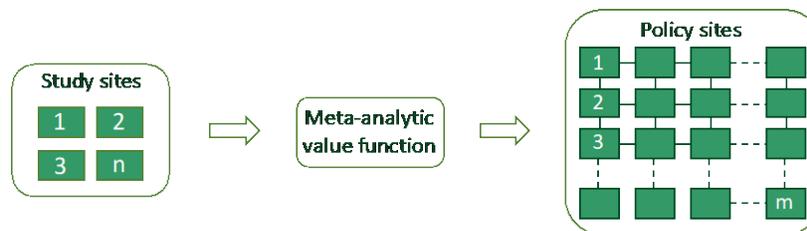


Figure 3 Methodology for meta-analytic value transfer

For the valuation of mangrove provisioning services in Bangladesh, the methodology involves obtaining a database of mangrove valuation results in other locations and countries, estimating a value function using a meta-regression, and applying this to predict the value of provisioning services for policy sites in Bangladesh. The steps in this approach are:

1. Obtain a global database of value estimates for mangrove “study sites”. We use data from the Ecosystem Services Valuation Database (ESVD),² which contains around 380 value estimates for mangrove provisioning services (e.g. fisheries, timber, other raw materials) from both developing and developed countries.
2. Standardize estimated values to a common currency and price level, and set of spatial, temporal, and beneficiary units. We propose to use USD/ha/year for all relevant beneficiaries at 2020 price levels. This is used as the dependent variable in the estimated meta-analytic value function.
3. Add spatially defined variables from available global data sets that help explain variation in ecosystem service values (e.g., mangrove extent, population density, distance to towns, road density, night-time light, ecosystem condition, presence of invasive species etc.).
4. Conduct meta-regression analysis to estimate a value function that explains variation in the dependent variable (value in USD/ha/year) by a set of explanatory variables (including characteristics of the ecosystem and ecosystem service beneficiaries). In this application we make use of a value function developed within another ongoing World Bank project.
5. Construct a database of “policy site” mangroves in Bangladesh including data on the same set of explanatory variables.
6. Input policy site characteristics into the value function to estimate site-specific unit values (USD/ha/year) and multiply by policy site areas to estimate the annual value of service flow from each policy site.
7. Aggregate to policy relevant spatial level (e.g., polders, districts).

The estimated value function for mangrove provisioning services is presented in Table 3. The dependent variable is defined as USD per hectare per year. The explanatory variables include the area of the ecosystem patch in hectares; the population density within 30km radius of the ecosystem; the GDP per capita also for the 30km radius of the valued ecosystem; the human modification index of the ecosystem; and the percentage of the area within 30km radius of the ecosystem that is designated as protected area. The explanatory variables have expected signs in terms of how they influence variation in ES values and are all statistically significant. The overall explanatory power is comparable to similar analyses in the literature. ES values per unit area decline slightly with the size of the ecosystem patch, i.e., total values increase less than proportionately with the size of the ecosystem, which reflects diminishing marginal benefits. ES values also decline with the extent of human disturbance (human modification) and the extent of protected area

² <https://www.esvd.net/>

designation, which is likely to reduce direct use of provisioning services. Population density and income both have positive correlations with ES values, representing demand-side factors.

Table 3 Mangrove provisioning service value function. Dependent variable: USD/ha/year (ln)

	Coefficient	P.
Constant	-0.144	0.935
Area (hectares; ln)	-0.188	0.001
GDP per capita (USD; ln)	0.617	0.001
Population Density (ln)	0.52	0.001
Human Modification index	-2.52	0.001
Protected Area (% of area)	-0.288	0.011
Adjusted R ²	0.179	
N	371	

2.2.3. Carbon sequestration benefits

The value of avoided carbon emissions and additional sequestration by mangroves is estimated using methods and parameters described in the literature (Pendleton, et al., 2012; Murray, Pendleton, & Jenkins, 2011; World Bank, 2024), taking the following steps:

1. Computation of additional carbon sequestration under NBS relative to the baseline by multiplying the cumulative increase in mangrove area by the carbon sequestration rate per unit area for Bangladesh: 14 tCO₂/ha/year (Uddin, Aziz, & Lovelock, Importance of mangrove plantations for climate change mitigation in Bangladesh, 2023).³
2. Computation of avoided release of carbon stored in biomass and substrate by multiplying the avoided loss of mangrove area by the rate of carbon release. The rate at which stored carbon is released following ecosystem loss is different for biomass and substrate carbon and depends on the extent of disturbance to substrate. For mangroves, we follow the assumption that 75% of biomass carbon is released immediately and that the remaining 25% decays with a half-life of 15 years (i.e., a further 12.5% is released within 15 years, a further 6.25% is released within 15 years after that, etc.) (Murray, Pendleton, & Jenkins, 2011). We further assume that mangrove soil organic carbon has a half-life of 7.5 years (i.e., 50% of the stored carbon is released in the first 7.5 years, 25% in the following 7.5 years, etc.).
3. Computation of total additional carbon stored in each year of the analysis (i.e., sum estimates from steps 1 and 2 for each year).
4. Computation of the value of additional carbon stored in each year of the analysis by multiplying the estimated total quantity (from step 3) by the value per tonne CO₂ for each year. The relevant value per tonne of CO₂ is the social cost of carbon (SCC), which is the monetary value of damages caused by emitting one more tonne of CO₂ in a given year (Pearce, 2003). The SCC therefore also represents the value of damages avoided for a small

³ Note that the rate of carbon sequestration is a constant across locations and does not reflect potentially significant spatial variation in sequestration rates due to differences in mangrove species, condition, age structure and other factors.

reduction in emissions, in other words, the benefit of a reduction in atmospheric CO₂ in a given year. The SCC increases over time due to the increasing marginal damage caused by additional tonnes of CO₂ in the atmosphere. In our analysis we use the US Interagency Working Group series of SCC estimates for the period 2010-2050 (Interagency Working Group, 2013), which range from USD/tCO₂e 89-129 over the period 2022-2050. These SCC values are of similar magnitude to the World Bank carbon pricing scenario consistent with compliance with a 2°C? warming target.

2.3. Potential costs of mangrove restoration

The potential costs of mangroves restoration are estimated using data on ecosystem restoration costs from the literature (World Bank, 2024). These data are used in meta-regression analyses to estimate a function that relates the costs of restoration to the characteristics and context of the restoration activity. The estimated functions are subsequently applied to predict location-specific costs accounting for variation in relevant explanatory factors (e.g., size of the restoration site, type of intervention, purchasing power parity).

Data on the costs of mangrove restoration are obtained from Bayraktarov et al. (Bayraktarov, et al., 2016) and Su et al. (Su, Friess, & Gasparatos, 2021). Country level information on purchasing power parity (PPP) and GDP per capita are added to the dataset from the World Development Indicators. An OLS regression model was estimated with the dependent variable defined as restoration cost in USD per hectare at 2020 price levels. The explanatory variables include the area of the restoration site in hectares, a binary variable indicating whether the intervention includes both hydrological restoration and mangrove planting, the PPP adjustment factor for the country, the GDP per capita, and the number of years over which the restoration activities are implemented. The estimated mangrove cost function is presented in Table 4. The explanatory variables have expected signs in terms of how they influence variation in costs and are mostly statistically significant. The estimated coefficient on ‘site area’ is not statistically significant but is retained in the model to provide a means of varying unit cost with the scale of restoration. The overall explanatory power is relatively high. Mangrove restoration that includes both hydrological works and planting has substantially higher costs. Restoration costs also increase with higher price levels, income per capita, and the number of years over which the intervention is implemented. Costs per unit area decline slightly with the size of the restoration site, i.e., total costs increase less than proportionately with the size of the restoration site. Although the estimated model is able to explain a relatively high proportion of variation in restoration costs, there are likely to be several other factors that will determine the cost of mangrove restoration in practice including the species and age of propagules, the mode of afforestation, and the level of protection post planting.

Table 4 Mangrove restoration cost function. Dependent variable: USD/ha (ln)

	Coefficient	P.
Constant	-2.14	0.210
PPP Factor	2.245	0.079

GDP per capita (ln)	0.938	0.001
Site area (hectares; ln)	-0.005	0.929
Cost years (ln)	0.748	0.003
Restoration hydrological and planting	1.274	0.002
Adjusted R ²	0.645	
N	132	

3. Results

3.1. Potential locations for mangroves

The locations of existing mangrove belts at the water side of embankments are shown in Figure 4. The range of mangrove patch lengths (along the embankment), widths (in the direction across the embankment), and total surface areas is shown in Table 5. The mean width and length of the forests are calculated in ArcGIS, based on the geometry of a rectangle with the same surface area as the polygons of Figure 4. Most of the sites identified have relatively narrow widths. In particular, out of the 255 identified sites, 156 had widths below 100 m, 99 had widths longer than 100 m, and only 32 had widths exceeding 500 m.

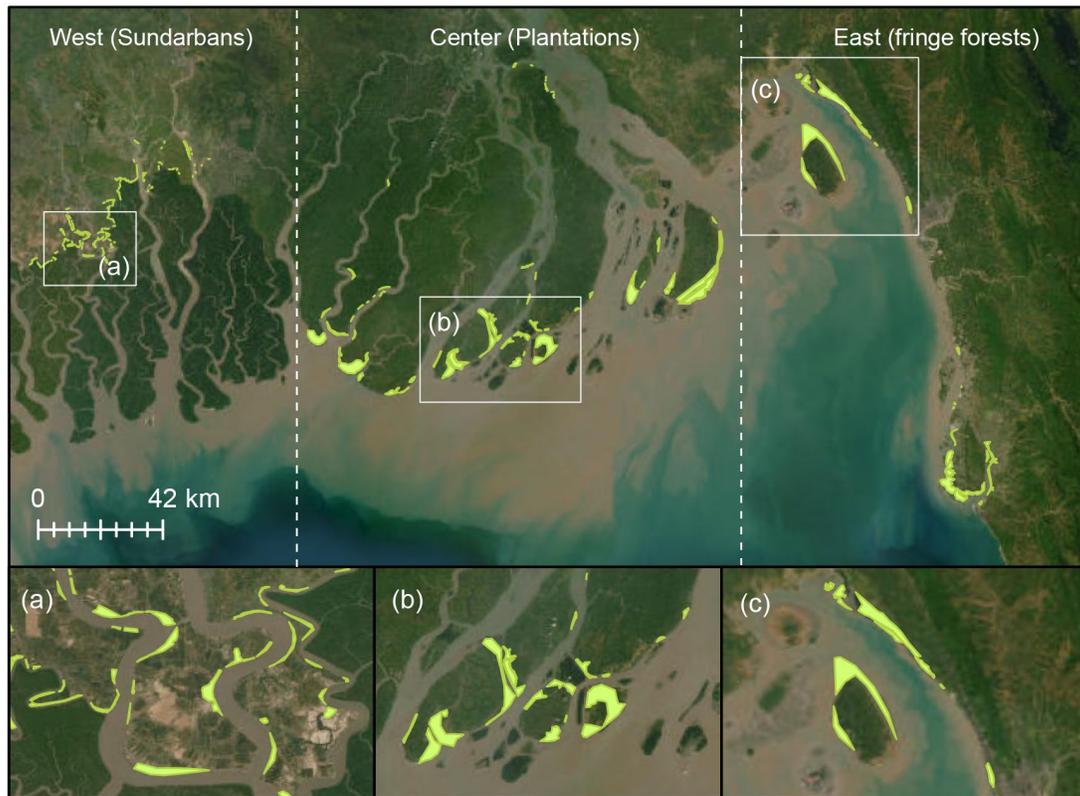


Figure 4 Location of existing and potential embankments (light green polygons) in Bangladesh at the west, center, and east of the country. (a-c) show close ups of the existing mangrove sites.

Table 5 Characteristics of existing and potential sites where mangroves could be integrated into embankment designs, based on the areas shown in Figure 4.

