SAVi Sustainable Asset Valuation

How Can Indonesia Foster Sustainable Infrastructure Solutions That Deliver Low-Carbon Development and Bring Additional Benefits?

TECHNICAL ANNEX

IISD International Institute for Sustainable Development

UKaid from the British people

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International Institute for Sustainable Development

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Technical Annex to How Can Indonesia Foster Sustainable Infrastructure Solutions That Deliver Low-Carbon Development and Bring Additional Benefits?

July 2021

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About this technical report

This technical report explains how the Sustainable Asset Valuation (SAVi) methodology can be used for selected asset types.

This report presents the methodological framework for selected types of assets and explains how it can be combined with the Ministry of National Development and Planning's (Bappenas) core model for the appraisal of climate and green development policies, Indonesia Vision 2045 (IV2045) and, potentially, with spatial models used in the Low Carbon Development Initiative (LCDI).

IV2045 is a system dynamics model used by Bappenas for LCDI policy analysis.

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Acronyms and Abbreviations

BAU	business as usual
CAPEX	capital expenditures
CBA	cost-benefit analysis
GHG	greenhouse gas
IRR	internal rate of return
IN2045	Indonesia Vision 2045
InVEST	Integrated Valuation of Environmental Services and Trade Offs
LCOE	levelized cost of electricity
N	nitrogen
NBI	nature-based infrastructure
NbS	nature-based solutions
O&M	operation and management
OPEX	operating expenses
PM	particulate matter
RCP	Representative Concentration Pathway
SAGCOT	Southern Agricultural Growth Corridor of Tanzania
SAVi	Sustainable Asset Valuation
SCC	social cost of carbon
TEEB	The Economics of Ecosystems and Biodiversity

1.0 Introducing Sustainable Asset Valuation

1.1 Sustainable Asset Valuation

Infrastructure is pivotal to combating climate change and achieving sustainable development. Renewable energy, sustainable transport, digital infrastructure, and nature-based solutions (NbS) literally pave the way for sustainable societies. However, if infrastructure is not de-carbonized and built in a sustainable manner, we cannot realize the climate mitigation and adaptation objectives in the Paris Agreement. It is critical to calculate the costs of risks and externalities of infrastructure and thus steer capital to low-carbon, climate-resilient, and overall sustainable infrastructure assets.

The International Institute for Sustainable Development and KnowlEdge have developed and applied the Sustainable Asset Valuation (SAVi) methodology since 2016. The SAVi methodology is a simulation-based assessment that was developed to calculate the costs of environmental, social, governance, and climate risks, as well as the costs of externalities in infrastructure projects—for example, health costs and how they relate to carbon dioxide, particulate matter, sulfur dioxide, and nitrogen oxide emissions. The features of SAVi include:

- **Simulation**: SAVi combines the outputs of systems thinking and system dynamics simulation and project finance modelling.
- **Valuation**:
  - Cost of Risk: SAVi simulates the value of climate economic, social, and environmental risks. It then shows how these risks affect the financial performance of infrastructure projects and portfolios across their life cycles. Such risks are overlooked in traditional financial valuations. The system dynamics simulation is built using Vensim[1]; the project finance model was built in accordance with Corality SMART.[2]
  - Cost of Externalities: SAVi identifies and places a euro value on the externalities that arise as a direct consequence of infrastructure projects. An example of an externality is the impacts on human health caused by carbon dioxide, particulate matter, sulfur dioxide, and nitrogen oxide emissions. SAVi thus helps policy-makers and investors to appreciate the wider, second-order gains and trade-offs of infrastructure investments that may otherwise not be apparent under a traditional valuation.
  - Costs of Emerging Risks: SAVi shows how externalities today can transform into direct project risks tomorrow. Such valuations help stakeholders make decisions in favour of sustainable infrastructure.
- **Customization**: SAVi models can be customized to individual infrastructure projects, portfolios, and policies. SAVi can therefore value the cost of risks and externalities that are directly material to each asset.

[1] www.vensim.com

[2] http://www.corality.com/consulting/smart

1.2 SAVi Analysis: Integrated cost-benefit analysis and project finance assessment

SAVi enables an assessment of the outcomes of proposed investments using three main thematic areas of the analysis: investments, avoided costs, and added benefits, taking into account both social and environmental avoided costs and added benefits in addition to the more traditional economic ones. Nature-based infrastructure (NBI) to improve water management—which reduces water pollution, vulnerability to extreme events, and provides water supply for new uses—illustrates this approach.

Investments: Investments are required to either purchase equipment or a service. These represent the cost of implementation of a project or policy. In the context of NBI, the investments required have to do with the preparation of the area, the cost of planting trees or vegetation, and the operation and maintenance of the area. These are examples of indicators relevant to wetland revegetation, but many other types of projects could be used.

Avoided costs: The implementation of the project may lead to cost savings for a variety of cost items that are directly or indirectly connected to the project. In the case of a wetland, avoided costs emerge for water purification (e.g., due to the natural filtration offered by plants and soil), water supply (e.g., due to the buffering effect that a wetland can provide during periods of droughts and rain), water regulation (e.g., by increasing climate resilience to extreme precipitation events and reducing infrastructure damage), and carbon sequestration (e.g., by avoiding the need to invest in other areas to reduce greenhouse gas [GHG] emissions, due to the carbon sequestration offered by the wetland).

Added benefits: These benefits emerge from the implementation of the project and would not be accrued otherwise, or with a built infrastructure (competing) option, such as by installing a grey culvert to channel water to a different location. Examples include additional employment and income creation, if this option is more labour intensive than the construction of the grey culvert, the potential to generate revenues from products (e.g., cattail) being produced in the wetland, or the possible increase in revenues from agricultural production that may benefit from year-round irrigation thanks to the water storage capacity of the wetland. Other additional benefits may be intangible (or less "material") than the ones described above, such as the creation of cultural and recreational value.

Investments, avoided costs, and added benefits are brought together in an integrated cost-benefit analysis (CBA) to assess the net benefit of a specific infrastructure project. SAVi can also add a comparison with other technologies that deliver the same range of infrastructure services. This same analysis is performed with project finance models to determine whether the proposed project is financially viable and how it compares with other options. An innovation of the SAVi approach is the inclusion of social and environmental externalities in the project finance assessment.

Across the different types of infrastructure, SAVi allows for a more robust stress-testing of projects by demonstrating that, in the case of sustainable infrastructure, key variables that drive revenues, operating expenses (OPEX), and capital expenditures (CAPEX) can be less volatile under a range of alternative scenarios. The additional risks modelled include climate risks (floods, droughts, increased climate variability) that result in a reduction in resale value, as well as risks related to the application of more stringent regulatory requirements on emissions and waste.

Furthermore, SAVi allows for a more accurate estimation of sensitivities related to human health costs and volatile real estate prices, and it can support an assessment of infrastructure's contribution to employment creation and productivity improvements. Short-term side effects, such as disruptions during construction and operation due to low social acceptance of the project, are also taken into account. These considerations are critical for the long-term valuation and refinancing of the asset.

Policy-makers can use SAVi to appreciate the co-benefits and avoided costs of sustainable infrastructure as well as to justify spending on assets that may cost more to plan and build but are more resilient during operation, maintenance, and end-of-life decommissioning. Investors can use SAVi to understand how sustainable infrastructure is more resilient to a range of external risks and hence more bankable than traditional solutions.

1.3 Modelling Approach

SAVi combines three modelling approaches. The predominant one is system dynamics, a semi-continuous modelling approach built on differential equations that was designed to better understand dynamic responses between attributes in an inflow-stock-outflow environment. One of the key characteristics is the ability to quantify causality, which makes it possible to visualize and run scenarios with (positive and negative) feedback loops and, eventually, system behaviour or even system archetypes (limits to growth, race to the bottom, etc.). SAVi uses systems thinking (a sister methodology of system dynamics, but qualitative) to define an asset as part of a system, which in turn can be expanded as far as relevant for an investor, government, or other key stakeholder.

The second modelling approach is project finance modelling. This is used by investors to calculate the expected financial performance of an infrastructure project. In the case of SAVi, the financial model is applied to calculate the extent to which the valued risks and externalities impact the financial performance of infrastructure assets. Asset-specific risks and externalities are integrated into the calculation of levelized costs, gross margin, net present value, internal rate of return (IRR), and credit ratios.

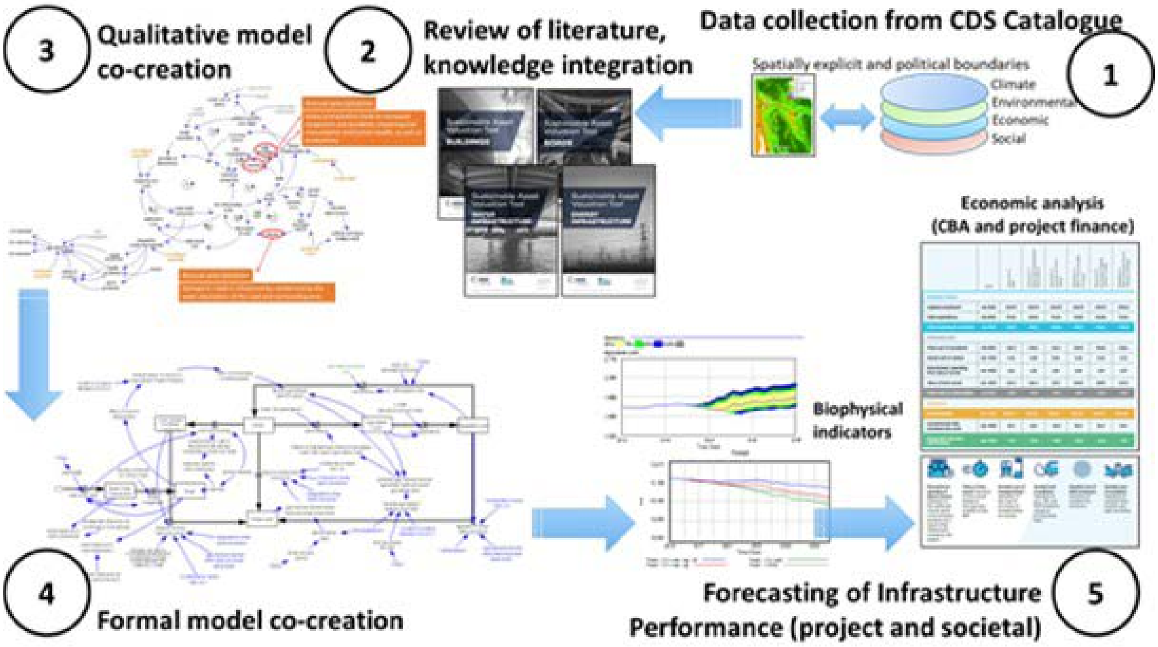
The third modelling approach is spatially explicit. It is used to estimate land-cover changes and the resulting impacts on ecosystem service provisioning. The use of spatially explicit models allows the assessment of NbS in alignment with the System of Environmental and Economic Accounts, with a focus on ecosystem extent, condition, services, and the economic valuation of ecosystem services. These are estimated in relation to the changes brought about by specific investments in a variety of assets.

