Mangroves for climate: Public, private and community partnerships for mitigation and adaptation in Ecuador

Annex 3b. Economic Analysis

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Summary

This report provides a narrative explanation and interpretation of the economic cost benefit analysis that is included in the accompanying Microsoft Excel workbook submitted as Annex 3a of the Funding Proposal.

The project economic analysis has been applied to four scenarios: a baseline/ business as usual 'without project' situation and three alternative designs of the project. The three designs are 1) the project as it is designed and described in the Funding Proposal, 2) an alternative project that only focuses on mangrove restoration and not the conservation of existing mangroves outside of protected areas, and 3) an alternative project that only includes activities to conserve existing mangroves (using the same approach to conservation as in the designed project).

The economic cost-benefit analysis examines the costs and environmental service benefits of the four scenarios. The two environmental services for which most research on their valuations in Ecuador's mangroves has been done are included in the analysis: fisheries benefits and coastal protection benefits. These two environmental service benefits alone hugely outweigh the costs of mangrove protection and restoration in all four scenarios. In addition, GHG emissions reductions associated with each scenario have been included in the economic analysis as benefits. The value of recreation/tourism services in Ecuador's mangroves has been estimated based on estimates of the number of visitors that the mangrove areas receive. Finally, published estimates from global studies have been used to estimate the value of ecosystem services for which Ecuador-specific information is lacking. These include wood for timber, wood for energy and harvesting of wild honey. The huge economic benefits of maintaining and restoring mangroves are consistent with existing literature on the value of mangroves both within Ecuador and globally. Since the objective of the analysis is to examine whether the economic benefits of the project activities outweigh the related costs, rather than to get an absolute value for all environmental benefits, we have not therefore attempted to include a value on other services such as fodder, pharmaceuticals, pollution abatement, protection from sedimentation, nutrient cycling, protection from salt intrusion and aesthetic value that are also associated with mangroves.

The economic analysis results, under the model assumptions, show that in all four scenarios the economic benefits outweigh the costs. For example, the net present value (NPV) of maintaining mangroves under the current 'without project' scenario is estimated at USD 6.9 billion over 20 years. This figure rises to USD 7.1 billion if the proposed project is implemented. The restoration and conservation scenarios have NPVs over 20 years of USD 7.0 billion and USD 7.0 billion respectively.

The results of the economic analysis are also presented for the incremental change due to the three project scenarios by showing the difference in NPVs for the three project scenarios by comparison to the 'without project scenario'. The incremental comparison of NPVs shows how

the NPV of all three project scenarios is negative at the mid-term (year 4) point and end of the project implementation but becomes positive by the end of the project lifetime Over the estimated 20-year lifetime of the project, the project scenario has an NPV of USD 158 million more than the 'without project' scenario. The 'project' scenario has a benefit to cost ratio of 4.7. The restoration only scenario has the lowest benefit to cost ratio (3.4) and an NPV over 20 years of USD 59 million more than the 'without project' scenario). The 'conservation only' scenario has a benefit to cost ratio of 3.4 and an NPV over 20 years of USD 82 million more than the 'without project' scenario.

Since this is a publicly funded project focused on delivering public goods and services and is not expected to generate revenues, no financial analysis has been included.

The Project Economic Analysis

Model assumptions

The economic analysis examines the overall costs and benefits of the project scenarios rather than just focusing on specific components of them. The scenarios are described in the section below and the details of the analysis for each of the scenarios can be seen in the green worksheets in the accompanying Excel file, Annex 3a. In the case of this project the design is such that all three components contribute synergistically towards achieving the impact of increasing mangrove cover, which is the natural capital from which the economic benefits, in the form of ecosystem services, are derived. Therefore, separating out the benefits achieved by each component (as suggested in GCF guidance for Economic and Financial Analyses[1]) is difficult for this project. It could only be done through very subjective estimation of the relative benefits derived from each of the components. However doing this would be counterintuitive to the design of the project, which recognizes that the three components need to work together to achieve the project benefits (see the Theory of change presented in Figure 1).

