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Sustainable Asset Valuation (SAVi) of Forest Restoration in the Brantas River Basin, Indonesia

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Sustainable Asset Valuation (SAVi) of Forest Restoration in the Brantas River Basin, Indonesia

December 2021

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Author contributions: all authors are listed in alphabetical order. A.M. Bassi conceptualized the assessment; R. Bechauf contributed to writing the report; E. Cutler led the integrated cost-benefit analysis and the writing process; M. Gouett conducted the financial analysis; and M. Guzzetti performed the spatial modelling.

Executive Summary

In the Brantas River Basin of East Java, Indonesia, deforestation for agriculture has led to increased soil erosion, loss of biodiversity, and decreased water retention. These impacts have made floods more severe and reduced groundwater recharge. Downstream, water scarcity has become a problem during the dry season. Floods and droughts are expected to worsen with climate change, and if no action is taken, land degradation will continue.

Maintaining and Enhancing Water Yield through Land and Forest Rehabilitation (MEWLAFOR) is a Global Environment Facility (GEF)-funded project designed to restore degraded land in the Brantas River catchment. It will establish 387 hectares of upstream agroforestry systems and 150 hectares of riparian bamboo plantations. In total, the project will improve management practices of 3,697 ha in a buffer zone and ultimately bring 26,033 hectares under improved management. The project will also construct absorption wells and biopori holes to enhance water retention. The project will benefit 278,600 people (153,230 men and 125,360 women) and address the priorities to restore land as defined in the National Medium Term Development Plan 2020–2024 (RPJMN). Ultimately, the goals of the Sustainable Asset Valuation (SAVi) of Forest Restoration in the Brantas River Basin, Indonesia are: 1) to estimate whether the project is economically viable for investors and at the societal level, and 2) to demonstrate how the multistakeholder approach adopted for this project could be scaled up to address widespread land degradation in the country and the region.

In this report, we present the SAVi assessment for the MEWLAFOR project. The assessment quantifies the ecosystem services and economic impacts of the planned reforestation and water retention wells. We combine this information in an integrated cost-benefit analysis (CBA) that considers project performance under two climate change scenarios: Representative Concentration Pathway (RCP) 4.5, which assumes that emissions peak in 2040, and RCP 8.5, which assumes continued high reliance on fossil fuel-based energy. Results are presented in Table E 1.

Table E1. Undiscounted and uninflated integrated CBA. Numbers in italics depend on climate scenario. Net benefits are equal to avoided costs plus added benefits minus investment costs. Net benefits are positive and increase with greater climate variability. All values are in 2020 million USD.

	20-year lifetime (2021–2040)		**30-year lifetime (2021–2050)**	
	RCP 4.5	**RCP 8.5**	**RCP 4.5**	**RCP 8.5**
Added Benefits				
Value of bamboo exports	0.21	0.21	0.35	0.35
Value of agroforestry benefits	2.12	2.12	3.35	3.35
Tree planting wages	0.52	0.52	0.52	0.52
Carbon storage benefit	31.99	31.99	31.99	31.99
TOTAL ADDED BENEFITS	**34.84**	**34.84**	**36.21**	**36.21**
Avoided Costs				
Avoided flood damages to households	*24.00*	*24.53*	*486.79*	*77.96*
Avoided flood damages to agriculture	*12.06*	*14.00*	*193.73*	*36.90*
Avoided erosion damages to agriculture	*17.85*	*42.64*	*41.65*	*52.56*
Avoided nitrogen pollution	17.10	17.10	25.65	25.65
Avoided phosphorus pollution	8.08	8.08	12.12	12.12
TOTAL AVOIDED COSTS	**79.09**	**106.34**	**759.93**	**205.18**
Investment and Maintenance Costs				
Improved land management investment cost	8.94	8.94	8.94	8.94
Absorption wells and biopori investment cost	0.56	0.56	0.56	0.56
Annual maintenance costs	0.10	0.10	0.14	0.14
TOTAL COSTS	**9.60**	**9.60**	**9.64**	**9.64**
NET BENEFITS	**104.34**	**131.59**	**786.50**	**231.75**
BENEFIT-TO-COST RATIO	**11.87**	**14.71**	**82.56**	**25.03**

The assessment also calculates the net present value (NPV) and internal rate of return (IRR) of the project, for which the avoided costs and added benefits are accounted as revenue streams of the project. Upon extending the integrated CBA analysis to account for inflation as well as the time value of money, we found the following sustainable net present values (S-NPV) and sustainable internal rate of returns (S-IRR) under the different climate scenarios and lifetime scenarios.

Table E2. NPV and internal rate of return for all scenarios. S-NPV and S-IRR include added benefits, avoided costs, and investment and maintenance costs. We also calculate S-NPV and S-IRR excluding the carbon benefit and a conventional NPV and IRR that do not include the carbon benefit or the intangible avoided costs. All values are in 2020 thousand USD.

Lifetime of project	**20-year lifetime (2021–2040)**		**30-year lifetime (2021–2050)**	
Climate scenario	**RCP 4.5**	**RCP 8.5**	**RCP 4.5**	**RCP 8.5**
S-NPV	63,539	71,551	208,593	92,259
S-IRR	62.8%	74.8%	62.9%	74.8%
S-NPV (excluding carbon benefit)	41,850	49,861	186,903	70,569
S-IRR (excluding carbon benefit)	56.5%	69.5%	56.6%	69.5%
NPV (excluding carbon benefit and avoided costs)	-8,330	-8,330	-8,136	-8,136
IRR (excluding carbon benefit and avoided costs)	-11.0%	-11.0%	-4.8%	-4.8%

Based on the results in Table E1 and Table E2:

- The MEWLAFOR project, in the Indonesian context, has positive net benefits that far exceed the costs when externalities are considered.
- The project is economically viable for investors and generates net benefits for society when considering both material economic impacts, including the carbon benefit but no avoided costs (with an IRR of 22.5%), as well as all material impacts and externalities (with an IRR above 62%).
- The project would still have positive net benefits without including carbon payments when considering avoided costs. The avoided costs are not monetized for investors but generate considerable benefits for society, with an IRR of 56.5%–69.5% over 20 years and 56.6%–69.5% over 30 years.
- On the other hand, the project would have a negative NPV when considering only material impacts and excluding carbon payments. When referencing material impacts, this includes the agroforestry benefits, value of bamboo exports, investment and maintenance costs. When only these are considered, the IRR would be -11.0% over 20 years and -4. 8% over 30 years. This highlights that carbon payments in Indonesia play a critical role in stimulating investments in nature-based infrastructure (NBI). Such payments can tip the balance toward a positive return for the investment when using a conventional economic and financial approach. If the MEWLAFOR project successfully avoids the loss of intact forest and carbon payments are available, then the carbon storage benefit alone is greater than the investment and maintenance costs.
- The carbon payment enables the project and hence creates a variety of additional benefits and avoided costs that otherwise would not be realized.

- The value of the project increases when climate variability is greater because there are more avoided damages. In the climate projections we used, there is an exceptionally large precipitation event in 2044 under Representative Concentration Pathway (RCP) 4.5 (Copernicus Climate Change Service, 2018) that would cause widespread damage. Reforestation and avoided deforestation mitigate much of the expected destruction. Hence, the avoided costs (i.e., benefits) of the project increase, which explains the large net benefits over 30 years under RCP 4.5. This highlights that nature contributes to climate resilience and increased adaptive capacity.

Although not included in the CBA, we also estimate downstream impacts of widespread forest restoration and water retention wells. We find that improved land management on a large scale could increase groundwater recharge by up to 6.1% per year. Absorption wells will further increase groundwater availability and could mitigate approximately one third of downstream flood damage.

Finally, we estimate that tree planting will create 484 jobs in the first year of the project and that from the second year onward, there will be 97–145 agroforestry jobs

When considering social and environmental externalities, the MEWLAFOR project is economically feasible. However, the conventional NPV and IRR show that without internalizing externalities, the project has a negative NPV. Carbon payments would be one way to unlock investments in land restoration and improved water management. Alternatively, avoided costs, disbursed among many different economic actors, justify the investment. Although the societal value is large, the project underscores the need for broad coordination among stakeholders to replicate and scale similar projects. The MEWLAFOR project is a demonstration of the benefits that can be reaped when this coordination is achieved across sectors and geographies, and stakeholders are able to restore degraded land and improve water management.

Table E3. How decision-makers can use the results of the assessment

Stakeholder	Role in the project	How can the stakeholder use the results of the assessment?
Donors and funders	Funding of NBI projects	Donors can include the results in their reporting to demonstrate the impacts of their investments. For example, the GEF investments of USD 1.44 million would generate USD 5.22 million in added benefits and USD 8.15–10.96 million in avoided costs over 20 years (see Table C1) The results can also help make the case for further reforestation and water management projects, as they illustrate the considerable benefits for climate adaptation and mitigation. For example, the net benefits of the project are up to USD 131.59 million over 20 years (see Table E1) Donors can use the results to identify and bring together relevant stakeholders who benefit from reforestation projects. For example, reforestation could avoid flood and erosion damages to agriculture of up to USD 56.64 million over 20 years.

Stakeholder	Role in the project	How can the stakeholder use the results of the assessment?
Government	Design, implementation, and finance of NBI projects	Government authorities can use the results to justify investments in reforestation and water management projects and scale up such projects, as the assessment illustrates the considerable benefits for climate adaptation and mitigation. For example, the net benefits of the project are up to USD 131.59 million over 20 years (see Table E1). The greater the climate variability, the greater the benefits of the project. These benefits will result in higher public revenues and lower public costs, thus making resources available for new investments. The results highlight the benefits of the projects in different sectors and can help government authorities to mobilize funding and support from diverse sources, including through carbon offset schemes. For example, the project provides a carbon storage benefit of USD 31.99 million over 20 years (see Table E1). Government authorities can use the results to acknowledge the project's contribution to meeting climate commitments and low-carbon development. For example, the project stores an additional 2.64 million tons of carbon (9.69 million tons of carbon dioxide) compared to a business-as-usual scenario. Policy-makers can use the results to make decisions on water management, biodiversity and forest conservation, sustainable agriculture, and economic development. For example, the reforestation project leads to higher agriculture productivity and increases biodiversity. Government authorities can use the results to compare the cost of NBI to grey infrastructure that provides similar services. For example, the project purifies water and avoids flood damage, which reduces the need for other forms of water treatment and flood control. The results demonstrate the value of public–private partnerships to meet climate commitments. For example, the project benefits a wide variety of both public and private economic actors, who can all contribute to restoration projects.
Industry/ private sector	Project co-funders, users of natural resources	Businesses can use the results to reduce risks from water shortages, price hikes, and floods by contributing to reforestation and improved water management. For example, the project improves water retention and infiltration, which increases groundwater availability (see Section 4.3).

Stakeholder	Role in the project	How can the stakeholder use the results of the assessment?
Civil society organizations and farmers	Consultation with government agencies on NBI projects	Civil society organizations can use the economic valuations of ecosystem services to fine-tune forest restoration and conduct more targeted advocacy. They can also use the benefits from the project to call for investments in reforestation, improved water management, and sustainable agriculture. For example, the net benefits of the project are USD 131.59 million over 20 years under a high climate change scenario (see Table E1). Civil society organizations can also use the results to promote climate adaptation and mitigation. For example, the reforestation could avoid flood and erosion damages to agriculture of USD 56.64 million over 20 years, and the carbon storage benefit amounts to USD 31.99 million over the same period (see Table E1). Civil society organizations can use the results to raise awareness of the value of NBI. For example, the benefits of the project far exceed the costs, but this is only apparent when considering system-wide impacts across multiple sectors.

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Glossary

Causal loop diagram: A schematic representation of key indicators and variables of the system under evaluation that shows the causal connections between them and contributes to the identification of feedback loops and policy entry points.

Discounting: A finance process to determine the present value of a future cash value.

Feedback loop: "A process whereby an initial cause ripples through a chain of causation ultimately to re-affect itself" (Roberts et al., 1983).

Indicator: Parameters of interest to one or several stakeholders that provide information about the development of key variables in the system over time and trends that unfold under specific conditions (United Nations Environment Program [UNEP], 2014).

Internal Rate of Return (IRR): An indicator of the profitability prospects of a potential investment. The IRR is the discount rate that makes the net present value of all cash flows from a particular project equal to zero. Cash flows net of financing give us the equity IRR.

Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST): "A suite of models used to map and value the goods and services from nature that sustain and fulfill human life. It helps explore how changes in ecosystems can lead to changes in the flows of many different benefits to people" (Natural Capital Project, 2019)

Methodology: The theoretical approach(es) used for the development of different types of analysis tools and simulation models. This body of knowledge describes both the underlying assumptions used as well as qualitative and quantitative instruments for data collection and parameter estimation (UNEP, 2014).

Model transparency: The degree to which model structure and equations are accessible and make it possible to directly relate model behaviour (i.e., numerical results) to specific structural components of the model (UNEP, 2014).

Model validation: The process of assessing the degree to which model behaviour (i.e., numerical results) is consistent with behaviour observed in reality (i.e., national statistics, established databases) and the evaluation of whether the developed model structure (i.e., equations) is acceptable for capturing the mechanisms underlying the system under study (UNEP, 2014).

Net benefits: The cumulative amount of monetary benefits accrued across all sectors and actors over the lifetime of investments compared to the baseline, reported by the intervention scenario.

Net Present Value (NPV): The difference between the present value of cash inflows net of financing costs and the present value of cash outflows. It is used to analyze the profitability of a projected investment or project.

Optimization: A stream of modelling that aims to identify the policy or set of policies that deliver the best possible outcome from a set of alternatives, given a set of criteria (i.e., parameters to optimize) and/or constraints (i.e., available budget) (UNEP, 2014) .

Scenarios: Expectations about possible future events used to analyze potential responses to these new and upcoming developments. Consequently, scenario analysis is a speculative exercise in which several future development alternatives are identified, explained, and analyzed for discussion on what may cause them and the consequences these future paths may have on our system (e.g., a country or a business).

Simulation model: Models can be regarded as systemic maps in that they are simplifications of reality that help to reduce complexity and describe, at their core, how the system works. Simulation models are quantitative by nature and can be built using one or several methodologies (UNEP, 2014).

Sustainable Internal Rate of Return (S-IRR): An indicator of the net benefit prospects of a potential investment. The S-IRR is the discount rate that makes the net present value of benefits from a particular project equal to zero.

Sustainable Net Present Value (S-NPV): The difference between the present value of benefits and avoided costs net of financing costs and the present value of cash outflows. It is used to analyze the net value of a projected investment or project.

1.0 Introduction

Deforestation of the Brantas River basin in East Java, Indonesia, has degraded the land, causing problems downstream. Reduced water retention worsens flooding and exacerbates water scarcity during the dry season.

PT Multi Bintang, a local subsidiary of Heineken beverage company, operates a brewery in the lower catchment area of the Brantas River. Multi Bintang, working with the United Nations Industrial Development Organization (UNIDO) and the Indonesian Ministry of Environment and Forestry, convened a stakeholder workshop in 2016 to identify priority measures to reduce water stress. These priorities included reforestation in three sub-catchments in the upper reaches of the Brantas River basin.

In line with these priorities, Maintaining and Enhancing Water Yield through Land and Forest Rehabilitation (MEWLAFOR) is a project designed to restore degraded land in the Brantas River catchment. It will establish upstream agroforestry systems and riparian bamboo plantations, bringing 26,033 hectares (ha) under improved management. The Global Environment Facility (GEF) will invest USD 876,983 to plant 400 trees/ha on 251 ha for agroforestry. The funding will also create 130 ha of bamboo forest with 400 stools/ha. Co-financing of USD 8,064,994 from PT Multi Bintang, the Mojokerto Regional Government, and the Ministry of Public Works and Housing will establish 136 ha of agroforestry with 1,000 trees/ha and put an additional 3,180 ha under improved management. In total, the project will improve management practices of 3,697 ha in a buffer zone. This will prevent the loss of 2,407 ha of protected forest and 19,929 ha of conservation forest.

In addition, USD 558,330 of GEF funding will be used to establish 597 absorption wells, each 2 metres x 2 metres x 2 metres. These wells enhance water retention. Consequently, they reduce runoff and increase groundwater recharge. The project will also install 8,000 biopori, holes that are approximately 10 cm across and 1 metre deep, designed to further improve water absorption.

The project will benefit 278,600 people (153,230 male and 125,360 female) and address the land restoration and watershed management priorities identified in the National Medium Term Development Plan 2020–2024. Ultimately, the project's goal is to demonstrate how the multistakeholder approach could be scaled up to address widespread land degradation.

In this report, we present the Sustainable Asset Valuation (SAVi) assessment for the MEWLAFOR project. The assessment quantifies the ecosystem services and economic impacts of the planned reforestation and water retention wells. We combine this information in an integrated cost-benefit analysis (CBA) that considers project performance under two climate change scenarios. The assessment also calculates the net present value (NPV) and internal rate of return (IRR) of the project, for which the avoided costs and added benefits are counted as revenue streams. We discuss whom the project affects and the feasibility of similar projects at larger scales.

We collaborated with UNIDO throughout the modelling process to identify the impacts of the MEWLAFOR project. These discussions informed our modelling approach and our choice of relevant indicators to include in the assessment. UNIDO also coordinated with Multi Bintang and the Indonesia Ministry of Environment and Forestry to provide data for the analysis.

2.0 Modelling Approach

The SAVi assessment uses a systems approach to develop a project-specific integrated CBA. It relies on a spatially explicit model that quantifies biophysical indicators and other data sources.

The integrated CBA is presented under two different climate scenarios relying on data from the Copernicus Climate Data Store. Specifically, we use the Copernicus European Centre for Medium-Range Weather Forecasts Reanalysis 5th generation (ERA5) database for historical observations and the Coupled Model Intercomparison Project Phase 5 (CMIP5) for projections.

2.1 Causal Loop Diagram

A causal loop diagram (CLD) is an analytical tool that captures the dynamics of a system. Creating a CLD is the first step in customizing the assessment to the local context. By showing the interconnectedness of key socio-economic and environmental indicators, it exposes potential impacts of a project and how these impacts unfold through the system. Our counterparts at UNIDO provided information that informed the CLD for the MEWLAFOR project and validated the diagram that we developed (Figure 1).

At the centre of the diagram is the variable representing the area of agricultural land. In Indonesia, expanding agriculture has generated income for the local population but has come at the expense of lost forest land. The negative side effects of this deforestation include soil erosion, loss of biodiversity, and decreased water retention. These impacts have worsened floods and reduced groundwater recharge. Ultimately, these effects reduce land productivity, and, although deforestation cannot continue forever, it becomes necessary to clear more land. These dynamics are represented in Figure 1 by the arrows pointing from “forested land,” moving clockwise around the diagram.

Precipitation replenishes the water supply, but most comes during the rainy season. Water scarcity is a problem during the dry season and is expected to become more severe in the future. With less groundwater recharge, downstream economic activity slows. These impacts are shown on the righthand side of the diagram.

At the other extreme, heavy precipitation is also predicted to worsen with climate change, leading to more flooding and soil erosion. The arrows pointing left from “precipitation” capture this impact. To emphasize that precipitation is a climate input, the variable is highlighted in pink in Figure 1.

Conversely, investing in reforestation to establish bamboo plantations and agroforestry schemes and constructing water retention wells can mitigate many of these problems. These interventions are highlighted in orange. As shown in the diagram, soil erosion and flood risk decline, and biodiversity increases. Enhanced water retention and better land management upstream stimulate economic growth downstream. Reforestation has the added benefits of purifying water and sequestering carbon. Agroforestry and bamboo plantations are also sources of revenue for the local community.

The following feedbacks, labelled in Figure 1, help explain the historical pattern of deforestation and demonstrate how interventions could support sustainable land management:

a) R1 – deforestation increases soil erosion, which decreases land productivity. With lower productivity per hectare, more agricultural land is needed, leading to more deforestation.

b) R2 – deforestation reduces water retention, and hence, peak discharge and runoff volume are larger. This increases flood risk. Flooding lowers land productivity, so demand for land increases, and more forest land is cleared.

c) R3 – deforestation leads to lower biodiversity. This decreases the productivity of agricultural land, which creates a need for more land, resulting in further deforestation.

d) B1 – more groundwater increases the water available for industry. With more water, production is higher, which leads to more groundwater extraction and a decrease in groundwater.

e) R4 – reforestation with new agroforestry and bamboo plantations increases biodiversity, leading to higher productivity in agroforestry systems. This raises income, lowering the need for agricultural land and deforestation.

f) R5 – with reforestation, erosion decreases. This makes agroforestry systems more productive and results in more income from agroforestry. This decreases the need for agricultural land, resulting in less deforestation.

g) R6 – more forested land increases soil water retention. There is, thus, more water available for agroforestry. This increases productivity, which lowers the need for agricultural land and reduces deforestation.

h) R7 – forested land increases water retention and reduces runoff and flood risk. Hence, there is less damage to agroforestry systems. This increases productivity and income. There is thus less demand for agricultural land and, therefore, a further decrease in deforestation.

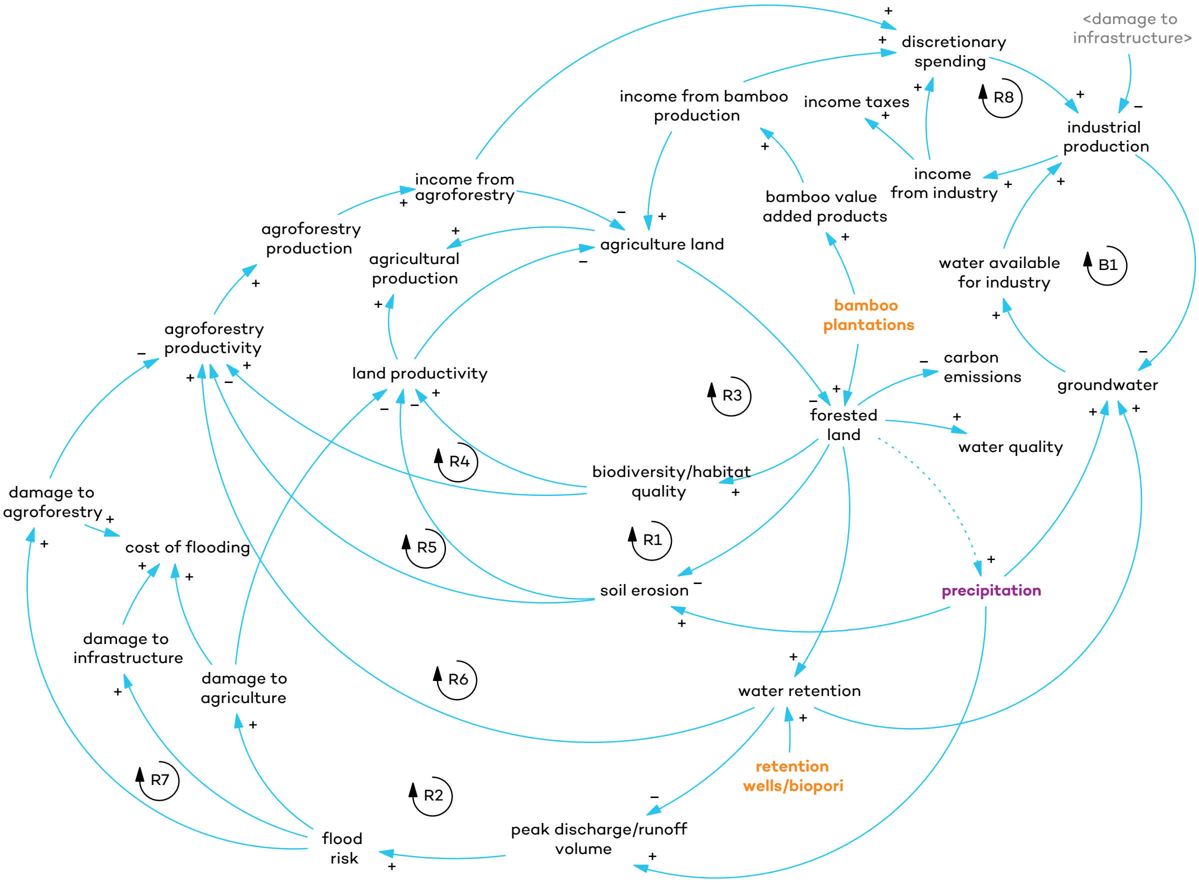
i) R8 – industrial production downstream generates income, a portion of which goes toward discretionary spending. With increased spending, there can be more production.

It is also possible that an increase in forest cover would change the micro-climate, such that humidity and precipitation increase. This relationship would create additional balancing feedback loops, in which loss of forest decreases precipitation, leading to less soil erosion and flooding. This increases productivity, reducing the need for land, so deforestation slows.

Feedback loops R5–R8 show how investing in agroforestry schemes and bamboo plantations can reverse the vicious cycles of deforestation. As the forest cover grows, the increase in productivity will limit the need for cleared land. Furthermore, R9 demonstrates that improved land and water management can support the continued growth of downstream economic activity. Through these interventions, it is possible to create more sustainable sources of income and generate co-benefits.

Figure 1. Causal loop diagram.

Variables displayed in pink are climate inputs. Variables displayed in orange are proposed policy actions. These interventions can reverse the vicious cycles of deforestation and create more sustainable sources of income. See the text for a description of the dynamics and feedback loops represented in this diagram.



Source: Authors' diagram.