As a result, SAVi is used to inform the economic valuation of externalities and climate risks for selected investments at the project, portfolio, or chosen policy level. Examples are:

- Loss of power generation under different climate projections, same for labour productivity and land productivity.
- Economic valuation of life-cycle emissions of assessed infrastructure projects.
- Losses of and damage to infrastructure from sea-level rise, storm surges, salt intrusion, sedimentation, or erosion; avoided damage in cases of climate-resilient infrastructure alternatives.
- Co-benefits of adaptation, NbS for water quality, biodiversity, or ecosystem services.

Figure 1 shows the information flow from data collection (e.g., including Copernicus's Climate Data Store), through literature review, conceptual modelling (which would be co-created with the final users of the model and analysis), model creation, and generation of outputs.

Figure 1. The SAVi conceptual modelling framework



Source: IISD.

1.3.1 SYSTEM DYNAMICS

System dynamics serves as a knowledge integrator, generating a conventional CBA as well as a more comprehensive assessment of the broader social, economic, and environmental impacts of sustainable and grey infrastructure. This includes the estimation of required investments and resulting co-benefits, avoided costs, and project risks. For example, forecasted impacts could include reduced fish stocks following the installation of a hydropower dam. An example of avoided costs could be reduced energy consumption in sustainable buildings or reduced construction costs in the case of better road siting. An example of an added benefit could be increased productivity triggered by improved human health, which in turn was afforded by improved ambient air quality. This methodology also allows project risks to be identified and estimated quantitatively, filling an important information asymmetry for investors. Examples of these risks include:

- **Regulatory risks**: Carbon taxes, changes in feed-in tariffs, changes in availability payments, air pollution laws.
- **Market risks**: Price volatility and disruptions in the supply of inputs (coal, building materials, water, feedstock) and outputs (energy and water services).
- **Technology risks**: Unexpected costs in installation and operation and management (O&M), losses related to poor performance, cost of decommissioning, losses related to extreme weather, and insufficient track records.

- **Social risks**: Issues related to land acquisition, disputes and delays related to environmental impact assessments and social impact assessments, disputes and delays related to other safeguards, such as clearances and permits.
- **Climate risks**: Related to extreme weather events (e.g., in the context of coastal resilience and related damage to infrastructure) or to the strengthening of climate change (e.g., in relation to the impact of growing temperature on power generation efficiency or on road maintenance costs).

1.3.2 PROJECT FINANCE

SAVi makes use of a dedicated project finance model to carry out project financing analyses. The project finance model is built in accordance with and validated by Corality SMART. SAVi can help make investment decisions based on not only the financial attractiveness of a project but also on its contribution to climate mitigation, adaptation, and performance against the United Nations Sustainable Development Goals.

The Corality SMART Financial Modelling Methodology is used as the framework to demonstrate how the project risks identified as part of the sustainable development modelling influence the financial viability of sustainable versus business-as-usual (BAU) infrastructure projects. These additional risk variables are integrated into the sensitivity analysis as part of the financial assessment. Lenders and equity investors build project finance models to estimate the financial sustainability and profitability of the project by mapping the various cash flows during the life of the asset. Using financial models built with Corality SMART Financial Modelling Methodology, SAVi demonstrates how the different project variables (such as CAPEX, construction time, OPEX, operational efficiency, corporate tax rate, etc.) change under a wide range of risk scenarios. The scenarios modelled illustrate how the elements identified as part of the sustainable development model influence the overall bankability of green versus the BAU infrastructure projects. Such elements include changes in carbon pricing policy; delays in construction; disruptions in operation due to social or technological risks; and the impacts of climate change, such as heatwaves, on the operation of the asset, among others.

The Corality SMART Financial Modelling Methodology also allows policy-makers and investors to assess how fiscal and financial incentives are important to increasing the deployment of sustainable infrastructure. For example, tax rebates and allowances for sustainable infrastructure can positively enhance project finance parameters such as base interest rates and corporate tax rates. Similarly, financial instruments to hedge against currency risks could allow a greater crowding in of domestic inventors and suppliers that would, in turn, increase productivity and green industrialization in the domestic economy.

1.3.3 SPATIAL MODELS

Several variables in the SAVi model require input that is location specific. Data may be available from land-cover maps (e.g., hectares of land), while others have to be calculated (e.g., carbon sequestration based on local types of vegetation). The Integrated Valuation of Environmental Services and Trade Offs (InVEST) modelling platform, developed by the Natural Capital Project, is most commonly used to calculate these data inputs. InVEST enables an estimate of ecosystem services from land-cover maps, provided that additional data inputs and assumptions are provided. InVEST is designed to inform decision-makers by providing information on the supply of ecosystem services in a given area that considers terrestrial, freshwater, and marine ecosystems (Sharp, 2018).

InVEST models generate results that are either aggregated (e.g., total carbon sequestration for the area studied) or spatially explicit (e.g., carbon sequestration for each pixel of the land-cover map). These results are used in SAVi both in the form of biophysical indicators (e.g., for the calculation of additional, indirect, and induced impacts on the performance of infrastructure) or in the form of economic indicators for the CBA and project finance assessment. InVEST can be easily coupled with SAVi analysis, as it enables a definition of the spatial resolution required and uses both global and local data, depending on the quality and availability of such data (Sharp, 2018).

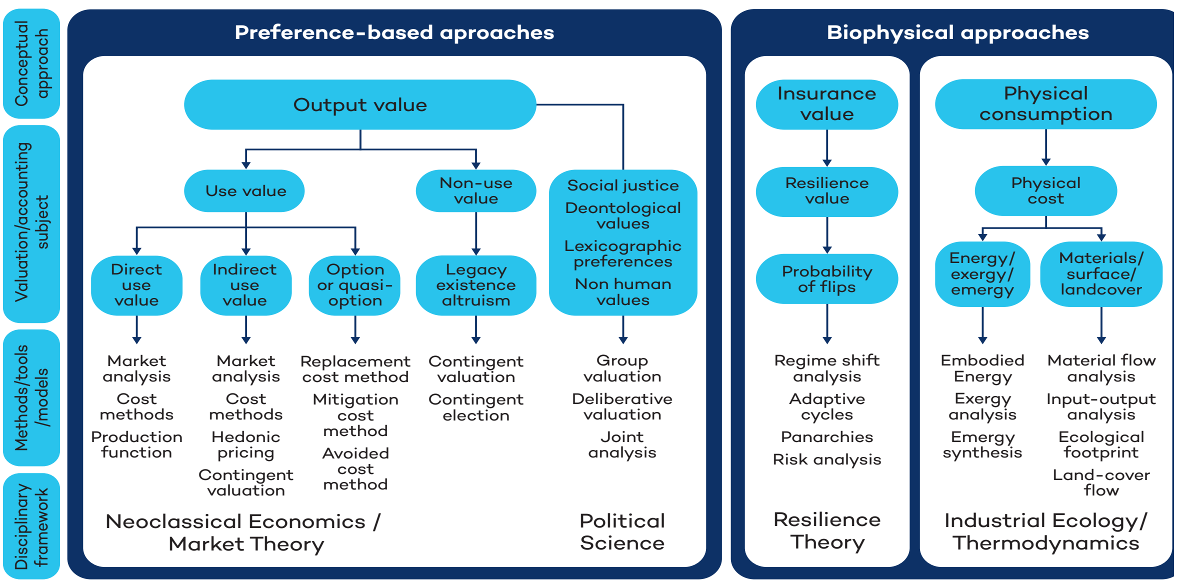
1.3.4 FROM BIOPHYSICAL TO ECONOMIC VALUE

1.3.4.1 Overall Approach to Modelling Ecosystem Services

Some of the ecosystem services provided by nature can be compared to infrastructure services. For this reason, it is important that these contributions by nature are assessed in the same way as we assess infrastructure services. In other words, we have to estimate the ecosystem service provided (De Groot et al., 2002) and then proceed with the estimate of the economic value of the service. The economic valuation can be based on the direct value provided by nature or the cost of providing the same service with built infrastructure. In both cases, it is important to consider the time of intervention and the usefulness of the service provided by nature (The Economics of Ecosystems and Biodiversity [TEEB], 2010).

To produce the simulation-based NBI assessments, the SAVi tool uses secondary research and considers a variety of methods and approaches to the economic valuation of ecosystem services. This includes benefit transfer, use, and one-use values (Figure 2).

Figure 2. Various approaches to ecosystem valuation



Source: TEEB, 2010, Ch. 5, Fig. 1

Many methods can be used to estimate the value of a given ecosystem service as it is provided by nature. These methods include market prices and the appreciation of the ecosystem service by different stakeholders. These stakeholders—the beneficiaries of ecosystem services, those who are providing the services, those involved in or affected by the use, and the actors involved at different levels of decision-making—need to be clearly identified (De Groot et al., 2002). In more complex situations, monetary valuations may be less reliable or unsuitable. In these instances, we work at recognizing value (using, for instance, direct and indirect use value, option or quasi option valuation, or contingent valuation) (TEEB, 2010).

Different discount rates are used in SAVi assessments in relation to investments and other cash-flow indicators, as well as for ecosystem services and societal impacts that are non-material for the project. The literature shows that often lower discount rates are used for ecosystem services and climate change mitigation when compared to conventional investments (Goldstein, 2012). As TEEB points out, a variety of discount rates, including zero and negative rates, may be used, depending on the nature of the assets being valued, the time period involved, the degree of uncertainty, and the scope of the project or policy being evaluated (TEEB, 2010).