Location	Width_min (m)	Width_max (m)	Length_min (m)	Length_max (m)	Area_min (m ²)	Area_max (m ²)
West	15	268	209	3898	3596	911773
Center	11	1821	164	20840	1842	26419582
East	13	1438	124	28068	17325	14136721

3.2. Potential effect of the vegetation in terms of coastal protection

Western part of the coastal zone

Mangrove locations identified at the west of Bangladesh are characterized by relatively narrow mangrove belts (see shaded grey areas/rectangles in Figure 5), with widths varying between 15-268 m, which limits the benefits that mangroves could provide. In the west region the average forest width is 60 m, associated to a reduction of the revetment thickness of 3%-6%, and a shear stress reduction of 7%-16%. For the maximum forest width of 268 m, the reduction of the revetment block thickness reaches up to 18%-30%, and the reduction of the shear stresses up to 40%-55%. Mangroves have a small effect (<4%) on the total water level (and hence the crest height) for all modeled widths (Figure 5a) because the design water level is dominated by the surge, which is unaffected by mangroves in our model. However, even assuming the largest surge reduction rate ever observed in the field, 0.2 m/km (Krauss, Doyle, Doyle, Swarzenski, & From, 2019; Montgomery, Bryan, Mullarney, & Horstman, 2019), the maximum surge reduction by mangroves would be 6 cm for the widest transect (268 m), which is less than 2% of the total surge height.

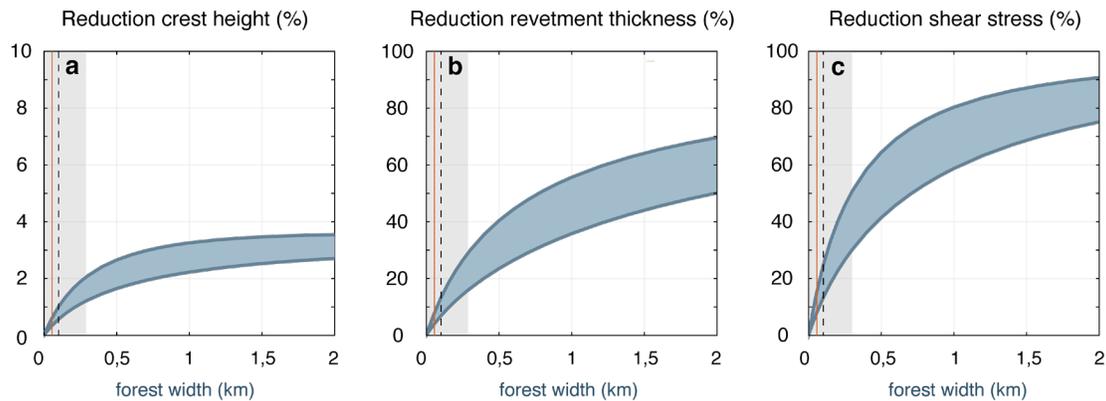


Figure 5 Effect of mangrove afforestation in the west of Bangladesh (just north of the Sundarbans), in terms of (a) crest height reduction, (b) reduction of the revetment thickness, (c) and reduction of the shear stresses. Blue areas show the range of wave reduction estimates for each belt width. Grey areas show the available belt widths in the region, the black dashed line marks a belt width of 100 m and the orange line indicates the average belt width of 60 m.

Center part of the coastal zone

Larger mangrove widths (shown by grey areas in Figure 6) and higher waves (Table 1) are found at the center of the country compared to the west. This implies that mangroves can provide relatively larger benefits by reducing the revetment (Figure 6b) and bank protection (Figure 6c). The average

mangrove belt width is 349 m, associated to revetment thickness reductions of 17%-50% and shear stress reductions of 30%-78%. For the widest belt, of 1.8 km, the revetment reduction would be 47%-82% and the shear stress reduction 71%-96%. The effect of mangroves on design water levels and crest heights is still low for all forest widths, and crest height reductions due to the presence of a forest remain below 6%.

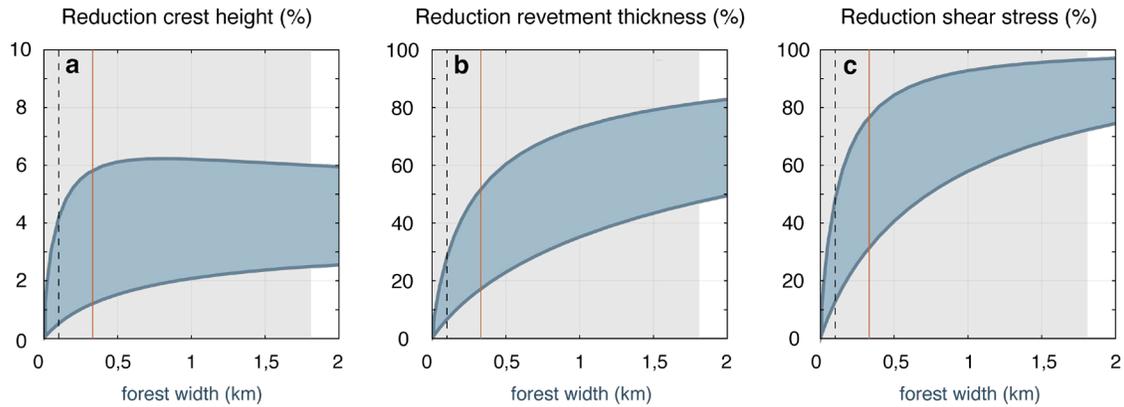


Figure 6 Effect of mangrove afforestation at the center of Bangladesh, in terms of (a) crest height reduction, (b) reduction of the revetment thickness, (c) and reduction of the shear stresses. Blue areas show the range of wave reduction estimates for each plantation width. Grey areas show the available belt widths in the region, the black dashed line marks a belt width of 100 m, and the orange line indicates the average belt width of 349 m.

Eastern part of the coastal zone

The east region shows similar results to the center of the country (Figure 7). Overall, mangrove belts have an average width of 477 m, which is associated to a revetment thickness reduction of 27%-50%, and to a shear stress reduction of 45%-72% at the toe of the structure. The longest belts reach widths of 1.4 km, where the vegetation can largely reduce the required revetment (53%-77%) and shear stresses (79%-96%). The east coast is exposed to the largest surge levels and wave heights (Table 1), and due to this exposure, mangroves tend to grow behind natural obstacles to wave action (such as the island of Sandwip). Water level reduction remains below 7% for all forest widths.

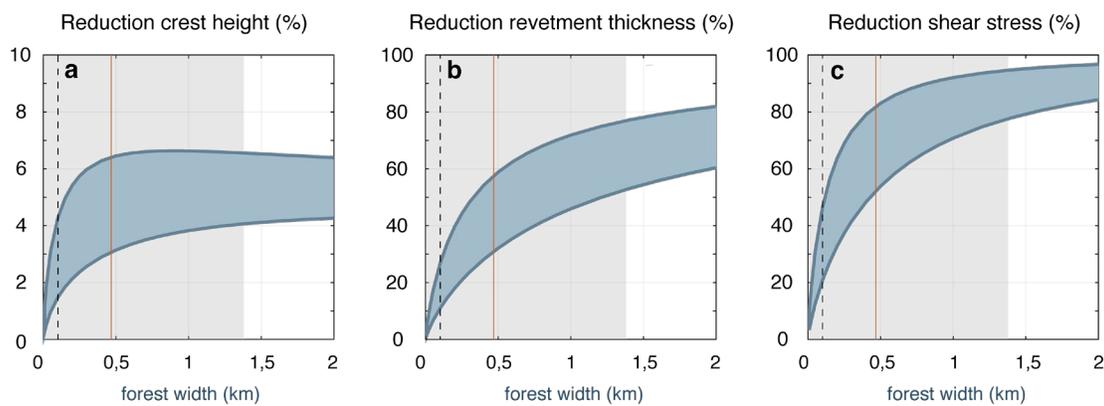


Figure 7 Effect of mangrove afforestation at the east of Bangladesh, in terms of (a) crest height reduction, (b) reduction of the revetment thickness, (c) and reduction of the shear stresses. Blue areas show the range of wave reduction estimates

for each plantation width. Grey areas show the available belt widths in the region, the black dashed line marks a belt width of 100 m, and the orange line indicates the average belt width of 477 m.

The comparison between the effect of mangroves in the three regions can be seen in Figure 8, which shows the areas of most revetment reduction benefits in the center and east of Bangladesh.

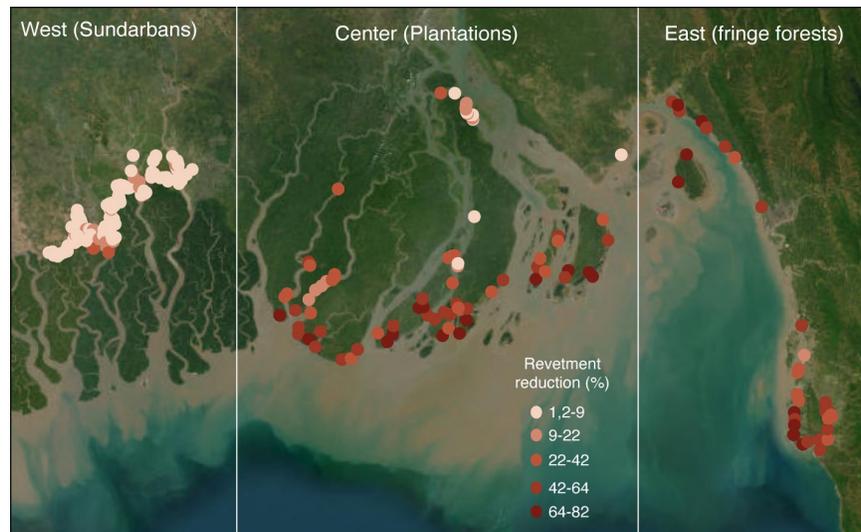


Figure 8 Potential revetment reduction in Bangladesh (%), corresponding with the upper values of Figure 5 (b), Figure 6 (b) and Figure 7 (b).

At the west of the coastal zone, the sites with most potential to be integrated into dike designs are located at the southwest of polder 7/1 (Shahnagar) (Figure 9a), with a mean width of 206 m and a maximum width of 376 m, and on the south of polder 15 (Shymnagar) (Figure 9b), with a mean width of 234 m, and a maximum width of 351 m.

At the center of the coastal zone, seven patches with widths exceeding 1 km were identified, which could largely shelter coastal embankments from cyclones. The largest two are located just south from polder 45 (Amtali) (Figure 9c), with a mean length of 1.77 km and a maximum length of 3 km, and a mangrove belt surrounding the Kukri-Mukri polder (Figure 9d), with a mean width of 1.82 km and a maximum width of 3 km.

At the east of the coastal zone, three sites had widths longer than 1 km. Sandwip has wide mudflat areas surrounding the north and north-east of polder 72 (with a mean length of 1.3 km), and their suitability for mangroves could be investigated in local assessments. The plantations of Mirersarai (Figure 9e) can significantly shelter the embankments that surround polder 61/2, with a mean forest width of 1.2 km. The mangroves surrounding polder 69 (Boro Moheshkhali) (Figure 9f) can also protect coastal embankments from the impact of extreme events, with mean forest widths of 1.4 km and maximum widths of 3.5 km.

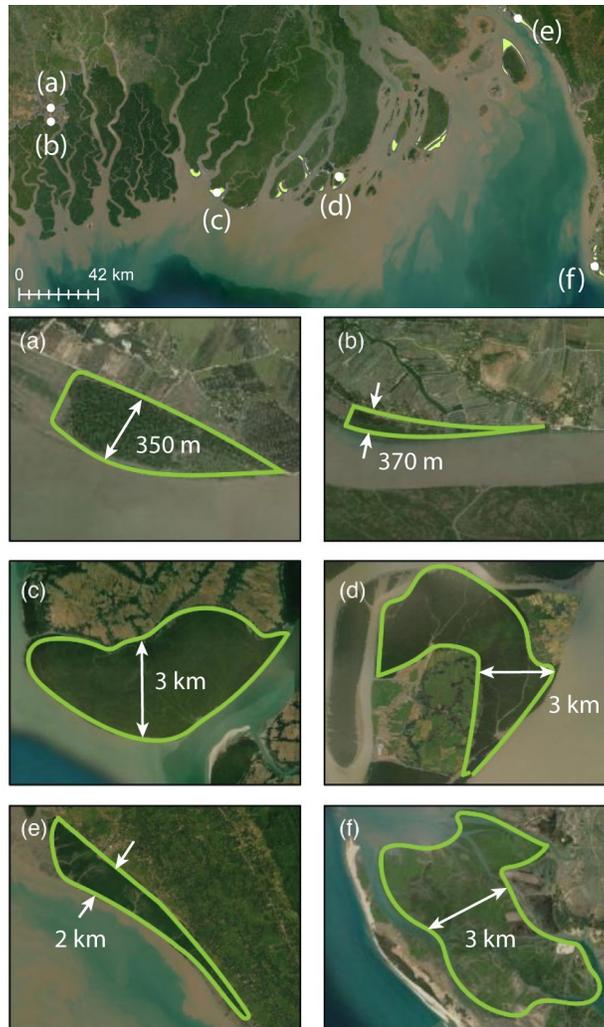


Figure 9 Wide mangrove belts that could reduce embankment design requirements in Bangladesh in (a) Shamnagar (polder 7/1), (b) Shymnagar (polder 15), (c) Amtali (polder 45), (d) Kukri-Mukri, (e) Mirersarai (polder 61/2), (f) Boro Moheshkhali (polder 69).