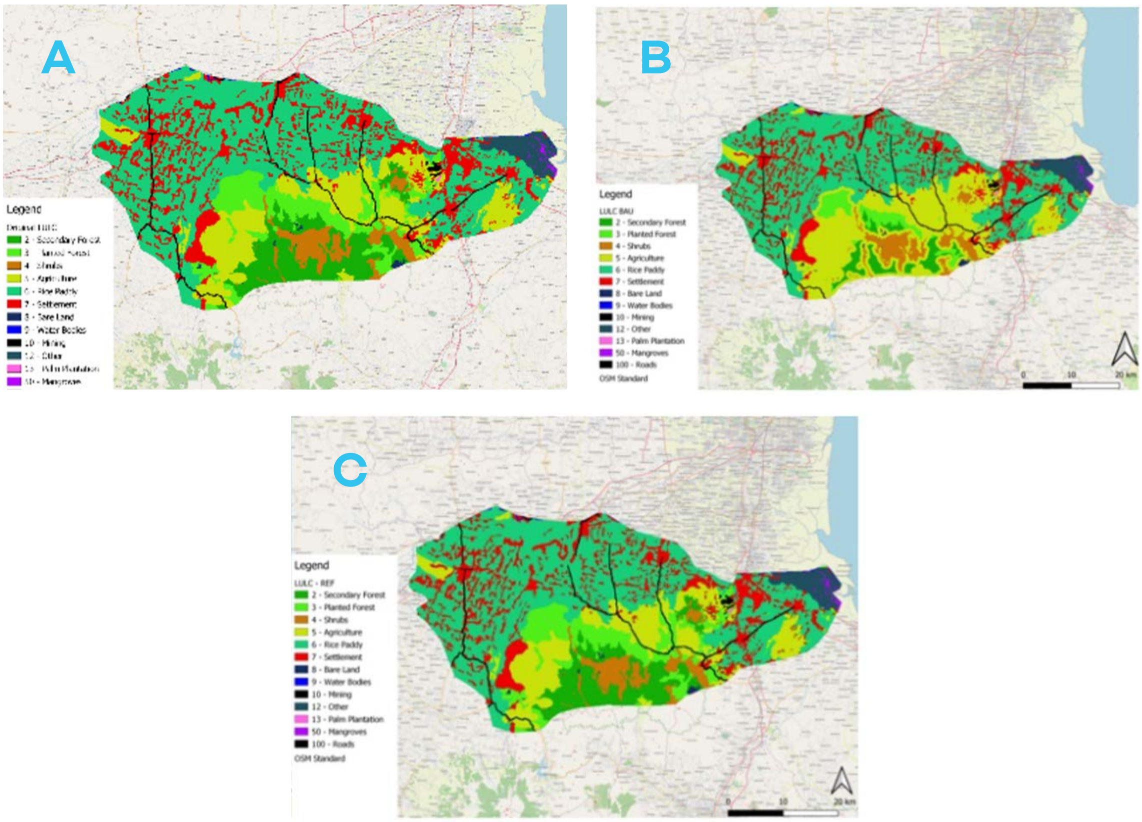
2.2 Spatially Explicit Analysis

The Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) model was used to quantify changes in ecosystem services if the degraded land is reforested. The analysis used a land cover map from 2018 developed by the Ministry of Environment and Forestry (Ministry of Environment and Forestry Indonesia [Kementerian Lingkungan Hidup dan Kehutanan], n.d.-b). Each indicator was simulated under two land cover scenarios:

- A business-as-usual (BAU) scenario, in which 22,336 ha of forest are lost relative to the 2018 map
- A reforestation (REF) scenario, in which 3,697 ha are reforested

See Figure 2 for maps of 2018 land cover and the two simulated scenarios.

Figure 2. Land cover maps for (a) 2018, (b) the BAU scenario if deforestation continues and (c) the REF scenario with improved land management



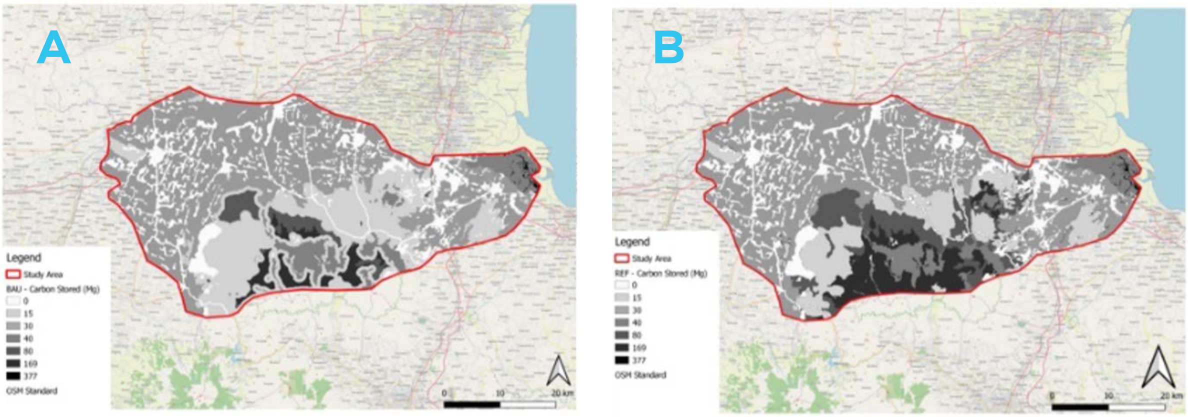
Source: Authors' diagram based on data from Ministry of Environment and Forestry Indonesia (Kementerian Lingkungan Hidup dan Kehutanan), n.d.-b. Background map data from OpenStreetMap (© OpenStreetMap contributors, https://www.openstreetmap.org/copyright).

Here, we provide a brief overview of the spatially explicit indicators that were included in the integrated CBA. For a more thorough discussion on the spatial analysis methods and results, see Appendix B.

2.2.1 Increased Carbon Storage

Figure 3 shows the increase in carbon storage in the REF scenario compared to the BAU scenario. Compared to BAU, the project stores an additional 2.64 million tons of carbon. We convert this to tons of carbon dioxide (CO_2) emissions avoided by multiplying by 44/12. This multiplier corresponds to the ratio between the mass of carbon and the mass of CO_2. From this, we conclude that the project avoids 9.69 million tons of direct CO_2 emissions. Full descriptions of the carbon storage methodology and results can be found in Appendix B (Section B.1.2).

Figure 3. Carbon storage for the (a) BAU and (b) REF scenarios. The project stores an additional 2.64 million tons of carbon

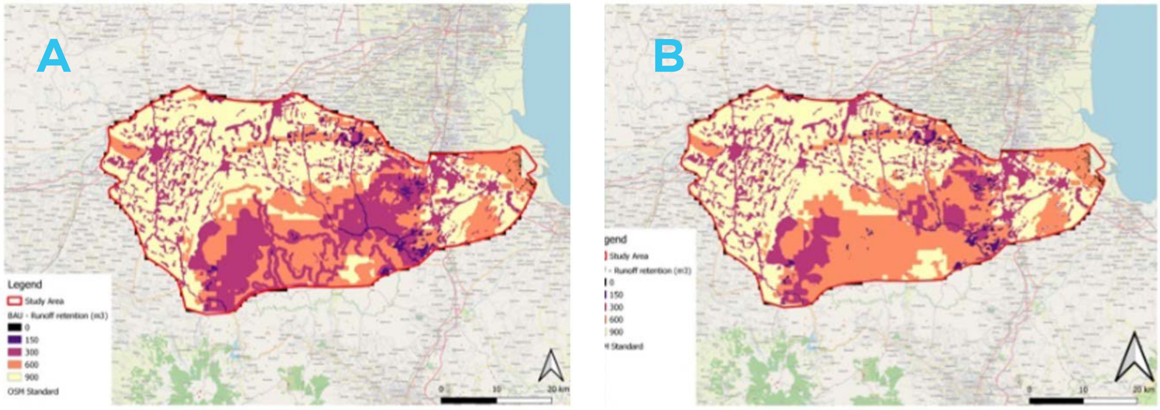


Source: Authors' diagram based on InVEST model output. Background map data from OpenStreetMap (© OpenStreetMap contributors, https://www.openstreetmap.org/copyright).

2.2.2 Enhanced Water Retention

Figure 4 shows the increase in water retention in the REF scenario compared to the BAU scenario for a 231 mm rainfall event (also see Figure B8 and Table B7). Full descriptions of the water retention methodology and detailed results can be found in Appendix B (Section B.1.4).

Figure 4. Water retention for the (a) BAU and (b) REF scenarios. For a 231 mm rainfall event, the project retains an additional 7.98 million cubic metres



Source: Authors' diagram based on InVEST model output. Background map data from OpenStreetMap (© OpenStreetMap contributors, https://www.openstreetmap.org/copyright).

Using the same methodology, the change in water retention was also calculated for monthly rainfall under the current climate and high and low climate scenarios (Table 1). The precipitation values are 5-year averages from the Copernicus climate data products (Copernicus Climate Change Service, 2018). See Section 3.3.2 for a full description of how these rainfall values were selected.

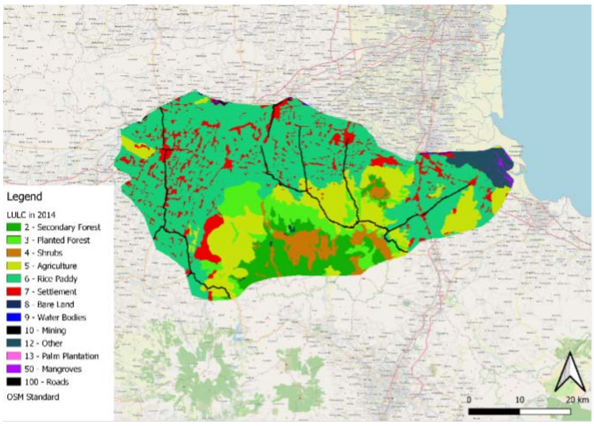
Table 1. Water retention statistics under current, low, and high climate scenarios. Precipitation data are 5-year averages from the Copernicus ERA5 and CMIP5 data products

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Current climate													
Precipitation (mm)	473.3	561.7	494.5	285.9	95.0	62.2	28.1	17.1	49.1	116.3	293.1	400.2	2,876.4
Water retention BAU (10^6 m^3)	147.7	150.8	148.5	136.0	97.5	79.7	48.1	32.1	69.9	105.6	136.6	144.2	1,296.7
Water retention REF (10^6 m^3)	157.2	160.6	158.1	144.5	102.7	83.5	49.6	32.7	72.9	111.5	145.2	153.4	1,372.0
Difference (BAU-REF) (10^6 m^3)	-9.5	-9.8	-9.6	-8.5	-5.2	-3.8	-1.5	-0.6	-3.0	-5.9	-8.6	-9.2	-75.3
Low rainfall scenario													
Precipitation (mm)	364.8	431.2	419.2	278.0	117.5	80.9	42.6	47.8	13.9	22.7	131.0	271.8	2,221.4
Water retention BAU (10^6 m^3)	142.1	145.8	145.2	135.2	106.0	90.8	64.1	68.8	26.9	40.7	110.3	134.6	1,210.4
Water retention REF (10^6 m^3)	151.2	154.5	154.5	143.7	112.0	95.5	66.7	71.7	27.2	41.8	116.5	143.0	1,278.2
Difference (BAU-REF) (10^6 m^3)	-9.1	-8.7	-9.3	-8.5	-5.9	-4.7	-2.6	-2.9	-0.4	-1.1	-6.3	-8.4	-67.8
High rainfall scenario													
Precipitation (mm)	585.5	566.3	458.1	255.4	248.8	221.4	91.1	88.7	87.3	103.5	241.5	347.0	3,294.4
Water retention BAU (10^6 m^3)	151.5	150.9	147.0	132.8	132.1	128.5	95.8	94.7	94.0	101.0	131.2	140.9	1,500.3
Water retention REF (10^6 m^3)	161.4	160.8	156.5	141.1	140.2	136.4	100.8	99.6	98.9	106.4	139.3	149.9	1,591.3
Difference (BAU-REF) (10^6 m^3)	-9.9	-9.8	-9.5	-8.2	-8.2	-7.9	-5.1	-5.0	-4.9	-5.5	-8.1	-9.0	-91.0

To compare project impacts to historical conditions, we also simulated water retention using a land cover map from 2014 (Figure 5). This was done for daily rainfall with return periods ranging from 2 to 100 years based on three climate projections (Table 2) (Directorate General for Water Resources, 2019).

In Appendix B (Section B.1.5), we also present the change in annual water yield using the historical average (1970–2000) annual precipitation. Water yield in the reforestation scenario is 106 million cubic metres smaller than BAU (Table B9). As expected, water yield decreases when water retention increases. More water is retained when the project is implemented, so there is less surface water (i.e., lower water yield). Similarly, water retention can enhance groundwater recharge, which would increase water availability downstream.

Figure 5. 2014 land cover map



Source: Authors' diagram based on data from Ministry of Environment and Forestry Indonesia (Kementerian Lingkungan Hidup dan Kehutanan, n.d.-a). Background map data from OpenStreetMap (© OpenStreetMap contributors, https://www.openstreetmap.org/copyright).

Table 2. Daily rainfall projections used to calculate runoff

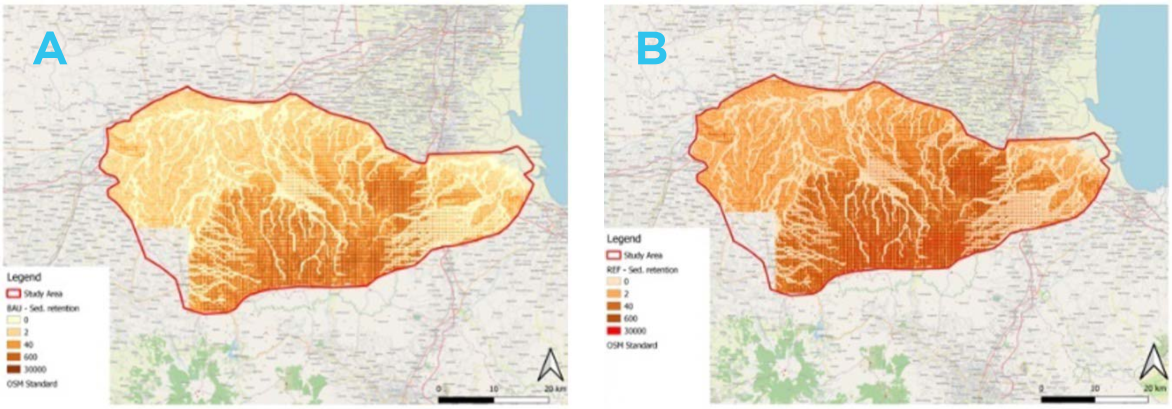
	Climate scenario		
Return period (year)	**Low**	**Medium**	**High**
2	45.25	45.25	49.25
5	56.75	56.75	61.75
10	61.75	64.75	70.5
30	72.5	76	85.75
50	74	81.25	95.5
100	80.75	88.5	108

Source: Authors' calculations based on data from Directorate General for Water Resources, 2019.

2.2.3 Reduced Erosion

As shown in Figure 6, the REF scenario retains an additional 18.2 million tons of sediment compared to the BAU scenario. Methods and complete results for changes in sediment delivery are in Appendix B (Section B.1.6).

Figure 6. Sediment retention for the (a) BAU and (b) REF scenarios. The project retains an additional 18.2 million tons of sediment.

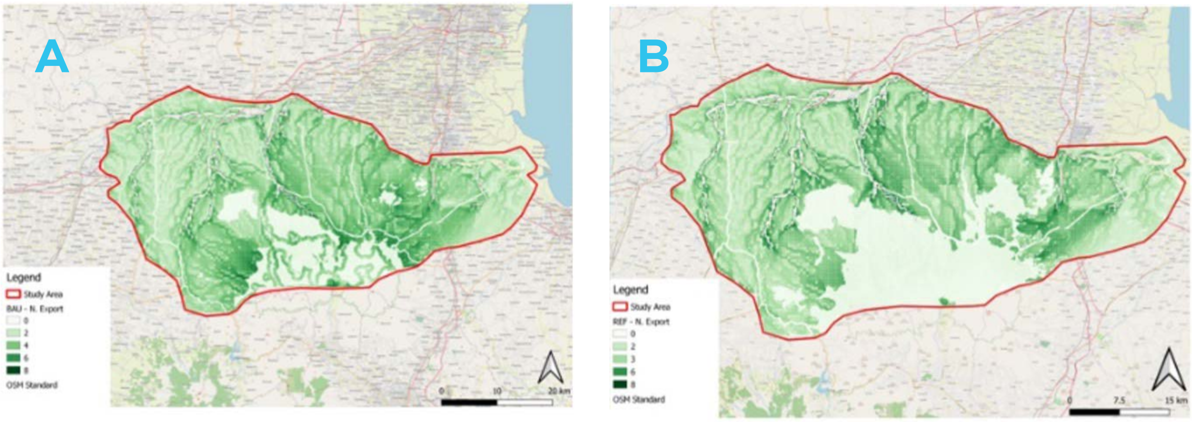


Source: Authors' diagram based on InVEST model output. Background map data from OpenStreetMap (© OpenStreetMap contributors, https://www.openstreetmap.org/copyright).

2.2.4 Decreased Nutrient Delivery

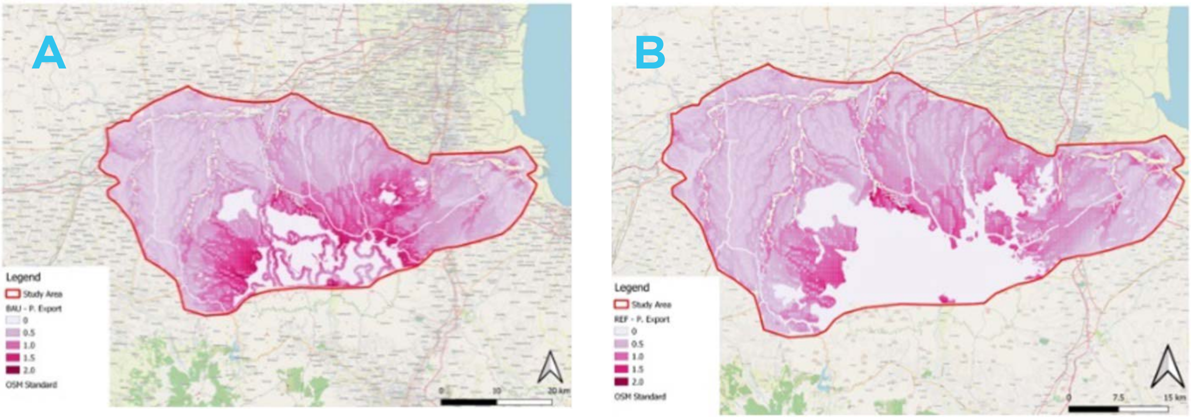
Under the reforestation scenario, nitrogen export is 121 tons lower, and phosphorus export is 35.1 tons lower than in the BAU scenario (Figures 7 and 8). Full descriptions of the nitrogen and phosphorus retention methodology and results may be found in Appendix B (Section B.1.7).

Figure 7. Nitrogen export for the (a) BAU and (b) REF scenarios. The project reduces nitrogen export by 121 tons.



Source: Authors' diagram based on InVEST model output. Background map data from OpenStreetMap (© OpenStreetMap contributors, https://www.openstreetmap.org/copyright).

Figure 8. Phosphorus export for the (a) BAU and (b) REF scenarios. The project reduces phosphorus export by 35.1 tons.



Source: Authors' diagram based on InVEST model output. Background map data from OpenStreetMap (© OpenStreetMap contributors, https://www.openstreetmap.org/copyright).

2.2.5 Flood Mitigation

The above sections assess the biophysical impacts of reforestation. Here, we quantify the effect of water absorption wells. This additional way to enhance water retention is assessed by calculating the reduction in runoff.

The Hydrologic Modeling System (HEC-HMS 4.7.1) was used to simulate runoff volume and peak discharge under the BAU scenario and a scenario that includes water retention wells and biopori in the agricultural area. Runoff was calculated for the daily rainfall amounts shown in Table 2. From these results, the average percent reduction in runoff volume if the project is implemented is 33.1% (Table 3). See Appendix B (Section B.2.1) for a detailed description of the HEC-HMS model. Additional results assessing changes in direct runoff are presented in Appendix B (Sections B.2.2 and B.3.1.2).

Table 3. Direct runoff volume for the BAU scenario, REF scenario with wells and holes simulated in agricultural area and the percent decrease between the two scenarios. The average percent decrease (33.1%) is used as the percent reduction in flood damage. Runoff volumes are calculated using the HEC-HMS model using rainfall predictions from the Directorate General for Water Resources (2019).

HEC-HMS - Direct runoff volume (1,000 m^3)

Return period (year)	Climate scenario								
	Low			Medium			High		
	BAU	REF	Percent change	BAU	REF	Percent change	BAU	REF	Percent change
2	27.40	15.40	43.8	27.40	15.40	43.8	31.40	18.40	41.4
5	39.10	24.50	37.3	39.10	24.50	37.3	44.30	28.70	35.2
10	44.30	28.70	35.2	47.50	31.30	34.1	49.40	32.80	33.6
30	55.80	38.30	31.4	59.70	41.60	30.3	70.40	50.90	27.7
50	57.50	39.70	31.0	65.40	46.50	28.9	81.30	60.50	25.6
100	64.90	46.10	29.0	73.40	53.50	27.1	95.40	73.30	23.2

2.3 Integrated CBA

The integrated CBA estimates the direct and indirect benefits and direct costs of improved management of 26,033 ha and installing the retention wells. The full study area considered to assess impacts is three sub-watersheds of the Brantas River, covering 179,142 ha. This area intersects seven regencies and two municipalities.

The model combines the results of the spatially explicit analysis with data from the Indonesia National Statistics Office, the East Java Statistics Office, and the Indonesia Ministry of Environment and Forestry. Additional data gaps were filled using numbers from international literature.

We calculate the net benefits for the project, assuming a 20-year lifetime and also consider how the net benefits would change if the lifetime were extended to 30 years.

2.4 Financial Analysis

While the integrated CBA estimates the direct and indirect benefits and direct costs of the project, it does not consider how prices change over time, the time value of money, and the opportunity cost of the investment. To account for these issues, we also conduct a financial analysis to adjust for these questions by assuming an inflation rate of 2% for all modelled benefits and costs[1] and use a discount rate of 8.5% per annum to determine the present value of costs and benefits at the time of intervention. We calculate the NPV of the intervention and the IRR assuming a 20-year lifetime and a 30-year lifetime of the intervention.

In wanting to present a more nuanced picture of the value of the project, we have also included a scenario in which we consider the opportunity investment cost. With any investment, there is a cost associated with choosing one alternative over another. As we push the boundaries of financial analysis by considering unaccounted-for benefits, we think it also important to consider unaccounted-for costs. To do so, we scale the investment amount by a fiscal multiplier of 1.6, the estimated multiplier that Ilzetzki et al. (2013) found for fiscal spending by governments in developing countries. This opportunity cost is spread over the first 5 years of the financial analysis.

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[1] We used a higher inflation rate of 3% per annum to calculate the value of the carbon storage benefit as we expect the value of carbon storage to increase more rapidly. This estimation is more conservative than the estimation made by Gollier (2021) that has carbon prices set to grow at 4% plus inflation.

3.0 Data and Assumptions

3.1 Analysis Indicators

Data for the integrated CBA and the financial analysis are drawn from a variety of sources indicated in Table 4. Table 4 also explains the assumptions made to calculate each indicator. In cases where data were available at the regency/municipality level, values for the study area were calculated using area weighted averages based on the area of each regency/municipality in the study area. All monetary data values, regardless of whether they are included in the integrated CBA and/or the financial analysis, have been adjusted to be reported in 2020 USD by inflating the data in its base currency to 2020 values and then converting to USD based on the 2020 average annual exchange rate.

Table 4. Indicators, assumptions, and data sources used for the cost-benefit analyses

Indicator	Assumptions
Added benefits	
Value of bamboo exports	• Bamboo plantations will be established on 130 ha (as reported in the GEF project information form). • The national bamboo export value is USD 151.2 million, and there are 1.4 million ha of bamboo in gardens and farms (International Bamboo and Rattan Organization, n.d.). Therefore, the export value of bamboo products is USD 108.02 per ha. • Bamboo export value is realized every year starting in 2026, which is 5 years after plantations are established.
Agroforestry revenue	• Agroforestry systems are established on 387 ha. • In the first year after trees are planted, annual agroforestry income is USD 264.94 per ha (Rahman et al., 2016). • Agroforestry benefits increase by 1% every year for 20 years, at which point they are constant at 120% of the initial value.
Wages from tree planting for agroforestry	• Jobs created per ha of reforestation are equal to tree planting jobs per ha for a 2016 reforestation and agroforestry project funded by PT Multi Bintang in the Cisadane Watershed in West Java. • Reforestation occurs on 387 ha. • Average annual agriculture and forestry wages in East Java are USD 1,079.52 (BPS Provinsi Jawa Timur, 2021).
Carbon storage	• Compared to the BAU land cover scenario, the project stores an additional 2.64 million tons of carbon (see Section 2.2.1), equal to 9.69 million tons of carbon dioxide. • Value of carbon storage is USD 3.3 per ton of carbon dioxide (Satrio, 2021). • Total value is evenly distributed across years 6–9 of the project (2026–2029).

Indicator	Assumptions
Avoided costs	
Avoided flood damages to households	• Flooding occurs in any month with over 600 mm of rain. • There are 673,819 households in the study area. • Average damage per household in the inundated area is USD 37.18 (Prihantini, 2020). • Implementing the project mitigates 33% of damage compared to the BAU land cover scenario (see Section 2.2.5). • The number of households inundated is related to precipitation according to $h=0.045\ p^3-5.8\ p^2+290\ p$, where h is the number of inundated. Households and p is monthly precipitation over 600 mm (see Appendix A for an explanation of how this equation was derived).
Avoided flood damages to agriculture	• Agricultural income is USD 794 per ha without flooding impacts, and there are 104,142 ha of agricultural land in the study area (see Appendix A for an explanation of how these assumptions were derived). • Flooding occurs in any month with over 600 mm of rain. • Implementing the project mitigates 33% of damage compared to the BAU land cover scenario (see Section 2.2.5). • There is a 10% yield reduction in inundated areas. • The area inundated is related to precipitation according to $A=0.0070\ p^3-0.90\ p^2+44\ p$, where A is agricultural area inundated and p is monthly precipitation over 600 mm (see Appendix A for an explanation of how this equation was derived).
Avoided erosion damages to agriculture	• Agricultural income is USD 794 per ha without erosion impacts, and there are 104,142 ha of agricultural land in the study area (see Appendix A for an explanation of how these assumptions were derived). • Compared to the BAU land cover scenario, the project retains an additional 18 million tons of sediment, corresponding to 102 tons per hectare (see Section 2.2.3). • Erosion damage occurs for 5 years after any year with over 3,200 mm of rain. • Avoided erosion damage is assumed to be a percent of what the agricultural income would be if there is no flooding or erosion. Over the 5-year period, this percent linearly decreases to zero. • If there is another year with over 3,200 mm of rain during this 5-year period, the avoided erosion damages reset to the maximum value. • Avoided erosion damages in the first year following a year with over 3,200 mm of rain are 6% of agricultural income (Magrath & Arens, 1989)
Avoided nitrogen pollution	• Compared to the BAU land cover scenario, the project retains an additional 121.4 tons of nitrogen (see Section 2.2.4). • The value of avoiding nitrogen pollution is EUR 4,612 per ton of nitrogen (Hernández-Sancho et al., 2010).

Indicator	Assumptions
Avoided phosphorus pollution	• Compared to the BAU land cover scenario, the project retains an additional 35.1 tons of phosphorus (see Section 2.2.4). • The value of avoiding nitrogen pollution is EUR 7,533 per ton of nitrogen (Hernández-Sancho et al., 2010).
Investment and maintenance costs	
Improved land management	• GEF incremental funding will provide USD 876,983 (as reported in the GEF project information form). • Co-financing will provide an additional USD 8,064,994 for a total of USD 8,941,977 (as reported in the GEF project information form). We include the co-financing in the project cost because we assess the impact of the project on the full 26,033 ha study area, which has been restored and conserved through a combination of GEF funding and co-financing. • These investments are made in the first year of the project.
Retention wells and biopori	• GEF incremental funding will provide USD 558,330 (as reported in the GEF project information form). • The GEF funding covers the full cost of installing retention wells and biopori (any co-financing was used for other, related projects). These investments are made in the first year of the project.
Annual maintenance cost	• Annual costs are estimated to be 0.5% of initial investment.
Investment opportunity cost	• The opportunity cost of funders investing in this project instead of other projects is based on a total fiscal multiplier of 1.6 (Ilzetzki et al., 2013). This multiplier is the cumulative multiplier to a “pure” public investment shock in developing countries. • This opportunity cost is evenly distributed across the first 5 years of the project.
Other relevant information	
Inflation rate	• All values based on prior to 2020 data were inflated in their base currency to 2020 values and then converted to USD based on the 2020 average annual exchange rate. Inflation rates used for this process were sourced from the World Bank (n.d.). • Future inflation of USD-based figures is 2% per annum based on the 20-year average of U.S. inflation from 2000 to 2020. • Carbon storage benefit is adjusted by 3% per annum.
Discount rate	• Discount rate of 8.5% is the average 20-year sovereign bond rate of Republic of Indonesia for 2000 to 2020 period (Trading Economics, n.d.). • We have not included a risk premium to the discount rate as project funds are grants.