The economic valuation of climate change impacts draws from the historical data and climate projections by the Copernicus Climate Data Store. Precipitation and temperature are among the main climate variables, together with the leaf cover index (based on historical data only), that impact the performance of NBI. Indicators worth considering are rainwater harvesting, water absorption capacity through vegetation or soil, and water purification potential. NBI, in its hybrid form, can reduce extreme weather impacts on buildings (e.g., reduce flood impact), curb demand for water (via rainwater harvesting), and reduce stress on wastewater treatment plants. It is also good to treat and absorb high precipitation as well as wastewater through restored or natural wetlands and mangroves, among others. These services produced by NBI are estimated using spatial maps and models using geographic information system (GIS) (spatially explicit) data. This process is required to correctly capture land-cover change in space, as well as the resulting change in ecosystem conditions and services, and ultimately perform an economic valuation of ecosystem services. Location is critical in this respect because the quality of the ecosystems that are impacted by built infrastructure and the potential to improve ecosystem services when using NBI depend on the initial conditions of the ecosystem, which is information that can be obtained from spatial maps.

1.3.4.2 Narrowing Down to Infrastructure Services

NBI includes many ecosystems, such as wetlands, mangroves, forests, lakes, lagoons, dunes, rivers, croplands, and grasslands. The System of Environmental and Economic Accounting *Experimental Ecosystem Accounting* is the main framework available for quantifying and estimating the value of ecosystem services.[3]

Ecosystem services that are valued by SAVi in economic terms include provisioning, regulating, habitat, and cultural services; the exact mix is determined by the climate

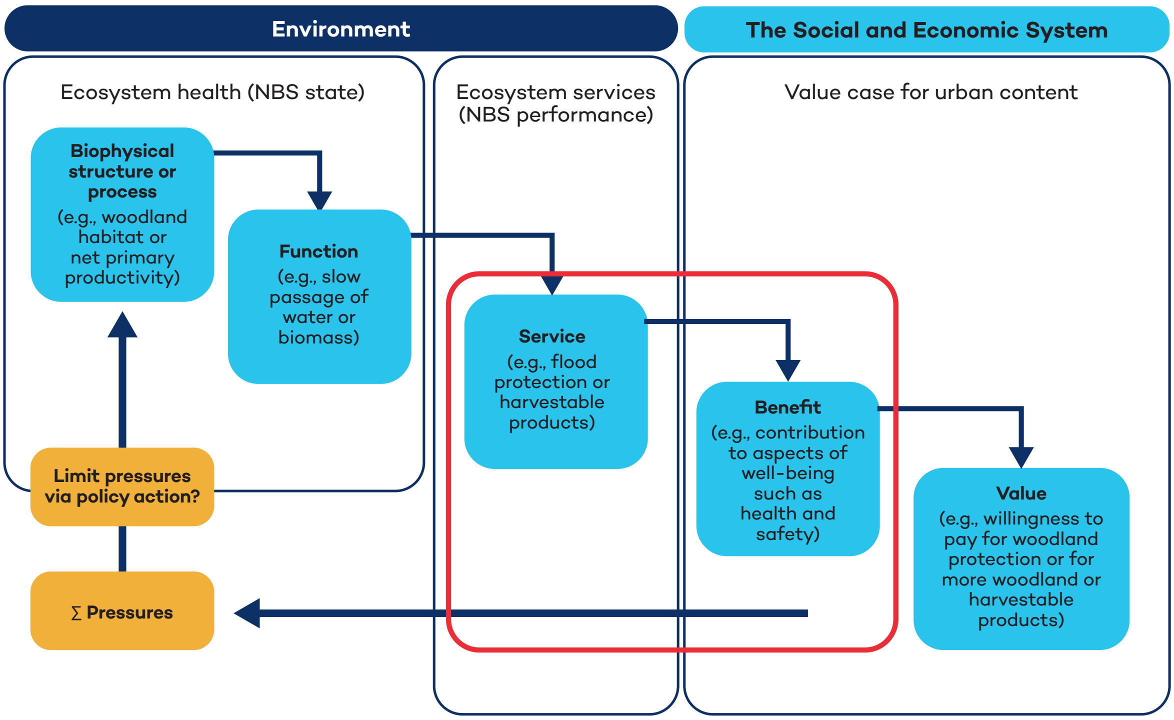
[3] For more information on this framework, see: https://seea.un.org/ecosystem-accounting

adaptation and infrastructure priorities of local stakeholders. Priority is generally given to (Alvarado, 2020):

- Ecosystem services that enable specific socio-economic activity, reduce the cost of operations for both private and public actors, or reduce or avoid extra-budgetary costs, such as by reducing the costs of adaptation and damage related to climate hazards.
- Ecosystem services that can complement and even replace grey built infrastructure to provide adaptation benefits/services—for example, water storage, prevention of erosion, protection against water scarcity and drought, protection against floods, and soil formation and composition.
- Ecosystem services that provide wider "infrastructure service co-benefits"—for example, water storage, carbon sequestration, air purification, nutrient filtration/ water purification, water supply and discharge, protection against water scarcity and drought, protection against floods, and soil formation and composition.
- Cultural services that make a direct contribution to primary and service sector outputs—for example, recreation, tourism, fisheries, agriculture, cottage industries, etc.

To provide for the fundamentals of funding and financing climate adaptation, the valuation performed with the SAVi tool also compares the restoration and maintenance costs of natural ecosystems with the CAPEX and OPEX that would be required to build and maintain grey, civil-engineered alternatives that would provide the same magnitude of services.

Figure 3. Conceptual presentation of the infrastructure services offered by NbS



Source: Alvarado, 2020.

2.0 Overview of SAVi Models

2.1 Energy

2.1.1 OVERVIEW

In the energy sector, various electricity generation options are compared to identify economic, social, and environmental advantages and disadvantages. These are assessed for various economic actors (i.e., private sector, government, and households) to gain a comprehensive view of the existing motives for investing in grey versus green infrastructure. The SAVi model customized to electricity supply includes macroeconomic drivers to estimate demand, which in turn drives the estimation of required investments, capacity construction, and, ultimately, electricity supply from conventional thermal options (i.e., oil, coal and gas), renewables (i.e., wind, solar, biomass, and hydropower), and nuclear power. Employment and income are estimated for both the construction and O&M of these plants. In addition to plant capacity and labour, other direct inputs to production are energy sources (e.g., fossil fuels) and water. Land use, along with the cement and steel used, are also estimated for each technology across its lifetime. Finally, CO_2, NO_X, SO_2 emissions and particulate matter (PM) are estimated, including their economic valuation (e.g., using the social cost of carbon [SCC]). Risks to production are also assessed through scenarios, which include the impact of climate change (e.g., on water use for the cooling of thermal capacity).

2.1.2 DATA NEEDS

Table 1. Data needs for the SAVi energy model

Economic	Social	Environmental
Investment	Employment (construction & O&M)	Land use
O&M costs	Discretionary spending (labour income)	Water use
Labour costs	SCC	CO_2 emissions from fossil fuel consumption
Fuel use and costs	Health costs of $PM_{2.5}$, SO_2, and NO_x emissions	(Life-cycle) CO_2 emissions
Revenues from electricity generation		$PM_{2.5}$, SO_2, and NO_x emissions
Carbon tax		Cement use
Climate change impact on efficiency		Steel use

Economic	Social	Environmental
Costs of climate change per MWh		
Levelized cost of investment		
Electricity price per unit of output		

2.1.3 EXAMPLE: ONSHORE WIND PORTFOLIO IN GERMANY

2.1.3.1 Description of the Model

This SAVi assessment valued a range of environmental, social, and economic costs and benefits for an onshore wind portfolio in the central part of Germany (Uzsoki et al., 2020). The performance of this 29 MW-capacity portfolio was compared to a hypothetical gas-fired power plant with the same power generation capacity. To compare the costs and benefits caused by the two energy generation assets, a range of externalities were valued in the assessment:

- Income spending from road construction and construction of energy capacities, as well as maintenance activities.
- Biodiversity management costs based on impeded agriculture production in a semi-natural area that is created to provide an alternative wildlife habitat.
- Land-use costs based on foregone profit and foregone tax revenues from impeded agriculture production.
- Cost of emissions, valued with the SCC, and, alternatively, the health costs of air pollution.
- Real estate value depreciation near the energy asset based on international literature, assuming 4% and 2% value reductions.

2.1.3.2 Key Assumptions

For the gas-fired power plant, a lifetime of 40 years was assumed, while the lifetime for the 14 wind turbines of the onshore wind farm was 23 years. The valuation considered direct job creation in the manufacturing, construction, and operation of the power plant, and a SCC of USD 31/MWh. In addition, the assessment considered the cost implications of operational inefficiencies caused by an air temperature increase of 1.5°C and the imposition of a carbon tax of EUR 25/tCO_2 for operational emissions from electricity generation. Financial and technical assumptions of the energy assets were based on the local German characteristics as far as possible.

2.1.3.3 Results of the Assessment

The assessment included three components: a CBA for the two assets, a calculation of the levelized cost of electricity (LCOE), and a financial analysis showing performance results for the equity and project IRR. The results from these elements show that the hypothetical gas-fired power plant loses its investment attractiveness when the valuation includes potential costs from climate change risks or when externalities are monetized and integrated into the assessment.

In contrast, the performance of the onshore wind portfolio is not impaired by the climate risks. The assessment results of the wind portfolio decrease when the externalities are monetized and internalized into the CBA, the LCOE, or the financial analysis. Nonetheless, the CBA of this asset remains considerably positive, the LCOE increases only slightly when the externalities are included, and the equity IRR and project IRR remain positive (approximately 5% and 4%, respectively). In conclusion, the assessed wind farm is, therefore, the more resilient and more profitable investment choice than the gas-fired power plant. The SAVi valuation also shows that the wind farm is the more beneficial and less costly energy generation asset from a societal point of view.