The main variable that generates differences between the four scenarios is the area of mangrove expected each year under the different scenarios. These values come from Annex 22 and are explained in the Annex 22 narrative report and the accompanying Annex 22 Excel file (and provided in the yellow 'mangrove cover scenarios' worksheet in Annex 3a). However, an important difference with the figures presented in Annex 22 is that for the economic analysis we assume that environmental benefits[2] only start to be realized 10 years after mangrove restoration/planting activities, rather than immediately after planting. The restoration activities only apply to the 'restoration only' and 'with project scenarios' considered in the economic analysis

All analyses and the figures quoted in this report are done with a discount rate of 6% by default unless specified otherwise, but this value can be modified in the Excel file if needed (on the 'Parameters' sheet). NPV values for discount rates of 0%, 3%, 7% and 12% are also displayed by default for each scenario on the green 'scenario' tabs in the Excel file. In line with similar analyses by multilateral organizations in Ecuador and neighboring countries, the default value of 6% was chosen since this is a project focused on public goods/services rather than a revenue-generating project. Modifications to discount rate are also captured in the % change to costs variable in the sensitivity analyses described below in this report.

Other variables that are included in the economic analyses are described in the subsections below.

[1] Green Climate Fund. Appraisal Guidance, Annex 6: Economic and Financial Analysis (EFA) Guidance. https://www.greenclimate.fund/document/annex-vi-economic-and-financial-analysis-efa-guidance

[2] An exception is the GHG emissions reductions, which follow the method outlined in Annex 22.

Economic Benefits of the Project

The project benefits are shown in the project's Theory of change (Figure 1). The three project components will contribute synergistically to increase mangrove cover in Ecuador by comparison to the baseline, business-as-usual scenario. Mangroves provide important ecosystem service benefits to human society and various studies have calculated economic valuations for these (e.g. de Groot *et al*., 2012; Mukherjee *et al*., 2014). For this economic analysis, estimates of the value of the key benefits (flood risks to communities, increased fisheries value and GHG emissions reductions) have been calculated using Ecuador-specific data for the project area. A variety of other ecosystem services are also captured in the Theory of Change diagram under the term "Increased biodiversity and ecosystem service benefits". To estimate the economic value of these we have used average estimates from peer-reviewed published studies conducted around the world. Table 1 lists the main ecosystem services that are associated with mangroves (following the classification provided by Mukherjee *et al*., 2014) and provides the average valuations that have been used in the economic analysis along with the source of information used.

Figure 1 also shows other co-benefits of the project that we have not attempted to value separately. The "Increased economic resilience of coastal communities" will be achieved because the communities will capture a greater proportion of the ecosystem service values than they do in the current baseline situation. This is because they will have greater rights to use the ecosystem services (through the community management arrangements that the project will put in place) and through livelihood projects and small community enterprises that ultimately aim to retain a higher proportion of the value of ecosystem services (in particular fisheries value) at the community level. For example, improved cold storage facilities at the community level will reduce fish waste and improve fish quality at the point of sale and therefore provide greater revenue to communities (but potentially at the expense of other parts of the value chain). While there may be some additional value created, we haven't attempted to include this since there's a risk of double counting with the "increased fisheries value" already included in the model. Also, the exact community livelihood activities that will be supported through a small grants program are to be defined during project implementation depending on the needs of each community and it's therefore hard to include them in the model at this stage.

Similarly, we have not attempted to quantify the value of "increased sustainability of shrimp production". The shrimp production itself will be done by shrimp farms and is not directly supported by the project. The project activity with respect to shrimp farms is to promote adoption of more environmentally sustainable approaches and standards. As such the main sustainability achieved by the project will be in respect to reducing mangrove loss (i.e. adoption by shrimp farms of 'zero deforestation' and where possible, active restoration of mangroves). Therefore, the sustainability benefit is again largely already captured by the "increased cover of mangroves" from which the economic benefits of the project are derived. While shrimp farms may adopt some other sustainability measures that aren't the focus of this project, we haven't tried to value those.