The analysis was completed considering the full 26,033 ha that will come under improved management using both GEF incremental funding and co-financing from PT Multi Bintang, the Mojokerto Regional Government, and the Ministry of Public Works and Housing.

We also estimate the share of benefits attributable to GEF funding. GEF incremental funds will be used to restore 381 ha in the buffer zone, whereas co-financing will be used to restore 3,316 ha in the buffer zone. Therefore, we attribute 10.3% of the flood, erosion, water quality and carbon storage benefits to GEF incremental funding. Furthermore, all bamboo production benefits are due to GEF funding, and GEF funding is responsible for agroforestry and tree planting benefits on 251 ha.

Finally, we compare the cost of the MEWLAFOR project to the cost of constructing a reservoir (or reservoirs) with storage capacity equal to the annual retention volume of reforestation. Table 5 displays the construction and operation and maintenance costs for small (less than 0.75 million m^3) and large reservoirs per m^3 of retention capacity. We use the median estimates multiplied by the increase in water retention due to the MEWLAFOR project to estimate the cost of a grey infrastructure alternative.

Table 5. Capital and operation and maintenance costs per unit volume of storage capacity for large and small reservoirs

	Capital costs (USD per 1,000 m^3)			Lifetime operation and maintenance costs (USD per 1,000 m^3)		
	Low	Median	High	Low	Median	High
Large reservoirs	110	270	1,600	2	5	32
Small reservoirs	130	320	2,200	7	17	110

Source: Based on data from Keller et al., 2000.

3.2 Other Indicators Analyzed

In addition to the indicators included in the integrated CBA and the financial analysis, we also analyzed the impact of the project on water availability downstream, jobs created, income tax revenue and discretionary spending.

3.2.1 Water Availability and Requirements

Enhanced water retention is expected to reduce flooding and increase groundwater availability downstream. However, the area included in this assessment is small compared to the entire Brantas River Basin, which is approximately 1.2 million ha (Directorate General for Water Resources, 2019). Therefore, this project, in isolation, will have a negligible impact downstream.

In contrast, if similar reforestation projects were implemented at a larger scale, there could be a noticeable change in downstream flooding and water availability. To assess the downstream impacts of reforestation, we estimate the percent change in runoff and water retention from the MEWLAFOR project and extrapolate the results.

We make the following assumptions:

- Surface water availability is equal to precipitation minus evaporation minus water retention.
- Upstream water requirements are estimated using data from a 2019 water balance study conducted by PT Multi Bintang in the Cumpleng sub-watershed of the Brantas River.
- Upstream water requirements will be met first through surface water. Groundwater will only be extracted if surface water is insufficient to meet demand.

We use the results of the InVEST model to calculate the percent change in water retention for three rainfall scenarios. To assess groundwater availability downstream, we compare annual surface water availability with upstream water requirements.

3.2.2 Jobs Created

We calculate the number of jobs created from planting trees for reforestation and from the new agroforestry systems based on the following assumptions:

- Jobs created from planting trees
    - Tree planting occurs in the first year of the project.
    - Full-time equivalent (FTE) jobs created per ha of reforestation are equal to tree planting jobs per ha for a 2016 reforestation project funded by PT Multi Bintang in the Cisadane Watershed in West Java.
    - Reforestation occurs on 387 ha.

- Jobs created from agroforestry
    - Agroforestry jobs are created the year after tree planting and are constant for the remainder of the simulation.
    - The land converted to agroforestry was previously unused.
    - Agroforestry creates 0.25-0.375 FTE per ha (Del Pino et al., 2020).
    - Agroforestry systems are established on 387 hectares.

3.2.3 Additional Income Tax and Discretionary Spending

Based on the total agroforestry revenue and tree planting wages (from the integrated CBA), we calculate additional income tax and discretionary spending. We exclude discretionary spending and income tax from the CBA because they are part of the total agroforestry and tree planting revenue.

We assume that the income tax rate is 5% (Deloitte Tax Solutions, 2016) and that the discretionary spending rate is 22.6%. This is calculated using a weighted average of discretionary spending data broken down by age (Credit Suisse Research Institute, 2019) and the age distribution of East Java (BPS Provinsi Jawa Timur, 2021).

3.3 Climate Data Inputs

Climate data come from the Copernicus Climate Data Store. Historical and present-day observations are taken from the Copernicus ERA5 database (Hersbach et al., 2019). Climate projections use the CMIP5 data products (Copernicus Climate Change Service, 2018).

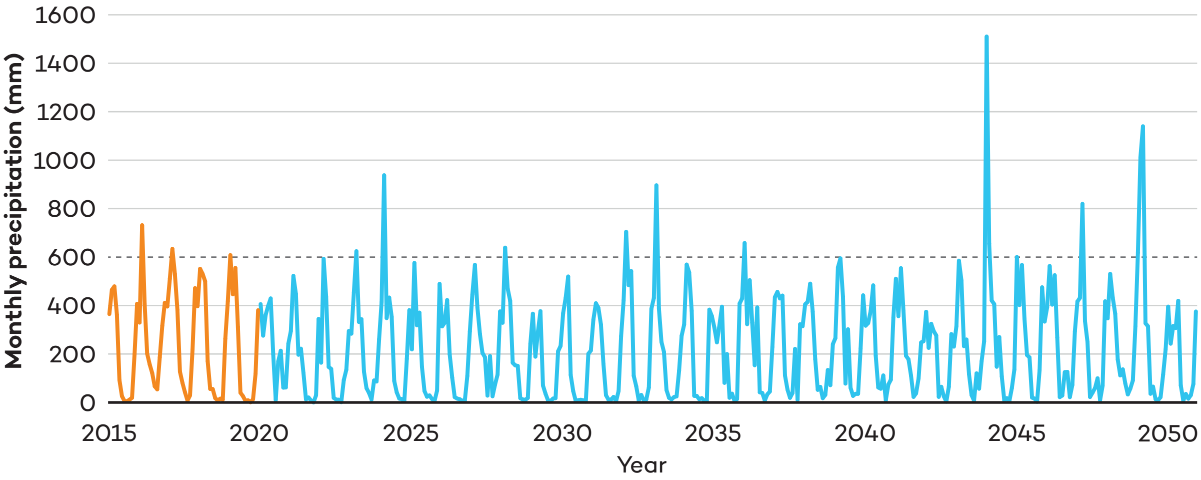
3.3.1 Climate Scenarios

We assess project performance under two climate scenarios:

- A low climate change scenario, Representative Concentration Pathways (RCP) 4.5, which assumes emissions peak in 2040 and then begin to decline.
- A high climate change scenario, RCP 8.5, which assumes continued high reliance on fossil fuel-based energy.

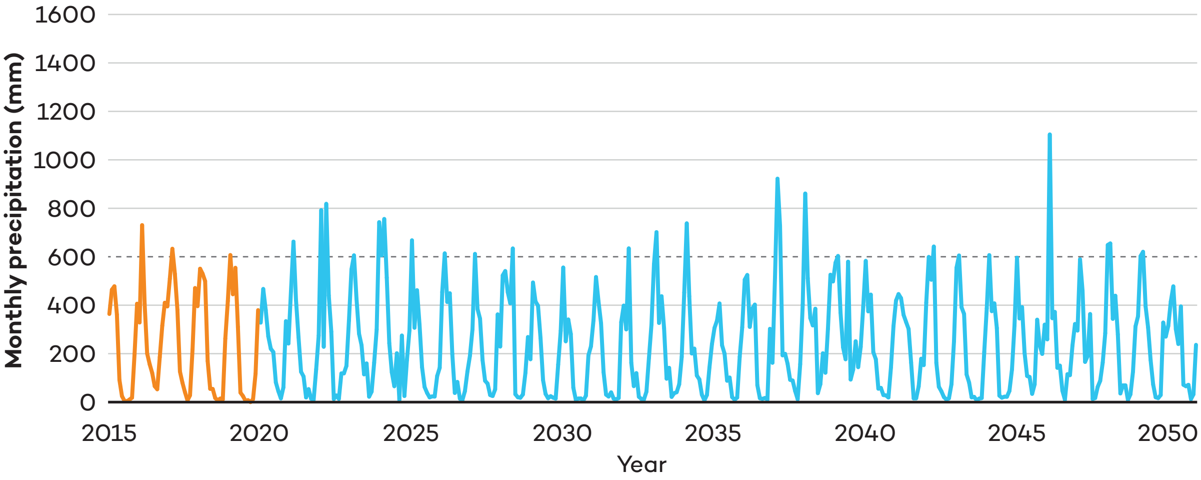
We use monthly rainfall projections, shown in Figure 9 and Figure 10, from these two climate scenarios for the flood and erosion calculations.

Figure 9. Monthly precipitation for the low climate change scenario. The orange line shows historical observations, and the blue line is the model projection. The dashed grey line is the cutoff, above which we assume flooding occurs. 2015–2019 values are observations from ERA5 (Hersbach et al., 2019). 2020–2070 values are projections from CMIP5 (Copernicus Climate Change Service, 2018).



Source: Authors' diagram.

Figure 10. Monthly precipitation for the high climate change scenario. The orange line shows historical observations, and the blue line is the model projection. The dashed grey line is the cutoff, above which we assume flooding occurs. 2015–2019 values are observations ERA5 (Hersbach et al., 2019). 2020–2070 values are projections CMIP5 (Copernicus Climate Change Service, 2018).



Source: Authors' diagram.

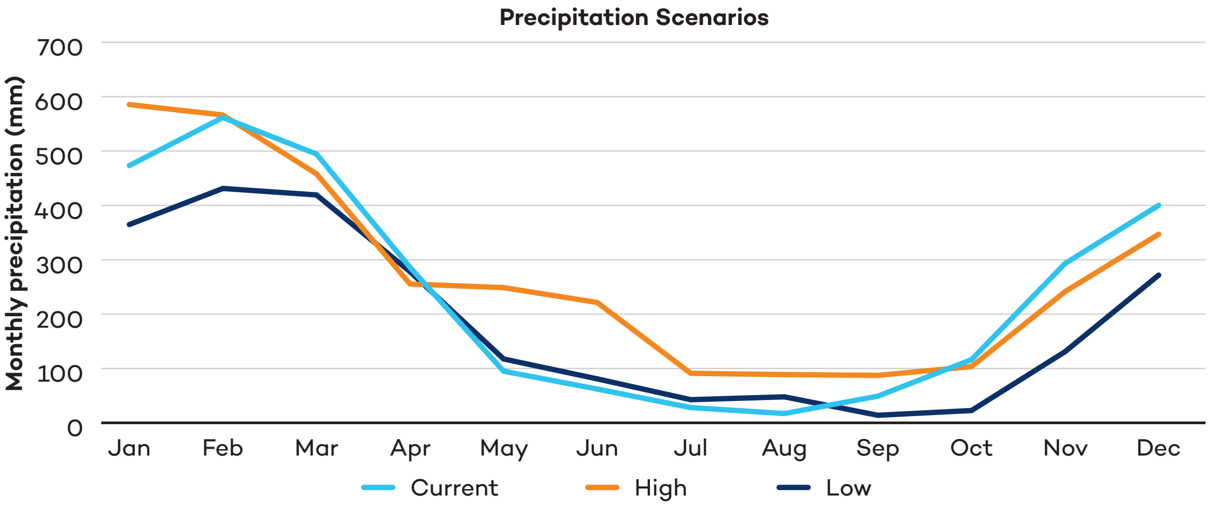
For both climate scenarios, we calculate annual values for all indicators for the years 2021–2050. We present the financial analyses for both a 20-year (2021–2040) and a 30-year (2021–2050) project lifetime. Comparing these two timespans enhances insight into the impact of climate variability on the MEWLAFOR project.

3.3.2 Other Climate Data

We use Copernicus climate data to estimate the impact of increased water retention, not included in the CBA. From the precipitation data shown in Figure 9 and Figure 10, we create three rainfall scenarios to model water retention (Figure 11):

1. Current rainfall: 2015–2019 monthly average precipitation taken from the ERA5 dataset. Annual rainfall is 2,876.4 mm.
2. High rainfall: 2037–2041 monthly average precipitation taken from the RCP 8.5 climate scenario. These years have the highest five-year average annual rainfall across the RCP 4.5 and RCP 8.5 climate scenarios for the years 2020–2050. Annual rainfall is 3,294.4 mm.
3. Low rainfall: 2026–2030 monthly average precipitation taken from the RCP 4.5 climate scenario. These years have the lowest 5-year average annual rainfall across the RCP 4.5 and RCP 8.5 climate scenarios for the years 2020–2050. Annual rainfall is 2,221.4 mm.

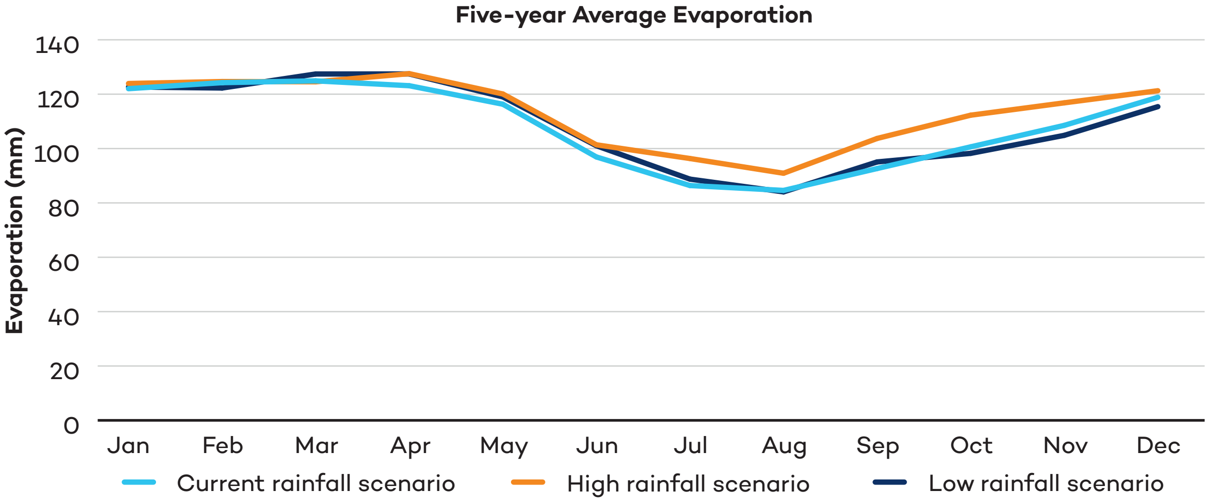
Figure 11. Monthly precipitation for the three rainfall scenarios. Current rainfall is the average of 2015–2019 observations from ERA5 (Hersbach et al., 2019). High rainfall is the average of 2037–2041 projections under the high climate change scenario (Copernicus Climate Change Service, 2018). Low rainfall is the average of 2026–2030 projections under the low climate change scenario (Copernicus Climate Change Service, 2018).



Source: Authors' diagram.

To calculate the water retention impacts, we also use Copernicus evaporation data (Copernicus Climate Change Service, 2018). We calculate 5-year evaporation averages for the same years and climate scenarios as precipitation. That is, we calculate monthly averages from the ERA5 dataset for the years 2015–2019, monthly averages from the RCP 4.5 projection for the years 2026–2030, and monthly averages from the RCP 8.5 projection for the years 2037–2041. These 5-year averages are shown in Figure 12.

Figure 12. Monthly evaporation for the three rainfall scenarios. Evaporation for the current scenario is the average of 2015–2019 observations from ERA5 (Hersbach et al., 2019). Evaporation for the high rainfall scenario is the average of 2037–2041 projections under the high climate change scenario (Copernicus Climate Change Service, 2018). Evaporation for the low rainfall scenario is the average of 2026–2030 projections under the low climate change scenario (Copernicus Climate Change Service, 2018).



Source: Authors' diagram.

4.0 Results

4.1 Highlights

Key results from this analysis are:

- The MEWLAFOR project has positive net benefits that far exceed the costs when externalities are considered.
- The project is economically viable for investors and generates net benefits for society when considering both material economic impacts, including the carbon benefit but no avoided costs (with an IRR of 22.5%), as well as all material impacts and externalities (with an IRR above 62%).
- The project would still have positive net benefits without including carbon payments if avoided costs are considered. The avoided costs are not monetized for investors but generate considerable benefits for society, with an IRR of 56.5%–69.5% over 20 years and 56.6%–69.5% over 30 years.
- On the other hand, the project would have a negative NPV when considering only material impacts and excluding carbon payments. The IRR would be -11.0% over 20 years and -4. 8% over 30 years. This highlights that carbon payments in Indonesia play a critical role in stimulating investments in NBI. Such payments can tip the balance toward a positive return for the investment when using a conventional economic and financial approach. If the MEWLAFOR project successfully avoids the loss of intact forest and carbon payments are available, then the carbon storage benefit alone is greater than the investment and maintenance costs.
- The carbon payment enables the project and hence creates a variety of additional benefits and avoided costs that otherwise would not be realized.
- The value of the project increases when climate variability is greater because there are more avoided costs. Reforestation and avoided deforestation mitigate flooding and erosion damages. Hence, when the potential for these damages is larger, the avoided costs (i.e., benefits) of the project increase. This highlights that nature contributes to climate resilience and increased adaptive capacity.
- The benefits of improved land and water management are split among many different economic actors. Thus, although the societal benefits are large, widespread coordination would be necessary for similar projects on a larger scale.

4.2 Integrated CBA

Bringing 26,033 hectares of the upper Brantas River Watershed under protection, as proposed by this project, has positive net benefits for the three sub-watersheds included in the analysis. For the 20-year lifetime, net benefits are between USD 104.34 million and USD 131.59 million (undiscounted and uninflated) (Table 6). An integrated CBA table including costs and benefits of only the GEF incremental funding is in Table C1.

Table 6. Undiscounted and uninflated integrated CBA. Net benefits are positive and increase with greater climate variability. All values are in 2020 million USD. Numbers in italics depend on the climate scenario. Net benefits are equal to avoided costs plus added benefits minus investment costs.

	20-year lifetime (2021–2040)		**30-year lifetime (2021–2050)**	
	RCP 4.5	**RCP 8.5**	**RCP 4.5**	**RCP 8.5**
Added Benefits				
Value of bamboo exports	0.21	0.21	0.35	0.35
Value of agroforestry benefits	2.12	2.12	3.35	3.35
Tree planting wages	0.52	0.52	0.52	0.52
Carbon storage benefit	31.99	31.99	31.99	31.99
TOTAL ADDED BENEFITS	**34.84**	**34.84**	**36.21**	**36.21**
Avoided Costs				
Avoided flood damages to households	*24.00*	*24.53*	*486.79*	*77.96*
Avoided flood damages to agriculture	*12.06*	*14.00*	*193.73*	*36.90*
Avoided erosion damages to agriculture	*17.85*	*42.64*	*41.65*	*52.56*
Avoided nitrogen pollution	17.10	17.10	25.65	25.65
Avoided phosphorus pollution	8.08	8.08	12.12	12.12
TOTAL AVOIDED COSTS	**79.09**	**106.34**	**759.93**	**205.18**
Investment and Maintenance Costs				
Improved land management investment cost	8.94	8.94	8.94	8.94
Absorption wells and biopori investment cost	0.56	0.56	0.56	0.56
Annual maintenance costs	0.10	0.10	0.14	0.14
TOTAL COSTS	**9.60**	**9.60**	**9.64**	**9.64**
NET BENEFITS	**104.34**	**131.59**	**786.50**	**231.75**
BENEFIT-TO-COST RATIO	**11.87**	**14.71**	**82.56**	**25.03**

The CBA demonstrates that the avoided costs are greater than the added benefits. Carbon storage, bamboo exports, agroforestry, and tree planting wages account for only 24.7%–30.6% of the total benefits over 20 years and 4.5%–15% over 30 years. Nevertheless, the cash flow benefits are greater than the costs. However, if the carbon storage benefit is excluded, the material benefits are less than the costs. Thus, if the carbon benefit is not material, then the avoided costs are needed to justify the investment.

Comparing the two investments, absorption wells contribute more to climate resilience, but without extreme flooding, land management has a higher payoff. We assume that avoided flood damages are due to the absorption wells, the remaining benefits come from improved land management, and the maintenance costs are evenly split between the two investments. Following these assumptions, absorption wells have a benefit-to-cost ratio of 59.5–63.6 over 20 years and 182.4–1,080.9 over 30 years, due to the increase in avoided flood damages over the 30-year timeframe. For land restoration, the benefit-to-cost ratio is 8.7–11.4 over 20 years and 12.8–14.0 over 30 years. Furthermore, all cash flows included in this analysis are due to land management. Thus, although absorption wells can mitigate much of the potential future flood damage, land restoration may be a more viable investment.

Comparing the 20-year and 30-year lifetimes, net benefits increase when there is more climate variability. This is because, with more extreme rainfall, it is expected that there would be more flooding and erosion damage. Thus, the avoided costs are larger. This is demonstrated by the fact that, when considering a 20-year lifetime, avoided costs are greater for the high climate change scenario than for the low climate change scenario (USD 106.34 million compared to USD 79.09 million) (Table 6). However, under the low climate change scenario, there will be an extreme rainfall event in 2044 (Figure 9). Thus, for the 30-year lifetime, avoided flood damages are larger for the low climate change scenario (USD 759.93 million compared to USD 205.18 million). This explains why, as shown in Table 6, the undiscounted net benefits are so high when considering a 30-year lifetime (USD 231.75–786.50 million), particularly under the low climate change scenario.

4.3 Financial Analysis

The main purpose of the SAVi financial analysis is to assess the financial viability of the project and calculate the expected return on investment when the environmental, social, and economic benefits are counted. NBI projects tend not to generate direct revenues; however, as seen in the previous section, they provide a range of direct benefits as well as avoided costs.

To demonstrate the investment worthiness of NBI through the calculation of the NPV and IRR, the SAVi financial analysis model treats those avoided costs as revenues. This approach makes sense for decision-makers who want to take a more holistic approach when assessing whether the project would deliver value for money to society over its life cycle. When the NPV and IRR calculations integrate avoided costs, they are referred to as S-NPV and S-IRR, respectively.

4.3.1 Base Financial Analysis

The results of the financial analysis, when accounting for inflation and applying a discount rate of 8.5%, underline the positive returns associated with the project that are presented above. Table 7 shows that, when the adjustments are made, the project has a positive NPV (S-NPV) of USD 63.4 million–71.6 million over a 20-year period depending on the assumed climate scenario. The benefit flows are structured in such a way that the project would deliver a compounded average annual benefit (S-IRR) that is 62.8%–74.8% higher than the estimated costs.

Table 7. S-NPV and S-IRR under all scenarios accounting for all added benefits, added avoided costs, and investment and maintenance costs. All values are in 2020 thousand USD.

Lifetime of project	20-year lifetime (2021–2040)		30-year lifetime (2021–2050)	
Climate scenario	**RCP 4.5**	**RCP 8.5**	**RCP 4.5**	**RCP 8.5**
S-NPV	63,539	71,551	208,593	92,259
S-IRR	62.8%	74.8%	62.9%	74.8%

Over the longer project lifetime scenario of 30 years, the S-NPV increases to a range of USD 92.3 million–208.6 million under the different climate scenarios, while the S-IRR is projected to be between 62.9% and 74.8% per annum. We note that the finding of the S-NPV figure being larger under the 30-year lifetime scenario and a less variable climate scenario (RCP 4.5) is counterintuitive. However, this larger S-NPV is simply capturing the extreme rainfall event in 2044 (Figure 9) mentioned above. Interestingly, the S-IRR under the 30-year lifetime scenario and the more variable climate scenario (RCP 8.5) is still higher because the avoided costs under the RCP 8.5. are more consistently elevated over the 30-year period.

4.3.2 Base Financial Analysis Exclusive of Carbon Storage Benefit

To highlight the impact that the carbon payment would have on the S-NPV and S-IRR, we calculated the same scenarios outlined in Section 4.3.1 but excluded the assumed carbon payment we expected the project to realize from Year 6 to Year 9. This exclusion resulted in the project still having a positive S-NPV of USD 41.9 million–49.9 million over a 20-year period depending on the assumed climate scenario and a S-IRR that is 56.5%–69.5% (Table 8).

Table 8. S-NPV and S-IRR under all scenarios accounting for added benefits exclusive of carbon storage benefit, added avoided costs, and investment and maintenance costs. All values are in 2020 thousand USD.

Lifetime of project	20-year lifetime (2021–2040)		30-year lifetime (2021–2050)	
Climate scenario	**RCP 4.5**	**RCP 8.5**	**RCP 4.5**	**RCP 8.5**
S-NPV	41,850	49,861	186,903	70,569
S-IRR	56.5%	69.5%	56.6%	69.5%

Under a 30-year lifetime scenario, the S-NPV increases to between USD 70.6 million–186.9 million, and the S-IRR increases to a range of 56.6%–69.5%: approximately 6% per annum less than when the carbon payment is included in the calculation.

4.3.3 Financial Analysis Considering Investment Opportunity Cost

As mentioned in Section 2.4, in wanting to present a more nuanced picture of the value of the project, we have also included a scenario in which we consider the opportunity investment cost. With any investment, there is a cost associated with choosing one alternative over another. By using the estimated multiplier that Ilzetzki et al. (2013) found for fiscal spending by governments in developing countries, we estimated the opportunity cost of money being spent toward this project as opposed to other projects. Obviously, the multiplier used in calculating the opportunity cost would change depending on the sectors of the alternative investment considered; however, the government multiplier provides an adequate estimate.

When these costs are taken into consideration, Table 9 shows the project still has a significance positive net present value (S-NPV) of USD 50.9 million–58.9 million over a 20-year period depending on the assumed climate scenario and USD 79.6 million–195.9 million over a 30-year period. The benefit flows are structured in such a way that the project would deliver a compounded average annual benefit (S-IRR) that is 44.0%–51.2% higher than the estimated costs over a 20-year investment horizon and 44.4%–51.2% over a 30-year investment horizon.

Table 9. S-NPV and S-IRR under all scenarios accounting for added benefits, avoided costs, investment and maintenance, and opportunity costs. All values are in 2020 thousand USD.