Table 2. Net results of the integrated CBA: Comparison of a gas-fired power plant versus the onshore wind portfolio

Cost and benefit position	Gas-fired power plant (in EUR million)	Onshore wind (in EUR million)
Conventional costs: CAPEX and OPEX	(65.73)	(49.89)
Revenues	82.13	75.05
(1) Net results (conventional)	16.40	25.16
(2) Potential costs induced by climate change risks	(7.57)	0.00
(3a) Externalities (emissions valued as SCC)	(11.70)	(3.58)
(3b) Externalities (emissions valued as health cost of air pollution)	(6.37)	(4.02)
(4a) SAVi net results (1 + 2 + 3a)	(2.87)	21.58
(4b) SAVi net results (1 + 2 + 3b)	2.46	21.14

Note: Negative values are in brackets.

2.2 Buildings

2.2.1 OVERVIEW

The SAVi buildings model assesses the construction, material manufacture, O&M, and demolition process of buildings. As a result, the definition of a sustainable building used by SAVi accounts for economic, social, and environmental outcomes. The technologies considered include construction materials; solar photovoltaic and solar heat water; heating, ventilation, and air conditioning; lighting; water recycling; and appliances.

2.2.2 DATA NEEDS

Table 3. Data needs for the SAVi buildings model

Economic	Social	Environmental
Investment	Employment (construction & O&M)	Land use
O&M costs	Discretionary spending (labour income)	Water use
Labour costs	SCC	CO_2 emissions from buildings
Fuel use and costs	Health costs of $PM_{2.5}$, SO_2, and NO_x emissions	(Life-cycle) CO_2 emissions per m^2
Carbon tax	Climate change impact on labour productivity	$PM_{2.5}$, SO_2, and NO_x emissions
Climate change impact on heating/cooling		Water use
Costs of climate per m^2		Electricity use
Levelized costs of investment		
Costs per m^2 (lighting, heating, cooling etc.)		
Cost effectiveness of technologies		

2.2.3 EXAMPLE: PATERSON PARK'S BUILDING INFRASTRUCTURE, JOHANNESBURG, SOUTH AFRICA

2.2.3.1 Description of the Model

The SAVi methodology was used to estimate how much better "green" buildings perform relative to the current ones in the Paterson Park District of Johannesburg in South Africa. The Paterson Park Precinct project is part of the city's Corridors of Freedom Initiative, which aims to improve social cohesion in the urban environment. It encompasses the construction of a new library, swimming pool, and sports facilities, as well as the retrofitting of a multi-purpose recreation centre.

The SAVi assessment comprised an economic and financial valuation of the buildings of the Paterson Park Project, a comparative economic and financial valuation of buildings with higher energy and water efficiencies, as well as a simulation of these values under different climate scenarios. The project finance model examined the performance of investments in solar panels considering the climate scenarios and scenarios with and without inflation of the cost of electricity.

The following factors were considered:

- CAPEX and OPEX (e.g., for building maintenance)
- Energy expenditure
- Water expenditure (based on predicted water usage of the building and water price)
- Externalities:
    - Cost of GHG emissions based on SCC
    - Discretionary spending generated by employment in construction and maintenance.

2.2.3.2 Key Assumptions

To assess the performance of the conventional and green buildings under different climate scenarios, site-specific climate data from the Copernicus Climate Data Store was integrated into the simulation (precipitation patterns, temperature changes, and heating and cooling degree days). The assessment compared the Representative Concentration Pathway (RCP) 4.5 and RCP 8.5 scenarios to RCP 2.6 and assumed a project life cycle of 40 years.

2.2.3.3 Results of the Assessment

The SAVi valuation shows significant cost savings in energy and maintenance expenditures for green buildings when their whole life cycle is considered. Conventional buildings generate costs of up to ZAR 462 million, which includes externalities such as the cost of GHG emissions and discretionary spending from the generated employment. In comparison, the green building scenario results in a significantly lower cost of up to ZAR 312 million over the project life cycle due to cost savings related to energy, maintenance, and avoided GHG emissions.

The assessment also indicates that climate change raises the life-cycle cost both for conventional and green buildings. However, solar panel installations prove to be a worthwhile investment under all scenarios as they avoid significant costs by generating electricity that would otherwise need to be purchased.

Table 4. Integrated CBA under the RCP 4.5 scenario (in ZAR)

Integrated CBA (ZAR)	RCP 4.5	
	BAU	Green
Project-related investment and costs		
CAPEX	120,225,960	122,679,944
O&M cost	270,695,456	162,417,472
Energy expenditure	65,994,008	31,389,680
Water expenditure	6,294,502	6,294,502
Subtotal (1) project-related investment and costs	**450,864,560**	**310,436,232**
Externalities		
Costs of GHG emissions	15,787,837	6,540,845
Discretionary spending	(4,569,268)	(4,569,268)
Subtotal (2) externalities	**11,218,570**	**1,912,552**
TOTAL net cost	**462,083,129**	**312,348,784**

Note: Negative values are in brackets.

2.3 Roads

2.3.1 OVERVIEW

The SAVi roads model defines a sustainable road as one that limits environmental impacts throughout its life cycle, including the manufacture of materials, construction, use, and decommissioning. Environmental concerns are related to the design of the road, the materials used in construction, and use patterns. In addition to addressing environmental and natural resource needs, the development of a sustainable road should focus on social concerns such as access (not just mobility), moving people and goods (not just vehicles), and providing people with transportation choices, such as safe and comfortable routes for walking, cycling, and transit. Three main cost categories are considered: (1) construction, maintenance, pavement upgrade, and end-of-life costs; (2) vehicle operation, travel delay, social impact, and road accidents; and (3) environmental costs such as noise, air quality, water quality, resource consumption, and solid waste generation.

2.3.2 DATA NEEDS

Table 5. Data needs for the SAVi roads model

Economic	Social	Environmental
Investment	Employment (construction & O&M)	Land use
O&M costs	Discretionary spending (labour income)	Water use
Labour costs	SCC	Resource use (gravel, sand, asphalt, etc.)
Fuel use and costs	Health costs of $PM_{2.5}$, SO_2, and NO_x emissions	CO_2 emissions from fossil fuel consumption
Carbon tax	Traffic accidents (frequency and costs)	(Life-cycle) CO_2 emissions
Costs per km of road		$PM_{2.5}$, SO_2, and NO_x emissions
Levelized costs of investment		Runoff pollution from roads (e.g., stormwater)
		Costs of water/pollution management
		Wildlife accidents (frequency and costs)

2.3.3 EXAMPLE: ROAD INFRASTRUCTURE INVESTMENTS IN BORNEO

2.3.3.1 Description of the Model

This SAVi assessment examined the costs and benefits of the Pan Borneo Highway in Malaysia, which is currently under construction and cuts through one of the world's most biodiverse regions, the Heart of Borneo. The assessment encompassed a valuation of the capital and operational costs and benefits of the highway, a spatial analysis of land-cover change, and subsequent ecosystem services deterioration caused by the road construction, as well as a valuation of trade-offs like carbon emissions (Guzzetti et al., 2020). These steps culminated in a reassessment of the costs and benefits of the highway if measures to mitigate and offset some of the trade-offs were incorporated into the project's cost. The following factors were valued in the SAVi simulation:

- Capital and O&M costs
- Added benefits:
    - Value of travel time reductions based on the decreased travel time between Miri and Semetan, estimated miles driven on the highway by people impacted by the construction, and the average Malaysian hourly wage.

  - Wage generation from jobs indirectly created through the new highway based on local estimates that the highway will lead to 400,000 additional jobs.
  - Increased tourism revenues, assuming that the length of tourist stays in the region grows by 10%.
- Negative externalities:
  - Value of carbon emissions from deforestation and cement production, based on an SCC of USD 31/tonne.
  - Cost of biodiversity-related services lost.
  - Increased spending on flood damages because of deforestation.
- Costs for mitigation of the negative externalities:
  - Cost of flood control.
  - Cost of wildlife crossings.
  - Cost of reforestation to replace forested areas lost from road construction.
  - Investments in solar energy generation in the range of 9.02 GW and 14.15 GW to replace between 13,429 GWh and 21,075 GWh of coal energy generation to indirectly offset carbon emissions from deforestation and cement production.

2.3.3.2 Key Assumptions

The SAVi simulation examined the costs and benefits of the project over a period of 25 years. It included several societal costs of the Pan Borneo Highway that are unaccounted for in traditional project assessments: For example, the road construction will lead to job creation and increased tourism-related revenue because of better access. This will also, however, give rise to deforestation and consequently a loss of carbon sequestration and habitat quality. The highways project is also expected to have adverse effects on other ecosystem goods and services that are important for local communities.

2.3.3.3 Results of the Assessment

From a purely economic point of view, the construction of the Pan Borneo Highway appears appealing, as it is estimated to generate a return of USD 1.06 for every USD 1 invested. However, the project is much less appealing to society when the negative environmental impacts of the highway are considered: the negative externalities amount to USD 665.5 million over the course of 25 years, reducing the return on every USD 1 invested to USD 0.97.

The SAVi assessment considered different options for mitigating and offsetting these adverse impacts, including reforestation, wildlife crossings, and offsetting carbon emissions by replacing coal power generation with solar energy generation. It is estimated that for every USD 1 invested in the highway's construction and offsetting measures, approximately USD 1.04 or 1.05 will be returned. But even with the mitigation and offsetting measures, the project yields a low societal return on investment.

Strikingly, the investments in mitigating and offsetting negative impacts of roads generate a much better return on investment than spending the same amount on the new highway: for every USD 1 invested in reforestation of forest lost because of road construction, negative externalities in the range of USD 6.17–USD 9.43 are avoided, and for every USD 1 invested in solar energy generation that offsets carbon emissions from coal energy generation, the simulation results suggest that costs in the range of USD 18.87–USD 28.83 are avoided. These results illustrate that new infrastructure developments like the highway are not necessarily the best investments, as investments in avoiding and repairing damages offer a higher return on investment, avoid parts of the irreversible biodiversity loss, and create economic growth in other sectors of the Malaysian economy.