Finally, we have not tried to put an economic value on the "strengthened institutional framework" benefit. Again, the main focus of the project is to achieve the reduced mangrove deforestation objective and therefore our main interest is how strengthened institutions and land-use planning contribute to that. That benefit is therefore already included in the increased mangrove cover benefit even though there may be some additional benefits, for example in terms of coastal land-use planning.

Figure 1. The Project's Theory of Change diagram

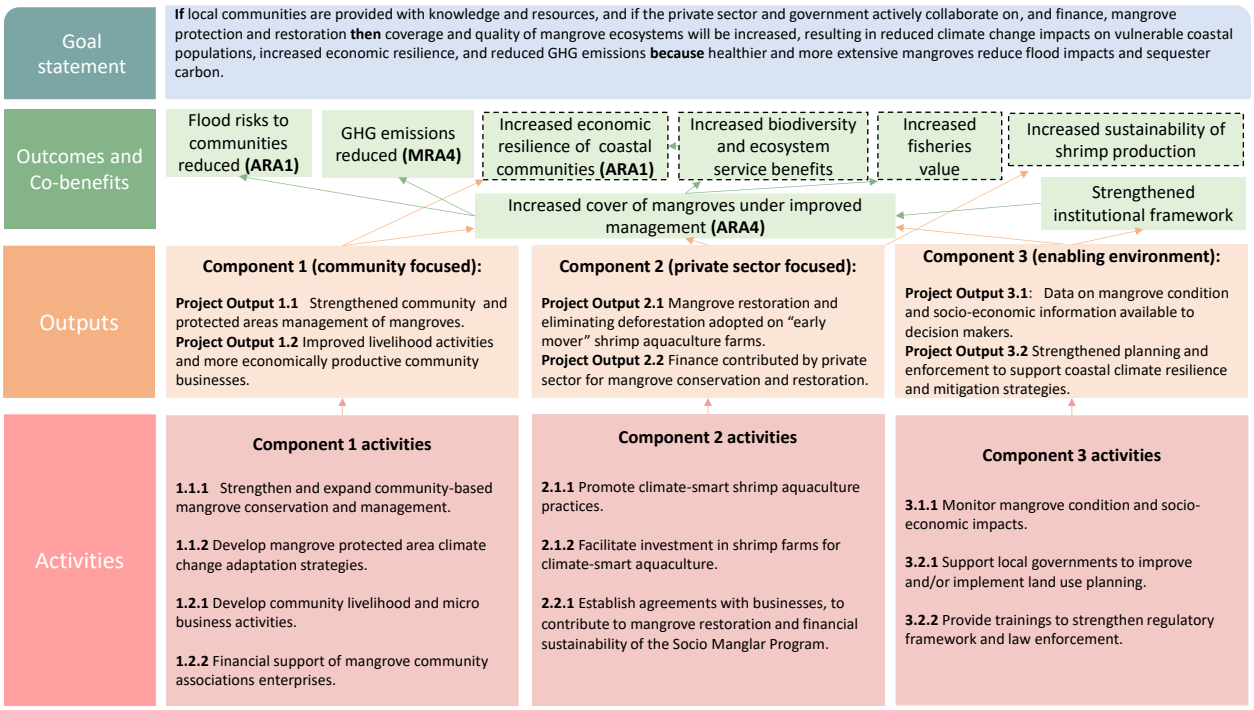

Table 1. Ecosystem Service Benefits from Mangroves.