3.3. Other potential benefits of mangroves

3.3.1. Potential effect of the vegetation in terms of livelihood benefits

Livelihood benefits of mangrove restoration vary between 3,700 USD and 86,000 USD ha⁻¹ (Figure 10), with mean values of 22,039 USD ha⁻¹ at the west, 22,579 USD ha⁻¹ at the center, and 30,330 USD ha⁻¹ at the east. These benefits comprise the sum of mangrove provisioning services (e.g. fisheries, timber, other raw materials). All values are present values computed over a 29-year time horizon using a 6% discount rate. Local variations within each region are driven by differences in population density, with denser locations being associated with higher livelihood benefits per hectare of restored mangrove (shown by darker shades of green in Figure 10). Average livelihood benefits (multiplying unit benefits by patch size and calculating the mean value of each region) range between 0.1 million USD at the west, 3 million USD at the center, and 9 million USD at the east. The larger benefits of central and eastern patches are due to their larger mean size. The largest livelihood

benefits are obtained in the east region, due to the occurrence of large patches at locations with high benefits per unit area.

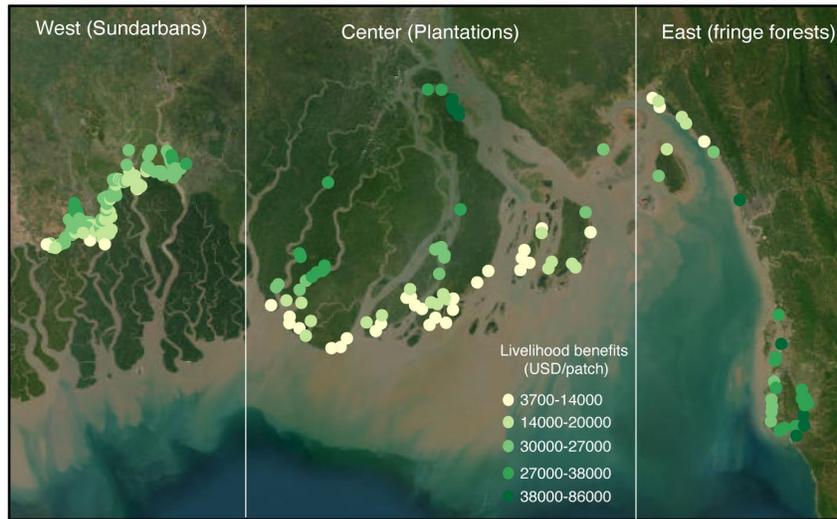


Figure 10 Potential livelihood benefits per patch in Bangladesh with 6% discount rates in million USD

3.3.2. Potential effect of the vegetation in terms of carbon sequestration

Carbon benefits of mangrove restoration have an estimated present value of 13,120 USD ha⁻¹ at all sites, over the period 2022-2050 using a 6% discount rate. Figure 11 represents the significant spatial variation in carbon benefits, which is driven by variation in the area of restored mangroves. At a patch level, potential carbon benefits are higher in the east than in the center and west of the country because these patches have a larger extent.

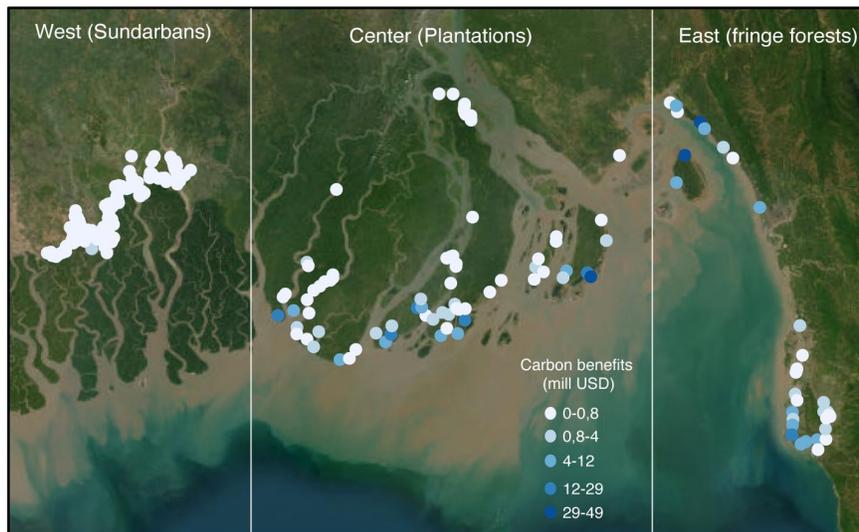


Figure 11 Potential carbon service benefits in Bangladesh 2022-2050 with 6% discount rates in million USD

3.4. Potential costs of mangrove restoration

Mangrove restoration costs have mean values of 7,700 USD ha⁻¹ across the country, with a mean cost per patch of 961,164 USD (Figure 12). Regional unit costs vary slightly between 7,720 USD ha⁻¹ at the west, 7,660 USD ha⁻¹ at the center, and 7,600 USD ha⁻¹ at the east due to difference in patch sizes (larger patches have lower unit costs).

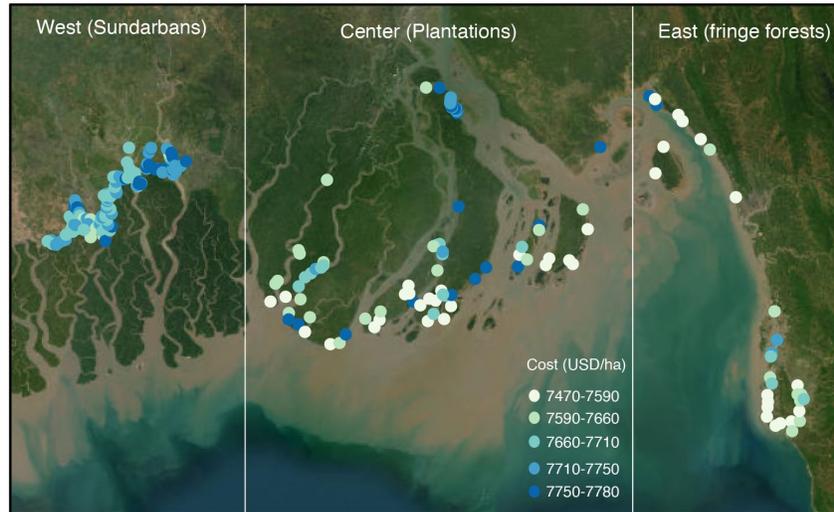


Figure 12 Potential costs of mangrove restoration across Bangladesh, in USD per ha.

4. Discussion and conclusions

Our results highlight the effect of mangrove belts on embankment designs, livelihood benefits, and carbon sequestration in Bangladesh. Below we have summarized our main conclusions and discussion points.

4.1. Costs and benefits of mangrove belts

Considering the comparison between mangrove restoration costs and direct benefits, direct livelihood benefits associated to provisioning services like fisheries, timber, and other raw materials (22,039 USD ha⁻¹ – 30,330 USD ha⁻¹) already exceed the restoration costs (7,467 USD ha⁻¹-7,781 USD ha⁻¹) in 252 of 255 sites. Next to those benefits, mangroves could provide direct cost reductions by influencing embankment designs. The translation of revetment thickness reduction into a decrease in costs depends on the types of revetments that are locally used, the class sizes that are implemented per revetment type, and the local material and construction costs, which should be assessed in local studies.

To give an order of magnitude of revetment costs, rectangular concrete blocks of 40x40x20 cm with geotextile have a cost of 20 USD m⁻² (Alam & Hasan, 2010). For a dike with a height of 5 m with a slope of 1:3, the revetment costs would be 170 USD m⁻¹. Considering a section fronted by a mangrove

belt with average width of 1.8 km, length of 22 km, and a total area of approximately 400 ha (representative of the widest belts in the center of the country), the revetment costs along the mangrove section would be 373,369 USD (approximately 1,000 USD ha⁻¹), neglecting the effect of mangroves. This 1.8-km mangrove belt could decrease the required revetment thickness by 80% - which does not directly imply that the revetment cost would become 200 USD ha⁻¹, as revetments can be provided in fixed class sizes/weights, but could imply a significant cost reduction as lighter revetment alternatives could be considered.

Existing mangroves are likely reducing embankment maintenance costs at the locations where they are already present, e.g. in the sites highlighted in Figure 9. In Viet Nam, avoided embankment repairs due to mangrove presence varied between USD 80,000 and 295,000 for sites between 100 and 900 ha, corresponding with 327-800 USD ha⁻¹ (IFRC, 2014). Similar assessments, comparing costs at sites with and without mangroves, and evaluating the cost-reduction as a function of the forest properties, could also be done in Bangladesh to quantify the value provided by existing mangrove forests.

At sites where mangroves are present, but not considered in coastal protection designs, mangroves also provide indirect benefits by reducing flood damages. In Viet Nam, avoided flood damages due to mangroves were estimated to range between 810 and 15,738 USD ha⁻¹ (IFRC, 2014). Avoided flood damages could be much larger in densely populated areas, and lower in sites with low exposed assets.

4.2. Limitations of mangrove models

The west sites are the locations where the vegetation properties may differ most from the assumptions of this study, since we extrapolated the characteristics of coastal plantations in the east of the country (Table 2) and used the properties of the most-planted species *Sonneratia apetala*. By contrast, the potential sites north of the Sundarbans are largely inhabited by *Heritiera fomes* and *Excoecaria agallocha*. Discerning how these other species would affect wave attenuation results is not straightforward. Both *Sonneratia apetala* and *Heritiera fomes* are relatively tall species, while *Avicennia officinalis* and *Excoecaria agallocha* are relatively shorter and similar in height, but we lack information about their surface area, distribution and composition of heights and diameters, and density. Collecting local data is therefore recommended to optimize predictions in future studies. Within the central region, wave reduction at some sites could be larger than predicted in this study.

Comparison of biomass in plantations at the center (15.4 Mg C ha⁻¹) and east (16.4 Mg C ha⁻¹) of Bangladesh shows very similar values, except closest to the Sundarbans, where biomass almost doubles (31.6 Mg C ha⁻¹). This implies that, for instance, we identified a mangrove site just south of polder 40/1 (Pathargatha), with a mean width of 1.6 km, that according to our model could reduce the revetment thickness between approximately 40%-80%. However, this reduction may be even larger in view of the larger biomass observed in this region (Uddin, Aziz, & Lovelock, Importance of mangrove plantations for climate change mitigation in Bangladesh, 2023). Plantations near the

Sundarbans also showed steeper growth curves and the highest success rate, 42.5%, while survival rates decrease to 10.5% eastward. Nevertheless, accretion and coastal expansion are larger near the mouth of the Meghna River, offering opportunities for mangrove establishment. Overall, the central region is where most plantations are expected in the future, extrapolating from current plantation rates.

4.3. Reflection for strategic planning of the coastal zone

Despite the significant potential benefits of mangroves, there are several practical and technical considerations that may hinder the actual implementation of a large-scale mangroves program. First, the opportunity map underscores that mangrove width is the binding physical constraint. Roughly 60% of the candidate foreshore reaches are < 100 m wide in their current or restorable state, and only a handful of the patches exceed the 500 m threshold that can provide meaningful wave-attenuation and storm-surge reduction benefits. For most polders, therefore, mangroves can complement—but not replace—grey infrastructure such as slope armoring, crest raising, or other embankment upgrades. Policy instruments should be explicit about this “hybrid” role: foreshore belts can slow front-wave energy and limit routine toe-scour, buying valuable design margins and maintenance savings, yet critical-event safety will still hinge on engineered levels and redundancy.