Lifetime of project	**20-year lifetime (2021–2040)**		**30-year lifetime (2021–2050)**	
Climate scenario	**RCP 4.5**	**RCP 8.5**	**RCP 4.5**	**RCP 8.5**
S-NPV	50,862	58,874	195,916	79,582
S-IRR	44.0%	51.2%	44.4%	51.2%

4.3.4 Financial Analysis Considering Only Added Benefits and Investment and Maintenance Costs

As NPV and IRR are traditionally associated with cash flows, we thought it important to demonstrate that the project delivers a positive return even when only added benefits (inclusive of carbon payments) and investment and maintenance costs are considered. As can be seen in Table 10, under the assumption of a 20-year project lifetime, the project still has a positive S-NPV of USD 13.4 million under both climate scenarios because the investment and maintenance costs and benefits are not influenced by the different scenarios. The S-NPV for the 30-year lifetime assumption is slightly higher at USD 13.6 million. Similarly, the compounded average annual monetized benefits (S-IRR) that accrue due to costs incurred are 22.5% and 22.6% higher than the costs, depending on the lifetime of the project.

Table 10. S-NPV and S-IRR under all scenarios accounting for added benefits and investment and maintenance costs. All values are in 2020 thousand USD.

Lifetime of project	20-year lifetime (2021–2040)		30-year lifetime (2021–2050)	
Climate scenario	**RCP 4.5**	**RCP 8.5**	**RCP 4.5**	**RCP 8.5**
S-NPV	13,359	13,359	13,554	13,554
S-IRR	22.5%	22.5%	22.6%	22.6%

4.3.5 Financial Analysis Considering Only Added Benefits Exclusive of Carbon Storage Benefit and Investment and Maintenance Costs

Similar to the presentation of results in Section 4.3.2, below are the NPV and IRR figures when the carbon payment has been excluded from the calculation. It should be noted that we have dropped the “sustainable” qualifier to the NPV and IRR terms since the calculation below considers only material monetary flows. Under both the 20-year and 30-year lifetime scenarios, both the NPV and IRR of the project are negative. This result holds under both climate scenarios (Table 11).

Table 11. NPV and IRR under all scenarios accounting for added benefits exclusive of carbon storage benefit and investment and maintenance costs. All values are in 2020 thousand USD.

Lifetime of project	20-year lifetime (2021–2040)		30-year lifetime (2021–2050)	
Climate scenario	**RCP 4.5**	**RCP 8.5**	**RCP 4.5**	**RCP 8.5**
S-NPV	-8,330	-8,330	-8,136	-8,136
S-IRR	-11.0%	-11.0%	-4.8%	-4.8%

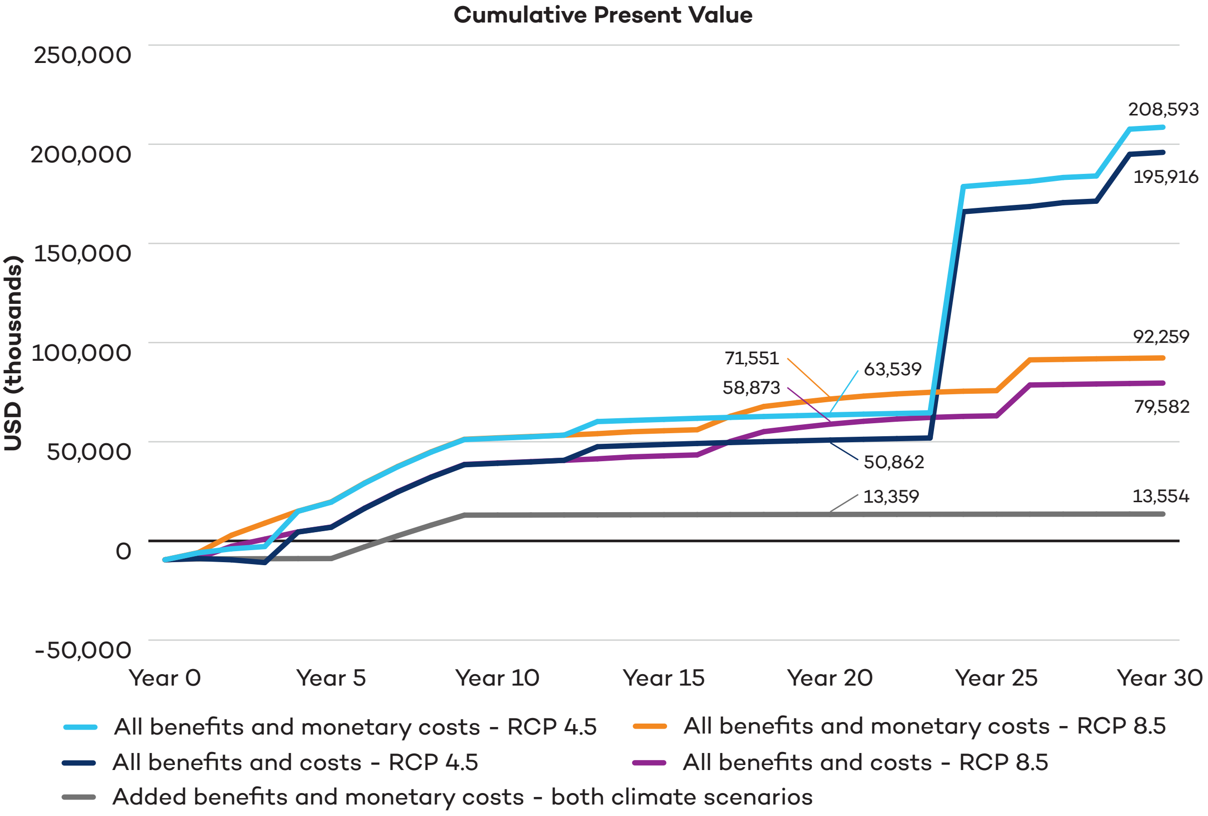
These results, and the ones in the preceding sections, point to the importance of the carbon payment because the project in and of itself does not generate enough revenue from bamboo exports, agroforestry, and tree planting wages to offset the upfront costs and annual maintenance. This issue is further exacerbated by the dispersion of material benefits and how groups enjoying the revenue from bamboo exports, agroforestry, and tree planting wages are likely different. Without a centralized revenue to offset centralized costs of development and maintenance, coordination is key among stakeholders.

4.3.6 Cumulative S-NPV

By illustrating the cumulative present value calculation in Figure 13, we can see how the assumptions made for our financial analysis impact the S-NPVs. The most obvious and striking point is the impact that the projected extreme rainfall event in 2044 has on the S-NPVs of the RCP 4.5 scenarios. When comparing the two climate scenarios over the 30-year lifetime, the cumulative S-NPV under the less variable scenario is at least 2.2 times higher than under the more variable scenario. This demonstrates the impact of extreme events on the S-NPV.

Related, it is interesting that it is only after the first 10 years of the project when the avoided costs really take hold and lead to divergences in the trajectory of the S-NPV. During the first 10 years, the shapes of the scenarios are quite similar because they are mostly influenced by the expectation that the carbon storage benefit will only be monetized in Years 6 through 9.

Figure 13. Calculated cumulative present value



Source: Authors' diagram.

Figure 13 also illustrates that the S-NPV of a project, when environmental, social, and economic benefits are counted, demonstrates itself to be positive earlier. In all four cases in which all benefits were taken into account, the project has a positive S-NPV by Year 4. In essence, the project has demonstrated value for money after 4 years; quite an impressive performance for any USD 9.5 million infrastructure project. Moreover, it is important to note that the financial assessments were done under the assumption that the project has an operating life of 20 years or 30 years. We believe this to be quite a conservative assumption and believe that even after 30 years of "operation," the project could still offer significant benefits at little cost, which implies a significant terminal value.

4.4 Interpreting Results in Light of Limitations for This Study

To interpret our results, it is important to understand the limitations of this study. The integrated CBA includes impacts on society at large without considering who pays and who benefits. However, the impacts on individual actors may determine who will invest in further restoration. Similarly, we have not quantified downstream impacts. We did not have the necessary data, but a full assessment of water management in the Brantas River Basin should consider the entire watershed. These limitations imply that the net benefits may be larger than our estimate, but we do not know how these benefits are distributed or how they compare to other investment options.

4.4.1 Benefits for Specific Actors

The project has large net benefits and a return on investment of over 50%. Furthermore, the carbon storage benefit, on its own, is greater than the investment and maintenance costs. Indonesia has historically been active in carbon financing programs, such as Reducing Emissions from Deforestation and Forest Degradation (REDD+) (Satrio, 2021). It is, therefore, reasonable to assume that payments would be made for the carbon stored through the MEWLAFOR project. However, money may not be available for several years. For example, REDD+ is a results-based program, and payments are not granted until it is demonstrated that a project has been successful (Kill, 2019). Furthermore, it is often unclear who will receive the money (Angelsen, 2020). Thus, an individual actor may be hesitant to incur the costs of reforestation despite the large societal benefits.

A similar issue exists with the other benefits considered in this analysis. To quantify the value of bamboo production, we have used the export value. This money will be apportioned among bamboo producers, individuals who create value-added products, government agencies, and others.

The income from tree planting and agroforestry will also be split among different actors. We estimate that tree planting will create 484 jobs in the first year of the project. From the second year onward, there will be 97–145 agroforestry jobs. A share of the money earned will directly benefit the farmers, while a portion will be paid to the government as income tax, and some will be reinvested into the community through discretionary spending. Table 12 contains the cumulative undiscounted income tax and discretionary spending for the 20-year project lifetime.

Table 12. Income tax and discretionary spending from tree planting wages and agroforestry revenue. All values are cumulative for the 20-year project lifetime, undiscounted and uninflated.

	Income tax (USD)	Discretionary spending (USD)
Tree planting	26,100	118,000
Agroforestry	106,000	479,000

No individual stakeholder group will reap all benefits of the avoided costs either. Households, farmers, and the government will each benefit from the avoided flood damages. Avoided erosion damages will mostly affect farmers and public agencies working in the upstream area. The water quality benefits, however, may be more pronounced downstream.

Thus, although the benefits far outweigh the costs, for a given individual economic actor, that may not be the case. Funding would have to come from a wide range of sources, requiring coordination across sectors and geographies. The small-scale MEWLAFOR project, including GEF funding and co-financing, may demonstrate the value of improved land and water management and catalyze the necessary collaboration. Ultimately, this could enable up-scaling of these interventions.

4.4.2 Downstream Flood Mitigation and Water Availability

Water retention increases when the land is reforested. Regardless of whether the project is implemented, annual available surface water (equal to precipitation minus evaporation minus retention) is greater than upstream annual water demand in the current and high rainfall scenarios. However, Table 13 shows that there is no surface water available from May through October using current rainfall and from July through October under the high rainfall scenario. Thus, due to seasonal variations in precipitation and irrigation requirements, groundwater may be required during some months to meet demand.

With low rainfall, annual available surface water is less than total demand, and there is none available from May through November. In this case, groundwater would be required to meet upstream demand, particularly during the dry season, in both the BAU and reforestation scenarios. Note that reservoirs may be able to provide some surface water near the beginning of the dry season, so we cannot say precisely when or how much groundwater would be needed to meet upstream demand.

Table 13. Monthly available surface water for three precipitation scenarios under BAU land cover and if reforestation occurs. Although annual surface water is higher than annual upstream requirements for the current and high precipitation scenarios, groundwater may be required to meet demand during the dry season. For the low rainfall scenario, annual demand is greater than the available surface water.

	Precipitation Scenario					
	Current		High		Low	
	BAU	REF	BAU	REF	BAU	REF
January	268.82	263.49	376.99	371.47	162.81	157.75
February	353.30	347.82	357.37	351.88	227.51	222.63
March	286.68	281.31	251.47	246.17	210.77	205.56
April	86.85	82.09	53.69	49.09	75.11	70.39
May	0.00	0.00	54.97	50.41	0.00	0.00
June	0.00	0.00	48.26	43.87	0.00	0.00
July	0.00	0.00	0.00	0.00	0.00	0.00
August	0.00	0.00	0.00	0.00	0.00	0.00
September	0.00	0.00	0.00	0.00	0.00	0.00
October	0.00	0.00	0.00	0.00	0.00	0.00
November	108.33	103.55	51.42	46.90	0.00	0.00
December	200.85	195.69	147.03	142.03	81.28	76.59

Nevertheless, even with some upstream groundwater extraction, there will be more groundwater available downstream if the project is implemented. Comparing the three precipitation scenarios, years with more rainfall have a larger percent increase in water retention, ranging from 5.6% to 6.1% (Table 1). Assuming that groundwater infiltration is proportional to water retention, land restoration could increase groundwater recharge by up to 6.1% per year. This benefit may be realized in the lower areas of the Brantas watershed if reforestation occurs on a larger scale.

Planting trees and constructing retention wells and biopori reduces runoff volume by an average of 33% for 24-hour rainfall events of 45.25–108 mm (Table 3). In our analysis, therefore, we assumed that 33% of flooding in the upstream study area would be avoided. Extrapolating this result to the full watershed implies that with widespread reforestation and water retention wells, 33% of flood damage downstream could be mitigated.

Additionally, the reduction in runoff due to retention wells would further increase groundwater recharge, above what could be achieved with land restoration alone. Thus, although the MEWLAFOR project, in isolation, is too small to have a noticeable impact lower in the watershed, scaling up these interventions could benefit individuals and businesses downstream.

We do not quantify this benefit, but comparisons with historical conditions can provide a frame of reference for downstream impacts. Simulated runoff retention for both the BAU and the reforestation land cover scenarios was lower than runoff modelled using 2014 land cover. The percent change in runoff retention between 2014 and the BAU scenario is approximately double the percent difference between 2014 land cover and the reforestation scenario (Appendix B, Section B.3.1.1). Although we do not have data on the precise changes in water availability, droughts during the dry season have become more severe in recent years, implying that the groundwater reservoir has been depleted. Thus, compared to a scenario in which deforestation continues, the MEWLAFOR project would result in water availability closer to historic conditions.

4.4.3 Comparison With Grey Infrastructure

The MEWLAFOR project results in an additional 67.8–91.0 million m3 of water retention, depending on rainfall scenario (Table 1). Taking the median estimates from Keller et al. (2000), we calculate that lifetime water storage costs, including construction and operation and maintenance, are USD 275 per 1,000 m3 for a large reservoir and USD 337 per 1,000 m3 for a small reservoir (Table 5). Thus, a reservoir with capacity equal to the retention of the MEWLAFOR project would cost a minimum of USD 18.6 million (assuming a low rainfall scenario using small reservoirs) and could cost up to USD 30.7 million (if designed for a high rainfall scenario using a large reservoir).

Regardless of the rainfall scenario used and the size of reservoir built, the grey infrastructure alternative costs more than the USD 9.5 million invested in the MEWLAFOR project. Furthermore, a constructed reservoir would not provide the additional benefits of bamboo production, agroforestry and carbon storage. These results highlight that, in this context, NBI is cheaper than the alternative and provides multiple co-benefits that support the local community.

5.0 Conclusions

We used SAVi to assess the environmental, economic, and social impacts of improved land and water management in the Brantas River Basin. We quantified spatially explicit changes in ecosystem services and incorporated these biophysical indicators into an integrated CBA. We focused our assessment on the upstream area included in the MEWLAFOR project but demonstrated the value of reforestation and water retention on larger scales.

The MEWLAFOR project has large societal benefits and is more cost effective than building a reservoir for water storage. We found that the carbon storage benefit alone covers the costs of planting trees, installing water retention wells, and maintaining these investments for at least 30 years. The project also avoids large costs due to flooding, erosion, and nutrient runoff, which are more than three times larger than the value of carbon storage. These avoided costs are larger when climate variability is greater.

The MEWLAFOR project is also instructive with regard to funding NBI. First, when using a conventional approach to carry out the economic and financial analysis, carbon pricing makes the project economically attractive. Without carbon pricing, given the many intangible avoided costs and benefits of the project, securing funding would be challenging. This is also reflected in the low investment in NBI observed in the past decades worldwide, a trend that may change soon.

Second, the distribution of accrued benefits across many individuals and sectors from the reforestation and improved water management meant that single-source financing for the project was unlikely at the outset and should not be a priority. Catalytic grant funding and in-kind contributions from the GEF and UNIDO crowded-in a multitude of other grant funders from both the public and private sectors.

Third, while small in scale, the MEWLAFOR project provides insight regarding the potential benefits of reforesting larger areas and installing water retention wells more widely. It also demonstrates the value of coordinating across sectors and geographies to restore degraded land and improve water management.

In conclusion, our assessment identifies factors that enabled successful fundraising for the MEWLAFOR project. We estimate outcomes for biophysical, economic, and financial indicators. We highlight the benefits for different economic actors, considering both increased production and avoided costs, in light of climate trends. Using mixed methods and knowledge integration under different scenarios, the SAVi assessment for the MEWLFOR project highlights how investments to restore forest in the Brantas River Basin in Indonesia can contribute to sustainable development.

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Appendix A. General SAVi methodology and models

A.1 Calculation of Agricultural Area and Income

Data from the Ministry of Environment and Forestry show that in the study area, there are 75,530 ha of paddy land and 28,612 ha of other agriculture, for a total of 104,142 ha of cropland (UNIDO & Ministry of Environment and Forestry [MOEF], personal communication, February 25, 2021). There are three annual rice harvests in Indonesia (USDA, n.d.). We assume that 33% of the paddy land is cultivated for each harvest.

Almost all of the cropland in the regencies and municipalities that intersect the study area is dedicated to rice, maize, and soybeans, with only small areas used to cultivate other fruits and vegetables (BPS Provinsi Jawa Timur, 2021). We, therefore, assume that the entire 28,612 ha of other agricultural land is used for maize and soybean. Within the regencies and municipalities that intersect the study area, there is approximately 11 times more area used for maize than for soybeans (BPS Provinsi Jawa Timur, 2021). From this, we assume that 92% of the 28,612 ha is under maize cultivation and 8% is used for soybeans.

Annual net income per ha of rice production is USD 732.28. Net income per ha of maize is USD 1,022.42, and per ha of soybeans is USD 445.36 (UNIDO & MOEF, personal communication, February 25, 2021). Weighting these values by the area under cultivation for each crop, we calculate that the total agricultural income in the study area is USD 82,700,000 and, therefore, USD 794 per ha.

A.2 Calculation of Inundated Households and Agricultural Land

We estimate the total households in the study area using the number of households in each of the seven regencies and two municipalities that intersect the three sub-watersheds of the study area. We weight these totals by the percent of each jurisdiction in the study area. Using this method, we estimate that there are 673,819 households in the study area. Data for the number of households and size of each regency/municipality come from the East Java Statistics Office (BPS Provinsi Jawa Timur, 2021).

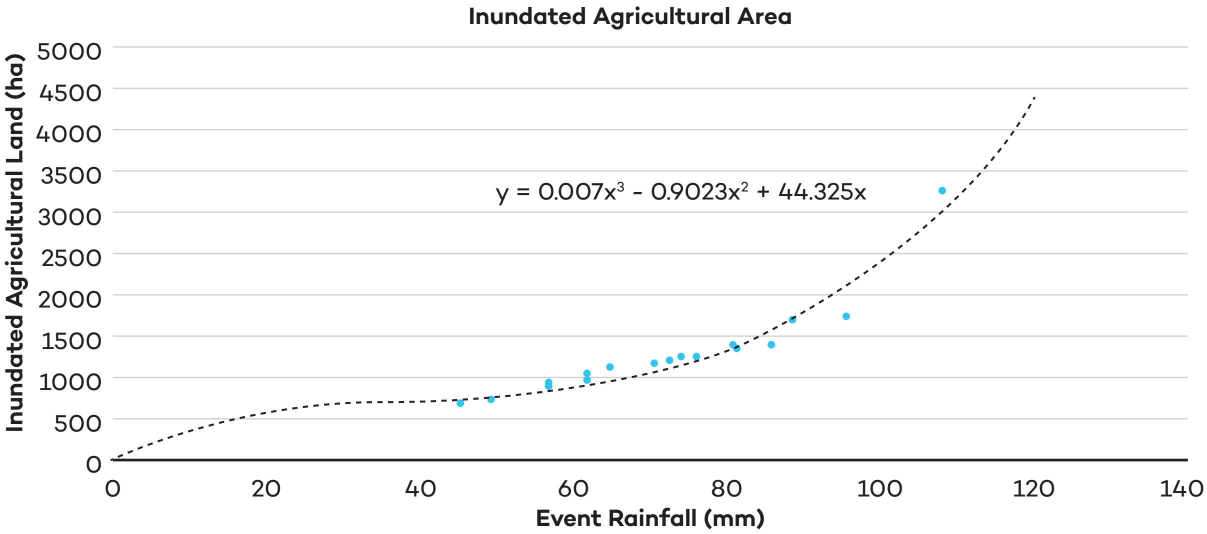
To calculate agricultural area and households inundated, we start with an estimate for the area of irrigated land in the Sadar sub-watershed of the Brantas River that is inundated after 45.25–108 mm of rain (Japan International Cooperation Agency, 2019) and calculate the agricultural area and number of households inundated in the full study area after a rainfall event of any given size over 600 mm. We make the following assumptions:

1. Ninety-nine percent of wetland paddy is irrigated (Japan International Cooperation Agency, 2019), and no other crops are irrigated
2. Fifty-eight percent of land is agricultural

3. There are 75,530 ha of paddy, 26,236 ha of maize and 2,376 ha of soybean
4. Forty-one percent of all land is irrigated (based on assumptions 1–3 and the size of the study area)
5. The percent of land and the percent of households inundated in the study area are equal to the percent of land inundated in the Sadar sub-watershed

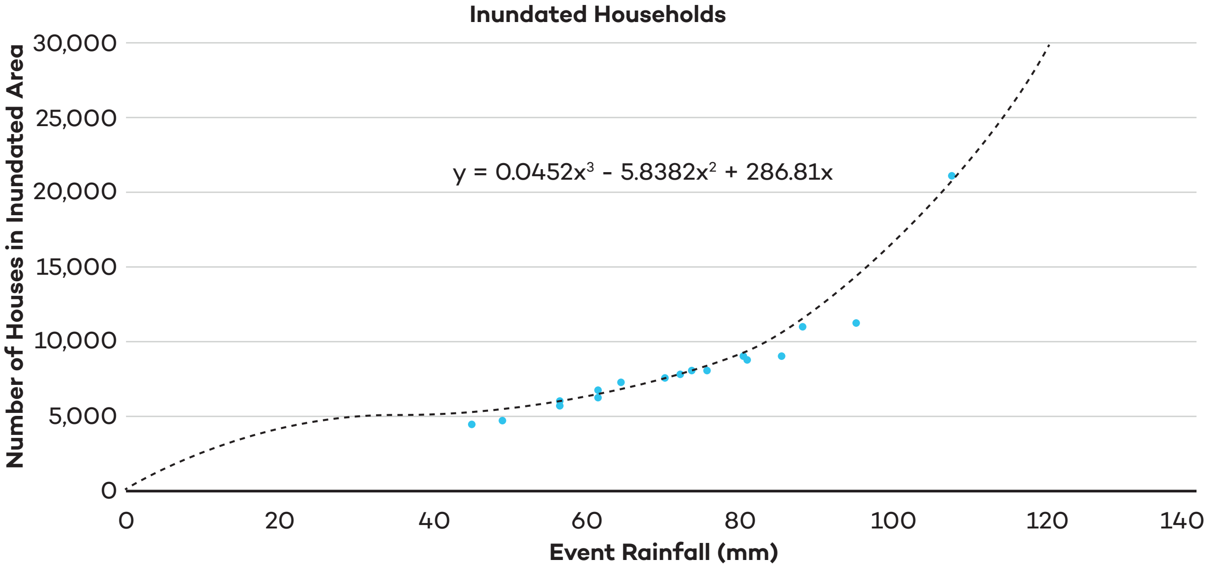
From these assumptions and the total number of households in the study area, we establish relationships between rainfall and agricultural area inundated and between rainfall and number of households inundated (Figure A1 and Figure A2). We can then use the Copernicus precipitation data to calculate the inundated area and households in any month, and, therefore, any year.

Figure A1. Relationship between rainfall and inundated agricultural area. Data points are estimated using inundation data from (Directorate General for Water Resources, 2019) and land-use information. The regression equation is used to estimate inundated agricultural area for all months, assuming that event rainfall is equal to monthly precipitation over 600 mm.



Source: Authors' diagram.

Figure A2. Relationship between rainfall and inundated households. Data points are estimated using inundation data from (Directorate General for Water Resources, 2019) and number of households in the study area. The regression equation is used to estimate inundated households for all months, assuming that event rainfall is equal to monthly precipitation over 600 mm.



Source: Authors' diagram.

Appendix B. Assessing Ecosystem Services Supply in Indonesia by Applying InVEST and HEC-HMS Tools

This appendix presents an overview of the InVEST model and the Hydrologic Engineer Center Hydrologic Modeling System (HEC-HMS) model. Biophysical indicators included are:

- Carbon storage
- Habitat quality
- Water retention
- Water yield
- Sediment retention
- Nutrient (nitrogen and phosphorus) delivery
- Direct runoff speed and volume

Section B.1 describes the methodology and presents results from the InVEST model for two land-cover scenarios. Section B.2 introduces the HEC-HMS model and provides runoff calculations for scenarios with and without retention wells. Section B.3 includes additional water retention and runoff calculations under a variety of rainfall scenarios.

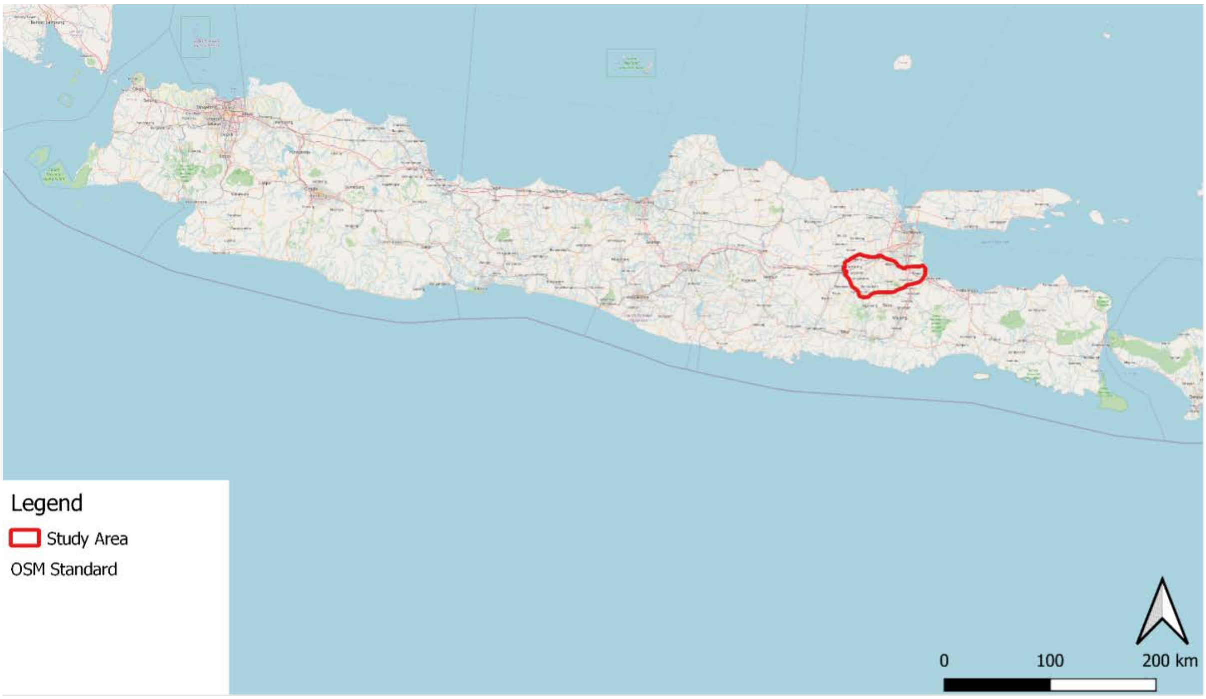
B.1 InVEST

B.1.1 Model Setup

B.1.1.1 STUDY AREA

The study area of this analysis is located within the island of Java, Indonesia. Figure B1 illustrates the boundaries defined for the spatial assessment.