Category of Ecosystem Service	Description of the ecosystem service	Economic value (USD/ha/year)	Source of economic valuation
Provisioning	**Fisheries Value**. Value of fish and crustaceans caught for self-consumption and sale	2,213	Calculated based on surveys conducted as part of project preparation. See tab "fisheries benefits"
	Honey. Value of honey harvested from mangroves	6	Based on global estimate published by Mukherjee et al. 2014 updated to 2023 USD equivalent
	Wood and timber. Value from provision of wood as timber and for other uses	363	Based on global estimate published by Mukherjee et al. 2014 updated to 2023 USD equivalent
	Fodder. Value of mangrove-based fodder for livestock		Not included due to lack of global estimates of economic value
	Energy. Value of biomass-based energy sources from mangroves	451	Based on global estimate published by Mukherjee et al. 2014 updated to 2023 USD equivalent
	Pharmaceuticals. Value of medicinal plants and animals		Not included due to lack of global estimates of economic value
Regulation and Maintenance	**Climate regulation.** GHG emissions reductions	3.2 USD/tCO2e	Calculated based on GHG emissions reductions calculations presented in Annex 22 and a low estimate of carbon price (see parameters tab)
	Coastal protection. Flood protection of vulnerable people	1,600	Calculated based on per hectare valuation of flood protection to assets (see Menendez et al. study presented in Annex 2, Appendix 6
	Pollution abatement		Not included due to highly site specific nature of this ecosystem service and valuation. However note that Mukherjee et al. 2014 show that global estimates for this service have one of the highest economic values at 7860 USD/ha/year (2007 USD), equivalent to 11,550 USD/ha/year in 2023 USD.
	Protection from sedimentation		Not included due to highly site specific nature of this ecosystem service and valuation. Note that Mukherjee et al. 2014 only found one estimate for this service globally of 579 USD/ha/year (2007 USD) equivalent to 851 USD/ha/year in 2023 USD.
	Nutrient cycling		Not included due to the difficulty of valuing. Note that de Groot et al. 2012 provide a figure of 45 USD/ha /year (2007 USD) equivalent to 66 USD/ha/year in 2023 USD.
	Protection from salt intrusion. Value of protecting adjacent lands from salt intrusion		Not included due to lack of global estimates of economic value
Cultural	**Recreation.** Value of mangrove-based tourism activities	0.48	Calculated based on surveys conducted as part of project preparation. See tab "Tourism benefit"
	Aesthetic value		Not included due to the difficulty of valuing

Colour legend:	Indicates a co-benefit included as part of the "increased biodiversity and ecosystem service benefits" in the project Theory of Change
	Indicates a benefit or co-benefit included as part of the project Theory of Change
	Indicates an ecosystem benefit that has not been included in the valuation due to lack of useable economic estimates

Notes: List of ecosystem services adapted from Mukherjee et al., 2014. References to “tabs” refer to worksheet tabs in the accompanying Excel file, Annex 3a of the Funding Proposal.

Economic analysis

Scenario costs – actual project costs are included for the 'project' scenario. See presentation of the scenarios for explanation of the activity costs for the other scenarios.

Table 2. Default parameter values used in the economic analysis

Variable	Value	Justification
Fisheries production per hectare of mangrove	USD 2,213 per hectare per year	This value is derived from studies of the value of mangrove fisheries in the four estuaries targeted by the project (CIIFEN, 2019). The detailed calculations are provided on the orange worksheet 'Fisheries benefits' in the accompanying Excel file. This figure also includes the parameter below, related to the % of production entering the human food/supply chain. The figure is consistent with similar values of mangrove fisheries globally.
% of fisheries production being caught and used/sold by fishers	20%	The CIIFEN (2019) report on the value of fisheries suggested using a figure of 40% for this variable. We conservatively use 20% by default.
Coastal protection benefit	USD 1,600 per hectare per year	This is a value derived from the Menendez et al. model described in Annex 2, the Feasibility Study and in Annex 25
Mangrove planting cost	USD 2,000 per hectare	This is the cost used in the budget development based on prior experience in Ecuador.
Estimate of the cost in 2025 of managing the 7 Protected Areas in Ecuador with mangroves	USD 2.5 million per year	This is the approximate annual cost of managing Ecuador's protected areas with significant mangrove areas. The estimate is an internal calculation by CI and MAATE from a GEF-funded project focused on protected area management.
Other government enforcement costs related to mangroves (Estimate to reflect other costs borne by enforcement agencies, judiciary and local government.)	USD 2.5 million per year	We believe this is a conservative estimate of the costs of enforcing legislation related to mangroves based on the hypothesis that it will be similar to the costs for management of mangrove protected areas. Getting an actual estimate of this figure across all government department and agencies would be very difficult but we believe this value is a conservative overestimate of the costs involved for government.
Other ecosystem service benefits		See values provided in Table 1.