Table 6. Overview of the SAVi simulation results (in USD)

	Cumulative value (25 years)
Benefit per USD 1 invested in the highway	***1.06***
Benefit per USD 1 invested, including the costs of negative externalities	***0.97***
Benefit per USD 1 invested in highway and reforestation	***1.04***
Benefit per USD 1 invested in highway and solar energy generation	***1.05***
Return per USD 1 invested in reforestation (low- and high-end value for deforestation)	6.17–9.43
Return per USD 1 invested in solar energy generation (low- and high-end value for deforestation)	18.87–28.83

2.4 Wastewater

2.4.1 OVERVIEW

The SAVi water model addresses sustainability issues relating to (1) water supply (e.g., surface water and groundwater, including hydropower effects and diversions for irrigation), (2) water demand (e.g., losses in distribution and efficiency in the use of water), and (3) water management (e.g., water treatment and urban runoff and pollution). The model supports the analysis of Sustainable Urban Water Management options, addressing growing concerns over community well-being (rather than just public health), ecological health, and sustainable development.

2.4.2 DATA NEEDS

Table 7. Data needs for the SAVi wastewater model

Economic	Social	Environmental
Investment	Employment (construction & O&M)	Coverage of wastewater treatment
O&M costs	Discretionary spending (labour income)	Water use
Labour costs	SCC	Total nitrogen (N) loads (before and after treatment)
Carbon tax	Health costs of $PM_{2.5}$, SO_2, and NO_x emissions	N loads from: • Agriculture (fertilizer) • Population (wastewater) • Land use (atmospheric deposition) • Livestock
Costs per m^3 of wastewater treated	Health impacts infrastructure coverage (e.g., diarrhea)	CO_2 emissions from wastewater treatment
Levelized costs of investment	Beach visits	(Life-cycle) CO_2 emissions
Costs of water quality	Property value	$PM_{2.5}$, SO_2, and NO_x emissions
Property tax revenues		Impact of N load on fish landings
		N concentration in water bodies

2.4.3 EXAMPLE: CLEANUP AND REHABILITATION OF BEIRA LAKE, COLOMBO, SRI LANKA

2.4.3.1 Description of the Model

The SAVi assessment examined the economic value of investing in different ecological restoration options for southwest Beira Lake in Sri Lanka (Bassi, Pereira et al., 2019). Beira Lake is a shallow artificial freshwater lake in the centre of Colombo that is suffering from pollution and is in poor ecological condition. The assessment included a CBA of three different restoration interventions and their comparison to a BAU scenario. One intervention scenario addressed the pressing eutrophication and algae bloom problems with improved wastewater treatment, another explored the impacts of dredging sediments from the lake, and the last scenario combined dredging and wastewater treatment measures. The following factors were considered in the assessment:

- Costs for wastewater treatment upgrades (nitrogen and phosphorus removal)
- Cost of sediment removal
- Externalities:
    - Property value net change by the end of 2025
    - Additional spending for recreation by the local population and tourists.

2.4.3.2 Key Assumptions

The SAVi assessment focused on developments between 2020 and 2025. In the BAU scenario, historical trends continue, for example, only 80% of the wastewater reaching southwest Beira Lake is treated. In the wastewater treatment scenario, both the share of treated wastewater and the treatment effectiveness linearly increase between 2020 and 2025. The dredging scenario assumed that the dredging interventions increase the average water depth by about 1 metre and that this removal of sediments reduces internal phosphorus loadings that could otherwise re-enter the lake from the bottom layer.

Upgraded wastewater treatment and dredging can reduce pollution and nutrient loadings in Beira Lake, which improves the water clarity. It was assumed that tourists and people living near the lake would visit it more often and spend more on leisure activities when the water clarity of Beira Lake reaches a threshold of 0.4 metres. Increased water clarity was also assumed to significantly improve the economic value of properties surrounding the water body.

2.4.3.3 Results of the Assessment

The SAVi assessment showed that reducing the inflow of nutrients from sewage is crucial for solving the eutrophication and algae bloom problems of Beira Lake. Improved wastewater treatment alone would significantly improve the water clarity, increase local property values by more than USD 14 million at the end of 2025, and boost recreational spending from locals and tourists by more than USD 10 million. With a benefit-to-cost ratio of nearly 40, the assessed wastewater treatment upgrades prove to be a very worthwhile investment for Colombo.

Dredging sediments from the lake leads to slightly improved water clarity and economic benefits but would be particularly beneficial when combined with improved wastewater treatment. In this scenario, property values around the lake increase by more than USD 43 million by the end of 2025 compared to the BAU scenario, and the great improvement in water clarity facilitates additional recreational spending of more than USD 19.5 million between 2020 and 2025.

Table 8. Cumulative costs and benefits per intervention scenario (2020–2025) relative to BAU, in USD and discounted

Costs and benefits	Scenarios			
	BAU	Wastewater treatment	Dredging of lake deposits	Combined
Costs for wastewater treatment upgrades (2020–2025)	N/A	620,032	5,712,616	6,332,648
Property value net change by end of 2025	(172,770)	14,266,034	5,098,886	43,221,392
Additional spending for recreation by the local population	N/A	656,674	433,114	1,240,463
Additional spending for recreation by tourists	N/A	9,676,134	6,427,039	18,373,396
Total benefits (by end of 2025)	(172,770)	24,598,842	11,959,039	62,835,251
Net results	(172,770)	23,978,810	6,246,424	56,502,603
Benefit-to-cost ratio	N/A	39.67	2.09	9.92

Note: Negative values are in brackets.

2.5 Irrigation

2.5.1 OVERVIEW

The SAVi irrigation model estimates water demand by crop, considering seasonality and the growing schedule of the crop analyzed and using monthly time steps. The starting point is the estimation of the water requirement by crop, which is then compared to precipitation (resulting in the estimation of the net water demand) and irrigation available from surface water and groundwater. Various options are available for irrigation infrastructure, primarily centred around flood irrigation, centre pivot, and drip irrigation. Climate information is used as input to the model for precipitation and evapotranspiration. The model also allows a simulation of changes in the timing of the rainy season, using both climate data and user input. Investments in irrigation are used to estimate the potential increase (or avoided decline) in land productivity and, hence, revenues. From a societal perspective, water efficiency leads to improved access to water, and increased crop production results in better access to food and nutrition.

2.5.2 DATA NEEDS

Table 9. Data needs for the SAVi irrigation model

Economic	Social	Environmental
Investment	Employment (construction & O&M)	Coverage of irrigation capacity
O&M costs	Discretionary spending (labour income)	Water requirements per hectare of farmland
Labour costs	SCC	Total water use
Fuel costs	Overall food production	CO_2 emissions from wastewater treatment
Carbon tax	Conflict for water	(Life-cycle) CO_2 emissions
Revenues per hectare of agriculture land		$PM_{2.5}$, SO_2, and NO_x emissions
Costs per hectare irrigated		Impact of water availability on yields
Levelized costs of investment		Share of agricultural land under irrigation
Stranded (unproductive) land		
Added value of different irrigation options		

2.5.3 EXAMPLE: SUSTAINABLE AGRICULTURE IN THE SOUTHERN AGRICULTURAL GROWTH CORRIDOR OF TANZANIA

2.5.3.1 Description of the Model

The Southern Agricultural Growth Corridor of Tanzania (SAGCOT) initiative aims to strengthen Tanzania's agriculture sector by greatly expanding agricultural land. While this foreseen increase in production and processing of agricultural goods offers an opportunity for improving farmers' livelihoods, it will also increase the pressure on natural resources because large quantities of water are needed for irrigation. The SAVi assessment compared the financial performance and socio-economic impacts of implementing either flood irrigation or more water-saving drip irrigation. The SAGCOT initiative considered three externalities (Bassi, Casier et al., 2018):

- Valuation of the use of water
- Valuation of additional revenues and costs related to the additional irrigated land
- Valuation of carbon dioxide emissions through the SCC.

2.5.3.2 Key Assumptions

The SAVi valuation compared the use of flood irrigation (with an assumed irrigation efficiency of 25%) with the use of drip irrigation (assuming an irrigation efficiency of 82%). Within the drip irrigation scenario, simulations were run for low and high capital costs (USD 1,500/ha and USD 3,000/ha, respectively). For flood irrigation, the capital cost of the technology was estimated at USD 81.50/ha. For each of the irrigation scenarios, the valuation considered scenarios of unconstrained water supply and constrained water supply, where water availability is consistent with historical water flows and current estimates of groundwater extraction for irrigation purposes.

2.5.3.3 Results of the Assessment

The results demonstrate that the assumed capital costs greatly influence the net benefits of using the two different irrigation technologies: while the implementation of drip irrigation with high capital costs yields a net benefit of about USD 4 million, the same technology leads to a net benefit of more than USD 39 million if low capital costs are assumed. In comparison, the scenario with flood irrigation is estimated to provide benefits of nearly USD 14 million. This means that the net benefits of the use of drip irrigation would only outweigh the benefits of flood irrigation when the low capital costs are assumed.

The SAVi valuation illustrates that the bankability of efficient drop irrigation technologies depends on the capital cost and the added revenues gained from additional land that can be used for agriculture when water resources are freed up. In the face of stranded agricultural land due to water scarcity, drip irrigation provides a compelling case for investors, as it unlocks an additional 10,600 hectares of productive agricultural land and provides a more stable revenue stream due to continuous land productivity and production. In addition, the SAVi assessment indicates that the implementation of drip irrigation reduces unsustainable work-related migration patterns and improves overall food security in Tanzania's Kilombero Valley.

Table 10. SAVi's integrated CBA (in USD millions)

Costs and benefits	Scenarios		
	SAGCOT flood irrigation	**SAGCOT drip irrigation (high CAPEX)**	**SAGCOT drip irrigation (low CAPEX)**
Capital investment	3.26	57.43	29.59
O&M costs	11.53	16.88	16.88
Externality 1: Water costs	89.97	74.71	74.71
Externality 2: Costs of exploiting the additional land, unlocked because of the use of drip irrigation (capital and O&M costs)		15.62	8.23
Externality 3: Avoided SCC		0.34	0.34
Revenue (including additional revenue from unlocked land in case of drip irrigation)	117.65	168.61	168.61
Net benefit	**12.88**	**3.98**	**39.21**

2.6 Natural Infrastructure

2.6.1 OVERVIEW

Natural infrastructure and NbS are terms used to represent a variety of natural assets. These may include mangroves and wetlands, peatland and forests, considering both inland and coastal areas, and more. In SAVi, each type of NbS is represented as a separate module in order to capture asset-specific costs and benefits. As a result, unlike energy or buildings, there are several SAVi NbS models, each different from the others, especially when customization is performed to better represent the local context.