Second, livelihood dividends will not materialize automatically. Fisheries and eco-tourism, for instance, require tenure clarity, extension support, cold-chain links and, crucially, time for trees to mature. In Bangladesh’s complex land ownership system (Akhtaruzzaman, et al., 2022), many of the narrow front-sides of the embankments have status where ownership is ambiguous. Projects should therefore pair restoration finance with governance and market enablers—e.g., issuing community stewardship leases, facilitating contract-growing arrangements with corporate buyers, and sponsoring mangrove commodity producer groups. Without such measures, local households are unlikely to perceive near-term income gains and may oppose planting if they fear losing their land.

Finally, the carbon story is one of scale and aggregation. The monitoring, reporting and verification (MRV) costs of a stand-alone project can exceed the credit value at today’s voluntary-market prices. Aggregating multiple narrow sites under a single program—and aligning with Bangladesh’s Article 6.2 cooperative-approach registry—would lower per-hectare transaction costs and make credits bankable. Until then, carbon income should be treated as an upside, not a core funding pillar. Blended-finance models that stack modest carbon revenue on top of adaptation grants and concessional loans remain the most realistic pathway to move from pilot patches to a landscape-scale, investable mangrove portfolio.

Despite these limitations, we recommend translating the revetment reduction results into specific technical options for designs, especially in sites with sufficient mangrove width. In some cases, the reduced revetment thickness (with mangroves) may not be feasible from a constructive point of view. Concrete blocks may come in specific sizes, and reductions in thickness may only offer a cost reduction if the decreased size is small enough and belongs to a lower class-size. Alternatively,

economic assessments can evaluate whether mangroves, instead of being implemented in designs, are used to reduce maintenance costs of hard structures or to reduce potential flood damages.

4.4. Future studies

Additional mangrove opportunities may be present along the coastal system if other types of restoration are considered, such as the conversion of shrimp ponds into mangrove forests or realigning embankments to expand mangrove plantations landward. In this assessment we only considered the potential of existing mangroves and bare areas with some mangrove presence on the water side of embankments.

For future studies, we recommend assessing the effect of mangroves on embankments using 2D flow and wave models, which will provide more accurate assessments at sites with complex flows (e.g., at sites near estuaries, or with non-uniform coastal morphologies). Local ecological studies and field measurements are also necessary for precise assessments of vegetation performance, and to include additional mangrove species in wave reduction studies. Given that mangrove plantations are already present across the country, measuring their morphodynamics effect (wave and surge reduction, sediment accumulation compared to unvegetated sites) and their resilience (through surveys before and after cyclones) would provide very valuable information on how these ecosystems reduce the hydraulic loads acting on embankments.

This study provides a rapid assessment to scope potential mangrove benefits, while more detailed assessments, further into the project cycle, could improve livelihood and carbon benefit estimates using local data. For instance, co-benefit predictions for the design and feasibility stage of a project could incorporate information about local market prices of ecosystem services, high resolution datasets of ecosystem presence and condition, and/or stated preference surveys (see van Zanten et al. (Van Zanten, et al., 2023) for a full overview). Local studies would also help improve the estimates of mangrove restoration costs, which currently assume that the full mangrove area should be restored (while some areas may already be in good condition) and do not distinguish between different types of restoration.

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Appendix 1. Model equations

A.1.1. Model for the effect of mangroves on embankments

Wave attenuation over a mangrove belt is calculated by applying a wave energy balance from the seaward boundary towards the land (Méndez & Losada, 2004):

$$\frac{dEc_g}{dx} = -\epsilon_v - \epsilon_b \quad (1)$$

where Ec_g is the wave energy flux, equal to the product of the wave energy E (J/m²) times the wave group celerity c_g (m/s), and x is the distance in the cross-shore direction (m). According to Equation 1, any wave energy losses across the profile are due to dissipation by the vegetation (ϵ_v) or due to dissipation by wave breaking (ϵ_b), as the effect of bottom friction is assumed negligible in comparison with ϵ_v (Méndez & Losada, 2004).

The wave dissipation by coastal vegetation is calculated integrating the work done by the forces acting on the plants, given by the Morison equation (Morison, Johnson, & O'Brien, 1950):

$$F_w = \frac{1}{2}\rho c_{D,w}AN_vu^2 + \rho c_MVN_v\frac{du}{dt} \quad (2)$$

Where F_w is the force acting on the trees per unit area (N/m²), which consists of a drag term dependent on the flow velocity squared (left term) and an inertial term dependent on the flow acceleration (right term). ρ is the water density (kg/m³), $c_{D,w}$ is the (empirical) drag coefficient for waves (-), A is the frontal tree area perpendicular to the wave direction (m²), N_v is the number of trees per unit m², and u is the wave-driven water velocity relative to the tree motion (m/s). In the inertial force component, c_M is an empirical inertia coefficient (-), V is the volume of the tree (m³), and du/dt is the wave-driven flow acceleration (m/s²).

The average wave energy dissipated over a wave cycle ϵ_v is equal to the work done by the drag forces, resulting in Equation 3:

$$\epsilon_v = \frac{1}{T} \int_0^{h_v} \int_0^T (F_w u) dz dt \quad (3)$$

Where h_v is the vegetation height (m) and T is the wave period (s). Mendez and Losada (Méndez & Losada, 2004) developed an expression for the wave dissipation ϵ_v assuming negligible plant motion, that the wave-driven flow can be defined using linear wave theory, and that waves are irregular and follow a Rayleigh distribution, resulting in Equation 4:

$$\epsilon_v = \frac{1}{2\sqrt{\pi}} \rho c_{D,w} b_v N_v \left(\frac{k_p g}{2\sigma_p} \right)^3 \frac{\sinh^3(k_p h_v) + 3\sinh(k_p h_v)}{3k_p \cosh(k_p h)} H_{rms}^3 \quad (4)$$

Where b_v is the average plant width (m), k_p is the wave number associated to the peak wave period (rad/m), σ_p is the frequency associated to the peak wave period (rad/s), h is the water depth (m), and H_{rms} is the root mean square wave height (m).

Energy dissipation due to wave breaking is calculated using the method of Thornton and Guza (Thornton & Guza, 1983):

$$\epsilon_b = \frac{3\sqrt{\pi}}{16} \rho g \frac{B^3 f_p}{\gamma_{br}^4 h^5} H_{rms}^7 \quad (5)$$

Where f_p is the peak frequency (s^{-1}), and B (-) and γ_{br} (-) are empirical coefficients that are set to the default values used by Mendez and Losada (2004): $B = 1$ and $\gamma_b = 0.6$.

A.1.2. Embankment height design

The height of an embankment is usually chosen to ensure the overtopping discharge remains below a critical threshold. The overtopping discharge over a structure q can be calculated using empirical equations, such as the equation of van der Meer (Van der Meer, et al., 2018):

$$q = \sqrt{g \cdot H_{m0}^3} \cdot \frac{0.026}{\sqrt{\tan \alpha}} \cdot \gamma_b \cdot \xi_{m-1,0} \cdot e^{-\left(2.5 \frac{h_{crest} - h}{\xi_{m-1,0} H_{m0} \gamma_b \gamma_f \gamma_\beta \gamma_v}\right)^{1.3}}, \quad (6)$$

where q is the overtopping discharge per meter (m^2/s), g is the gravitational acceleration (m/s^2), and H_{m0} is the spectral significant wave height (m), which relates to H_{rms} according to $H_{m0} = \sqrt{2} H_{rms}$. α is the angle of the outer slope (-), $\xi_{m-1,0}$ is the breaker parameter (-), γ_b is the influence factor for a berm (-), γ_f is the influence factor for roughness elements on the slope (-), γ_β is the influence factor for oblique wave attack (-), γ_v is the influence factor for vertical wall, h_{crest} is the crest level (m), and h is the water level (m).

A.1.3. Slope protection design

Wave attenuation by mangroves can also reduce the stone weight required to protect the embankment slope. The slope protection of the embankment can be calculated with the expression of van der Meer (Van der Meer J. , 1988).

$$\frac{H_{m0}}{\Delta d_{n50}} = \left(c_p P^{0.18} \left(\frac{S}{\sqrt{N}} \right)^{0.2} \xi_{m-1,0}^{-0.5} \right) \text{ for } \xi_{m-1,0} < \xi_{cr} \quad (7)$$

Where H_{m0} is the spectral significant wave height at the toe of the structure (m), d_{n50} is the mean diameter of the protection stone blocks (m), Δ is the relative density of stone with respect to water (-), c_p is an empirical parameter set to 5.2, P is the dike permeability (-), S is the acceptable level of damage (-), N is the number of storms that the structure should withstand during storm conditions (-), and ξ_{cr} is the critical Iribarren number (-), defined as:

$$\xi_{cr} = \left(\frac{c_p}{c_s} P^{0.31} \sqrt{\tan(\alpha)} \right)^{\frac{1}{P+0.5}} \quad (8)$$

Where c_s is an empirical parameter equal to 0.87, and α is the slope of the embankment (-). For $\xi_{m-1,0}$ values larger than the critical value, the size of the protection block scan be calculated according to Equation 9:

$$\frac{H_{m0}}{\Delta d_{n50}} = \left(c_s P^{-0.13} \left(\frac{S}{\sqrt{N}} \right)^{0.2} \xi_{m-1,0}^P \cotan(\alpha) \right) \text{ for } \xi_{m-1,0} > \xi_{cr} \quad (9)$$

A.1.4. Erosion at the toe

Wave attenuation by mangroves reduces the shear stresses acting at the toe of the embankment, and hence decreases the erosion rates. The effect of wave attenuation by mangroves on the shear stresses (τ_w) acting on the embankment toe can be calculated according to Equation 10:

$$\tau_w = \frac{1}{4} \rho f_w u_{rms}^2 \quad (10)$$

Where f_w is an empirical friction factor (-) and u_{rms} is the near-bed velocity associated to H_{rms} (which decreases in the presence of a mangrove belt) in m/s. The friction factor can be determined as:

$$f_w = \min \left(\exp \left(-6 + 5.2 \left(\frac{u_{rms}}{2.5 D_{n50} \omega_m} \right)^{-0.19} \right), 0.3 \right) \quad (11)$$

With D_{n50} being the mean grain size (m) and ω_m the mean wave frequency (rad/s).