The four scenarios

The baseline (without project) scenario

Under this scenario, mangrove deforestation and natural recovery continues following the 2008-2018 baseline trend, which results in a net recovery of mangroves over time. No active mangrove restoration occurs. There are no project costs. Costs of current protected area management are assumed to continue and to be covered by the government budget. Some costs related to enforcement of regulations on mangrove are assumed to be included within the budgets of other government agencies (law enforcement, judiciary and local government) and are assumed to be covered by the government budget. Note that both the protected areas budget and other enforcement costs and budget are assumed for all four scenarios. It is also assumed that the government continues to fund the existing AUSCEMs based on the Socio Manglar model. This intent has been communicated to us by the Government during project preparation (and committed as co-finance for the project implementation period) and is assumed to be the case for all four of the scenarios.

The project scenario

Under the 'project' scenario, the costs as described in the project document are included. These broadly relate to restoration done by communities and the private sector, community mangrove conservation activities through the AUSCEM community management model, and the activities under Outcome 3 to create long terms enabling conditions for the project results to continue. All the project costs are included. As for the baseline situation, it is assumed that current mangrove protected areas management, other government enforcement of mangrove regulations and existing community management under AUSCEMs continues and that the government provides the budget for these. Long-term, post project implementation costs related to supporting the AUSCEMs through the Socio Manglar model are also included.

The restoration only scenario

Under the 'restoration only' scenario, the project costs related to mangrove conservation activities are not included, whereas the restoration costs are included. Costs related to monitoring and evaluation, project management and the outcome 3 enabling conditions are still included. No additional costs related to new AUSCEMs are included during or beyond project implementation. As noted above, this scenario does assume that current AUSCEMs continue to be supported by the government and/or other donors. Gains in mangrove cover (over and above those under the baseline scenario) only come from restoration in this scenario.

The conservation only scenario

Under the 'conservation only' scenario, none of the project costs related to restoration are included but, as for the 'restoration only' scenario, the costs related to monitoring and

evaluation, project management and the outcome 3 enabling conditions are still included. Long-term costs related to the additional AUSCEMs created by the project are also included. No mangrove cover gain from restoration is included.

The Economic Analysis results and interpretation

As shown in Table 3, the NPVs of the 'without project' and the 3 scenarios for different project designs are positive and very large. The NPVs range from USD 6.9 billion over 20 years for the 'without project' scenario up to USD 7.2 billion for the 'project' scenario. These very high NPVs reflect the enormous economic value provided by mangroves, especially in terms of coastal protection and fisheries benefits. As shown in Table 1, there are additional ecosystem benefits from mangroves that we have not been able to model due to lack of reliable data. However, the the economic analysis in this case is to examine whether the economic project benefits outweigh the project costs, not to get an accurate valuation of mangrove ecosystem service benefits. Clearly, given the NPV values, the economic benefits do outweigh the costs by a huge margin and therefore we have not tried to include other benefits for valuations that are less certain or well-studied as it would add nothing to the economic analysis for our purposes.

Table 3. Economic Analysis for the four scenarios

			Net Present Value (USD)			
Scenarios	Present Value of Costs (USD)	Present Value of Benefits (USD)	4 years	7 years	20 years (lifetime of Project)	Benefit to Cost Ratio
Without project	62,499,601	6,973,170,009	2,054,471,209	3,297,619,291	6,910,670,408	112
Project as proposed	104,964,802	7,173,569,401	2,009,794,796	3,276,125,706	7,068,604,599	68
Restoration only	87,014,182	7,056,493,601	2,018,083,628	3,275,373,358	6,969,479,420	81
Conservation only	97,138,609	7,090,245,808	2,014,862,178	3,281,683,251	6,993,107,199	73

Of more interest than the absolute NPVs for each scenario is an incremental economic cost benefit analysis, which examines costs and benefits of each of the three project scenarios, by comparison to the baseline 'without project' scenario. Table 4 shows the NPVs of each of the three project scenarios by comparison to the 'without project' scenario. The results are presented for three time frames: after 4 years (approximating the project mid-term), after 7 years (end of project) and after 20 years (the estimated lifetime of the project following GCF's definition). The benefit to cost ratio for each scenario is also provided. The table shows that for each of the three project scenarios, costs outweigh the benefits at the project mid-term point and the end of the implementation period but that by the end of the project lifetime, all three

scenarios have positive NPVs. The results show that the project scenario provides the highest incremental NPV over 20 years (USD 158 million) and the highest benefit to cost ratio (4.7)..