The SAVi model is customized to assess NbS in several ways. First, the SAVi model estimates the value of standing NbS, considering a variety of ecosystem services. Second, it estimates the cost of restoring NbS to provide services up to the amount required. Third, it compares the cost (e.g., O&M) of NbS with the cost required to build, operate, and maintain built infrastructure that would generate the same level of infrastructure services.

2.6.2 DATA NEEDS

The data requirement for NbS varies considerably from asset to asset. The only common data input to all projects is the size of the areas considered. Instead of presenting a generalized table, two examples of SAVi assessments are provided below to better capture the need for customization in data collection.

Table 11. Belgium case study: Planting trees and agroforestry

Investment and O&M
Capital
O&M cost
Total Investment and O&M (1)
Externalities – avoided costs/added benefits
Labour income agriculture & other industries
Value of selected ecosystem services
N removal
P removal
Water retention capacity
Carbon sequestration
Pollination
Total Externalities (2)
Revenues
Wood pellet production/biomass projects
Tourism and landscape
Fodder production
Milk production (reduced heat stress effect)
Agriculture production (windbreaker effect)
Total Revenues (3)

Table 12. Senegal case study: Wetland management

Investment and O&M
Organic agriculture
Mangrove restoration
Road construction
Efficient stoves
Avoided Costs
SCC
From wood fuel use
From sequestration in the wetland
From tractors
From land-based emissions
From road construction and maintenance
Cost of fertilizers
Avoided fuelwood
Added Benefits
Labour income
Labour income agriculture
Labour income from forestry (excluding NTFP)
Labour income fisheries[4]
Labour income industry
Labour income services
Labour income from interventions
Value of ecosystem services provided
N removal
From mangroves
Coastal erosion protection
Extreme weather protection
Carbon sequestration
Tourism, education, and research
From wetland
Edible plant collection
Collecting materials
Amenity and recreation
Water filtering
Biodiversity
Habitat nursery
Water supply
From non-timber forest products
Oil revenues

[4] The model does not predict changes in the labour income from fisheries, as the demand from the population is close to constant, and fish stocks remain constant as well (in the absence of data proving otherwise). Oil extraction potentially has a negative impact on fish stocks, but there was no available data.

2.6.3 EXAMPLE: THE ECONOMIC VALUE OF RESTORING TWO WETLANDS IN SARDINIA, ITALY

2.6.3.1 Description of the Model

The SAVi assessment calculated the economic and societal value generated by the S'Ena Arrubia and Corru S'Ittiri–Marceddì–San Giovanni wetlands in the Gulf of Oristano in Sardinia, Italy. Both wetlands are protected due to the presence of numerous plant and animal species and provide essential ecosystem services. They also contribute to the local economy by enabling agriculture, tourism, fisheries, and aquaculture. SAVi was used to model a range of scenarios and values of the two wetlands: the dollar value of the ecosystem services provided by the wetlands, the dollar value of the labour income generated in connection to the wetlands, and the capital and operating costs of built infrastructure that will provide the same level of services (Bassi, Bechauf et al., 2020). In addition, the assessment studied the financial feasibility of circular economy solutions that reuse agricultural waste and explored the options of retargeting direct income support in the agriculture sector toward improved environmental performance.

2.6.3.2 Key Assumptions

Both wetlands provide a wide range of important ecosystem services: they contribute to water filtration, supply, and flood control; remove nitrogen; provide materials and wildlife habitats; avoid SCC emissions; and have a recreational and amenity value. With the SAVi methodology, the value of these services was estimated. The circular business scenario assumed that half of the livestock manure generated around the wetlands could be reused to produce biogas, pellets, and compost. While biogas and pellets form a renewable energy source, the compost could reduce the local reliance on chemical fertilizers.

2.6.3.3 Results of the Assessment

The assessment included a scenario of continued degradation, where prevailing threats continue to degrade the ecosystem services provided by the wetlands, and a scenario where increased conservation efforts avoid any further damages. The SAVi results estimate that together both wetlands will generate ecosystem services worth EUR 306 million between 2020 and 2060 under the continued degradation scenario, while avoiding the degradation of the wetland quality could generate an additional value of EUR 171 million over this period. The assessment also indicates that reusing part of the livestock manure in the circular business scenario could provide a net benefit of more than EUR 200 million over 40 years.

When compared to the cost of wetland maintenance or the cost of built infrastructure solutions, the wetlands produce substantial economic and societal benefits at an attractive cost, making their conservation a worthwhile investment for local businesses, municipalities, and taxpayers. The results across the two scenarios also show how important the wetlands are for the local economy, as they support considerable labour incomes and tax revenues that are threatened if the wetland quality continues to deteriorate.

3.0 Integration in Vision 2045

3.1 Sectoral Additions

The *Indonesia Vision 2045* (IV2045) model is comprehensive and considers many sectors.[5] On the other hand, it uses a top-down approach, being parametrized with national statistics. For this reason, it misses, in certain instances, asset-specific modules. Below is an indication of the type of modifications that would be required for the integration of SAVi modules into IV2045.

- **Energy**: The IV2045 model includes power generation by technology in a manner analogous to SAVi. On the other hand, IV2045 misses several indicators that are included in SAVi, such as land requirements for the installation, construction, and operation of power generation capacity. It further misses water use and indications of the impact of climate change on both the integrity of the assets and the efficiency of operation (e.g., temperature effect on electricity generation efficiency). On the other hand, employment creation and a few basic air pollutants are included, as is the estimation of the LCOE. As a result, the integration of the SAVi power generation modules in IV2045 would represent an adaptation of the model rather than the addition of a new sector.
- **Buildings**: Buildings are not represented explicitly in IV2045. While energy consumption is captured in the residential and commercial sectors, the building stock and their specific features are not estimated in IV2045. The integration of the SAVi buildings module in IV2045 would require the addition of a module pertaining to the stock of m^2 of buildings, according to their use (e.g., residential, multi-apartment, or detached) and their features (e.g., depending on the level of energy efficiency, considering new green buildings and retrofits). Further, the stock of buildings would need to be disaggregated by energy service, considering the technologies used to provide such services. Examples include lighting and the availability of fluorescent versus LED lights, or heating and cooling, with options for conventional and more energy-efficient infrastructure (e.g., floor heating, centralized versus independent cooling, and energy-efficiency rating for new installations). Adding this level of detail would enable an estimate of various additional indicators, such as employment and air pollution. Other indicators would instead be estimated in more detail, such as in the case of energy consumption or water use.
- **Roads**: The stock of roads is included in IV2045, representing the national road network. The SAVi model includes various types of roads, such as highways, primary, and secondary roads, both paved and unpaved. It further considers the construction process of roads (e.g., layers and depth of each layer) and the materials utilized (e.g., amount of concrete and bitumen for the pavement). Adding this level of detail enables a more accurate estimation of the construction and maintenance costs. It also enables calculations of the impacts of extreme events on road maintenance and can connect this to a government budget. Further, adding precision on the stock of road also supported by spatial analysis allows a better assessment of the relationship

[5] For a description of the model, see Kementerian PPN/Bappenas & Low Carbon Development Indonesia (2019).

between road construction and deforestation in the context of economic development and the GHG emissions inventory.

- **Wastewater**: Wastewater is considered in IV2045 but in an aggregate manner. The SAVi model includes various technologies for wastewater management (e.g., direct filtration and reverse osmosis). The availability of specific technologies increases the accuracy of cost estimation as well as the identification of potential synergies (e.g., the creation of sludge could be estimated and then used for the calculation of waste-to-energy streams). The use of specific wastewater technologies coupled with a spatial assessment would support the analysis of water pollution and related economic and health implications.
- **Irrigation**: Irrigation is currently not included in IV2045. Analyzing water dynamics with a national model is very difficult, and often it is advisable not to include an in-depth assessment of water demand and supply in such a top-down model. This is because the average values obtained at the national level are not representative of the potential issues, with water scarcity faced at the local level, in the same way as the issues arising from flooding in a local landscape cannot be fully appreciated with a macro approach. Adding SAVi irrigation to IV2045 requires determining water demand for irrigation using a spatially explicit approach. Once the demand for irrigation is established, the use of different irrigation technologies can be assessed (i.e., flood, centre pivot, and drip), considering capital and O&M costs and resulting impacts on land productivity and water availability for other uses. The SAVi irrigation module is best applied at the local level or, primarily in the context of Indonesia, at the district level.
- **Natural infrastructure**: There are a few modules related to natural infrastructure in IV2045. Land, including primary and secondary forest and mangroves, is used to estimate a variety of ecosystem services, with the use of multipliers obtained from the literature. The level of ecosystem services is estimated with InVEST, as is habitat quality. Hence, it uses a spatially explicit approach. The integration of SAVi NbS in IV2045 would improve an assessment of the contribution of specific assets to the provisioning of ecosystem services, employment creation, and, in essence, the extent to which NbS enable economic and social activity. Practically, the main difference when using SAVi will be the replacement of generalized ecosystem services and economic valuation multipliers from national and regional literature to more context-specific values. This will enable the creation of a full CBA for each NbS rather than limiting the analysis only to the value currently being provided by natural infrastructure.

3.2 Resulting Analysis

Adding SAVi modules to IV2045 will increase the number of indicators available to assess the potential outcomes of national and sectoral development and investment plans. The advantage of the existing SAVi modules is that these can be used not only to inform strategy development but also to support the creation of an investment strategy in the phase of policy implementation. SAVi enables an estimate of the outcomes of specific investments with the identification of its beneficiaries and can hence support the creation of a project financing strategy.

3.2.1 SECTORAL LEVEL (ASSET BY ASSET)

The SAVi roads module values the time saved for transportation investments. For example, an assessment of a public bike-sharing program in India showed that investing in bicycle infrastructure could save between 1,160.32 and 2,497.28 hours every day, valued at INR 168,910–363,532/day (Wuennenberg, Bassi, & Pallaske, 2020). Similarly, in Senegal, the value of time saved associated with the Bus Rapid Transit System is between CFA 424,614 million and 657,517 million over the project lifetime (Bassi, Cassier et al., 2019). This value of time saved can translate into an increase in productivity.