Appendix 2. Site-level detailed results

A.2.1. Potential mangrove sites

Site	Polder name	Division	lat (deg)	lon (deg)	Width (m)	Area (m2)
M7	Shyamnagar	Khulna	89.1133	22.2086	44.8	36406.1
M9	Shyamnagar	Khulna	89.1136	22.2034	49.1	16861.4
M10	Shyamnagar	Khulna	89.1174	22.1952	49.1	89098.9
M14	Shyamnagar	Khulna	89.1392	22.1979	25.2	20988.7
M15	Shyamnagar	Khulna	89.1465	22.2028	34.9	28915.0
M16	Shyamnagar	Khulna	89.1563	22.2065	45.3	18138.3
M17	Shyamnagar	Khulna	89.1689	22.2110	38.1	23949.0
M18	Shyamnagar	Khulna	89.1635	22.2150	30.6	16901.6
M19	Shyamnagar	Khulna	89.1702	22.2306	38.4	50388.5
M20	Shyamnagar	Khulna	89.1964	22.2420	79.5	65619.0
M21	Shyamnagar	Khulna	89.1914	22.2532	83.0	95513.2
M22	Shyamnagar	Khulna	89.1956	22.2667	54.0	62624.4
M23	Shyamnagar	Khulna	89.1985	22.2718	91.2	66118.8
M24	Shyamnagar	Khulna	89.1935	22.2883	139.6	163759.0
M26	Shyamnagar	Khulna	89.1890	22.2973	140.5	213404.0
M27	Shyamnagar	Khulna	89.1846	22.3009	68.8	58168.2
M28	Shyamnagar	Khulna	89.2032	22.2691	28.5	12926.6
M29	Shyamnagar	Khulna	89.2183	22.2642	15.4	5049.7
M30	Shyamnagar	Khulna	89.2194	22.2588	32.8	22928.1
M31	Shyamnagar	Khulna	89.2093	22.2546	54.8	71016.1
M32	Shyamnagar	Khulna	89.2095	22.2508	55.0	145403.5
M36	Shyamnagar	Khulna	89.2424	22.2641	99.6	85784.7
M37	Shyamnagar	Khulna	89.2502	22.2844	108.3	80866.2
M38	Shyamnagar	Khulna	89.2440	22.2854	43.7	20803.5
M39	Shyamnagar	Khulna	89.2182	22.3020	47.5	49701.8
M40	Shyamnagar	Khulna	89.2124	22.3185	63.7	111351.7
M41	Shyamnagar	Khulna	89.2083	22.3317	18.8	19074.6
M42	Shyamnagar	Khulna	89.2028	22.3428	26.4	15672.3
M43	Shyamnagar	Khulna	89.2040	22.3392	30.4	7683.1
M44	Shyamnagar	Khulna	89.2053	22.3525	41.4	11276.1
M45	Shyamnagar	Khulna	89.2053	22.3634	38.0	41273.9
M46	Shamnagar	Khulna	89.2112	22.3391	22.4	16986.9
M47	Shamnagar	Khulna	89.2133	22.3358	17.2	3596.3
M48	Shamnagar	Khulna	89.2181	22.3261	44.9	11235.4
M49	Shamnagar	Khulna	89.2212	22.3154	36.8	34305.5
M50	Shamnagar	Khulna	89.2225	22.3105	44.9	12964.6
M51	Shamnagar	Khulna	89.2238	22.3041	63.7	53528.3

M52	Shamnagar	Khulna	89.2387	22.2923	206.2	340449.6
M53	Shamnagar	Khulna	89.2506	22.2918	26.4	29742.8
M54	Shamnagar	Khulna	89.2651	22.2896	170.1	318728.8
M55	Shymnagar	Khulna	89.2671	22.2788	156.6	362058.7
M56	Shymnagar	Khulna	89.2555	22.2714	23.5	14713.8
M57	Shymnagar	Khulna	89.2512	22.2579	43.9	30498.3
M59	Shymnagar	Khulna	89.2493	22.2464	24.5	25130.4
M60	Shymnagar	Khulna	89.2655	22.2209	233.9	911773.3
M61	Bedkashi	Khulna	89.3138	22.2278	104.9	243029.8
M62	Shymnagar	Khulna	89.2864	22.2560	192.8	578371.4
M63	Shymnagar	Khulna	89.2979	22.2719	132.1	197101.6
M64	Shymnagar	Khulna	89.3112	22.2762	58.6	63386.0
M65	Shymnagar	Khulna	89.3025	22.2709	24.8	14623.0
M67	Koyara	Khulna	89.3042	22.2919	50.2	100634.4
M68	Bedkashi	Khulna	89.3224	22.2782	53.3	156456.9
M69	Bedkashi	Khulna	89.3104	22.2433	99.5	53624.3
M70	Bedkashi	Khulna	89.3220	22.2059	267.6	484056.2
M71	Bedkashi	Khulna	89.3398	22.2470	173.5	169859.7
M72	Bedkashi	Khulna	89.3365	22.2550	64.6	68787.4
M73	Bedkashi	Khulna	89.3475	22.2619	39.3	16950.2
M74	Bedkashi	Khulna	89.3324	22.2691	51.1	47420.1
M77	Bedkashi	Khulna	89.3279	22.2879	62.2	141314.5
M78	Koyara	Khulna	89.3101	22.2967	34.3	17686.9
M79	Koyara	Khulna	89.3096	22.3024	32.2	27696.7
M80	Koyara	Khulna	89.3219	22.3028	57.5	89376.4
M81	Koyara	Khulna	89.3465	22.3115	27.1	19538.8
M82	Koyara	Khulna	89.3410	22.3301	80.4	177811.6
M83	Koyara	Khulna	89.3266	22.3359	37.0	17290.8
M84	Koyara	Khulna	89.3299	22.3453	53.0	86374.9
M85	Koyara	Khulna	89.3300	22.3604	34.4	36747.1
M86	Koyara	Khulna	89.3297	22.3652	120.0	70628.2
M87	Koyara	Khulna	89.3265	22.3662	51.5	21303.7
M89	Koyara	Khulna	89.3295	22.3682	108.0	82597.7
M90	Koyara	Khulna	89.3326	22.3712	48.6	21643.1
M91	Koyara	Khulna	89.3380	22.3901	85.5	64664.5
M92	Koyara	Khulna	89.3322	22.3894	46.5	29309.5
M93	Koyara	Khulna	89.3286	22.3883	63.6	23087.8
M94	Koyara	Khulna	89.3253	22.3873	43.7	22093.7
M95	Koyara	Khulna	89.3160	22.3819	83.8	61521.0
M96	Koyara	Khulna	89.3430	22.3793	57.7	104565.2
M97	Koyara	Khulna	89.3455	22.3894	62.2	63688.5
M98	Koyara	Khulna	89.3655	22.3930	35.9	15279.4

M99	Koyara	Khulna	89.3644	22.3964	32.4	20512.5
M100	Koyara	Khulna	89.3619	22.4071	28.0	38973.5
M101	Koyara	Khulna	89.3581	22.4151	62.0	74829.8
M102	Koyara	Khulna	89.3610	22.4268	61.9	65354.1
M103	Koyara	Khulna	89.3641	22.4346	45.4	53150.1
M104	Koyara	Khulna	89.3661	22.4508	27.2	28845.0
M105	Koyara	Khulna	89.3658	22.4570	53.4	36474.7
M106	Koyara	Khulna	89.3598	22.4550	44.3	32712.9
M107	Koyara	Khulna	89.3540	22.4510	75.9	43397.5
M108	Paikgachha	Khulna	89.3532	22.4537	68.5	74702.6
M109	Paikgachha	Khulna	89.3765	22.4543	61.1	56455.5
M110	Paikgachha	Khulna	89.3806	22.4514	51.4	42879.8
M112	Paikgachha	Khulna	89.3855	22.4489	66.2	42286.4
M113	Paikgachha	Khulna	89.3897	22.4480	46.8	28316.8
M114	Paikgachha	Khulna	89.3949	22.4446	52.9	41071.8
M115	Paikgachha	Khulna	89.4003	22.4465	54.4	14916.2
M116	Paikgachha	Khulna	89.4085	22.4506	46.2	92040.5
M117	Paikgachha	Khulna	89.4166	22.4672	37.4	75021.4
M118	Paikgachha	Khulna	89.4153	22.4856	91.9	196336.8
M119	Paikgachha	Khulna	89.4058	22.5098	56.6	52331.0
M120	Pankhali	Khulna	89.4132	22.5667	70.5	129066.0
M121	Kamarkhola	Khulna	89.4463	22.4175	111.9	98884.2
M122	Kamarkhola	Khulna	89.4430	22.4204	52.0	26941.2
M123	Kamarkhola	Khulna	89.4364	22.4494	93.7	71324.6
M125	Kamarkhola	Khulna	89.4363	22.4690	110.7	97077.1
M126	Kamarkhola	Khulna	89.4531	22.4350	28.1	6917.6
M127	Kamarkhola	Khulna	89.4612	22.4289	58.0	31083.5
M129	Kamarkhola	Khulna	89.4588	22.4265	17.8	6302.3
M130	Kamarkhola	Khulna	89.4512	22.4270	28.7	10733.6
M131	Kamarkhola	Khulna	89.4816	22.4854	52.2	29300.2
M132	Kamarkhola	Khulna	89.4811	22.4915	42.3	18371.4
M133	Kamarkhola	Khulna	89.4835	22.5044	24.8	18081.7
M134	Kamarkhola	Khulna	89.4901	22.4994	47.5	12661.3
M135	Kamarkhola	Khulna	89.4880	22.5460	39.7	10941.5
M136	Kamarkhola	Khulna	89.4898	22.5480	37.7	14437.4
M137	Kamarkhola	Khulna	89.4983	22.5632	27.8	7202.6
M138	Kamarkhola	Khulna	89.4982	22.5656	46.0	21190.6
M139	Kamarkhola	Khulna	89.5257	22.4845	41.5	44475.6
M140	Kamarkhola	Khulna	89.5135	22.4833	44.5	17050.3
M141	Kamarkhola	Khulna	89.5371	22.4853	52.3	16229.7
M142	Kamarkhola	Khulna	89.5370	22.4811	42.8	18661.4
M143	Kamarkhola	Khulna	89.5426	22.4711	35.2	17533.5

M144	Kamarkhola	Khulna	89.5840	22.4620	43.7	18205.1
M145	Kamarkhola	Khulna	89.5815	22.4816	38.1	10541.6
M146	Kamarkhola	Khulna	89.5814	22.4855	52.5	23728.4
M147	Kamarkhola	Khulna	89.5765	22.5151	15.7	7408.4
M148	Kamarkhola	Khulna	89.5750	22.5192	29.5	10757.9
M149	Kamarkhola	Khulna	89.5735	22.5231	39.0	17408.7
M150	Kamarkhola	Khulna	89.5725	22.5274	66.4	22120.2
M151	Kamarkhola	Khulna	89.5720	22.5298	52.4	16401.4
M152	Kamarkhola	Khulna	89.5710	22.5327	104.7	60594.8
M153	Kamarkhola	Khulna	89.5677	22.5458	135.9	351476.7
M154	Kamarkhola	Khulna	89.5593	22.5631	40.4	39828.5
M155	Rampal	Khulna	89.5769	22.5469	16.1	5231.2
M156	Rampal	Khulna	89.5784	22.5430	24.8	10857.7
M157	Rampal	Khulna	89.5815	22.5302	22.8	9766.4
M158	Rampal	Khulna	89.5903	22.4964	40.8	17979.5
M159	Rampal	Khulna	89.5934	22.4741	47.0	26438.1
M160	Rampal	Khulna	89.6114	22.4952	85.8	32242.7
M161	Rampal	Khulna	89.6333	22.5143	17.2	10118.5
						15919578.
M162	Patharghata	Barisal	89.9586	21.9722	1592.1	4
M163	Patharghata	Barisal	89.9779	22.0414	168.6	307573.7
M164	Patharghata	Barisal	89.9864	22.0522	151.9	461321.4
M165	Barguna Sadar	Barisal	90.0170	21.9906	418.4	4121659.2
M166	Amtali	Barisal	90.0743	21.9810	158.3	533062.1
M167	Betagi	Barisal	90.0667	22.1709	248.5	904464.9
M168	Barguna Sadar	Barisal	90.0715	22.1574	131.5	229980.5
M169	Barguna	Barishal	90.1764	22.4421	137.0	287209.6
M170	Barguna Sadar	Barisal	90.0673	22.0309	69.4	141157.1
M171	Barguna Sadar	Barisal	90.0917	22.0660	79.4	176574.5
M172	Barguna Sadar	Barisal	90.1146	22.0813	70.8	59793.3
M173	Barguna Sadar	Barisal	90.1330	22.0984	39.6	29169.3
M174	Barguna	Barisal	90.1632	22.1240	94.5	363504.3
M175	Amtali	Barisal	90.1632	22.1124	123.0	100327.7
M176	Amtali	Barisal	90.1539	22.1033	114.5	157199.4
M177	Amtali	Barisal	90.0295	21.9278	359.1	1254173.4
M178	Amtali	Barisal	90.0286	21.9031	314.5	698428.8
						21949539.
M179	Amtali	Barisal	90.0669	21.8839	1776.4	3
M180	Amtali	Barisal	90.1106	21.9116	365.3	1355468.2
M181	Kuakata	Barisal	90.0917	21.8549	548.2	2010892.8
M182	Kuakata	Barisal	90.1896	21.8076	571.3	3562927.7
M183	Kuakata	Barisal	90.2248	21.8120	164.5	650950.6