Table 4. Incremental Economic Analysis, showing the net present values with respect to the 'without project' scenario

			Net Present Value (USD)			
Scenarios	Present Value of Costs (USD)	Present Value of Benefits (USD)	4 years	7 years	20 years (lifetime of Project)	Benefit to Cost Ratio
Without project	0	0	0	0	0	not applicable
Project as proposed	42,465,202	200,399,392	-44,676,413	-21,493,586	157,934,191	4.7
Restoration only	24,514,581	83,323,593	-36,387,582	-22,245,933	58,809,012	3.4
Conservation only	34,639,009	117,075,800	-39,609,032	-15,936,040	82,436,791	3.4

Economic Internal Rates of Return (EIRR) for the three project scenarios are also high at 25% for the proposed project, 17% for the 'restoration only' scenario and 23% for the 'conservation only' scenario.

Tables 5 to 10 show the sensitivity of the EIRRs and NPVs to changes in costs and benefits. The figures are presented for the 20-year time-period. Each table shows the changes expected if costs are varied by + or – of up to 30% and if benefits are up to + or – 30% of the default values used in the models. All of these tables show that the economic benefits of the project are highly resilient to increased costs and reduced benefits. For example, in the case of the proposed 'project' scenario, increased costs of 30% and reduced benefits of 30% would still result in an incremental NPV of USD 110 million and an incremental EIRR of 15%.

Table 5. Values of the incremental EIRR over 20 years for the Project Scenario when costs and benefits are varied

		Changes to benefits						
		-30%	-20%	-10%	0%	10%	20%	30%
Changes to costs	30%	19%	20%	21%	22%	22%	23%	24%
	20%	20%	21%	22%	23%	24%	24%	25%
	10%	21%	22%	23%	24%	25%	26%	26%
	0%	22%	23%	24%	25%	26%	27%	28%
	-10%	24%	25%	26%	27%	28%	29%	29%
	-20%	26%	27%	28%	29%	30%	30%	31%
	-30%	28%	29%	30%	31%	32%	33%	34%

Table 6. Values of the incremental NPV over 20 years for the Project Scenario when costs and benefits are varied

		Changes to benefits						
		-30%	-20%	-10%	0%	10%	20%	30%
Changes to costs	30%	110,198,409	122,162,396	134,126,383	146,090,371	158,054,358	170,018,345	181,982,333
	20%	114,146,349	126,110,336	138,074,323	150,038,311	162,002,298	173,966,285	185,930,273
	10%	118,094,289	130,058,276	142,022,263	153,986,251	165,950,238	177,914,225	189,878,213
	0%	122,042,229	134,006,216	145,970,203	157,934,191	169,898,178	181,862,165	193,826,152
	-10%	125,990,169	137,954,156	149,918,143	161,882,131	173,846,118	185,810,105	197,774,092
	-20%	129,938,109	141,902,096	153,866,083	165,830,071	177,794,058	189,758,045	201,722,032
	-30%	133,886,049	145,850,036	157,814,023	169,778,011	181,741,998	193,705,985	205,669,972

Table 7. Values of the incremental EIRR over 20 years for the 'Restoration only' scenario when costs and benefits are varied

		Changes to benefits						
		-30%	-20%	-10%	0%	10%	20%	30%
Changes to costs	30%	13%	14%	14%	15%	16%	16%	17%
	20%	14%	15%	15%	16%	16%	17%	17%
	10%	15%	15%	16%	17%	17%	18%	18%
	0%	16%	16%	17%	17%	18%	19%	19%
	-10%	17%	17%	18%	18%	19%	19%	20%
	-20%	18%	18%	19%	19%	20%	21%	21%
	-30%	19%	19%	20%	21%	21%	22%	22%