Figure B1. Location of the study area



Source: Authors' diagram created using data from OpenStreetMap (© OpenStreetMap contributors, https://www.openstreetmap.org/copyright).

B.1.1.2 COORDINATION SYSTEM

The spatial assessment results are based on the world project coordinate system called "V WGS 84 / Pseudo-Mercator—Spherical Mercator—ESPG: 3857." Details on the coordinate system are provided in Figure B2.

Figure B2. Details of the coordinate system used for the spatial assessment

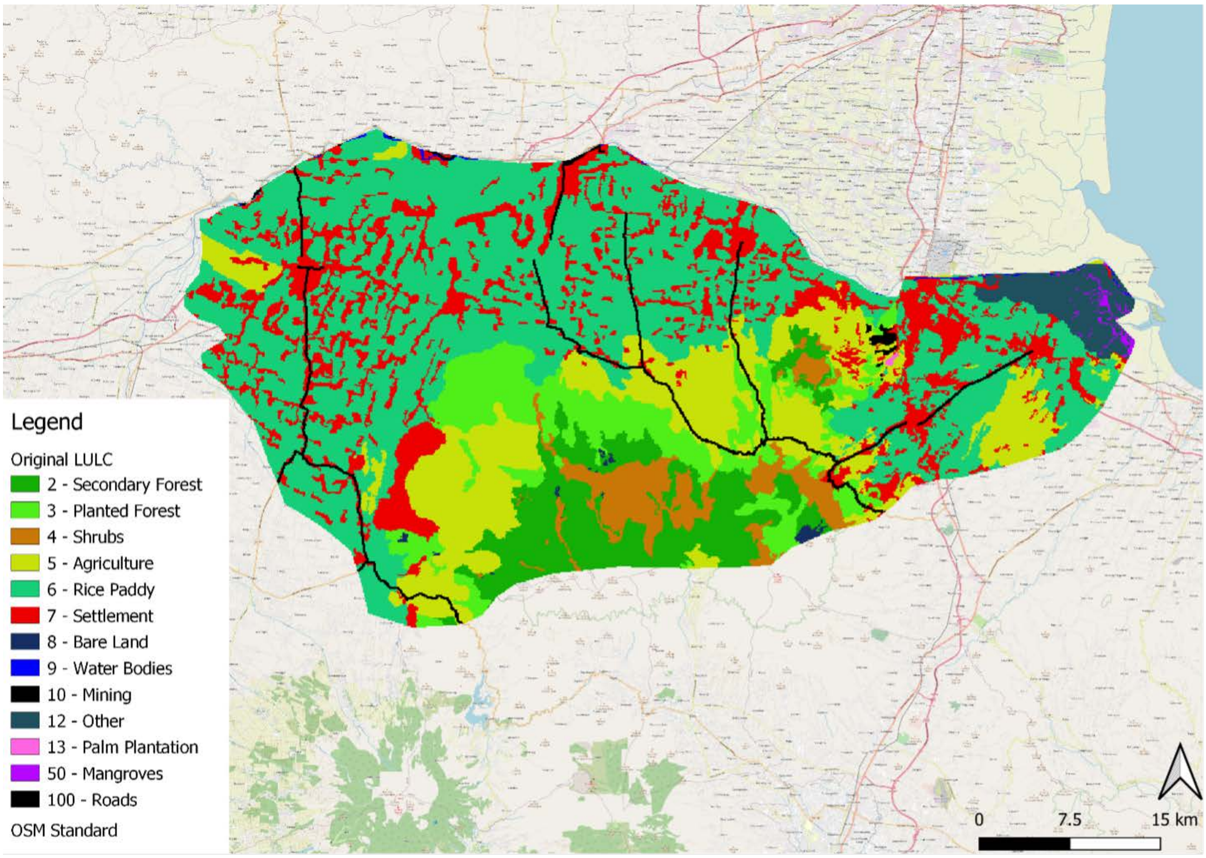
```
PROJCS["WGS 84 / Pseudo-Mercator",
  GEOGCS["WGS 84",
    DATUM["WGS_1984",
      SPHEROID["WGS 84",6378137,298.257223563,
        AUTHORITY["EPSG","7030"]],
      AUTHORITY["EPSG","6326"]],
    PRIMEM["Greenwich",0,
      AUTHORITY["EPSG","8901"]],
    UNIT["degree",0.0174532925199433,
      AUTHORITY["EPSG","9122"]],
    AUTHORITY["EPSG","4326"]],
  PROJECTION["Mercator_1SP"],
  PARAMETER["central_meridian",0],
  PARAMETER["scale_factor",1],
  PARAMETER["false_easting",0],
  PARAMETER["false_northing",0],
  UNIT["metre",1,
    AUTHORITY["EPSG","9001"]],
  AXIS["X",EAST],
  AXIS["Y",NORTH],
  EXTENSION["PROJ4","+proj=merc +a=6378137 +b=6378137 +lat_ts=0.0 +lon_0=0.0 +x_0=0.0 +y_0=0 +k=1.0 +units=m
+nadgrids=@null +wktext  +no_defs"],
  AUTHORITY["EPSG","3857"]]
```

Source: Authors' diagram.

B.1.1.3 MAPS USED

The national land-use land-cover (LULC) map developed by the Ministry of Environment in 2018 was used in this study. The LULC has a resolution of 100 m. We added to the map both mangroves and the primary road networks, which can be downloaded from https://data.unep-wcmc.org/datasets/45 and https://www.geofabrik.de/ respectively. We added these two additional classes to increase the accuracy of ecosystem services evaluation. Figure B3 shows the LULC map of the study area.

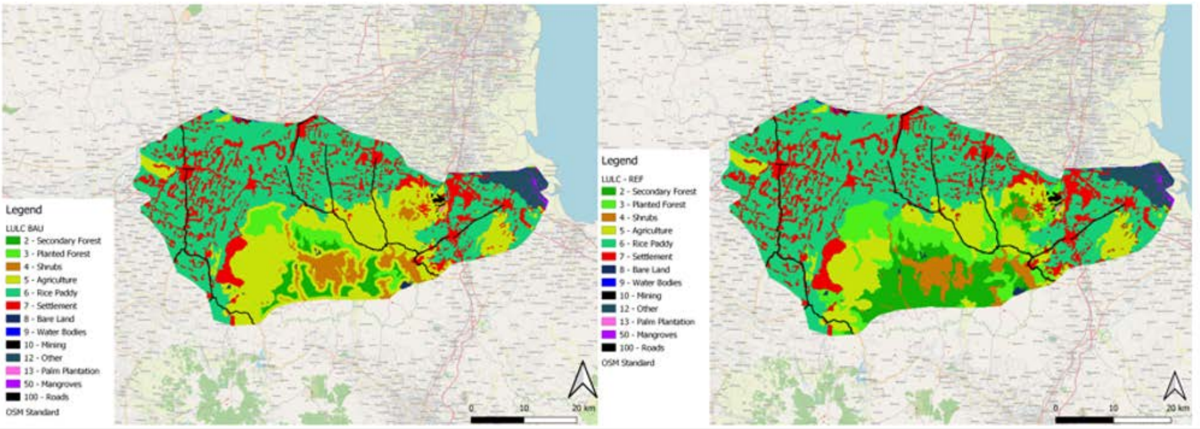
Figure B3. LULC map of the study area



Source: Authors' diagram based on data from Ministry of Environment and Forestry Indonesia (Kementerian Lingkungan Hidup dan Kehutanan), n.d.-b. Background map data from OpenStreetMap (© OpenStreetMap contributors, https://www.openstreetmap.org/copyright).

Because the GEF project aims to "put 3,697 ha of landscapes in forest buffer zones under improved management practices, avoiding the loss of 2,407 ha of protected forests and 19,929 ha of conservation forests," we created two LULC maps (Figure B 4). The one on the left represents the landscape under a BAU scenario, where 22,336 ha of forest will be lost. The other LULC map on the right represents the landscape of the study area after the reforestation of 3,697 ha (REF scenario).

Figure B4. LULC maps of two different scenarios (BAU and REF)



Source: Authors' diagram based on data from Ministry of Environment and Forestry Indonesia (Kementerian Lingkungan Hidup dan Kehutanan), n.d.-b. Background map data from OpenStreetMap (© OpenStreetMap contributors, https://www.openstreetmap.org/copyright).

B.1.1.4 SOFTWARE AND SIMULATION

The ecosystem services assessment has been performed using InVEST Software V.3.9.0[2]. The spatial data for the InVEST model have been prepared using QGIS-OSGeoW-3.4.2-1, an open source GIS platform.[3] The tabulated data will be managed and prepared in Microsoft Excel V. 2016.

B.1.2 Carbon Storage

B.1.2.1 INPUT DATA PREPARATION AND PROCESSING

1. **Current LULC –** The LULC maps showing the landscape under both the BAU and REF scenarios have been considered. Spatial resolution: 100 m.
2. **Carbon Pools –** Table of LULC classes, containing data on carbon stored in each of the four fundamental pools for each LULC class
   - Carbon above ground: The values of carbon density in aboveground mass (megagram per hectare [Mg/ha] or tons/ha) of each land-use type are shown in Table B1.
   - Carbon below ground: The values of carbon density in belowground mass (Mg/ha) of each land-use type are shown in Table B1.
   - Carbon stored in organic matter: The values of carbon density in dead mass (Mg/ha) of each land-use type are shown in Table B1.
   - Carbon stored in soil: The values of carbon density in dead mass (Mg/ha) of each land-use type are shown in Table B1.

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[2] Available at https://naturalcapitalproject.stanford.edu/invest/.

[3] Available at https://qgis.org/downloads/.

In these measurements, 1 Mg/ha is equivalent to one ton per hectare. Average carbon coefficients values were obtained from the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* report, chapter 4 "Agriculture, Forestry and Other Land Use" (IPCC, 2006). Average carbon coefficients values for mangroves and grassland have been retrieved from the samples of the InVEST Coastal Blue Carbon model.

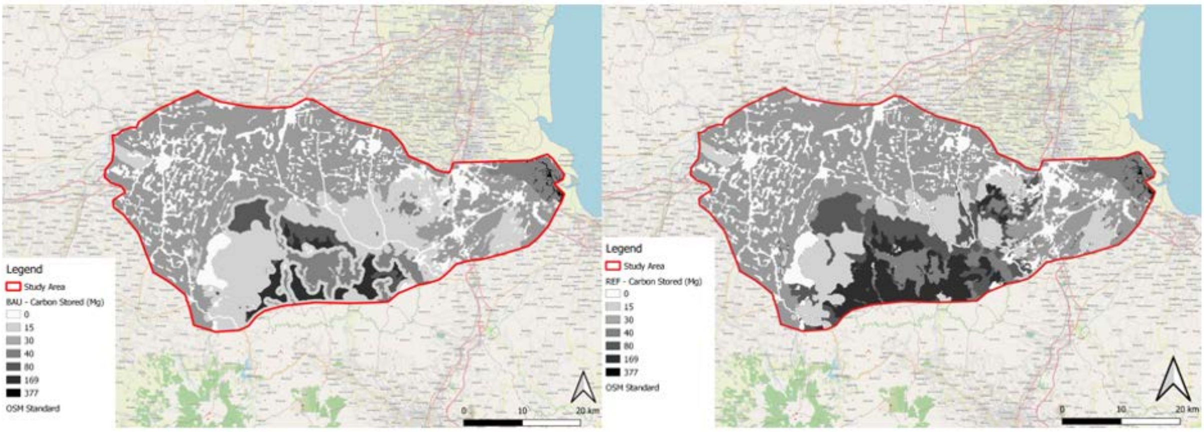
Table B1. Carbon pools for all land-use classes considered in the assessment

lucode	LULC_ Name	C_above	C_below	C_soil	C_dead
1	lc_1	131.6	48.69	1.36	0
2	lc_2	121.5	46.14	1.36	0
3	lc_3	56.4	20.87	1.36	0
4	lc_4	28.2	10.43	1.36	0
5	lc_5	9.87	3.65	1.36	0
6	lc_6	23.5	8.7	1.36	0
7	lc_7	0	0	0	0
8	lc_8	0	0	0	0
9	lc_9	0	0	0	0
10	lc_10	0	0	0	0
11	lc_11	0	0	0	0
12	lc_12	28.2	10.43	1.36	0
13	lc_13	56.4	20.87	1.36	0
50	lc_50	15.31	48.69	313	0
100	lc_100	0	0	0	0

B.1.2.2 RESULTS

Figure B5 shows the amount of carbon stored (Mg) per pixel (100 m x 100 m) in the study area in both the BAU and REF scenarios.

Figure B5. Carbon stored



Source: Authors' diagram based on outputs from InVEST model. Background map data from OpenStreetMap (© OpenStreetMap contributors, https://www.openstreetmap.org/copyright).

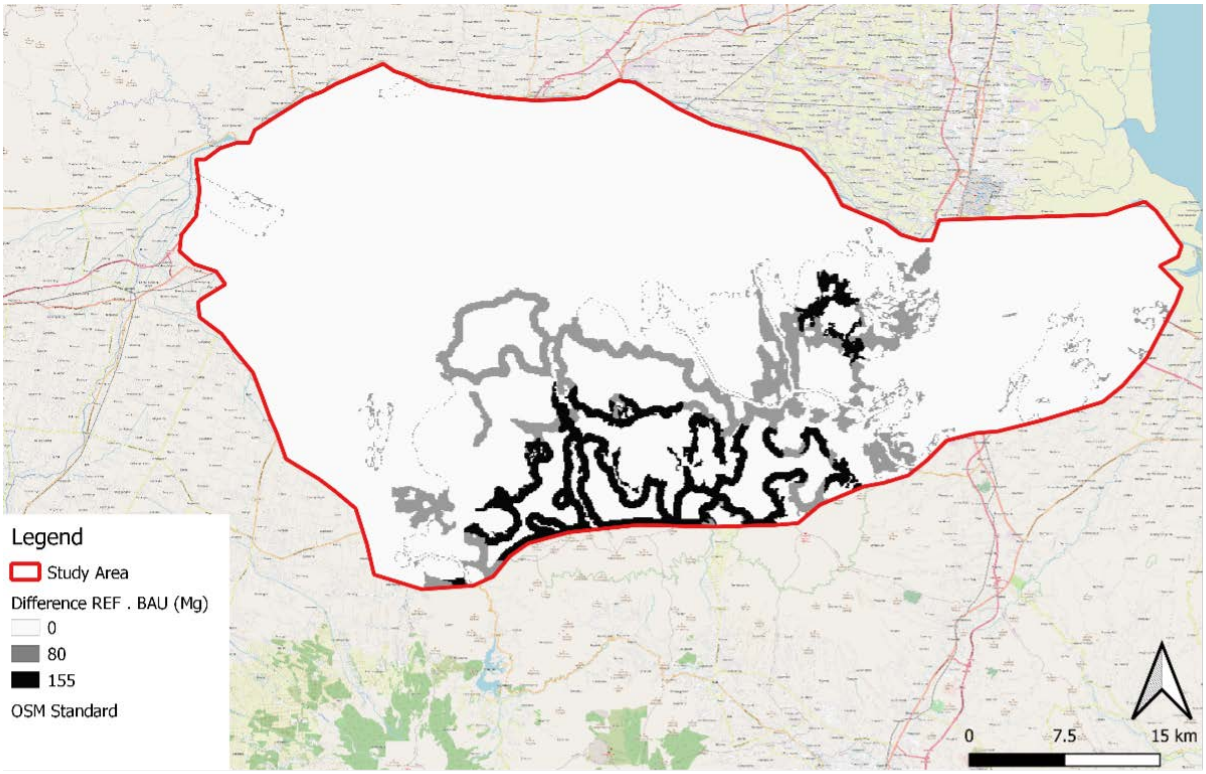
Table B2. Carbon pool statistics

LULC scenario	Total carbon stored (Mg)	Difference (BAU – REF) (Mg)
BAU	6,091,730.52	-2,643,462.00
REF	8,735,192.53	

As Table B2 shows, the carbon stored by the different land classes of the study area would increase under the REF scenario by roughly 2.6 million tons (or megagrams) compared to the BAU scenario. In other words, reforestation activities, as well as halting the loss of forest, would result in a difference of 43.39% in carbon stored between the two scenarios.

We also created a map showing the difference in carbon storage between the REF and BAU scenarios to locate the reforested areas (Figure B 6).

Figure B6. Difference in carbon storage between the REF and BAU scenarios



Source: Authors' diagram based on outputs from InVEST model. Background map data from OpenStreetMap (© OpenStreetMap contributors, https://www.openstreetmap.org/copyright).

B.1.3 Habitat Quality

B.1.3.1 INPUT DATA PREPARATION AND PROCESSING

1. **Current Land cover map:** The LULC maps showing the landscape under both the BAU and REF scenarios have been considered. Spatial resolution: 100 m.
2. **Threat data:** Several major threats such as cropland areas, urban areas, and road networks have been identified as the threat sources to the natural habitat and biodiversity. In general, we consider threats to be human-modified LULC types that cause habitat fragmentation, edge, and degradation in neighbouring habitats. For example, in many developing countries, roads are a threat to forest habitat quality on the landscape because of the access they provide to timber and non-timber forest harvesters. See Table B3. See Table B28 for data sources.

Table B3. Table of threat (maximum distance, weighted value, and decay function) for InVEST simulation

N.	Threat name	Max_Distance	Weighted value	Decay function
5	Other agriculture	4	0.7	linear
6	Rice paddy	0.5	0.5	exponential
7	Settlement	7.1	0.7	linear
10	Mining	5.6	1	linear
11	Airports/ports	7.1	0.7	linear
13	Palm plantation	6	0.7	linear
100	Primary roads	2.9	0.7	linear

3. **Half-saturation constraint:** The default value of 0.5 was used.
4. **Sensitivity of land cover types to each threat:** Table B4 characterizes each LULC type to be habitat or non-habitat and the type's sensitivity to the threats (see Table B29 for data sources). The table contains the following fields:
   - 4.1 **LULC** codes identify each LULC class
   - 4.2 **Name:** abbreviation of each LULC class
   - 4.3 **Habitat:** Score characterizing each LULC as habitat or non-habitat. The values of 0 and 1 are used for the purpose, in which 0 for non-habitat class and 1 for habitat class of LULC.
   - 4.4 **"Crop_5," "Crop_6," etc.:** These are columns for the relative sensitivity of LULC classes to the threat

Table B4. Table of sensitivity of land cover types to each threat for InVEST simulation

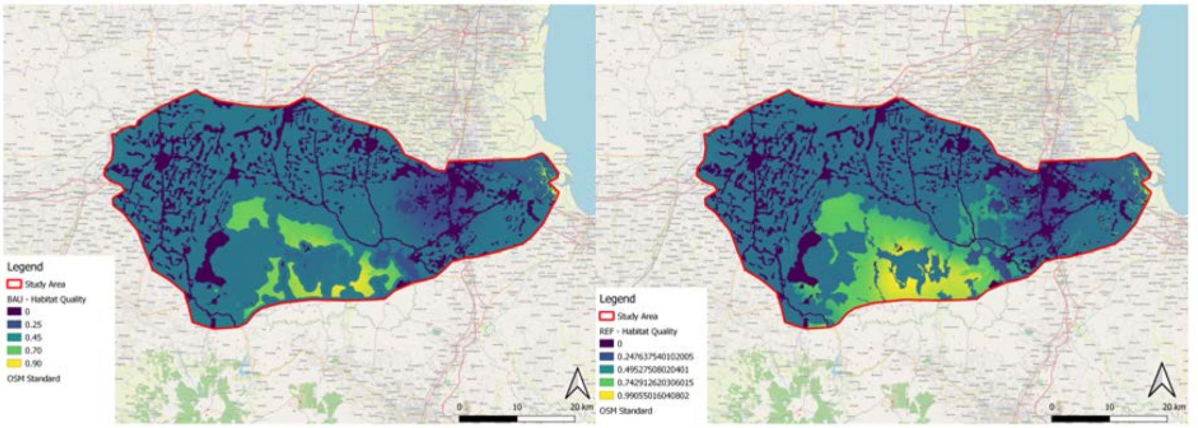
LULC	NAME	HABITAT	crop_5	crop_6	urb_7	min_10	palm_13	rd_100
1	lc_1	1	1	1	1	1	0.7	1
2	lc_2	1	1	1	1	1	0.7	1
3	lc_3	0.8	0.6	0.6	0.4	1	0.9	0.6
4	lc_4	0.4	1	1	1	1	0.7	1
5	lc_5	0.4	0.03	0.03	0.69	1	0	1
6	lc_6	0.4	0.03	0.03	0.69	1	0	1
7	lc_7	0	0	0	0	1	0	1
8	lc_8	0	0	0	0	0	0	0
9	lc_9	0	0	0	0	0	0	0

LULC	NAME	HABITAT	crop_5	crop_6	urb_7	min_10	palm_13	rd_100
10	lc_10	0	0	0	0	0	0	0
11	lc_11	0	0	0	0	1	0	1
12	lc_12	0.4	1	1	1	1	0.7	1
13	lc_13	0.4	0.2	0.2	0	1	0	1
50	lc_50	1	1	1	1	1	0.7	0
100	lc_100	0	0	0	0	0	0	0

B.1.3.2 RESULTS

Figure B7 shows the relative level of habitat quality in the study area in both the BAU and REF scenarios. Higher numbers indicate better habitat quality vis-a-vis the distribution of habitat quality across the rest of the landscape. Areas on the landscape that are not habitat get a quality score of 0. The habitat score values range from 0 to 1, where 1 indicates the highest habitat suitability.

Figure B7. Scores of habitat quality in the study area



Source: Authors' diagram based on outputs from InVEST model. Background map data from OpenStreetMap (© OpenStreetMap contributors, https://www.openstreetmap.org/copyright).

Table B5. Habitat quality statistics

LULC scenario	Mean (from 0 to 1)
BAU	0.323
REF	0.367

As Table B5 shows, the mean of habitat quality in the study area in the BAU and REF scenario would amount to 0.323 and 0.367 respectively. It means that the habitat quality in the REF scenario would be 13.62% higher than in the BAU scenario, proving that halting forest loss and reforesting 3,697 ha would improve the quality of the natural habitats in the study area.

B.1.4 Urban Flood Risk Mitigation

B.1.4.1 INPUT DATA PREPARATION AND PROCESSING

1. Watershed Vectors: This is the polygon shapefile representing the watersheds. We used the boundaries of the study area.
2. Current land cover map: The LULC maps showing the landscape under both the BAU and REF scenarios have been considered. Spatial resolution: 100 m.
3. Depth of rainfall in mm: For this analysis, we used 231 mm as a reference. This was the maximum value recorded on November 1, 2018, when heavy rainfalls caused severe flooding in West Java (Davies, 2018).
4. Soils Hydrological Group Raster: Raster of categorical hydrological groups. Pixel values must be limited to 1, 2, 3, or 4, which correspond to soil hydrologic group A, B, C, or D, respectively (used to derive the curve number [CN]). The dataset can be requested by Gijs Simons at https://www.futurewater.eu/our-team/gijs-simons/. Spatial resolution: 100 m.
5. Biophysical Table: A table containing model information corresponding to each of the land-use classes in the Land Cover Map (Table B6). All LULC classes in the Land Cover raster MUST have corresponding values in this table. These values have been derived from sample data provided by InVEST. Each row is a LULC class and columns must be named and defined as follows:
   - Lucode and use/land cover class code. LULC codes must match the "value" column in the Land Cover Map raster and must be integer or floating point values, in consecutive order, and unique.
   - CN values for each LULC type and each hydrologic soil group. Column names should be: CN_A, CN_B, CN_C, CN_D, which the letter suffix corresponding to the hydrologic soil group.

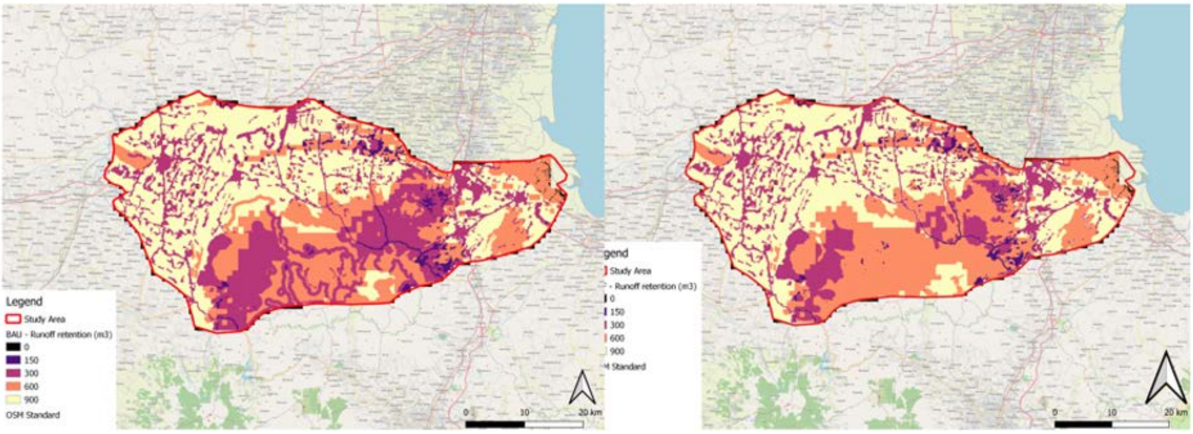
Table B6. Biophysical table – urban flood risk mitigation

lucode	CN_A	CN_B	CN_C	CN_D
2	40	60	70	80
3	40	60	70	80
4	50	70	80	80
5	60	75	80	90
6	35	60	70	80
7	90	90	90	95
8	90	90	90	95
9	0	0	0	0
10	90	90	90	95
12	50	70	80	80
13	60	75	80	90
50	0	0	0	0
100	90	90	90	95

B.1.4.2 RESULTS

Figure B8 shows the runoff retention volume (m^3) in the study area in both the BAU and REF scenarios. Natural infrastructure operates mainly by reducing runoff production, slowing surface flows, and creating space for water.