M184	Kalapara	Barisal	90.2486	21.8452	446.5	1457534.3
M185	Galachipa	Barisal	90.3593	21.8734	968.5	8933446.9
						13666775.
M186	Galachipa	Barisal	90.3792	21.9018	1374.9	3
M187	Galachipa	Barisal	90.3828	21.9335	413.4	894847.0
M188	Galachipa	Barisal	90.3240	21.9061	214.5	1245016.2
						13460931.
M189	Galachipa	Barisal	90.4770	22.0006	667.8	1
M190	Galachipa	Barisal	90.5095	21.9723	490.9	1552444.9
M191	Galachipa	Barisal	90.4938	22.0031	731.3	4955842.8
M192	Galachipa	Barisal	90.4905	22.0336	397.8	1647656.5
M193	Galachipa	Barisal	90.5363	21.9577	493.6	2836331.6
M194	Galachipa	Barisal	90.5710	21.9834	441.9	1814725.6
M195	Galachipa	Barisal	90.5950	21.9761	559.6	1965238.7
M196	Galachipa	Barisal	90.5651	21.8967	810.7	4946796.4
M197	Galachipa	Barisal	90.5875	21.9242	124.1	165663.1
M198	no name	no name	90.6282	21.9047	870.9	4752605.6
M199	no name	no name	90.6545	21.9545	1820.9	21962911.5
M200	Bhola	Barisal	90.6024	22.1921	49.6	76613.6
M201	Bhola	Barisal	90.6102	22.1947	98.9	111393.1
M202	Galachipa	Barisal	90.6020	22.0925	180.0	637476.5
M203	Galachipa	Barisal	90.5869	22.1860	130.3	317772.7
M204	Bhola	Barisal	90.6171	22.0143	456.8	2071183.6
M205	Bhola	Barisal	90.6331	21.9948	98.5	130230.3
M206	Bhola	Barisal	90.6561	21.9975	247.2	408323.1
M207	Bhola	Barisal	90.6236	21.9991	112.4	111351.0
M208	Bhola	Barisal	90.7475	22.0595	228.2	468509.3
M209	Bhola	Barisal	90.7900	22.1035	268.5	705669.4
M210	Bhola	Barisal	90.6777	22.7007	17.7	5783.7
M211	Bhola	Barisal	90.6761	22.7047	33.1	10255.9
M212	Bhola	Barisal	90.6766	22.7082	67.2	47407.0
M213	Bhola	Barisal	90.6771	22.7175	22.0	6421.1
M214	Bhola	Barisal	90.6733	22.7176	21.8	12692.8
M215	Bhola	Barisal	90.6696	22.7176	13.1	2320.7
M216	Bhola	Barisal	90.6576	22.7223	61.5	26747.1
M217	Bhola	Barisal	90.6552	22.7267	13.4	3940.7
M218	Bhola	Barisal	90.6543	22.7287	11.2	1842.0
M219	Bhola	Barisal	90.6535	22.7322	15.5	8981.6
M220	Bhola	Barisal	90.6518	22.7386	49.7	34022.9
M221	Bhola	Barisal	90.6514	22.7427	59.5	21713.4
M222	Bhola	Barisal	90.6528	22.7523	51.3	17467.1
M223	Bhola	Barisal	90.6534	22.7609	35.2	27469.5

M224	Bhola	Barisal	90.6107	22.7981	11.2	7165.6
M225	Bhola	Barisal	90.5586	22.7989	202.7	405567.5
M226	Bhola	Barisal	90.6216	22.1552	45.3	50724.3
M227	Bhola	Barisal	90.6226	22.1649	26.9	30894.6
M228	Bhola	Barisal	90.6833	22.3390	14.1	7164.1
						14543017.
M229	Manpura South	Barisal	90.9128	22.1068	1387.7	2
M230	Manpura South	Barisal	90.9182	22.1527	371.0	2054975.2
M231	Manpura South	Barisal	90.9284	22.1834	105.8	179389.2
M232	Manpura North	Barisal	90.9952	22.2662	304.1	745065.0
M233	Manpura North	Barisal	90.9941	22.2487	190.1	642374.5
M234	Manpura South	Barisal	90.9473	22.1346	91.1	226202.7
M235	Hatiya South	Chittagong	91.0331	22.1387	694.6	4791071.9
M236	Hatiya South	Chittagong	91.0203	22.1131	596.3	1804905.7
						18874656.
M237	Hatiya South	Chittagong	91.1105	22.1313	1064.5	4
						26419582.
M238	Hatiya South	Chittagong	91.1238	22.1169	1267.7	1
M239	Hatiya North	Chittagong	91.1814	22.2517	500.9	4992248.3
M240	Hatiya North	Chittagong	91.1625	22.3282	193.3	535017.0
						37823714.
M241	Sandwip	Chittagong	91.4736	22.5698	1347.6	2
M242	Sandwip	Chittagong	91.4426	22.4677	735.8	8838005.9
M243	Shudharam	Chittagong	91.2304	22.5693	13.1	1628.1
M245	no name	no name	91.4193	22.7661	516.7	1599458.8
M246	no name	no name	91.4461	22.7319	316.0	1465772.9
M247	no name	no name	91.4412	22.7543	758.8	3882550.5
						26868666.
M244	Sitakunda	Chittagong	91.5310	22.6934	1223.0	4
M248	Sitakunda	Chittagong	91.6169	22.5997	537.4	3798522.6
M249	Mirsharai	Chittagong	91.5470	22.6690	446.1	3721056.8
M250	Sitakunda	Chittagong	91.6526	22.5593	175.3	259853.7
M251	Patenga	Chittagong	91.7527	22.3755	601.8	3757520.4
M252	Banshkhali	Chittagong	91.9019	21.9344	341.5	959039.9
	Magnama_Ujanti					
M253	a	Chittagong	91.9117	21.8237	42.3	19803.4
	Magnama_Ujanti					
M254	a	Chittagong	91.8910	21.7730	137.7	130738.5
M255	Matarbari	Chittagong	91.8875	21.7599	110.8	82847.9
M256	NE	Chittagong	91.9904	21.6482	398.9	1950179.5
M257	Khangona	Chittagong	92.0046	21.6130	304.1	1084730.5
M258	NE	Chittagong	91.9905	21.6136	279.4	1150955.8
M259	Matarbari	Chittagong	91.8845	21.6788	198.1	976619.5

M260	Choto Moheshkhali	Chittagong	91.8914	21.6558	96.0	205392.8
M261	Choto Moheshkhali	Chittagong	91.8743	21.6110	925.9	5773347.6
M262	Choto Moheshkhali	Chittagong	91.8763	21.5852	638.6	2596338.4
M263	Choto Moheshkhali	Chittagong	91.8747	21.5638	905.6	3981517.1
M264	Choto Moheshkhali	Chittagong	91.8723	21.5274	1437.6	14136720.6
M265	Boro Moheshkhali	Chittagong	91.9060	21.4924	980.1	7006686.6
M266	Boro Moheshkhali	Chittagong	91.9239	21.5018	654.7	3536048.6
M267	Boro Moheshkhali	Chittagong	91.9668	21.5090	536.4	3936754.0
M268	Kurushkul	Chittagong	91.9697	21.4718	265.0	498821.1
M270	Kurushkul	Chittagong	91.9991	21.5105	185.0	652325.2
M271	Khangona	Chittagong	91.9974	21.5490	290.4	2095063.7
M272	Khangona	Chittagong	92.0008	21.5894	82.1	306430.0
M273	Khangona	Chittagong	92.0110	21.6018	121.2	235053.6
M274	Khangona	Chittagong	92.0144	21.5952	133.5	209026.8
M1b	Shyamnagar	Khulna	89.0995	22.2051	61.8	231063.6
M12b	Shyamnagar	Khulna	89.1323	22.1918	35.7	38381.6
M29b	Shyamnagar	Khulna	89.2072	22.2675	41.0	17325.4
M34b	Shyamnagar	Khulna	89.2387	22.2496	59.4	124515.8

A.2.2. Flood benefits

Name (-)	Width (m)	Region (-)	Crest_red_mi n (%)	Crest_red_ma x (%)	Rev_red_mi n (%)	Rev_red_ma x (%)	Shear_red_mi n (%)	Shear_red_ma x (%)
M7	44.8	West	0.17	0.48	2.37	4.50	4.15	10.53
M9	49.1	West	0.19	0.52	2.60	4.98	4.74	12.12
M10	49.1	West	0.19	0.52	2.60	4.98	4.73	12.11
M14	25.2	West	0.08	0.32	1.32	2.29	1.49	3.28
M15	34.9	West	0.13	0.40	1.84	3.38	2.81	6.87
M16	45.3	West	0.18	0.48	2.40	4.56	4.23	10.73
M17	38.1	West	0.14	0.42	2.01	3.74	3.24	8.04
M18	30.6	West	0.10	0.36	1.61	2.90	2.22	5.28
M19	38.4	West	0.14	0.43	2.03	3.78	3.28	8.17
M20	79.5	West	0.34	0.77	4.23	8.39	8.86	23.34
M21	83.0	West	0.36	0.80	4.42	8.78	9.34	24.62
M22	54.0	West	0.22	0.56	2.86	5.52	5.40	13.91
M23	91.2	West	0.40	0.87	4.86	9.70	10.46	26.71
M24	139.6	West	0.64	1.28	7.46	15.12	17.02	32.79
M26	140.5	West	0.64	1.29	7.51	15.23	17.14	32.90
M27	68.8	West	0.29	0.68	3.66	7.19	7.42	19.40
M28	28.5	West	0.09	0.34	1.50	2.67	1.95	4.53
M29	15.4	West	0.03	0.23	0.79	1.21	0.17	0.00
M30	32.8	West	0.11	0.38	1.72	3.15	2.52	6.08
M31	54.8	West	0.22	0.56	2.91	5.62	5.51	14.22
M32	55.0	West	0.22	0.57	2.92	5.64	5.54	14.29
M36	99.6	West	0.44	0.94	5.31	10.64	11.58	27.76
M37	108.3	West	0.48	1.01	5.78	11.61	12.77	28.86

M38	43.7	West	0.17	0.47	2.31	4.37	4.00	10.12
M39	47.5	West	0.19	0.50	2.51	4.79	4.51	11.51
M40	63.7	West	0.27	0.64	3.39	6.62	6.72	17.52
M41	18.8	West	0.05	0.26	0.97	1.58	0.62	0.93
M42	26.4	West	0.08	0.33	1.38	2.44	1.66	3.75
M43	30.4	West	0.10	0.36	1.60	2.88	2.20	5.21
M44	41.4	West	0.16	0.45	2.19	4.11	3.69	9.26
M45	38.0	West	0.14	0.42	2.00	3.73	3.23	8.02
M46	22.4	West	0.06	0.29	1.17	1.98	1.11	2.25
M47	17.2	West	0.04	0.25	0.89	1.41	0.41	0.36
M48	44.9	West	0.17	0.48	2.38	4.51	4.17	10.57
M49	36.8	West	0.13	0.41	1.94	3.60	3.07	7.58
M50	44.9	West	0.17	0.48	2.37	4.50	4.16	10.55
M51	63.7	West	0.27	0.64	3.39	6.62	6.73	17.52
M52	206.2	West	0.86	1.65	11.03	22.38	23.66	41.16
M53	26.4	West	0.08	0.33	1.38	2.44	1.66	3.75
M54	170.1	West	0.76	1.49	9.10	18.55	21.16	36.63
M55	156.6	West	0.72	1.42	8.37	17.03	19.33	34.93
M56	23.5	West	0.07	0.30	1.23	2.11	1.27	2.68
M57	43.9	West	0.17	0.47	2.32	4.39	4.03	10.18
M59	24.5	West	0.07	0.31	1.28	2.23	1.41	3.06
M60	233.9	West	0.93	1.77	12.52	24.36	25.32	44.65
M61	104.9	West	0.47	0.99	5.60	11.24	12.31	28.43
M62	192.8	West	0.82	1.59	10.32	21.09	22.86	39.48
M63	132.1	West	0.60	1.21	7.06	14.28	16.00	31.85
M64	58.6	West	0.24	0.60	3.11	6.04	6.03	15.62