Air pollution is another externality not typically included in CBAs that affects economic productivity. The SAVi model can value air quality associated with vehicle emissions, energy generation, and buildings. For the wind farm in Germany, the health costs of air pollution were calculated to be EUR 0.93/MWh, compared to EUR 4.53/MWh for the gas-fired power plant (Uzsoki et al., 2020). These health costs correspond to a loss of productivity. In Johannesburg, South Africa, the SAVi tool was used to value the indoor air quality of buildings. Results showed that under a high climate change scenario, a sustainable building avoided ZAR 4,678.85 in lost labour productivity due to heat stress.

The SAVi model values carbon emissions using the SCC. The SCC is the economic cost of an additional tonne of carbon dioxide equivalent emitted. It is only possible to include this cost if the emissions of a project are quantified. SAVi simulates the life-cycle emissions of a project and can compare this to the emissions of project alternatives. In this way, the model shows the economic costs—which affect total factor productivity—of GHG emissions from infrastructure investments. Climate change poses risks to infrastructure. For example, increases in temperature reduce thermal energy production efficiency. The SAVi model demonstrated that compared to a scenario without climate change, a 1.5°C increase in temperature would require a gas-fired power plant in Germany to consume additional fuel at a cost of EUR 3.54 million over a 40-year lifetime (Uzsoki et al., 2020). This increased cost in generation may increase energy costs for consumers. In contrast, temperature does not affect the onshore wind farms (Uzsoki et al., 2020). Considering the impact of temperature on energy generation efficiency shows how climate change may raise costs for consumers and how this could limit spending in other areas.

Job creation and spending generated through infrastructure investments are inputs for GDP calculations. Not only can this reduce unemployment, but spending generates benefits through increased economic activity. SAVi can quantify the number of jobs created and the increase in discretionary spending associated with infrastructure projects.

Many infrastructure projects impact land use. In Albania, flooding agricultural land for hydropower would eliminate production in these areas while also reducing tax revenues and discretionary spending due to lost agricultural employment (Wuennenberg, Bassi, Perera, et al., 2020). In Germany, it was shown that a gas-fired power plant would reduce agricultural production by EUR 0.03 million and that a wind farm would reduce agricultural production by EUR 0.18 million (Uzsoki et al., 2020). Simulating the land needed for these investments and valuing land-use changes using the opportunity cost of lost agricultural production can show how externalities from infrastructure projects may affect production in other sectors of the economy.

Other land-use impacts include a loss of biodiversity and habitat. Deforestation for the Pan Borneo Highway would reduce ecosystem services important for ecotourism and local livelihoods, both of which contribute to the national economy (Guzzetti et al., 2020). Quantifying the cost of biodiversity loss allows for these impacts to be considered in GDP calculations.

A traditional CBA does not include infrastructure externalities that may affect tourism and recreation, although they can be important parts of the economy. The SAVi model was used to assess the impact of treating wastewater that reaches Lake Beira in Colombo, Sri Lanka, and dredging the lake to remove nutrients. These interventions were shown to increase spending on recreation by the local population by more than USD 1.2 million and tourist spending by more than USD 18 million over the course of 10 years (Bassi, Perera et al., 2019). In Malaysia, the Pan Borneo Highway could increase tourism spending by USD 2.225 billion over 25 years (Guzzetti et al., 2020). In Albania, hydropower construction would reduce tourism. This would decrease business activity in the tourism sector, tax revenues from tourism, and discretionary spending from employment related to tourism (Wuennenberg et al., 2020). Including these impacts on tourism and recreation in an assessment shows how infrastructure projects can affect employment and economic activity.

SAVi can demonstrate that infrastructure externalities may generate benefits in one sector of the economy while negatively affecting another. For example, road construction in the Saloum Delta in Senegal creates jobs and income, valued at CFA 297,258 million but also increases social costs from carbon emissions by CFA 18,737 million (Bassi, Cassier et al., 2020). By quantifying these externalities, the SAVi model allows for the trade-offs to be considered in terms of their impacts on productivity, employment, and GDP.

National-level macroeconomic planning can use SAVi outputs such as job creation and increased spending. SAVi quantifies several additional externalities that directly or indirectly influence public finances and GDP. Other important outputs include energy prices from the energy mix, including and excluding externalities, as well as carbon emissions and changes in ecosystem services, which are already considered in the estimation of GDP in the IV2045 model.

3.2.2 NATIONAL-LEVEL POLICIES, STRATEGIES, AND ASSESSMENTS: SCALING-UP ASSET SPECIFIC DYNAMICS

The sections above have highlighted the specific contribution of each SAVi asset to the analysis currently performed with IV2045. It is important to mention that including these assets in IV2045 can bridge the current top-down approach with a bottom-up one. This will be critical if the goal for the future use of IV2045 is to inform the implementation of strategies, supporting the prioritization of investments and the creation of plans for financing projects (considering budget constraints, as well as the many and varied beneficiaries of such projects). At the moment, IV2045 is only used to inform strategy formulation rather than implementation.

A challenge is the scale-up of asset-specific dynamics at the national level. On the one hand, both SAVi and IV2045 could be used in isolation. In this scenario, IV2045 would be used to formulate a high-level strategy, and SAVi would be used to assess the economic viability of specific shortlisted projects. On the other hand, if SAVi assets are integrated into IV2045, this could be performed by focusing on large flagship projects or on an aggregation of projects across the country. The former approach (large flagship projects) would be a standard application of the SAVi model with the addition of macroeconomic impacts (e.g., employment and value additions). The latter approach (aggregation of projects) requires more research on the different project outcomes, depending on location and project design, because the impacts on different socio-economic and ecological contexts will differ. IISD has developed a database,[6] and others are also available, on the methods and values for ecosystem service valuation. In the absence of specific data on the projects in different locations, an average value could be extracted from the database to approximate the performance of the project portfolio.

[6] https://www.iisd.org/publications/savi-database-primer

References

Aburto-Oropeza, O., Ezcurra, E., Danemann, G., Valdez, V., Murray, J., & Sala, E. (2008). Mangroves in the Gulf of California increase fishery yields. *Proceedings of the National Academy of Sciences, 105*(30), 10456–10459. https://doi.org/10.1073/pnas.0804601105

Alvarado, O. A. (2020, July). A review of quantitative tools for measuring multiple urban ecosystem services. *SMC Magazine Special Issue: Climate Change Mitigation and Adaptation for Urban and Rural Landscapes, 1*, 31–35.

Barbier, E. B., Hacker, S. D., Kennedy, C., Koch, E. W., Stier, A. C., & Silliman, B. R. (2011). The value of estuarine and coastal ecosystem services. *Ecological Monographs, 81*(2), 169–193. https://doi.org/10.1890/10-1510.1

Bassi, A., Bechauf, R., Pallaske, G., Perera, O., Statzu, V., & Uzsoki, D. (2020). *An application of the Sustainable Asset Valuation (SAVi) methodology: Assessing the economic value of restoring the wetlands of S'Ena Arrubia and Corru S'Ittiri–Marceddì–San Giovanni in the Gulf of Oristano in Sardinia, Italy*. International Institute for Sustainable Development. https://www.iisd.org/publications/savi-wetlands-sardinia-italy?q=library/savi-wetlands-sardinia-italy

Bassi, A., Casier, L., Pallaske, G., Perera, O., & Uzsoki, D. (2018). *Sustainable Asset Valuation of the Southern Agricultural Growth Corridor of Tanzania (SAGCOT) initiative: A focus on irrigation infrastructure*. International Institute for Sustainable Development. https://www.iisd.org/savi/project/southern-agricultural-growth-corridor-of-tanzania

Bassi, A. M., Casier, L., Pallaske, G., Perera, O., & Bechau, R. (2020). *Sustainable Asset Valuation (SAVi) of Senegal's Saloum Delta*. International Institute for Sustainable Development. https://www.iisd.org/system/files/2020-08/savi-saloum-delta-senegal.pdf

Bassi, A. M., Casier, L., Pallaske, G., & Uzsoki, D. (2019). *Sustainable Asset Valuation (SAVi) of the Bus Rapid Transit Project in Senegal*. International Institute for Sustainable Development. https://www.iisd.org/publications/sustainable-asset-valuation-savi-bus-rapid-transit-project-senegal

Bassi, A., Perera, O., Wuennenberg, L., & Pallaske, G. (2019). *An application of the Sustainable Asset Valuation (SAVi) methodology in Sri Lanka: Assessing the economic value of restoring the ecological health of Beira Lake in Colombo*. https://www.iisd.org/savi/project/beira-lake-colombo-sri-lanka/

Dehghani, M., Farshchi, P., Danekar, A., Karami, M., & Aleshikh, A. A. (2010). Recreation value of Hara Biosphere Reserve using Willingness-to-pay method. *International Journal of Environmental Research, 4*(2), 271–280.

De Groot, R.S, Wilson, M.A., Boumans, R.M.J. (2002). A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics, 41*(3), 393–408.

Estrada, G. C. D., Soares, M. L. G., Fernadez, V., & de Almeida, P. M. M. (2015). The economic evaluation of carbon storage and sequestration as ecosystem services of mangroves: A case study from southeastern Brazil. *International Journal of Biodiversity Science, Ecosystem Services & Management, 11*(1), 29–35. https://doi.org/10.1080/21513732.2014.963676

Goldstein, J. H. (2012). *Integrating ecosystem-service tradeoffs into land-use decisions*. Proceedings of the National Academy of Sciences, 109(19).