Figure B8. Runoff retention volume in the study area



Source: Authors' diagram based on outputs from InVEST model. Background map data from OpenStreetMap (© OpenStreetMap contributors, https://www.openstreetmap.org/copyright).

Table B7. Urban flood risk mitigation statistics

LULC scenario	Total runoff retention (m^3)	Difference (BAU – REF) (m^3)
BAU	129,849,733.21	-7,981,341.45
REF	137,831,074.66	

As Table B7 shows, the volume of total runoff retention in the REF scenario is higher than the one in the scenario (+6.15%). Such an increase may be connected to the fact that in the REF scenario, there are more forested hectares that store more water in the soil.

B.1.5 Water Yield

B.1.5.1 INPUT DATA PREPARATION AND PROCESSING

1. **Precipitation:** A GIS raster dataset with a non-zero value for average annual precipitation for each cell. Its value is expressed in millimetres. The average precipitation (in mm) from 1970 to 2000 downloaded from WorldClim version 2 (www.worldclim.com) was used for this study. The dataset was released on June 1, 2016. The original spatial resolution of the data is 30 seconds x 30 seconds (which is approximately 1 km^2). The spatial resolution was reclassified to 100 m.

2. **Average annual reference evapotranspiration (ET0):** A GIS raster dataset with an annual average evapotranspiration value for each cell in millimetres. Reference evapotranspiration is the potential loss of water from the soil by both evaporation from the soil and transpiration by healthy alfalfa (or grass) if sufficient water is available. Its value is in millimetres. The dataset was downloaded from https://www.worldclim.org/. The spatial resolution was reclassified to 100 m.
3. **Root restricting layer depth:** These terms were defined as an average root restricting layer depth value for each cell. It is the soil depth at which root penetration is strangler inhibited because of physical or chemical characteristics. Root restricting layer depth may be obtained from some soil maps. If a root restricting layer depth is not available, soil depth can be used as a proxy. If several soil horizons are detailed, the root restricting layer depth is the sum of the depths of non-restrictive soil horizons. Its value is in millimetres. In this study, the absolute depth to bedrock downloaded from soilgrid.org stored in cm was used to present for root restricting layer depth. The spatial resolution was reclassified to 100 m.
4. **Plant-Available Water Content:** Plant-available water content (PAWC) is the fraction of water that can be stored in the soil profile that is available for plants' use. PAWC can be measured from 0 to 1. The format of PAWC for the model is a GIS raster dataset.

   PAWC is a fraction obtained from some standard soil maps. It is defined as the difference between the fraction of volumetric field capacity and permanent wilting point. The PAWC is often available as a volumetric value (mm). To obtain the fraction, it is necessary to divide it by soil depth. Soil characteristic layers are estimated by performing a weighted average from all horizons within a soil component. If PAWC is not available, raster grids obtained from polygon shapefiles of weight average soil texture (%clay, %sand, %silt) and soil porosity will be needed. In this study, the average calculation of available soil water capacity of the volumetric fraction of 2.0 (pF 2.0) from 0 to 2 m was used to represent the plant-available water contents for water yield model simulation. The spatial resolution was reclassified to 100 m.
5. **Current Land cover maps:** The LULC maps showing the landscape under both the BAU and REF scenarios have been considered. Spatial resolution: 100 m.
6. **Watersheds:** This is the polygon shapefile representing the watersheds. We used the boundaries of the study area.
7. **Biophysical Table:** A table of LULC classes containing data on biophysical coefficients used in this tool. These data are attributes of each LULC class rather than attributes of individual cells in the raster map. This table contains five variables included: [1] *lucode (Land-use code)*, [2] *LULC_desc*, [3] *LULC_veg*, [4] *root_depth*, and [5] K_c. Table B8 shows the biophysical table used in this study. Values have been derived from (Hoy et al., 2015).

7.1 **Lucode (Land-use code):** Unique integer for each LULC class (e.g., 1 for forest, 3 for grassland, etc.), must match the LULC raster above. LULC_desc: Descriptive name of LULC class (optional).

7.2 **LULC_desc:** Descriptive name of LULC class (optional).

7.3 **LULC_veg:** Values must be 1 for vegetated land use except wetlands, and 0 for all other land uses, including wetlands, urban, water bodies, etc.

7.4 **Root_depth:** The maximum root depth for vegetated land-use classes, given in integer millimetres. This is often given as the depth at which 95% of a vegetation type's root biomass occurs. For land uses where the generic Budyko curve is not utilized (i.e., where evapotranspiration is calculated based on the equation below, rooting depth is not needed). In these cases, the rooting depth should be set to NA. The equation can be found here in:

$$AET(x)=Min(Kc(\ell x)ET_0(x),P(x))$$

where

$ET_0(x)$ is the reference evapotranspiration.

$Kc(\ell x)$ is the evaporation factor for each land use and land cover.

Kc factor is the plant evapotranspiration coefficient for each LULC class. It is used to convert from reference evaporation to potential evaporation for each land use.

7.5 **Kc:** The plant evapotranspiration coefficient for each LULC class, used to obtain potential evapotranspiration by using plant physiological characteristics to modify the reference evapotranspiration, which is based on alfalfa. The evapotranspiration coefficient is thus a decimal in the range of 0 to 1.5 (some crops evapotranspire more than alfalfa in some very wet tropical regions and where water is always available).

Table B8. Biophysical table – water yield

lucode	LULC_desc	LULC_veg	root_depth	Kc
2	lc_2	1	7,300	1.1
3	lc_3	1	5,000	0.85
4	lc_4	1	5,100	0.4
5	lc_5	1	2,100	0.65
6	lc_6	1	2,100	0.85
7	lc_7	0	1	0.05
8	lc_8	0	1	100
9	lc_9	0	2,000	1
10	lc_10	0	1	0.05
12	lc_12	1	5,100	0.4
13	lc_13	1	5,000	0.85
50	lc_50	1	7,300	1.2
100	lc_100	0	1	0.05

Z parameter: Z is an empirical constant that captures the local precipitation pattern and hydrogeological characteristics, with typical values ranging from 1 to 30. It corresponds to the seasonal distribution of precipitation. This parameter is mainly used for model calibration; however, in this study, there is no observed data for the model calibration. Therefore, the recommended default value of the Z parameter equals 5 was used.

B.1.5.2 RESULTS

The main output of this model is a table containing biophysical output values per watershed, with the following attribute:

- wyield_vol (m^3): Volume of water yield in the watershed.

Table B9. Water yield volumes in different scenarios

LULC scenario	Total water yield volume (m^3)	Difference (BAU – REF) (m^3)
BAU	1,995,483,508.67	106,140,036.21
REF	1,889,343,472.45	

Table B9 shows the total water yield volume (m3) in both the BAU and REF scenarios. The results indicated that in the REF scenarios, the total water yield volume would decrease by 5.32% compared to the BAU scenario. This is because, as shown above, the reforestation project enhances water retention. With higher retention, more water may become available as groundwater, and consequently, less is available as surface water.

B.1.6 Annual Sediment Delivery Ratio

B.1.6.1 INPUT DATA PREPARATION AND PROCESSING

1. **Digital Elevation Model (DEM) Raster:** DEM is the hydrologically conditioned elevation dataset distributed by HydroSHEDS (https://www.hydrosheds.org/). It was downloaded on January 24, 2021, for InVEST sediment model input. The data was prepared for hydrological model input purposes mainly for flow direction, accumulation simulation, and river network and basin delineation. The original spatial resolution of the dataset is 3 arc-second (approximately 90 m at the equator), but was reclassified to 100 m.
2. **Rainfall Erosivity Index (R) Raster:** A GIS raster dataset containing erosivity index for each cell. This variable depends on the intensity and duration of rainfall in the area of interest. The greater the intensity and duration of the rainstorm, the higher the erosion potential. The erosivity index is widely used, but in case of its absence, there are methods and equations to help generate a grid using climatic data. Its value is $MJ*mm*(ha*h*yr)^{-1}$. The R factor dataset in spatial resolution of 25 km downloaded from https://www.nature.com/articles/s41467-017-02142-7 was employed for this study. The technical report of the data also can be found here: https://static-content.springer.com/esm/art%3A10.1038%2Fs41467-017-02142-7/MediaObjects/41467_2017_2142_MOESM1_ESM.pdf. The spatial resolution was reclassified to 100 m.
3. **Soil Erodibility (K) Raster:** A raster dataset of soil erodibility. It is a measure of the susceptibility of soil particles to detachment and transport by rainfall and runoff. It value is in $T*ha*h*(ha*MJ.mm)^{-1}$. The raster of soil erodibility was downloaded from https://www.nature.com/articles/s41467-017-02142-7 for use in this study. The spatial resolution was reclassified to 100 m.
4. **LULC maps:** The LULC maps showing the landscape under both the BAU and REF scenarios have been considered. Spatial resolution: 100 m.
5. **Watershed Polygons:** This is the polygon shapefile representing the watersheds. We used the boundaries of the study area.
6. **Biophysical Table:** A table containing model information corresponding to each of the LULC types (see Table B10). The table has the following field:
    - 6.1 **Lucode (Land-use code):** Unique integer to identifier for each LULC class.
    - 6.2 **LULC_desc:** Nominal name for each LULC class.
    - 6.3 **usle_c:** This refers to the cover management factor (sometimes called the cropping management factor) (C factor) for the Universal Soil Loss Equation (USLE). This value is used to calculate the cover management in USLE. The C factor represents the effect of surface cover and roughness on soil erosion. The C factor is the most common factor used to assess the impact of best management practices (BMPs) on reducing erosion because it represents the effect of land use on soil erosion (Renard et al., 1997). Erosion control blankets and surface-applied BMPs such as blown straw are represented as C factors

within the Revised Universal Soil Loss Equation (RUSLE). By definition, C = 1 under standard fallow conditions. As the surface cover is added to the soil, the C factor value approaches zero. For example, a C factor of 0.20 signifies that 20% of the amount of erosion will occur compared to continuous fallow conditions. C factors vary from region to region because they are strongly influenced by different Rainfall Erosivity Index (R factors) (Wischmeier & Smith, 1978). In the InVEST model, its value is stored in a float value ranging from 0 to 1.

6.4 **usle_p:** This refers to management practice, support, or conservation practice factor (P factor) in USLE. The P factor reflects the impact of support practices on the average annual erosion rate. P is the ratio of soil loss with a support factor to that with straight row farming up and down slope. Strip-cropping, contouring, and terracing are all activities that are considered support practices by RUSLE. The support factor is unitless, and its value is stored in a float value ranging from 0 to 1.

6.5 **sedret_eff:** The sediment retention factor for each LULC class. The column contains information in a floating value ranging from 0 to 1. It refers to the capacity of each LULC class to retain sediment. This value is a percent per pixel area. A value of 1 for LULC class means that the class contains the most natural vegetation (forest, natural pastures wetlands, and prairie) in that class. A value of 0 means this is not the case. The LULC class with a value of 0 includes pavement, roads, or urban areas.

Table B10. Biophysical table annual sediment delivery ratio

lucode	LULC_desc	LULC_veg	usle_c	usle_p	sedret_eff
2	lc_2	1	1	0.013	0.1
3	lc_3	1	1	0.015	0.1
4	lc_4	1	1	0.15	0.15
5	lc_5	1	1	0.5	0.4
6	lc_6	1	1	0.1	0.15
7	lc_7	0	0	0.5	0.1
8	lc_8	0	0	0.8	0.25
9	lc_9	0	0	0	0.01
10	lc_10	0	0	0.8	0.25
12	lc_12	1	1	0.5	0.4
13	lc_13	1	1	0.15	0.15
50	lc_50	1	0.013	0.07	0.8
100	lc_100	0	0	0.8	0.25

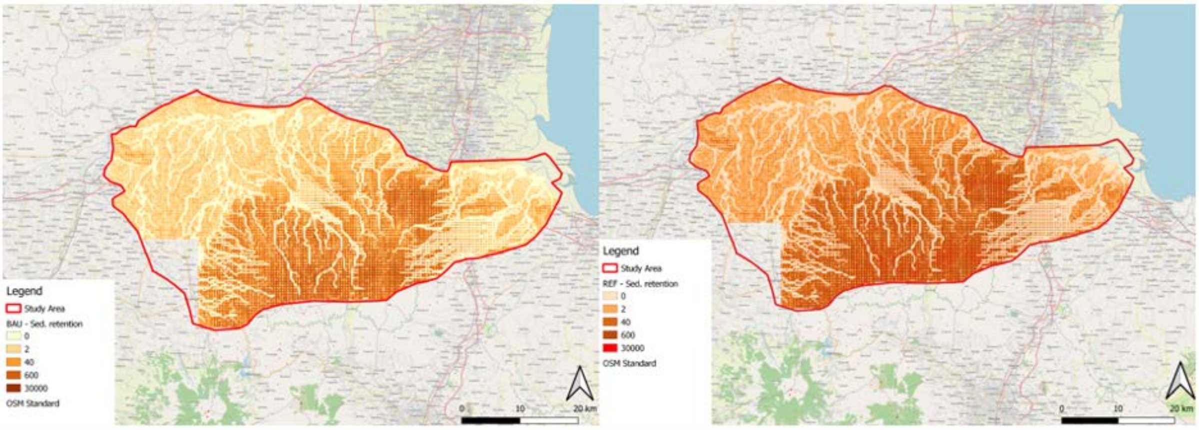
7. **Threshold flow accumulation:** The number of upstream cells that must flow into a cell before it is considered part of a stream, which is used to classify streams from the DEM. This threshold directly affects the expression of hydrologic connectivity and the sediment export result: when a flow path reaches the stream, sediment deposition stops, and the sediment exported is assumed to reach the catchment outlet. It is important to choose this value carefully, so modelled streams come as close to reality as possible. In this study, the value of 100 was used for this study as the pixel resolution of the model is 100 m.
8. **Borseli K parameter (kb) and Borseli IC0 parameter (IC_0):** Two calibration parameters that determine the shape of the relationship between hydrologic connectivity (the degree of connection from patches of land to the stream) and the sediment delivery ratio (percentage of soil loss that actually reaches the stream). The default values of kb=2 and IC_0=0.5 were used in the simulation.
9. **Max SDR value (SDRmax):** The maximum SDR that a pixel can reach, which is a function of the soil texture. More specifically, it is defined as the fraction of topsoil particles finer than coarse sand (1,000 μm) (Vigiak et al., 2012). This parameter can be used for calibration in advanced studies. Its default value of 0.8 was used.

B.1.6.2 RESULTS

The main output of this model are raster files containing biophysical output values per watershed, with the following attribute:

- sed_export (tons/pixel): Total amount of sediment exported from each pixel that reaches the stream.

Figure B9. Total sediment retention (tons/pixel) in the BAU and REF scenarios



Source: Authors' diagram based on outputs from InVEST model. Background map data from OpenStreetMap (© OpenStreetMap contributors, https://www.openstreetmap.org/copyright).

Table B11. Annual sediment retention statistics

LULC scenario	Sediment retention (tons)	Difference (BAU – REF) (tons)
BAU	81,335,596.32	-18,188,146.01
REF	99,523,742.33	

Table B11 shows the annual sediment retention (tons) in both the BAU and REF scenarios. More sediment is retained in the REF scenario (+22.36%) than in the BAU scenarios, indicating that the increased forest cover would help prevent soil loss in the area.

B.1.7 Nutrient Delivery Ratio

B.1.7.1 INPUT DATA PREPARATION AND PROCESSING

1. **DEM Raster:** A GIS raster dataset with an elevation value for each cell. It is the same DEM employed in the sediment retention model. Spatial resolution: 100 m.
2. **LULC maps:** The LULC maps showing the landscape under both the BAU and REF scenarios have been considered. Spatial resolution: 100 m.
3. **Nutrient Runoff Proxy Raster (Precipitation):** A GIS raster dataset with a non-zero value for average annual precipitation for each cell. Its value is in millimetres. In this study, the same precipitation dataset used in the water yield model was utilized. Spatial resolution: 100 m.
4. **Watershed Polygons:** This is the polygon shapefile representing the watersheds. We used the boundaries of the study area.
5. **Biophysical Table:** A table of LULC classes containing data on water quality coefficients used in this tool (Table B12). Note: these data are attributes of each LULC class rather than attributes of individual cells in the raster map. The table has the following field:

    5.1 **Lucode:** Unique identifier for each LULC class.

    5.2 **LULC_desc:** Nominal name for each LULC class.

    5.3 ***load_n / load_p:*** The nutrient loading for each land use. If nitrogen is being evaluated, supply values in load_n: for phosphorus, supply values in load_p. The potential for terrestrial loading of water quality impairing constituents is based on nutrient export coefficients. The nutrient loading values are given as integer values and have units of kg*ha^{-1} yr $^{-1}$. The values of the nutrient load were assumed.

    5.4 ***eff_n / eff_p:*** The vegetation filtering value per pixel size for each LULC class, as an integer percent between zero and one. If nitrogen is being evaluated, supply values in eff_n, for phosphorus, supply values in eff_p. This field identifies the capacity of vegetation to retain nutrients, as a percentage of the amount of nutrient flowing into a cell from upslope. For example, if the user has data describing that wetland of 5,000 m^2 retains 82% of nitrogen, then the retention efficiency that they should input into this field for eff_n is equal to (82/5000 * (cell size)^2). In the simplest case, when data for each LULC type are not available, high values

(60 to 80) may be assigned to all natural vegetation types (such as forests, natural pastures, wetlands, or prairie), indicating that 60-80% of nutrient is retained. An intermediary value also may be assigned to features such as contour buffers. All LULC classes that have no filtering capacity, such as pavement, can be assigned a value of zero. The values of the capacity of vegetation to retain nutrient by LULC were assumed.

5.5 ***crit_len_n (and/or crit_len_p)*** (at least one is required)**:** The distance after which is assumed that a patch of a particular LULC type retains nutrients at its maximum capacity, given in metres. If nutrients travel a distance smaller than the retention length, the retention efficiency will be less than the maximum value *eff_x*, following an exponential decay. This value represents the typical distance necessary to reach the maximum retention efficiency. It was introduced in the model to remove any sensitivity to the resolution of the LULC raster. In the absence of local data for land uses that are not forest or grass, it is possible to simply set the retention length constant, equal to the pixel size: this will result in the maximum retention efficiency being reached within a distance of only one pixel. Therefore, the value of 100 m was used for this parameters. It is the value of cell size used for model simulation.

5.6 ***proportion_subsurface_n or p (optional)*:** The proportion of dissolved nutrients over the total amount of nutrients, expressed as a floating point value (ratio) between 0 and 1. By default, this value should be set to 0, indicating that all nutrients are delivered via surface flow.

Table B12. Biophysical table – annual nutrient delivery ratio

lucode	LULC_desc	LULC_veg	load_n	load_p	eff_n	eff_p	load_subsurface_n	load_subsurface_p	proportion_subsurface_n	proportion_subsurface_p	crit_len_p	crit_len_n
2	lc_2	1	1.61	0.001	0.4	0.4	0	0	0	0	100	100
3	lc_3	1	1.61	0.001	0.4	0.4	0	0	0	0	100	100
4	lc_4	1	1.61	0.001	0.3	0.3	0	0	0	0	100	100
5	lc_5	1	11	3	0.15	0.15	0	0	0	0	100	100
6	lc_6	1	12.53	1.82	0.1	0.1	0	0	0	0	100	100
7	lc_7	0	10	2	0.05	0.05	0	0	0	0	100	100
8	lc_8	0	0.07	0.001	0.05	0.05	0	0	0	0	100	100
9	lc_9	0	0	0	0.6	0.6	0	0	0	0	100	100
10	lc_10	0	0.07	0.001	0.05	0.05	0	0	0	0	100	100
12	lc_12	1	11	3	0.15	0.15	0	0	0	0	100	100
13	lc_13	1	1	0.001	0.15	0.15	0	0	0	0	100	100
50	lc_50	1	0.5	0.001	0.3	0.3	0	0	0	0	100	100
100	lc_100	0	0.07	0.001	0.05	0.05	0	0	0	0	100	100

6. **Threshold flow accumulation value:** Integer value defining the number of upstream pixels that must flow into a pixel before it is considered part of a stream. This is used to generate a stream layer from the DEM. This threshold expresses where hydrologic routing is discontinued (i.e., where retention stops and the remaining pollutant will be exported to the stream). The default is 1 over the pixel area (in km^2) (i.e. ~1,000 for 30 m resolution). If the user has a map of stream lines in the watershed of interest, they should "calibrate" the threshold value by comparing the map with the *stream.tif* map output by the model. The default value of 1,000 was used in this simulation.
7. **Subsurface maximum retention efficiency (nitrogen or phosphorus):** the maximum nutrient retention efficiency that can be reached through subsurface flow, a value between 0 and 1. This field characterizes retention due to biochemical degradation in soils. The default value of 0.8 was used for this study.
8. **Subsurface_crit_len (nitrogen or phosphorus) (in metres):** The distance (travelled subsurface and downslope) after which it is assumed that soil retains nutrients at its maximum capacity. If dissolved nutrients travel a distance smaller than subsubsurface_crit_len, the retention efficiency is lower than the maximum value defined above. Setting this value to a distance smaller than the pixel size will result in the maximum retention efficiency being reached within one pixel only. The default value of 150 was used in this simulation
9. **Borselli k parameter:** Calibration parameter that determines the shape of the relationship between hydrologic connectivity (the degree of connection from patches of land to the stream) and the sediment delivery ratio (percentage of soil loss that actually reaches the stream). The default value is 2.

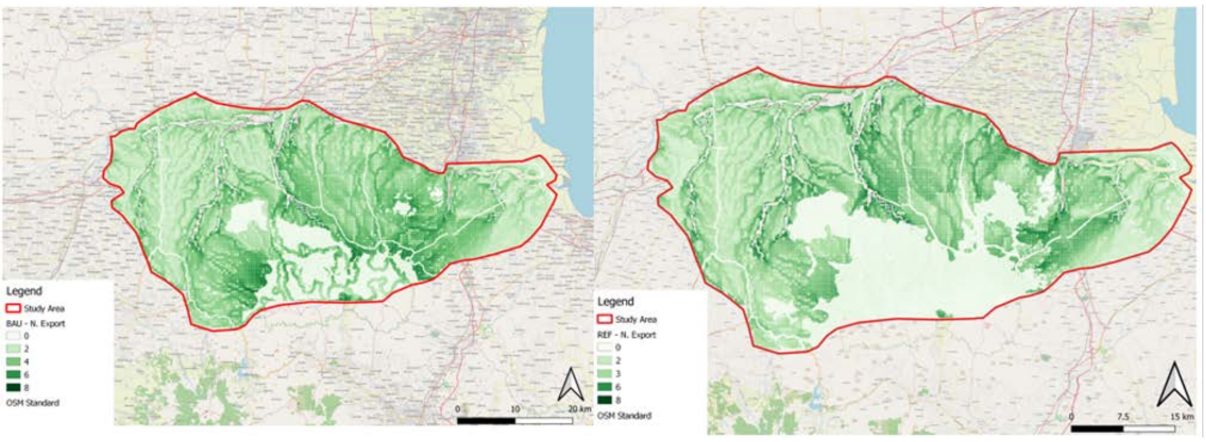
B.1.7.2 RESULTS – NITROGEN

The main output of this model are raster files containing biophysical output values per watershed, with the following attribute:

- N_export_tot (kg/watershed): Total nitrogen export from the watershed

Figure B10 shows the total nitrogen export (Kg/Watershed) for each scenario.

Figure B10. Total nitrogen export (kg/pixel)



Source: Authors' diagram based on outputs from InVEST model. Background map data from OpenStreetMap (© OpenStreetMap contributors, https://www.openstreetmap.org/copyright).

Table B13. Annual nutrient export (nitrogen) statistics

LULC scenario	Nitrogen export (Kg)	Difference (BAU – REF) (kg)
BAU	577,081.33	121,373.71
REF	455,707.63	

Table B13 shows the annual nitrogen export in both scenarios. Fewer kg of nitrogen are exported in the REF scenario than in the BAU scenario (-21.03%), indicating that the increased forest cover would help to prevent nitrogen export in the area.

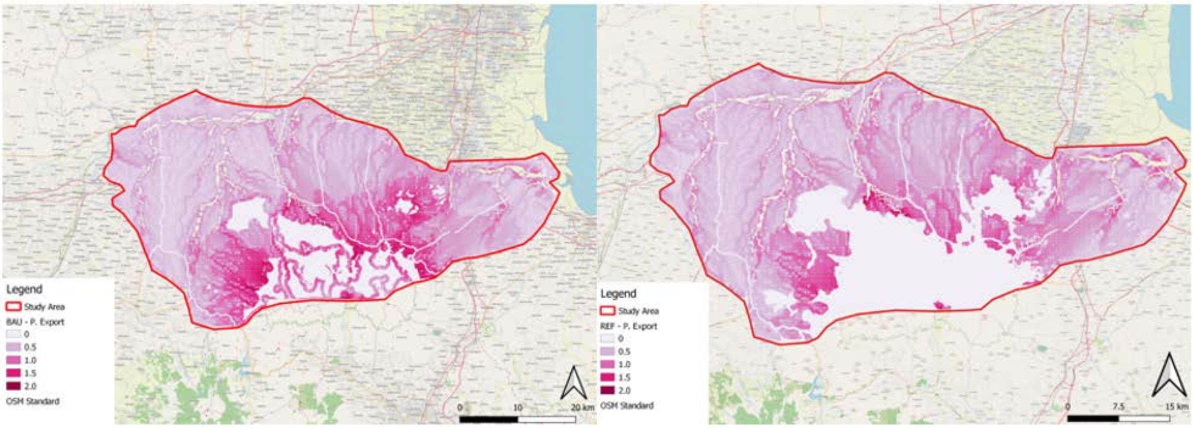
B.1.7.3 RESULTS – PHOSPHORUS

The main output of this model are raster files containing biophysical output values per watershed, with the following attribute:

- P_export_tot (kg/watershed): Total phosphorus export from the watershed

Figure B11 shows the total phosphorus export (kg/watershed) for each scenario.

Figure B11. Total phosphorus export (kg/pixel)



Source: Authors' diagram based on outputs from InVEST model. Background map data from OpenStreetMap (© OpenStreetMap contributors, https://www.openstreetmap.org/copyright).