M65	24.8	West	0.08	0.31	1.29	2.25	1.43	3.13
M67	50.2	West	0.20	0.53	2.66	5.11	4.89	12.53
M68	53.3	West	0.21	0.55	2.82	5.45	5.30	13.65
M69	99.5	West	0.44	0.94	5.31	10.63	11.58	27.75
M70	267.6	West	1.03	1.92	14.06	26.77	27.34	47.45
M71	173.5	West	0.77	1.50	9.28	18.93	21.63	37.06
M72	64.6	West	0.27	0.65	3.43	6.72	6.84	17.84
M73	39.3	West	0.15	0.43	2.07	3.88	3.40	8.48
M74	51.1	West	0.20	0.53	2.71	5.20	5.00	12.84
M77	62.2	West	0.26	0.63	3.30	6.44	6.51	16.93
M78	34.3	West	0.12	0.39	1.81	3.32	2.73	6.67
M79	32.2	West	0.11	0.37	1.69	3.08	2.44	5.87
M80	57.5	West	0.24	0.59	3.05	5.92	5.87	15.20
M81	27.1	West	0.09	0.33	1.42	2.52	1.76	4.01
M82	80.4	West	0.35	0.78	4.28	8.49	8.99	23.67
M83	37.0	West	0.14	0.41	1.95	3.62	3.10	7.66
M84	53.0	West	0.21	0.55	2.81	5.42	5.27	13.56
M85	34.4	West	0.12	0.39	1.81	3.33	2.74	6.68
M86	120.0	West	0.54	1.11	6.40	12.92	14.35	30.32
M87	51.5	West	0.21	0.54	2.73	5.24	5.06	12.98
M89	108.0	West	0.48	1.01	5.76	11.58	12.73	28.82
M90	48.6	West	0.19	0.51	2.57	4.92	4.67	11.93
M91	85.5	West	0.37	0.82	4.56	9.06	9.68	25.55
M92	46.5	West	0.18	0.49	2.46	4.69	4.38	11.15
M93	63.6	West	0.27	0.64	3.38	6.61	6.71	17.48
M94	43.7	West	0.17	0.47	2.31	4.38	4.01	10.13

M95	83.8	West	0.36	0.81	4.47	8.87	9.45	24.93
M96	57.7	West	0.24	0.59	3.07	5.95	5.91	15.31
M97	62.2	West	0.26	0.63	3.30	6.44	6.51	16.93
M98	35.9	West	0.13	0.41	1.89	3.49	2.94	7.23
M99	32.4	West	0.11	0.38	1.71	3.11	2.48	5.97
M100	28.0	West	0.09	0.34	1.47	2.62	1.88	4.35
M101	62.0	West	0.26	0.63	3.30	6.43	6.49	16.89
M102	61.9	West	0.26	0.62	3.29	6.42	6.48	16.84
M103	45.4	West	0.18	0.49	2.40	4.57	4.24	10.77
M104	27.2	West	0.09	0.33	1.42	2.52	1.76	4.02
M105	53.4	West	0.22	0.55	2.83	5.47	5.33	13.72
M106	44.3	West	0.17	0.48	2.35	4.45	4.09	10.36
M107	75.9	West	0.33	0.74	4.04	7.99	8.38	22.02
M108	68.5	West	0.29	0.68	3.64	7.15	7.37	19.27
M109	61.1	West	0.25	0.62	3.25	6.33	6.37	16.55
M110	51.4	West	0.21	0.54	2.73	5.24	5.05	12.97
M112	66.2	West	0.28	0.66	3.52	6.90	7.06	18.44
M113	46.8	West	0.18	0.50	2.48	4.72	4.42	11.26
M114	52.9	West	0.21	0.55	2.80	5.40	5.25	13.51
M115	54.4	West	0.22	0.56	2.89	5.57	5.46	14.07
M116	46.2	West	0.18	0.49	2.44	4.65	4.34	11.04
M117	37.4	West	0.14	0.42	1.97	3.66	3.15	7.79
M118	91.9	West	0.40	0.88	4.90	9.78	10.55	26.80
M119	56.6	West	0.23	0.58	3.00	5.82	5.75	14.88
M120	70.5	West	0.30	0.70	3.75	7.38	7.64	20.01
M121	111.9	West	0.50	1.05	5.97	12.02	13.26	29.31

M122	52.0	West	0.21	0.54	2.76	5.31	5.13	13.20
M123	93.7	West	0.41	0.89	4.99	9.98	10.79	27.02
M125	110.7	West	0.49	1.03	5.91	11.88	13.09	29.15
M126	28.1	West	0.09	0.34	1.47	2.62	1.88	4.36
M127	58.0	West	0.24	0.59	3.08	5.98	5.95	15.42
M129	17.8	West	0.04	0.25	0.92	1.47	0.49	0.56
M130	28.7	West	0.09	0.34	1.50	2.69	1.96	4.57
M131	52.2	West	0.21	0.54	2.77	5.32	5.15	13.25
M132	42.3	West	0.16	0.46	2.24	4.22	3.82	9.61
M133	24.8	West	0.08	0.31	1.30	2.26	1.44	3.16
M134	47.5	West	0.19	0.50	2.52	4.80	4.52	11.54
M135	39.7	West	0.15	0.44	2.10	3.92	3.46	8.64
M136	37.7	West	0.14	0.42	1.99	3.70	3.19	7.90
M137	27.8	West	0.09	0.34	1.46	2.59	1.85	4.27
M138	46.0	West	0.18	0.49	2.44	4.64	4.32	10.98
M139	41.5	West	0.16	0.45	2.19	4.12	3.70	9.30
M140	44.5	West	0.17	0.48	2.36	4.47	4.12	10.43
M141	52.3	West	0.21	0.54	2.77	5.34	5.17	13.30
M142	42.8	West	0.16	0.46	2.26	4.27	3.88	9.80
M143	35.2	West	0.13	0.40	1.85	3.42	2.85	6.98
M144	43.7	West	0.17	0.47	2.31	4.38	4.01	10.13
M145	38.1	West	0.14	0.42	2.01	3.74	3.24	8.05
M146	52.5	West	0.21	0.55	2.79	5.36	5.20	13.38
M147	15.7	West	0.03	0.24	0.81	1.23	0.20	0.00
M148	29.5	West	0.10	0.35	1.55	2.78	2.08	4.89
M149	39.0	West	0.15	0.43	2.06	3.84	3.36	8.38

M150	66.4	West	0.28	0.66	3.53	6.91	7.08	18.48
M151	52.4	West	0.21	0.54	2.78	5.35	5.19	13.35
M152	104.7	West	0.47	0.98	5.59	11.21	12.28	28.40
M153	135.9	West	0.62	1.25	7.26	14.71	16.52	32.33
M154	40.4	West	0.15	0.44	2.13	4.00	3.55	8.90
M155	16.1	West	0.03	0.24	0.83	1.28	0.26	0.00
M156	24.8	West	0.08	0.31	1.29	2.25	1.43	3.14
M157	22.8	West	0.07	0.30	1.19	2.03	1.17	2.42
M158	40.8	West	0.15	0.45	2.15	4.05	3.61	9.05
M159	47.0	West	0.18	0.50	2.49	4.74	4.45	11.32
M160	85.8	West	0.37	0.83	4.57	9.10	9.72	25.67
M161	17.2	Center	0.19	1.79	2.97	5.99	4.63	15.32
	1592.							
M162	1	Center	2.36	6.05	44.96	80.57	68.85	95.65
M163	168.6	Center	0.70	4.70	9.27	33.96	17.55	60.64
M164	151.9	Center	0.64	4.51	8.57	31.65	16.13	57.82
M165	418.4	Center	1.36	5.99	19.03	55.41	34.19	80.12
M166	158.3	Center	0.66	4.59	8.84	32.53	16.67	59.29
M167	248.5	Center	0.94	5.40	12.59	45.08	23.74	69.48
M168	131.5	Center	0.57	4.29	7.72	28.81	14.38	53.07
M169	137.0	Center	0.59	4.35	7.95	29.57	14.85	54.35
M170	69.4	Center	0.37	3.36	5.14	18.72	9.08	38.62
M171	79.4	Center	0.40	3.60	5.55	21.16	9.94	40.95
M172	70.8	Center	0.37	3.40	5.20	19.08	9.21	38.97
M173	39.6	Center	0.27	2.64	3.90	11.46	6.54	31.71
M174	94.5	Center	0.45	3.87	6.18	23.65	11.22	44.46

M175	123.0	Center	0.55	4.19	7.37	27.62	13.66	51.09
M176	114.5	Center	0.52	4.09	7.01	26.44	12.93	49.11
M177	359.1	Center	1.21	5.79	17.08	51.98	30.54	78.06
M178	314.5	Center	1.10	5.63	15.34	49.41	27.80	76.52
	1776.							
M179	4	Center	2.44	5.98	47.14	82.00	71.40	96.38
M180	365.3	Center	1.23	5.81	17.28	52.34	30.92	78.28
M181	548.2	Center	1.58	6.13	23.28	61.86	41.39	84.61
M182	571.3	Center	1.62	6.15	24.04	62.64	42.25	85.41
M183	164.5	Center	0.68	4.66	9.10	33.40	17.20	60.20
M184	446.5	Center	1.41	6.04	19.95	57.04	35.91	81.09
M185	968.5	Center	2.02	6.28	34.58	73.78	55.81	93.30
	1374.							
M186	9	Center	2.32	6.14	42.40	79.05	65.15	94.78
M187	413.4	Center	1.35	5.97	18.86	55.12	33.87	79.94
M188	214.5	Center	0.85	5.22	11.18	40.35	21.47	65.72
M189	667.8	Center	1.77	6.23	26.89	65.91	45.88	88.40
M190	490.9	Center	1.49	6.08	21.40	59.60	38.64	82.62
M191	731.3	Center	1.87	6.25	28.56	68.06	48.27	89.43
M192	397.8	Center	1.31	5.92	18.35	54.22	32.92	79.40
M193	493.6	Center	1.49	6.08	21.49	59.76	38.81	82.72
M194	441.9	Center	1.41	6.04	19.80	56.77	35.63	80.93
M195	559.6	Center	1.60	6.14	23.66	62.25	41.81	85.00
M196	810.7	Center	1.93	6.26	30.64	70.56	51.25	90.73
M197	124.1	Center	0.55	4.20	7.41	27.77	13.75	51.34
M198	870.9	Center	1.96	6.27	32.21	71.79	53.09	91.71

	1820.								
M199	9	Center	2.46	5.98	47.67	82.35	71.99	96.55	
M200	49.6	Center	0.30	2.88	4.32	13.90	7.40	34.03	
M201	98.9	Center	0.46	3.92	6.37	24.27	11.60	45.50	
M202	180.0	Center	0.73	4.83	9.74	35.55	18.52	61.90	
M203	130.3	Center	0.57	4.27	7.67	28.64	14.28	52.79	
M204	456.8	Center	1.43	6.05	20.29	57.64	36.55	81.44	
M205	98.5	Center	0.46	3.91	6.35	24.22	11.57	45.40	
M206	247.2	Center	0.93	5.40	12.54	44.90	23.66	69.33	
M207	112.4	Center	0.51	4.07	6.93	26.15	12.76	48.64	
M208	228.2	Center	0.88	5.33	11.74	42.25	22.49	67.23	
M209	268.5	Center	0.99	5.47	13.42	46.74	24.97	71.69	
M210	17.7	Center	0.19	1.84	2.99	6.13	4.68	15.80	
M211	33.1	Center	0.25	2.48	3.63	9.89	5.99	28.74	
M212	67.2	Center	0.36	3.31	5.05	18.19	8.90	38.12	
M213	22.0	Center	0.21	2.21	3.17	7.16	5.04	19.36	
M214	21.8	Center	0.21	2.21	3.16	7.13	5.03	19.23	
M215	13.1	Center	0.18	1.42	2.80	4.99	4.28	11.90	
M216	61.5	Center	0.34	3.17	4.81	16.80	8.41	36.79	
M217	13.4	Center	0.18	1.45	2.81	5.08	4.31	12.19	
M218	11.2	Center	0.17	1.25	2.72	4.54	4.12	10.32	
M219	15.5	Center	0.19	1.64	2.90	5.59	4.49	13.95	
M220	49.7	Center	0.30	2.88	4.32	13.91	7.40	34.04	
M221	59.5	Center	0.33	3.12	4.73	16.30	8.24	36.32	
M222	51.3	Center	0.31	2.92	4.39	14.32	7.54	34.43	
M223	35.2	Center	0.25	2.53	3.72	10.40	6.17	30.49	