Table 8. Values of the incremental NPV over 20 years for the 'Restoration only' scenario when costs and benefits are varied

		Changes to benefits						
		-30%	-20%	-10%	0%	10%	20%	30%
Changes to costs	30%	37,024,277	42,132,977	47,241,678	52,350,378	57,459,079	62,567,779	67,676,480
	20%	39,177,155	44,285,855	49,394,556	54,503,256	59,611,957	64,720,657	69,829,358
	10%	41,330,033	46,438,733	51,547,434	56,656,134	61,764,835	66,873,535	71,982,236
	0%	43,482,910	48,591,611	53,700,311	58,809,012	63,917,712	69,026,413	74,135,113
	-10%	45,635,788	50,744,489	55,853,189	60,961,890	66,070,590	71,179,291	76,287,991
	-20%	47,788,666	52,897,367	58,006,067	63,114,768	68,223,468	73,332,169	78,440,869
	-30%	49,941,544	55,050,245	60,158,945	65,267,646	70,376,346	75,485,047	80,593,747

Table 9. Values of the incremental EIRR over 20 years for the 'Conservation only' scenario when costs and benefits are varied

		Changes to benefits						
		-30%	-20%	-10%	0%	10%	20%	30%
Changes to costs	30%	16%	17%	18%	19%	20%	20%	21%
	20%	17%	18%	19%	20%	21%	22%	23%
	10%	18%	19%	20%	21%	22%	23%	24%
	0%	20%	21%	22%	23%	24%	25%	25%
	-10%	21%	22%	23%	24%	25%	26%	27%
	-20%	23%	24%	25%	26%	27%	28%	29%
	-30%	25%	26%	27%	28%	29%	31%	32%

Table 10. Values of the incremental NPV over 20 years for the 'Conservation only' scenario when costs and benefits are varied

		Changes to benefits						
		-30%	-20%	-10%	0%	10%	20%	30%
Changes to costs	30%	52,374,969	59,230,255	66,085,542	72,940,829	79,796,116	86,651,403	93,506,689
	20%	55,540,289	62,395,576	69,250,863	76,106,150	82,961,436	89,816,723	96,672,010
	10%	58,705,610	65,560,897	72,416,184	79,271,470	86,126,757	92,982,044	99,837,331
	0%	61,870,931	68,726,217	75,581,504	82,436,791	89,292,078	96,147,365	103,002,651
	-10%	65,036,251	71,891,538	78,746,825	85,602,112	92,457,398	99,312,685	106,167,972
	-20%	68,201,572	75,056,859	81,912,145	88,767,432	95,622,719	102,478,006	109,333,293
	-30%	71,366,893	78,222,179	85,077,466	91,932,753	98,788,040	105,643,327	112,498,613

Conclusions

All the project scenarios considered have very high economic benefits, reflecting the enormous value of ecosystem services provided by mangroves. The economic NPVs are resilient to changes in costs and benefits of up to + or - 30% demonstrating a wide margin of error for the project to deliver very significant and important economic benefits.

The 'project' scenario provides the most value of the scenarios considered over the project lifetime (20 years) and it gives a high benefit to cost ratio (4.7). Under the model assumptions, which we consider to be conservative, the 'project' scenario is expected to generate USD 158 million of economic value over and above the 'without project' scenario over a 20-year period (the project lifetime). The values used for calculating the per hectare economic benefit from mangroves are conservative and at the lower end of the ranges of published estimates for these benefits. In addition, the model includes an important assumption that restored mangroves will not provide any benefits until ten years after planting. Mangroves grow relatively quickly and therefore this is also likely to be a conservative assumption. Given that we have been conservative in the assumptions used in the model, it seems likely that the economic benefits of the project could be higher than presented in this economic analysis. As such, we believe that the project as designed provides excellent value for money as it will generate significant benefits to society Benefits are also likely to continue to accrue beyond 20 years because intact and restored mangroves will continue to provide significant economic benefits.

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