Table B14. Annual nutrient export (phosphorus) statistics

LULC scenario	Phosphorus export (Kg)	Difference (BAU – REF) (kg)
BAU	113,689.82	35,107.31
REF	78,582.52	

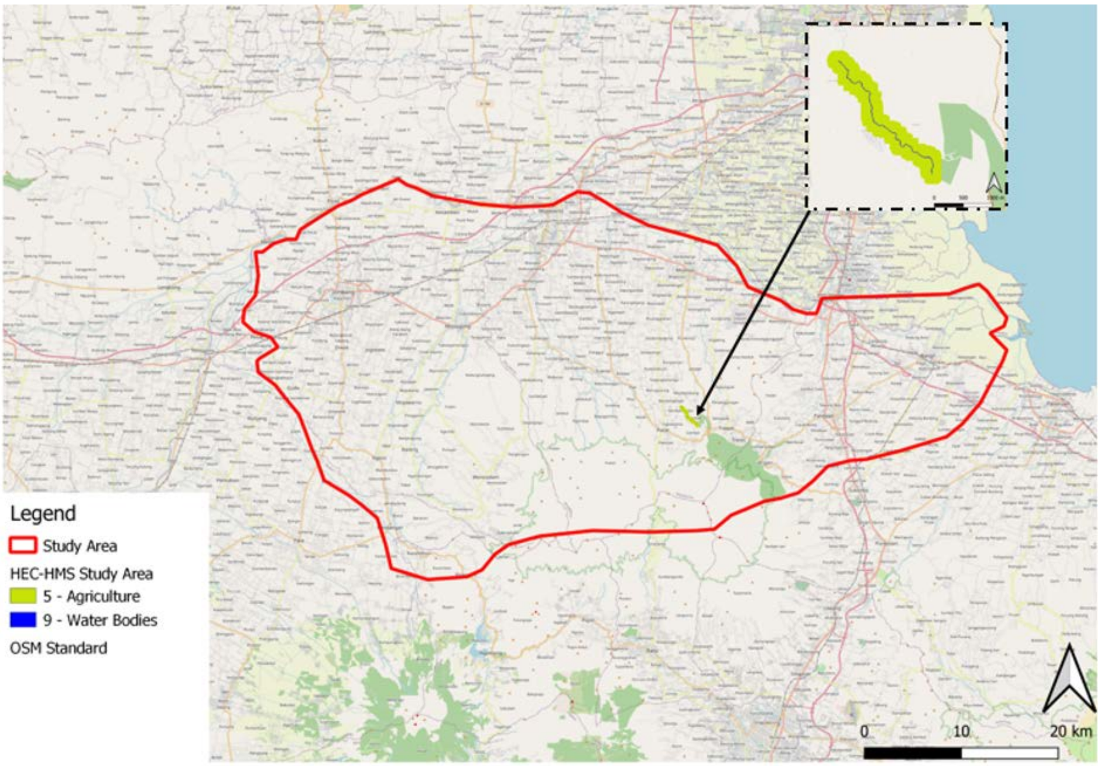
B.2 HEC-HMS

B.2.1 Model Setup

B.2.1.1 STUDY AREA

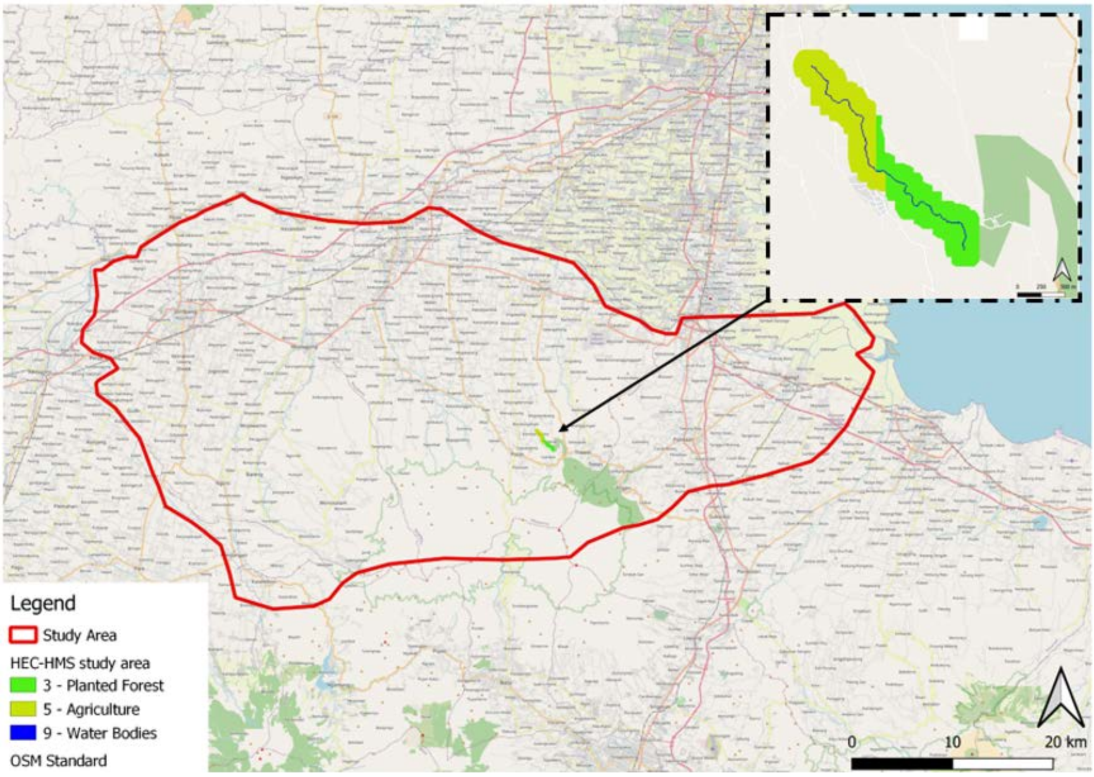
Within the study area of the InVEST analysis, we selected a region of 1.22 km^2 that we used in the HEC-HMS analysis, as shown in both Figure B12 and Figure B13. In this region, we considered a specific river, whose length is 2.5 km, as well as a buffer zone of 200 m. The river was downloaded from https://www.geofabrik.de/. Table B15 illustrates the amount of ha of forest and agriculture in both the BAU and REF scenarios.

Figure B12. HEC-HMS study area – BAU scenario



Source: Authors' diagram based on data from Geofabrik GmbH (2020) and OpenStreetMap (© OpenStreetMap contributors, https://www.openstreetmap.org/copyright).

Figure B13. HEC-HMS study area – REF scenario



Source: Authors' diagram based on data from Geofabrik GmbH (2020) and OpenStreetMap (© OpenStreetMap contributors, https://www.openstreetmap.org/copyright).

Table B15. Amount of forest and agriculture in BAU and REF scenarios

Ha of forest (secondary forest + plantation) and agriculture

Scenario	Description of land classes	Amount of ha	Unit
BAU	Forest	119.60	ha
	Agriculture	0	ha
REF	Forest	67.63	ha
	Agriculture	51.97	ha

B.2.1.2 SOFTWARE AND SIMULATION

The Hydrologic Modeling System (HEC-HMS 4.7.1[4]) was used to simulate the precipitation–runoff processes

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[4] Available at https://www.hec.usace.army.mil/software/hec-hms/.

B.2.1.3 CURVE NUMBERS

The CN method is an empirical parameter used in hydrology for predicting direct runoff or infiltration from rainfall excess (Cronshey, 1986). CN values are normally within a range from 30 to 100; lower numbers indicate low runoff potential, while larger numbers are for increasing runoff potential.

With this method it is possible to create a grid across the study area where each CN value is assigned to a specific pocket of land, based on land-use and soil hydrological group (see input data – InVEST Urban Flood Risk Model). Table B16 shows the corresponding CN values of land classes. Next, we extracted the average CN value of the study area representative of different scenarios, as illustrated in Table B17.

Table B16. CN values of land classes

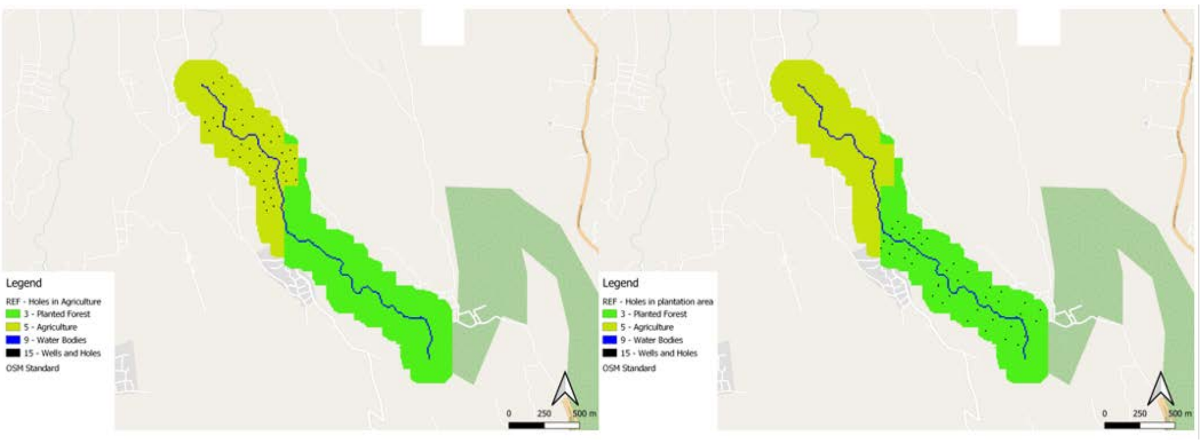
Value land classes	Description of land classes	CN values
2	Secondary forest	80
3	Plantation forest	80
4	Shrubs	80
5	Agriculture	90
8	Bare land	95
15	Absorption wells/biopori holes	30

Table B17. Average CN values in different land-use scenarios

Scenario	Average CN Value
BAU	90.00
REF (no wells and holes)	82.32
REF (wells and holes in agricultural areas)	82.12
REF (wells and holes in plantation areas)	82.15

To extract the average CN value in the REF landscape, we used the LULC map representative of such a scenario (see paragraph 1.1.3). In addition, in this scenario around 600 absorption wells (2x2 m) will be constructed, as well as 8,000 biopori holes (0.1 x 0.1 m). To include both the absorption wells and biopori holes into the LULC map, we reclassified the resolution to the REF LULC map from 100 m to 10 m. Next, we calculated that 160 are the pixels representing the biopori holes that can be included in the LULC REF map (assuming that a pixel of 10 m x 10 m contains 50 holes). Since their location is unknown, we assumed that only 20% are located into the study area. Thus their number falls to 32. We also added 8 pixels representing absorption wells (assumed). We changed the CN values of the pixels representing absorption wells/biopori holes to 30, the lowest value of runoff potential. **Note:** The CN values for absorption wells and biopori holes are assumed and it is possible that it could be even lower than 30.

Figure B14. Location of pixels with low CN values in the REF LULC map



Source: Authors' diagram based on data from Geofabrik GmbH (2020). Background map data from OpenStreetMap (© OpenStreetMap contributors, https://www.openstreetmap.org/copyright).

We located wells and holes in two different locations of the study area, as illustrated in Figure B14. In one scenario, we put them in the agricultural area of the REF LULC map. In the second scenario, we located wells and holes in the plantation area of the REF LULC map. In both cases, wells and holes cover 0.33% of the study area

B.2.1.4 DIGITAL ELEVATION MODEL

We used the DEM in QGIS to extract the elevation of two points of the river (start and end). The river begins at an elevation of 768 m and ends at 516 m.

B.2.1.5 PRECIPITATION

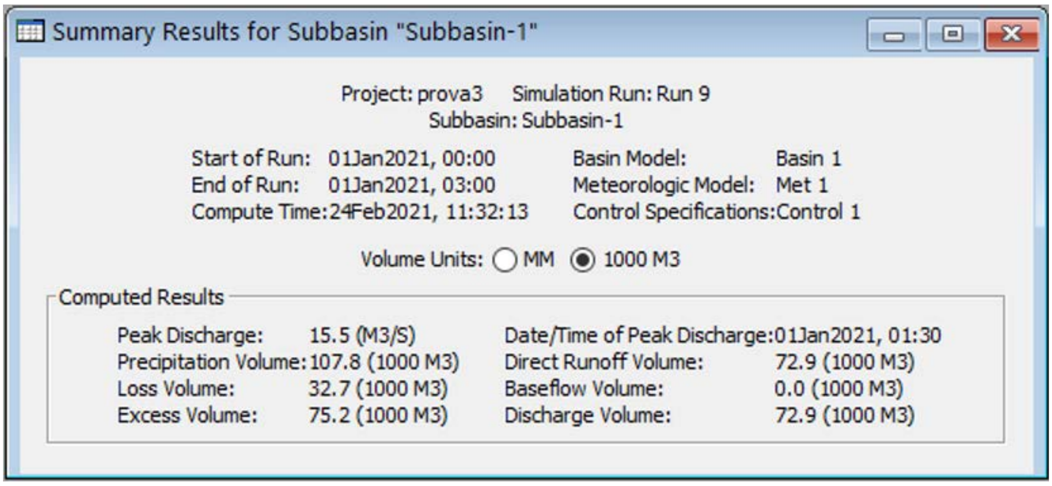
Setiawan et al. (2019) indicated that the annual average rainfall precipitation in the study area can reach 4,600 mm/year, which corresponds to roughly 88 mm/week. We used the weekly value in our simulation, since it could also correspond to a consistent rainfall event.

B.2.2 Results

B.2.2.1 SURFACE RUNOFF

Figures B15, B16, B17, and B18 show the outputs of the HEC-HMS analysis for four different scenarios: BAU, REF no wells and holes, REF with wells and holes in agricultural areas, and REF with wells and holes in plantation areas.

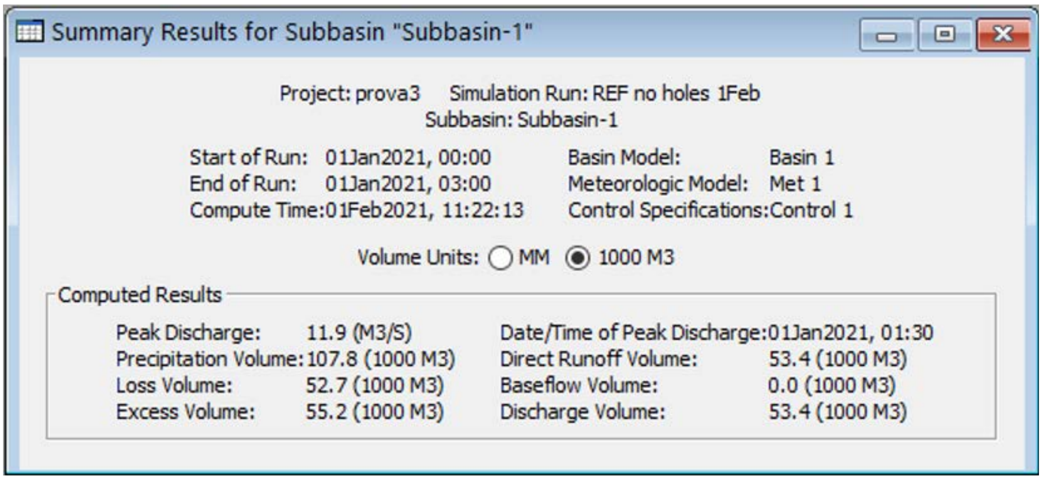
Figure B15. HEC-HMS results – BAU scenario



```
Summary Results for Subbasin "Subbasin-1"

                 Project: prova3     Simulation Run: Run 9
                          Subbasin: Subbasin-1

     Start of Run:   01Jan2021, 00:00        Basin Model:           Basin 1
     End of Run:     01Jan2021, 03:00        Meteorologic Model:    Met 1
     Compute Time:24Feb2021, 11:32:13        Control Specifications:Control 1

                   Volume Units: ○ MM   ● 1000 M3

Computed Results
     Peak Discharge:       15.5 (M3/S)        Date/Time of Peak Discharge:01Jan2021, 01:30
     Precipitation Volume:107.8 (1000 M3)     Direct Runoff Volume:       72.9 (1000 M3)
     Loss Volume:          32.7 (1000 M3)     Baseflow Volume:            0.0 (1000 M3)
     Excess Volume:        75.2 (1000 M3)     Discharge Volume:           72.9 (1000 M3)
```

Source: Authors' diagram.

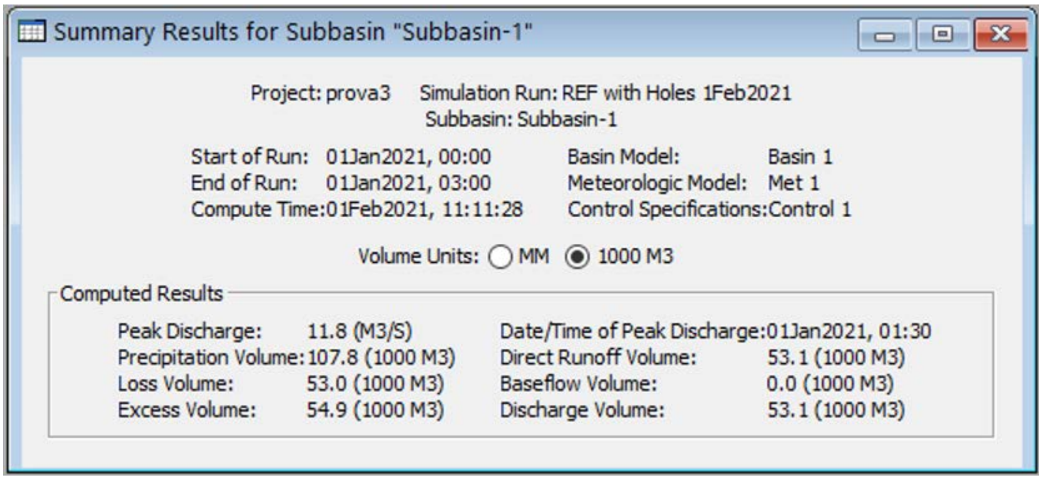
Figure B16. HEC-HMS results – REF scenario (no wells and holes)



```
            Project: prova3    Simulation Run: REF no holes 1Feb
                          Subbasin: Subbasin-1

      Start of Run:   01Jan2021, 00:00        Basin Model:          Basin 1
      End of Run:     01Jan2021, 03:00        Meteorologic Model:   Met 1
      Compute Time:01Feb2021, 11:22:13        Control Specifications:Control 1

                     Volume Units: ○ MM  ● 1000 M3

 Computed Results

     Peak Discharge:       11.9 (M3/S)          Date/Time of Peak Discharge:01Jan2021, 01:30
     Precipitation Volume:107.8 (1000 M3)       Direct Runoff Volume:       53.4 (1000 M3)
     Loss Volume:          52.7 (1000 M3)       Baseflow Volume:            0.0 (1000 M3)
     Excess Volume:        55.2 (1000 M3)       Discharge Volume:           53.4 (1000 M3)
```

Source: Authors' diagram.

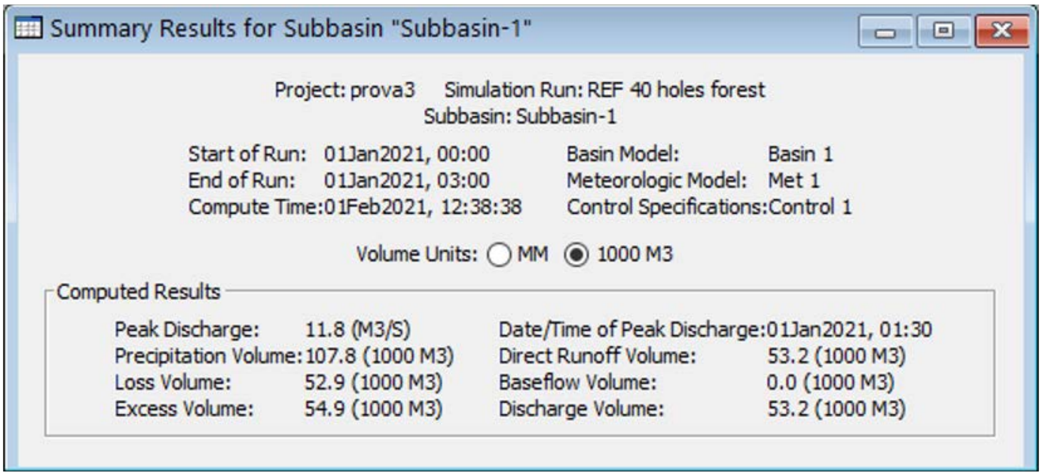
Figure B17. HEC-HMS results – REF scenario (wells and holes in agricultural areas)



```
          Project: prova3    Simulation Run: REF with Holes 1Feb2021
                          Subbasin: Subbasin-1

      Start of Run:   01Jan2021, 00:00        Basin Model:          Basin 1
      End of Run:     01Jan2021, 03:00        Meteorologic Model:   Met 1
      Compute Time:01Feb2021, 11:11:28        Control Specifications:Control 1

                     Volume Units: ○ MM  ● 1000 M3

 Computed Results

     Peak Discharge:       11.8 (M3/S)          Date/Time of Peak Discharge:01Jan2021, 01:30
     Precipitation Volume:107.8 (1000 M3)       Direct Runoff Volume:       53.1 (1000 M3)
     Loss Volume:          53.0 (1000 M3)       Baseflow Volume:            0.0 (1000 M3)
     Excess Volume:        54.9 (1000 M3)       Discharge Volume:           53.1 (1000 M3)
```

Source: Authors' diagram.

Figure B18. HEC-HMS results – REF scenario (wells and holes in plantation areas)



```
            Project: prova3    Simulation Run: REF 40 holes forest
                          Subbasin: Subbasin-1

      Start of Run:   01Jan2021, 00:00        Basin Model:          Basin 1
      End of Run:     01Jan2021, 03:00        Meteorologic Model:   Met 1
      Compute Time:01Feb2021, 12:38:38        Control Specifications:Control 1

                     Volume Units: ○ MM  ● 1000 M3

 Computed Results

     Peak Discharge:       11.8 (M3/S)          Date/Time of Peak Discharge:01Jan2021, 01:30
     Precipitation Volume:107.8 (1000 M3)       Direct Runoff Volume:       53.2 (1000 M3)
     Loss Volume:          52.9 (1000 M3)       Baseflow Volume:            0.0 (1000 M3)
     Excess Volume:        54.9 (1000 M3)       Discharge Volume:           53.2 (1000 M3)
```

Source: Authors' diagram.

As the results indicate, the speed of the peak discharge (when the river reaches its highest flow) during a precipitation event that would produce 88 mm of rainfall varies across different scenarios: 15.5m^3/s (BAU), 11.9 m^3/s (REF – no wells and holes), 11.8 m^3/s (REF – wells and holes in agricultural areas), and 11.8 (REF – wells and holes in plantation areas).

In other words, in the study area used in HEC-HMS, the afforestation efforts would decrease runoff speed by approximately 23.23% compared to the BAU scenario. Installing absorption wells and biopori holes in the REF scenario would increase the reduction of runoff speed by 23.87% compared to the BAU scenario. Our results also indicate that including wells and holes in the REF scenario would further help to reduce runoff speed by around 0.84%. On the other hand, according to this analysis, installing holes and wells in agricultural areas or in plantation areas would not considerably change the runoff speed.

B.2.2.2 WATER INFILTRATION

Figures B15, B16, B17, and B18 show the direct runoff analysis for four different scenarios: BAU, REF no wells and holes, REF with wells and holes in agricultural areas, REF with wells and holes in plantation areas (unit: 1,000 m3). We summarized the main results of the HEC-HMS model in Table B18; the table also shows the change (%) of direct runoff volume between the BAU scenario and all the REF scenarios (with no wells and holes, with wells and holes in agricultural areas, and with wells and holes in plantation areas), as well as the change (%) between the REF scenario (no wells and holes) and the other two REF scenarios (wells and holes in agricultural and plantation areas).

The results indicate that installing wells and holes in the plantation areas (in a REF scenario) would decrease water runoff volume by 0.38%, which is a percentage similar to the share of land covered by wells and holes in the study area. Compared to the BAU scenario, the water runoff would decrease by 37.03%. In other words, in this REF scenario (with holes in plantation areas), 19,700 m^3 of water is missing from the direct runoff volume compared to the BAU scenario; it is possible that at least part of this water can infiltrate into the soil, recharging groundwater. Assuming that each week, 20% of 19,700 m^3 of water reaches groundwater, the annual recharge in the study area utilized in HEC-HMS would amount to 204,880 m^3. Nevertheless, we stress the fact that our analysis is only preliminary due to limitations in data availability and that more studies are required to confirm our results.

If we consider the REF scenario where wells and holes are installed in the agricultural areas, water runoff volume would decrease by 0.56% compared to the same scenario that does not include them. Compared to the BAU scenario, the water runoff would decrease by 37.29 %.

We also compared the results obtained with HEC-HMS with the outputs of the InVEST Urban Flood Risk Model (see Section 1.4), using the value of 88 mm as the depth of rainfall. Table B18 shows that the changes (%) in runoff retention between different scenarios can be compared to the results obtained with HEC-RAS. In other words, the amount of runoff volume that is lost by increasing the plantation cover and/or by installing wells and holes is similar to the amount of runoff retention that increases due to the same management options, supporting the consistency of our analysis.

Table B18. Comparison between InVEST and HEC-HMS outputs

Wells and holes in agricultural areas

HEC-HMS: Direct runoff volume				InVEST: Urban Flood Risk Mitigation model			
Scenario	Volume (1,000 m^3)	Difference (BAU - REF) (1,000 m^3)	Change (%)	Scenario	Total runoff retention (m^3)	Difference (REF no holes - REF holes) (m^3)	Change (%)
REF with no wells and holes	53.4	0.30	0.56	REF no holes	45,744.11	-245.35	0.54
REF with wells and holes (holes in agriculture)	53.1			REF (holes in agriculture)	45,989.45		

HEC-HMS: Direct runoff volume				InVEST: Urban Flood Risk Mitigation model			
Scenario	Volume (1,000 m^3)	Difference (BAU - REF) (1,000 m^3)	Change (%)	Scenario	Total runoff retention (m^3)	Difference (BAU - REF) (m^3)	Change (%)
BAU	72.9	19.80	37.29	BAU	31,889.74	-14,099.72	44.21
REF with wells and holes (holes in agriculture)	53.1			REF (holes in agriculture)	45,989.45		

HEC-HMS: Direct runoff volume				InVEST: Urban Flood Risk Mitigation model			
Scenario	Volume (1,000 m^3)	Difference (BAU - REF) (1,000 m^3)	Change (%)	Scenario	Total runoff retention (m^3)	Difference (REF no holes - REF holes) (m^3)	Change (%)
REF with no wells and holes	53.4	0.20	0.38	REF no holes	45,744.11	-167.49	0.37
REF with wells and holes (holes in forest land)	53.2			REF (holes in forest)	45,911.60		

HEC-HMS: Direct runoff volume				InVEST: Urban Flood Risk Mitigation model			
Scenario	Volume (1,000 m^3)	Difference (BAU - REF) (1,000 m^3)	Change (%)	Scenario	Total runoff retention (m^3)	Difference (BAU - REF) (m^3)	Change (%)

Wells and holes in agricultural areas							
BAU	72.9	19.70	37.03	**BAU**	31,889.73	-14,021.86	43.97
REF with wells and holes (holes in forest land)	53.2			**REF (holes in forest)**	45,911.60		

B.3 Additional Spatial Flood and Water Retention Analysis

B.3.1 Comparisons for Rainfall Return Periods

A study from the Directorate General for Water Resources (2019) estimates the impacts from flooding for several return periods under present conditions and three climate scenarios for the year 2050. The study provides 2050 return periods for rainfall quantities at four locations in the Brantas River Basin for each climate scenario. Averaging across the locations to get one rainfall amount for each climate scenario and return period produces the numbers in Table B19. The study does not specify the timeframe for these rainfall amounts. We assumed that these are daily rainfall amounts. We use these scenarios to estimate water retention for a variety of rainfall events under several land-use scenarios.