M224	11.2	Center	0.17	1.25	2.72	4.54	4.12	10.33
M225	202.7	Center	0.81	5.08	10.69	38.71	20.46	64.41
M226	45.3	Center	0.29	2.78	4.14	12.86	7.03	33.03
M227	26.9	Center	0.22	2.33	3.37	8.37	5.46	23.51
M228	14.1	Center	0.18	1.51	2.84	5.25	4.37	12.76
	1387.							
M229	7	Center	2.32	6.14	42.55	79.14	65.38	94.83
M230	371.0	Center	1.24	5.83	17.47	52.67	31.27	78.47
M231	105.8	Center	0.49	4.00	6.65	25.23	12.19	47.10
M232	304.1	Center	1.07	5.59	14.90	48.80	27.15	75.62
M233	190.1	Center	0.77	4.94	10.16	36.96	19.38	63.02
M234	91.1	Center	0.44	3.83	6.04	23.18	10.94	43.68
M235	694.6	center	1.81	6.25	27.60	66.82	46.89	88.83
M236	596.3	center	1.66	6.17	24.86	63.49	43.19	86.27
	1064.							
M237	5	center	2.10	6.22	36.60	75.73	58.49	93.73
	1267.							
M238	7	center	2.26	6.14	40.90	78.30	63.18	94.41
M239	500.9	center	1.50	6.09	21.73	60.19	39.26	82.97
M240	193.3	center	0.78	4.98	10.29	37.40	19.65	63.37
	1347.							
M241	6	East	4.13	6.65	52.26	76.99	77.29	95.61
M242	735.8	East	3.55	6.68	38.66	65.86	61.01	89.32
M243	13.1	East	0.29	0.97	2.38	6.90	3.06	12.00
M245	516.7	East	3.19	6.48	32.30	59.16	52.95	84.51
M246	316.0	East	2.62	6.06	23.21	49.70	40.81	75.59
M247	758.8	East	3.58	6.67	39.32	66.51	61.76	89.75

	1223.								
M244	0	East	4.06	6.63	50.14	75.52	74.48	94.71	
M248	537.4	East	3.23	6.51	32.91	59.82	54.20	85.43	
M249	446.1	East	3.03	6.36	30.24	56.64	48.68	81.37	
M250	175.3	East	1.87	5.02	15.13	38.27	29.76	61.33	
M251	601.8	East	3.34	6.62	34.79	61.86	56.60	86.83	
M252	341.5	East	2.70	6.18	24.67	51.06	42.36	76.72	
M253	42.3	East	0.65	2.92	4.71	16.25	10.85	30.31	
M254	137.7	East	1.63	4.75	12.31	32.84	26.69	54.90	
M255	110.8	East	1.46	4.31	10.17	28.96	24.49	47.98	
M256	398.9	East	2.88	6.28	27.96	54.12	45.83	79.27	
M257	304.1	East	2.58	5.97	22.52	49.07	40.09	75.06	
M258	279.4	East	2.50	5.79	21.10	47.33	38.27	73.11	
M259	198.1	East	2.02	5.19	16.44	40.39	31.63	63.92	
M260	96.0	East	1.30	4.06	8.99	26.34	23.28	44.17	
M261	925.9	East	3.79	6.63	44.09	71.15	67.25	92.43	
M262	638.6	East	3.40	6.68	35.87	63.03	57.82	87.51	
M263	905.6	East	3.76	6.64	43.51	70.62	66.58	92.27	
	1437.								
M264	6	East	4.17	6.60	53.79	77.96	78.61	96.17	
M265	980.1	East	3.85	6.62	45.28	71.95	68.62	92.85	
M266	654.7	East	3.43	6.69	36.34	63.54	58.34	87.81	
M267	536.4	East	3.23	6.51	32.88	59.78	54.14	85.39	
M268	265.0	East	2.45	5.68	20.28	46.10	37.10	71.49	
M270	185.0	East	1.94	5.09	15.69	39.27	30.56	62.44	
M271	290.4	East	2.53	5.87	21.74	48.27	39.17	74.36	
M272	82.1	East	1.13	3.82	7.88	23.72	21.47	40.56	

M273	121.2	East	1.52	4.48	11.00	30.46	25.34	50.66
M274	133.5	East	1.60	4.69	11.98	32.24	26.35	53.83
M1b	61.8	West	0.26	0.62	3.28	6.41	6.46	16.81
M12b	35.7	West	0.13	0.40	1.88	3.47	2.91	7.15
M29b	41.0	West	0.16	0.45	2.16	4.07	3.63	9.12
M34b	59.4	West	0.24	0.60	3.16	6.14	6.14	15.93

A.2.3. Other benefits of mangroves

Name	Cost (US\$)	Provisioning benefit (US\$)	Carbon benefit (US\$)
M7	28112	73355	47765
M9	13056	34696	22122
M10	68541	155842	116898
M14	16240	42498	27537
M15	22347	58793	37936
M16	14041	38564	23797
M17	18522	50487	31421
M18	13087	37375	22175
M19	38858	107910	66110
M20	50547	137171	86092
M21	73452	203473	125313
M22	48250	140916	82163
M23	50930	150970	86748
M24	125621	382401	214852
M26	163498	511827	279986
M27	44831	154444	76317
M28	10017	31869	16960
M29	3921	12629	6625
M30	17735	52319	30082
M31	54685	149505	93173
M32	111602	290347	190769
M36	66002	178362	112550
M37	62234	182317	106097
M38	16097	51733	27294
M39	38331	129361	65209
M40	85572	292291	146093
M41	14764	57782	25026
M42	12138	48767	20562
M43	5961	24519	10080
M44	8741	35647	14794
M45	31855	121278	54151
M46	13153	52208	22287
M47	2794	11674	4718
M48	8710	34361	14741
M49	26496	95940	45009
M50	10046	37549	17010

M51	41269	139452	70229
M52	260247	740884	446670
M53	22985	73672	39023
M54	243721	658384	418172
M55	276683	696861	475021
M56	11398	34543	19305
M57	23566	65371	40014
M59	19432	52542	32971
M60	693617	1298653	1196247
M61	186080	352765	318855
M62	440976	924512	758823
M63	151065	350453	258597
M64	48834	118895	83162
M65	11328	30190	19185
M67	77372	192922	132032
M68	120045	266630	205271
M69	41343	92677	70355
M70	0	0	0
M71	130278	257326	222856
M72	52976	114057	90249
M73	8257	18279	13973
M74	36578	85221	62215
M77	108478	246734	185405
M78	13693	38455	23205
M79	21409	59051	36338
M80	68753	169258	117262
M81	15122	38319	25635
M82	136348	318615	233289
M83	13387	37572	22686
M84	66454	170043	113324
M85	28375	78960	48212
M86	54388	148742	92664
M87	16483	49509	27950
M89	63561	174793	108368
M90	16745	49251	28396
M91	49815	140411	84840
M92	22651	69553	38454
M93	17858	56633	30291
M94	17092	55589	28987

M95	47403	151769	80716
M96	80380	209854	137190
M97	49066	133341	83559
M98	11834	32201	20047
M99	15873	43104	26912
M100	30087	81438	51133
M101	57609	153461	98177
M102	50343	137656	85745
M103	27839	70766	47298
M104	22294	67724	37845
M105	28165	85790	47855
M106	25271	78460	42919
M107	33488	103327	56937
M108	57511	173863	98010
M109	36605	96503	62262
M110	29630	79497	50354
M112	12535	29846	21237
M113	21887	60212	37152
M114	18540	43746	31451
M115	8076	21382	13666
M116	50103	105948	85333
M117	57755	147401	98428
M118	140869	328092	241063
M119	40350	123128	68658
M120	99118	328404	169335
M121	76032	140824	129736
M122	20827	42859	35347
M123	54922	124304	93578
M125	74649	178660	127365
M126	4672	10496	7895
M127	24017	48141	40782
M129	4892	10545	8269
M130	8322	17933	14083
M131	10847	26355	18368
M132	2387	6101	4030
M133	13998	41019	23723
M134	3543	9818	5984
M135	8483	27066	14355
M136	11184	35279	18942

M137	5589	18359	9450
M138	16396	51534	27802
M139	12140	30863	20566
M140	2060	5689	3477
M141	3518	10227	5943
M142	1214	3402	2049
M143	11490	34206	19462
M144	14093	42926	23885
M145	8173	26654	13831
M146	18352	57878	31132
M147	5749	20146	9720
M148	8341	29028	14114
M149	13478	46010	22840
M150	17112	58205	29022
M151	12701	43982	21519
M152	46693	150052	79500
M153	268635	769784	461137
M154	30744	99224	52255
M155	4062	15030	6863
M156	8418	30249	14245
M157	7574	26983	12813
M158	13919	45718	23589
M159	20440	63141	34687
M160	24909	80677	42302
M161	7846	28332	13275
M162	11935205	19289758	20879402
M163	235232	686335	403537
M164	352122	1056252	605254
M165	3112056	7125937	5407617
M166	406593	1020504	699377
M167	688085	2570954	1186658
M168	176135	709184	301734
M169	219730	865167	376819
M170	108358	325682	185198
M171	135403	461508	231666
M172	46078	178944	78449
M173	22543	96680	38270
M174	277782	1055530	476918
M175	77137	320747	131630

M176	120612	481077	206246
M177	952587	1763519	1645475
M178	0	0	0
M179	0	0	0
M180	1029127	2518178	1778374
M181	1523762	2946304	2638291
M182	2692141	4471323	4674561
M183	496025	859502	854047
M184	0	0	0
M185	6719199	9239804	11720682
M186	10257514	15455847	17930809
M187	680804	1297697	1174039
M188	945666	1836766	1633461
M189	10103784	17592246	17660742
M190	0	0	0
M191	3738467	6890197	6502066
M192	1249756	2468349	2161725
M193	2145564	3660596	3721267
M194	1375818	2757070	2380920
M195	1489338	2953791	2578393
M196	3731677	4606157	6490197
M197	127074	217518	217350
M198	3585903	4506576	6235419
M199	16445097	25506360	28815340
M200	58976	184497	100517
M201	85604	265429	146148
M202	485807	1330630	836369
M203	242994	694560	416918
M204	1569217	3572720	2717393
M205	38660	74450	65771
M206	0	0	0
M207	85572	216906	146092
M208	0	0	0
M209	0	0	0
M210	4490	26426	7588
M211	7952	45740	13456
M212	36568	191439	62198
M213	4984	28348	8424
M214	9836	55215	16653

M215	1804	10837	3045
M216	20678	116048	35092
M217	3061	18636	5170
M218	1432	8836	2417
M219	6967	40852	11784
M220	26279	142560	44638
M221	16799	92923	28488
M222	13523	73230	22917
M223	21234	107739	36040
M224	5561	26607	9401
M225	309760	1218299	532105
M226	39116	128858	66550
M227	23872	80024	40534
M228	5560	26115	9399
M229	0	0	0
M230	1525106	1717016	2640630
M231	39780	52305	67685
M232	0	0	0
M233	489522	1078683	842795
M234	173256	318264	296778
M235	3614781	9089149	6285886
M236	1368410	3148956	2368036
M237	14143421	30734903	24763549
M238	19763846	40051142	34662492
M239	1405405	1852358	2432380
M240	408076	1292604	701942
M241	28244295	58721067	49624713
M242	6647771	18135198	11595464
M243	1266	3713	2136
M245	0	0	0
M246	0	0	0
M247	2932391	7884658	5093906
M244	20098101	48336721	35251690
M248	1986409	2972449	3443898
M249	2811015	7234786	4882027
M250	198897	685228	340928
M251	2838422	32313541	4929867
M252	729392	2915831	1258260
M253	15326	93057	25982

M254	33519	123935	56991
M255	63753	292519	108696
M256	1477982	6058821	2558636
M257	824482	3738722	1423166
M258	874562	3982349	1510054
M259	742695	2581430	1281325
M260	157389	610368	269475
M261	4351839	13738482	7574632
M262	1964885	6429091	3406396
M263	3006761	9207156	5223750
M264	10608436	29220086	18547377
M265	5276403	20138362	9192773
M266	2671932	11715557	4639296
M267	2973124	14413833	5165021
M268	380599	2169029	654453
M270	497067	2920775	855851
M271	1587219	8247825	2748724
M272	234361	1163731	402036
M273	180002	886777	308390
M274	160160	799700	274243
M1b	152943	283544	261827
M12b	29632	72289	50357
M29b	13414	41877	22731
M34b	95639	241007	163365