Table B19. Rainfall (mm) for three climate scenarios and six return periods

	Climate scenario		
Return period (yr)	**Low**	**Medium**	**High**
2	45.25	45.25	49.25
5	56.75	56.75	61.75
10	61.75	64.75	70.5
30	72.5	76	85.75
50	74	81.25	95.5
100	80.75	88.5	108

B.3.1.1 WATER RETENTION COMPARISONS

Table B20 and Table B21 show the runoff retention volume (m^3) in the BAU and REF scenario using the InVEST flood risk model.

Table B20. Runoff retention volumes – BAU (InVEST)

InVEST - Runoff retention (m^3) - BAU

Return period (yr)	Climate scenario		
	Low	Medium	High
2	66,515,154.41	66,515,154.41	69,990,585.52
5	75,889,849.54	75,889,849.54	79,436,792.14
10	79,436,792.14	81,435,201.13	85,021,892.58
30	86,200,398.11	88,183,992.78	93,235,033.09
50	87,062,472.27	90,985,356.15	97,688,009.39
100	90,727,044.06	94,546,613.97	102,683,422.55

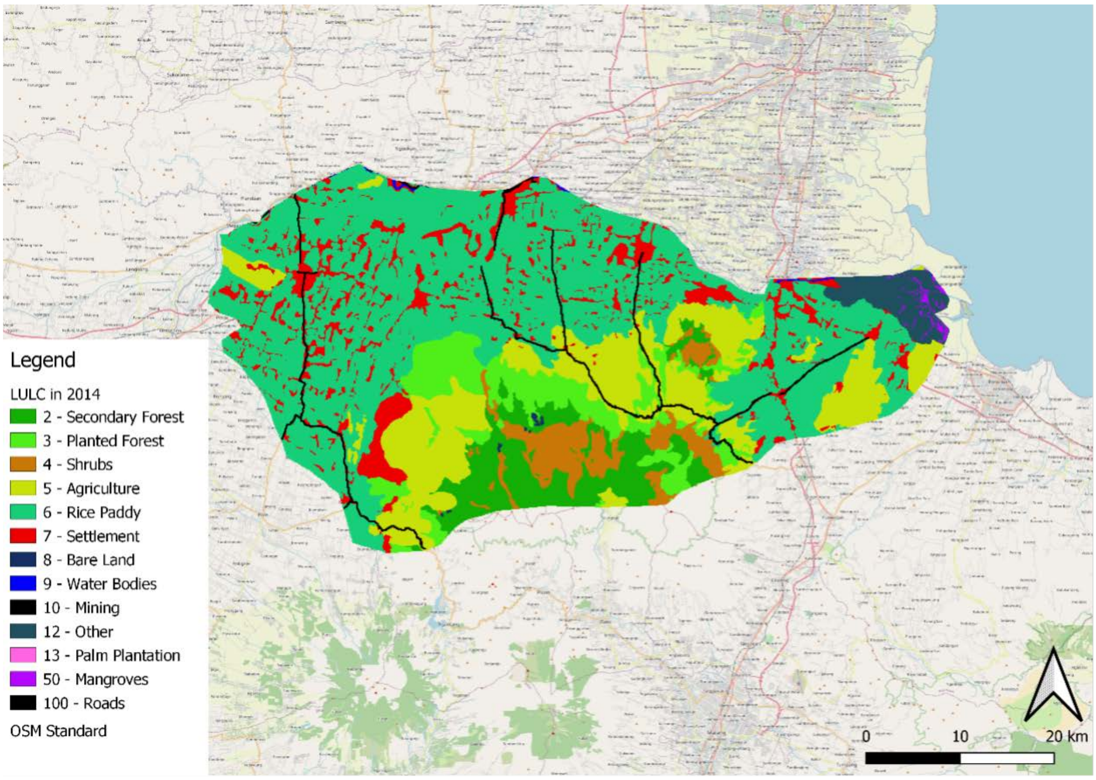
Table B21. Runoff retention volumes – REF (InVEST)

InVEST - Runoff retention (m^3) - REF

Return period (yr)	Climate scenario		
	Low	Medium	High
2	69,284,677.45	69,284,677.45	73,017,186.28
5	79,364,130.41	79,364,130.41	83,186,437.34
10	83,186,437.34	85,341,862.34	89,213,500.96
30	90,486,467.99	92,629,932.33	98,092,719.24
50	91,417,886.65	95,658,863.00	102,913,715.37
100	95,379,482.76	99,512,234.06	108,326,910.60

We also modelled the InVEST Urban Flood Risk Mitigation model using the rainfall values shown in Table B19 as well as a LULC of the study area from 2014 (we added mangroves and roads to it, as was done for the 2018 map). This land-cover map is shown in Figure B19. Table B22, which shows the results of this analysis, demonstrates that in 2014, runoff retention was higher than in the 2018 BAU and REF scenarios.

Figure B19. LULC of the study area in 2014



Source: Authors' diagram based on data from Ministry of Environment and Forestry Indonesia (Kementerian Lingkungan Hidup dan Kehutanan) (n.d.-a). Background map data from OpenStreetMap (© OpenStreetMap contributors, https://www.openstreetmap.org/copyright)

Table B22. Runoff retention volumes – 2014 LULC map

InVEST - Runoff retention (m^3) - BAU (2014)

	Climate scenario		
Return period (yr)	**Low**	**Medium**	**High**
2	71,324,514.78	71,324,514.78	75,249,139.95
5	81,932,629.38	81,932,629.38	85,963,259.94
10	85,963,259.94	88,237,938.10	92,326,875.45
30	93,672,131.71	95,938,234.48	101,718,593.75
50	94,656,701.11	99,142,375.86	106,825,562.46
100	98,846,742.59	103,221,770.08	112,565,870.51

B.3.1.2 DIRECT RUNOFF COMPARISONS

Tables B23, B24, B25, and B26 show the direct runoff retention volume (1,000 m^3) in the following scenarios: BAU, REF (no holes and wells), REF (with holes and wells in agricultural areas), and REF (with holes and wells in forested areas) scenario using HEC-HMS.

Table B23. Direct runoff volumes – BAU (HEC-HMS)

HEC-HMS - Direct runoff volume (1,000 m^3) - BAU

	Climate scenario		
Return period (yr)	**Low**	**Medium**	**High**
2	27.40	27.40	31.40
5	39.10	39.10	44.30
10	44.30	47.50	49.40
30	55.80	59.70	70.40
50	57.50	65.40	81.30
100	64.90	73.40	95.40

Table B24. Direct runoff volumes – REF (HEC-HMS)

HEC-HMS - Direct runoff volume (1,000 m^3) - REF

	Climate scenario		
Return period (yr)	**Low**	**Medium**	**High**
2	15.60	15.60	18.70
5	24.80	24.80	29.00
10	29.00	31.70	33.20
30	38.70	42.00	51.30
50	40.10	46.90	61.00
100	46.50	54.00	73.80

Table B25. Direct runoff volumes – REF Agriculture (HEC-HMS)

HEC-HMS - Direct runoff volume (1,000 m³) - REF (holes and wells in agriculture)

	Climate scenario		
Return period (yr)	**Low**	**Medium**	**High**
2	15.40	15.40	18.40
5	24.50	24.50	28.70
10	28.70	31.30	32.80
30	38.30	41.60	50.90
50	39.70	46.50	60.50
100	46.10	53.50	73.30

Table B26. Direct runoff volumes – REF Forest (HEC-HMS)

HEC-HMS - Direct Runoff Volume (1,000 m³) - REF(holes and wells in forest)

	Climate scenario		
Return period (yr)	**Low**	**Medium**	**High**
2	15.40	15.40	18.40
5	24.50	24.50	28.80
10	28.80	31.40	32.90
30	38.30	41.60	51.00
50	39.80	46.60	60.60
100	46.10	53.60	73.30

B.3.2 Monthly Water Availability

To assess annual changes in water availability, we use the InVEST Urban Flood Risk Mitigation model to simulate monthly water retention for three rainfall scenarios. The precipitation scenarios are created using the ERA5 database and the CMIP5 from the Copernicus Climate Data Store (Copernicus Climate Change Service, 2018). The scenarios are defined as follows:

1. Current rainfall: 2015–2019 monthly average precipitation taken from the ERA5 dataset. Annual rainfall is 2,876.4 mm.
2. High rainfall: 2037–2041 monthly average precipitation taken from the RCP 8.5 climate scenario. These years have the highest 5-year average annual rainfall across the RCP 4.5 and RCP 8.5 climate scenarios for the years 2020–2050. Annual rainfall is 3,294.4 mm.

3. Low rainfall: 2026–2030 monthly average precipitation taken from the RCP 4.5 climate scenario. These years have the lowest 5-year average annual rainfall across the RCP 4.5 and RCP 8.5 climate scenarios for the years 2020–2050. Annual rainfall is 2,221.4 mm.

Monthly precipitation, water retention for the BAU and REF scenarios and the difference in water retention between the two scenarios are shown in Table B27.

Table B27. Water retention statistics under current, low and high climate scenarios. Precipitation data are 5-year averages from the Copernicus ERA5 and CMIP5 data products.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Current climate													
Precipitation (mm)	473.3	561.7	494.5	285.9	95.0	62.2	28.1	17.1	49.1	116.3	293.1	400.2	2,876.4
Water retention BAU (10^6 m^3)	147.7	150.8	148.5	136.0	97.5	79.7	48.1	32.1	69.9	105.6	136.6	144.2	1,296.7
Water retention REF (10^6 m^3)	157.2	160.6	158.1	144.5	102.7	83.5	49.6	32.7	72.9	111.5	145.2	153.4	1,372.0
Difference (BAU-REF) (10^6 m^3)	-9.5	-9.8	-9.6	-8.5	-5.2	-3.8	-1.5	-0.6	-3.0	-5.9	-8.6	-9.2	-75.3
Low rainfall scenario													
Precipitation (mm)	364.8	431.2	419.2	278.0	117.5	80.9	42.6	47.8	13.9	22.7	131.0	271.8	2,221.4
Water retention BAU (10^6 m^3)	142.1	145.8	145.2	135.2	106.0	90.8	64.1	68.8	26.9	40.7	110.3	134.6	1,210.4
Water retention REF (10^6 m^3)	151.2	154.5	154.5	143.7	112.0	95.5	66.7	71.7	27.2	41.8	116.5	143.0	1,278.2
Difference (BAU-REF) (10^6 m^3)	-9.1	-8.7	-9.3	-8.5	-5.9	-4.7	-2.6	-2.9	-0.4	-1.1	-6.3	-8.4	-67.8
High rainfall scenario													
Precipitation (mm)	585.5	566.3	458.1	255.4	248.8	221.4	91.1	88.7	87.3	103.5	241.5	347.0	3,294.4
Water retention BAU (10^6 m^3)	151.5	150.9	147.0	132.8	132.1	128.5	95.8	94.7	94.0	101.0	131.2	140.9	1,500.3
Water retention REF (10^6 m^3)	161.4	160.8	156.5	141.1	140.2	136.4	100.8	99.6	98.9	106.4	139.3	149.9	1,591.3
Difference (BAU-REF) (10^6 m^3)	-9.9	-9.8	-9.5	-8.2	-8.2	-7.9	-5.1	-5.0	-4.9	-5.5	-8.1	-9.0	-91.0

B.4 Habitat Quality Tables

Table B28. Habitat Quality model – references "threat table"

Threat	Max distance	Max distance adopted sources	Weighted value	Weighted value adopted sources	Decay function	Decay function adopted sources
Other agriculture	4	(Terrado et al., 2016)	0.7	(Bhagabati et al., 2012)	linear	(Bhagabati et al., 2012)
Rice paddy	0.5	(Chu et al., 2018)	0.5	(Chu et al., 2018)	exponential	(Chu et al., 2018)
Settlement	7.1	(Terrado et al., 2016)	0.7	(Bhagabati et al., 2012)	linear	(Bhagabati et al., 2012)
Mining	5.6	(Terrado et al., 2016)	1	(Bhagabati et al., 2012)	linear	(Bhagabati et al., 2012)
Airports/ ports	7.1	(Terrado et al., 2016)	0.7	(Bhagabati et al., 2012)	linear	(Bhagabati et al., 2012)
Palm plantation	6	(Bhagabati et al., 2012)	0.7	(Bhagabati et al., 2012)	linear	(Bhagabati et al., 2012)
Primary roads	2.9	(Terrado et al., 2016)	0.7	(Bhagabati et al., 2012)	linear	(Bhagabati et al., 2012)

Table B29. Habitat Quality model – references "threat sensitivity table"

Value	Habitat	Habitat adopted sources	Sensitivity to agricultural sources	Sensitivity to agricultural adopted sources	Sensitivity to paved roads	Sensitivity to paved roads adopted sources	Sensitivity to mines	Sensitivity to mines adopted sources	Sensitivity to urban areas	Sensitivity to urban areas adopted sources	Sensitivity to palm oil plantations	Sensitivity to palm oil plantations adopted sources
2	1	(Bhagabati et al., 2012)	1	(Bhagabati et al., 2012)	1	(Bhagabati et al., 2012)	1	(Bhagabati et al., 2012)	1	(Bhagabati et al., 2012)	0.7	(Bhagabati et al., 2012)
3	0.8	(Bhagabati et al., 2012)	0.6	(Bhagabati et al., 2012)	0.6	(Bhagabati et al., 2012)	1	(Bhagabati et al., 2012)	0.4	(Bhagabati et al., 2012)	0.9	(Bhagabati et al., 2012)
4	0.4	(Terrado et al., 2016)	1	(Terrado et al., 2016)	1	(Terrado et al., 2016)	1	(Bhagabati et al., 2012)	1	(Terrado et al., 2016)	0.7	(Bhagabati et al., 2012)
5	0.4	(Terrado et al., 2016)	0.03	(Terrado et al., 2016)	1	(Terrado et al., 2016)	1	(Bhagabati et al., 2012)	0.69	(Terrado et al., 2016)	0	(Bhagabati et al., 2012)
6	0.4	(Terrado et al., 2016)	0.03	(Terrado et al., 2016)	1	(Terrado et al., 2016)	1	(Bhagabati et al., 2012)	0.69	(Terrado et al., 2016)	0	(Bhagabati et al., 2012)
7	0	(Bhagabati et al., 2012)	0	(Bhagabati et al., 2012)	1	(Bhagabati et al., 2012)	1	(Bhagabati et al., 2012)	0	(Bhagabati et al., 2012)	0	(Bhagabati et al., 2012)
8	0	(Bhagabati et al., 2012)	0	(Bhagabati et al., 2012)	0	(Bhagabati et al., 2012)	0	(Bhagabati et al., 2012)	0	(Bhagabati et al., 2012)	0	(Bhagabati et al., 2012)
9	0	(Bhagabati et al., 2012)	0	(Bhagabati et al., 2012)	0	(Bhagabati et al., 2012)	0	(Bhagabati et al., 2012)	0	(Bhagabati et al., 2012)	0	(Bhagabati et al., 2012)
10	0	(Bhagabati et al., 2012)	0	(Bhagabati et al., 2012)	0	(Bhagabati et al., 2012)	0	(Bhagabati et al., 2012)	0	(Bhagabati et al., 2012)	0	(Bhagabati et al., 2012)
12	0.4	(Bhagabati et al., 2012)	1	(Bhagabati et al., 2012)	1	(Bhagabati et al., 2012)	1	(Bhagabati et al., 2012)	1	Terrado et al., 2016)	0.7	(Bhagabati et al., 2012)
13	0.4	(Bhagabati et al., 2012)	0.2	(Bhagabati et al., 2012)	1	(Bhagabati et al., 2012)	1	(Bhagabati et al., 2012)	0	(Bhagabati et al., 2012)	0	(Bhagabati et al., 2012)
50	1	(Bhagabati et al., 2012)	1	(Bhagabati et al., 2012)	1	(Bhagabati et al., 2012)	1	(Bhagabati et al., 2012)	1	(Bhagabati et al., 2012)	0.7	(Bhagabati et al., 2012)
100	0	Assumed	0	Assumed	0	Assumed	0	Assumed	0	Assumed	0	Assumed

Appendix C. Other Results Tables

Table C1. Integrated CBA for the GEF contribution. The direct benefits attributable to the GEF are larger than the GEF funding contribution, even without considering the possibility of carbon financing. All values are in 2020 million USD.

	20-year lifetime (2021–2040)		30-year lifetime (2021–2050)	
	RCP 4.5	**RCP 8.5**	**RCP 4.5**	**RCP 8.5**
Added Benefits				
Value of bamboo exports	0.21	0.21	0.35	0.35
Value of agroforestry benefits	1.38	1.38	2.17	2.17
Tree planting wages	0.34	0.34	0.34	0.34
Carbon storage benefit	3.30	3.30	3.30	3.30
TOTAL ADDED BENEFITS	**5.22**	**5.22**	**6.16**	**6.16**
Avoided Costs				
Avoided flood damages to households	*2.47*	*2.53*	*50.17*	*8.03*
Avoided flood damages to agriculture	*1.24*	*1.44*	*19.97*	*3.80*
Avoided erosion damages to agriculture	*1.84*	*4.39*	*4.29*	*5.42*
Avoided nitrogen pollution	1.76	1.76	2.64	2.64
Avoided phosphorus pollution	0.83	0.83	1.25	1.25
TOTAL AVOIDED COSTS	**8.15**	**10.96**	**78.32**	**21.15**
Costs				
Improved land management cost	0.88	0.88	0.88	0.88
Absorption wells and biopori cost	0.56	0.56	0.56	0.56
TOTAL COSTS	**1.44**	**1.44**	**1.44**	**1.44**
TOTAL	**11.94**	**14.75**	**83.04**	**25.87**

Table C2. Project financial analysis. Includes all added benefits, added avoided costs, and investment and maintenance costs. All values are in 2020 thousands USD.

	20-year lifetime (2021–2040)		**30-year lifetime (2021–2050)**	
	Scenario RCP 4.5 USD	**Scenario RCP 8.5 USD**	**Scenario RCP 4.5 USD**	**Scenario RCP 8.5 USD**
PRESENT VALUE of ADDED BENEFITS and AVOIDED COSTS				
Added Benefits				
Value of bamboo exports	98	98	127	127
Value of agroforestry benefits	1,120	1,120	1,385	1,385
Tree planting wages	481	481	481	481
Carbon storage benefit	21,689	21,689	21,689	21,689
TOTAL ADDED BENEFITS	**5.22**	**5.22**	**6.16**	**6.16**
Avoided Costs				
Avoided flood damages to households	15,579	11,744	114,697	22,465
Avoided flood damages to agriculture	7,759	7,008	46,418	11,602
Avoided erosion damages to agriculture	12,829	25,426	17,265	27,979
Avoided nitrogen pollution	9,517	9,517	11,314	11,314
Avoided phosphorus pollution	4,496	4,496	5,345	5,345
TOTAL AVOIDED COSTS	**50,180**	**58,191**	**195,039**	**78,705**
TOTAL ADDED BENEFITS AND AVOIDED COSTS	**73,568**	**81,580**	**218,722**	**102,388**
PRESENT VALUE OF COSTS				
Capital cost – improved land management	8,942	8,942	8,942	8,942
Capital cost – absorption wells and biopori holes	558	558	558	558
Annual maintenance costs	529	529	629	629
Investment opportunity cost	-	-	-	-
TOTAL COSTS	**10,029**	**10,029**	**10,129**	**10,129**
S-NPV	**63,539**	**71,551**	**208,593**	**92,259**
S-IRR	**62.84 %**	**74.80 %**	**62.87 %**	**74.80 %**

Table C3. Project financial analysis. Includes added benefit without carbon storage benefit, added avoided costs, and investment and maintenance costs. All values are in 2020 thousands USD.

	20-year lifetime (2021–2040)		30-year lifetime (2021–2050)	
	Scenario RCP 4.5 USD	**Scenario RCP 8.5 USD**	**Scenario RCP 4.5 USD**	**Scenario RCP 8.5 USD**
PRESENT VALUE of ADDED BENEFITS and AVOIDED COSTS				
Added Benefits				
Value of bamboo exports	98	98	127	127
Value of agroforestry benefits	1,120	1,120	1,385	1,385
Tree planting wages	481	481	481	481
Carbon storage benefit	-	-	-	-
TOTAL ADDED BENEFITS	**1,699**	**1,699**	**1,994**	**1,994**
Avoided Costs				
Avoided flood damages to households	15,579	11,744	114,697	22,465
Avoided flood damages to agriculture	7,759	7,008	46,418	11,602
Avoided erosion damages to agriculture	12,829	25,426	17,265	27,979
Avoided nitrogen pollution	9,517	9,517	11,314	11,314
Avoided phosphorus pollution	4,496	4,496	5,345	5,345
TOTAL AVOIDED COSTS	**50,180**	**58,191**	**195,039**	**78,705**
TOTAL ADDED BENEFITS AND AVOIDED COSTS	**51,879**	**59,890**	**197,033**	**80,698**
PRESENT VALUE OF COSTS				
Capital cost – improved land management	8,942	8,942	8,942	8,942
Capital cost – absorption wells and biopori holes	558	558	558	558
Annual maintenance costs	529	529	629	629
Investment opportunity cost	-	-	-	-
TOTAL COSTS	**10,029**	**10,029**	**10,129**	**10,129**
S-NPV	**41,850**	**49,861**	**186,903**	**70,569**
S-IRR	**56.52 %**	**69.45 %**	**56.61 %**	**69.45 %**

Table C4. Project financial analysis. Includes added benefits, added avoided costs and all costs. All values are in 2020 thousands USD.

	20-year lifetime (2021–2040)		**30-year lifetime (2021–2050)**	
	Scenario RCP 4.5 USD	**Scenario RCP 8.5 USD**	**Scenario RCP 4.5 USD**	**Scenario RCP 8.5 USD**
PRESENT VALUE of ADDED BENEFITS and AVOIDED COSTS				
Added Benefits				
Value of bamboo exports	98	98	127	127
Value of agroforestry benefits	1,120	1,120	1,385	1,385
Tree planting wages	481	481	481	481
Carbon storage benefit	21,689	21,689	21,689	21,689
TOTAL ADDED BENEFITS	**23,389**	**23,389**	**23,683**	**23,683**
Avoided Costs				
Avoided flood damages to households	15,579	11,744	114,697	22,465
Avoided flood damages to agriculture	7,759	7,008	46,418	11,602
Avoided erosion damages to agriculture	12,829	25,426	17,265	27,979
Avoided nitrogen pollution	9,517	9,517	11,314	11,314
Avoided phosphorus pollution	4,496	4,496	5,345	5,345
TOTAL AVOIDED COSTS	**50,180**	**58,191**	**195,039**	**78,705**
TOTAL ADDED BENEFITS AND AVOIDED COSTS	**73,568**	**81,580**	**218,722**	**102,388**
PRESENT VALUE OF COSTS				
Capital cost – improved land management	8,942	8,942	8,942	8,942
Capital cost – absorption wells and biopori holes	558	558	558	558
Annual maintenance costs	529	529	629	629
Investment opportunity cost	12,667	12,667	12,667	12,667
TOTAL COSTS	**22,706**	**22,706**	**22,806**	**22,806**
S-NPV	**50,862**	**58,874**	**195,916**	**79,582**
S-IRR	**44.00 %**	**51.17 %**	**44.36 %**	**51.19 %**

Table C5. Project financial analysis. Includes all added benefits and investment and maintenance costs. All values are in 2020 thousands USD.

	20-year lifetime (2021–2040)		**30-year lifetime (2021–2050)**	
	Scenario RCP 4.5 USD	**Scenario RCP 8.5 USD**	**Scenario RCP 4.5 USD**	**Scenario RCP 8.5 USD**
PRESENT VALUE of ADDED BENEFITS and AVOIDED COSTS				
Added Benefits				
Value of bamboo exports	98	98	127	127
Value of agroforestry benefits	1,120	1,120	1,385	1,385
Tree planting wages	481	481	481	481
Carbon storage benefit	21,689	21,689	21,689	21,689
TOTAL ADDED BENEFITS	**23,389**	**23,389**	**23,683**	**23,683**
Avoided Costs				
Avoided flood damages to households	-	-	-	-
Avoided flood damages to agriculture	-	-	-	-
Avoided erosion damages to agriculture	-	-	-	-
Avoided nitrogen pollution	-	-	-	-
Avoided phosphorus pollution	-	-	-	-
TOTAL AVOIDED COSTS	**-**	**-**	**-**	**-**
TOTAL ADDED BENEFITS AND AVOIDED COSTS	**23,389**	**23,389**	**23,683**	**23,683**
PRESENT VALUE OF COSTS				
Capital cost – improved land management	8,942	8,942	8,942	8,942
Capital cost – absorption wells and biopori holes	558	558	558	558
Annual maintenance costs	529	529	629	629
Investment opportunity cost	-	-	-	-
TOTAL COSTS	**10,029**	**10,029**	**10,129**	**10,129**
S-NPV	**13,359**	**13,359**	**13,554**	**13,554**
S-IRR	**22.54 %**	**22.54 %**	**22.56 %**	**22.56 %**

Table C6. Project financial analysis. Includes all added benefits exclusive of carbon storage benefit and investment and maintenance costs. All values are in 2020 thousands USD.

	20-year lifetime (2021–2040)		30-year lifetime (2021–2050)	
	Scenario RCP 4.5 USD	**Scenario RCP 8.5 USD**	**Scenario RCP 4.5 USD**	**Scenario RCP 8.5 USD**
PRESENT VALUE of ADDED BENEFITS and AVOIDED COSTS				
Added Benefits				
Value of bamboo exports	98	98	127	127
Value of agroforestry benefits	1,120	1,120	1,385	1,385
Tree planting wages	481	481	481	481
Carbon storage benefit	-	-	-	-
TOTAL ADDED BENEFITS	**1,699**	**1,699**	**1,994**	**1,994**
Avoided Costs				
Avoided flood damages to households	-	-	-	-
Avoided flood damages to agriculture	-	-	-	-
Avoided erosion damages to agriculture	-	-	-	-
Avoided nitrogen pollution	-	-	-	-
Avoided phosphorus pollution	-	-	-	-
TOTAL AVOIDED COSTS	**-**	**-**	**-**	**-**
TOTAL ADDED BENEFITS AND AVOIDED COSTS	**1,699**	**1,699**	**1,994**	**1,994**
PRESENT VALUE OF COSTS				
Capital cost – improved land management	8,942	8,942	8,942	8,942
Capital cost – absorption wells and biopori holes	558	558	558	558
Annual maintenance costs	529	529	629	629
Investment opportunity cost	-	-	-	-
TOTAL COSTS	**10,029**	**10,029**	**10,129**	**10,129**
S-NPV	**-8,330**	**-8,330**	**-8,136**	**-8,136**
S-IRR	**-10.96 %**	**-10.96 %**	**-4.81%**	**-4.81%**

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