Guzzetti, M., Schlageter, A., Perera, O., & Wuennenberg, L. (2020). *Are investments in road infrastructure on Borneo a sustainable recovery strategy for Malaysia?* International Institute for Sustainable Development. https://www.iisd.org/sustainable-recovery/wp-content/uploads/2020/10/savi-sustainable-recovery-borneo.pdf

Kaiser, G., Scheele, L., Kortenhaus, A., Løvholt, F., Römer, H., & Leschka, S. (2011). The influence of land cover roughness on the results of high resolution tsunami inundation modeling. *Natural Hazards and Earth System Sciences, 11*(9), 2521–2540. https://doi.org/10.5194/nhess-11-2521-2011

Kauffman, J. B., Adame, M. F., Arifanti, V. B., Schile-Beers, L. M., Bernardino, A. F., Bhomia, R. K., Donato, D. C., Feller, I. C., Ferreira, T. O., Jesus Garcia, M. del C., MacKenzie, R. A., Megonigal, J. P., Murdiyarso, D., Simpson, L., & Hernández Trejo, H. (2020). Total ecosystem carbon stocks of mangroves across broad global environmental and physical gradients. *Ecological Monographs, 90*(2). https://doi.org/10.1002/ecm.1405

Kementerian PPN/Bappenas & Low Carbon Development Indonesia. (2019). *Low carbon development: A paradigm shift towards a green enocomy in Indonesia: Full report*. http://greengrowthknowledge.org/national-documents/low-carbon-development-report-paradigm-shift-towards-green-economy-indonesia

Kuenzer, C., & Vo, T. (2013). Assessing the ecosystem services value of Can Gio Mangrove Biosphere Reserve: Combining earth-observation- and household-survey-based analyses. *Applied Geography, 45*, 167–184. https://doi.org/10.1016/j.apgeog.2013.08.012

Laso Bayas, J. C., Marohn, C., Dercon, G., Dewi, S., Piepho, H. P., Joshi, L., van Noordwijk, M., & Cadisch, G. (2011). Influence of coastal vegetation on the 2004 tsunami wave impact in west Aceh. *Proceedings of the National Academy of Sciences, 108*(46), 18612–18617. https://doi.org/10.1073/pnas.1013516108

Menéndez, P., Losada, I. J., Torres-Ortega, S., Narayan, S., & Beck, M. W. (2020). The global flood protection benefits of mangroves. *Scientific Reports, 10*(1), 4404. https://doi.org/10.1038/s41598-020-61136-6

Sharp, R., Chaplin-Kramer, R., Wood, S., Guerry, A, Tallis, H., & Ricketts, T. (Eds.). (2020). *InVEST User's Guide 3.5.0*. The Natural Capital Project, Stanford University, Univristy of Minnesota, The Nature Conservancy, & World Wildlife Fund. http://invest-userguide.readthedocs.io/_/downloads/en/3.6.0/pdf/

The Economics of Ecosystems and Biodiversity (TEEB). (2010). *The Economics of Ecosystems and Biodiversity ecological and economic foundations*. Pushpam Kumar (Ed.). Earthscan.

Uzsoki, D., Wuennenberg, L., Perera, O., Bassi, A., & Pallaske, G. (2020). *Sustainability assessment of an onshore wind portfolio in Germany: An application of the Sustainable Asset Valuation (SAVi) for B Capital partners*. International Institute for Sustainable Development. https://www.iisd.org/savi/project/onshore-wind-parks-in-germany/

Walton, M. E. M., Samonte-Tan, G. P. B., Primavera, J. H., Edwards-Jones, G., & Le Vay, L. (2006). Are mangroves worth replanting? The direct economic benefits of a community-based reforestation project. *Environmental Conservation, 33*(4), 335–343. https://doi.org/10.1017/S0376892906003341

Wang, M., Zhang, J., Tu, Z., Gao, X., & Wang, W. (2010). Maintenance of estuarine water quality by mangroves occurs during flood periods: A case study of a subtropical mangrove wetland. *Marine Pollution Bulletin, 60*(11), 2154–2160. https://doi.org/10.1016/j.marpolbul.2010.07.025

Wuennenberg, L., Bassi, A. M., & Pallaske, G. (2020). *Sustainable Asset Valuation (SAVi) of a public bicycle sharing system in Dwarka, New Delhi, India*. International Institute for Sustainable Development. https://www.iisd.org/system/files/publications/savi-dwarka-india-bicycle-sharing-en.pdf

Wuennenberg, L., Bassi, A. M., Perera, O., Uzsoki, D., Pallaske, G., & Rugova, Q. (2020). *Sustainable Asset Valuation of the Kalivaç and Poçem hydropower projects: Assessing the environmental, social and economic impacts of energy pathways in Albania*. International Institute for Sustainable Development. https://www.iisd.org/system/files/2020-08/savi-hydropower-albania.pdf

Yanagisawa, H., Koshimura, S., Miyagi, T., & Imamura, F. (2010). Tsunami damage reduction performance of a mangrove forest in Banda Aceh, Indonesia inferred from field data and a numerical model. *Journal of Geophysical Research, 115*(C6). https://doi.org/10.1029/2009JC005587

Annex A. Method and Data Requirement for SAVi Land and Forest Rehabilitation

This annex illustrates the method and data requirement for a SAVi land and forest rehabilitation model in Indonesia.

Overview

We propose to carry out the following analysis to quantify the expected costs and benefits of improved land and water management considering changes in precipitation up to 2050:

1. Quantification of ecosystem services (biophysical value). The ecosystem services considered are:
    a. Soil erosion
    b. Water retention:
        i. Agriculture production
        ii. Floods (rainy season)
    c. Water supply (dry season)
    d. Carbon sequestration
    e. Nutrient uptake
2. Economic valuation of ecosystem services and co-benefits (positive externalities)
    a. Soil erosion: Land productivity, production, and revenues; job creation and income generation
    b. Water retention:
        i. Agriculture production: land productivity
        ii. Floods (rainy season): damage to agriculture and households
    c. Water supply (dry season): industrial production value and employment
    d. Carbon sequestration: carbon price related to reforestation projects
    e. Nutrient uptake: cost of water pollution for the environment and humans
    f. Agroforestry production: revenues and income generation
    g. Bamboo value-added products: export value
3. Integrated cost-benefit analysis to quantify the costs and benefits of nature-based infrastructure
    a. Simulation of different scenarios for precipitation using monthly time steps to 2040 and 2050 from an ensemble of global circulation models for the Representative Concentration Pathway (RCP) 4.5 and RCP 8.5 scenarios

Data Requirements

Quantification of ecosystem services (biophysical value)

- Land cover map
- Watershed and subwatershed delineation
- Precipitation and scenarios to use for future precipitation
- Parameters (e.g., for each land cover class) to estimate soil erosion, carbon sequestration, water retention, and nutrient uptake
- Agriculture production, by crop, based on land and land productivity (e.g., per hectare)

Economic valuation of ecosystem services and co-benefits (positive externalities)

- Farm price of crop production, including the cost of production input
- Average income per person per year for agricultural and non-agricultural activities
- Flood damage to agriculture and households based on case studies
- Foregone production value and employment for the reduction of economic activity due to water shortages in the dry season
- Carbon price related to reforestation projects
- Environmental cost of nutrient export
- Agroforestry revenue and employment per hectare
- Export value of bamboo products
- Income tax rate
- Discretionary spending rate

Methods for Estimating Ecosystem Services

CARBON STORAGE

Model

The InVEST model[7] estimates carbon stored in aboveground and belowground biomass, organic matter, and soil.

Inputs

- Land use/land cover: with associated carbon density aboveground, belowground, in organic matter and in soils
- Watersheds (boundaries): main and subwatersheds for points of interest

Outputs

- Total carbon stored (mg): the amount of carbon stored per pixel in the subwatershed

[7] For more on the InVEST model, see Sharp et al. (2018).

Approach

Two scenarios are considered. The only variable that will change is land-use/land-change maps:

1) **Business as usual (BAU)**: loss of 22,336 ha of forest
2) **Reforestation**: reforestation of 3,697 ha with no forest loss

The goal is to understand the impacts of reforested areas on carbon storage.

WATER RETENTION

Model

The InVEST model calculates the runoff reduction (i.e., the amount of runoff retained per pixel compared to the storm volume).

Inputs

- Climate variables: depth of rainfall in mm
- Soil proprieties: soils hydrological group raster
- Land use/land cover: with associated curve number values
- Watersheds (boundaries): main and subwatersheds for points of interest

Outputs

- Runoff_retention_m3.tif: raster with runoff retention values (in m^3)

Approach

Two land-use scenarios and three monthly rainfall scenarios will be considered for a total of 72 simulations. The only variables that will change are land-use land-change maps and monthly rainfall.

1) **BAU**: loss of 22,336 ha of forest for monthly high, low, and current rainfall
2) **Reforestation**: reforestation of 3,697 ha with no forest loss for monthly high, low, and current rainfall

The goal is to understand the impacts of reforested areas on runoff retention.

NUTRIENT EXPORT

Model

The InVEST model calculates the total nitrogen and phosphorus export from the watershed.

Inputs

- Digital elevation model raster: hydrologically conditioned elevation dataset
- Land use/land cover: with associated water quality coefficients
- Nutrient runoff proxy raster: average annual precipitation
- Watersheds (boundaries): main and subwatersheds for points of interest

- Threshold flow accumulation: minimum number of upstream cells that flow into a cell for the cell to be considered part of a stream
- Subsurface maximum retention efficiency: nutrient retention efficiency for nitrogen and phosphorus
- Subsurface_crit_len: distance travelled subsurface and downslope at which soil retains nitrogen or phosphorus at maximum capacity
- Borseli K parameter: calibration parameter

Outputs

- N_export_tot (tonnes/pixel): total nitrogen export from the watershed
- P_ export_tot (tonnes/pixel): total phosphorus export from the watershed

Approach

Two simulations will be considered. The only variables that will change are land-use/land-change maps:

3) BAU: loss of 22,336 ha of forest
4) Reforestation: reforestation of 3,697 ha with no forest loss

The goal is to understand the impacts of reforested areas on nutrient export.

SEDIMENT RETENTION

Model

The InVEST model calculates the total sediment retention in the watershed.

Inputs

- Digital elevation model raster: hydrologically conditioned elevation dataset
- Rainfall erosivity index raster: a measure of erosion potential, dependent on rainfall intensity and duration
- Soil erodibility raster: measure of susceptibility of soil particles to detachment and transport
- Land use/land cover: with associated management and sediment information
- Watersheds (boundaries): main and subwatersheds for points of interest
- Threshold flow accumulation: minimum number of upstream cells that flow into a cell for a cell to be considered part of a stream
- Borseli K parameter and Borseli IC0 parameter: two calibration parameters
- Max Sediment Delivery Ratio (SDR) value: parameter used for calibration

Outputs

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

Approach

Two simulations will be considered. The only variables that will change are land-use/land-change maps:

5) **BAU**: loss of 22,336 ha of forest
6) **Reforestation**: reforestation of 3,697 ha with no forest loss

The goal is to understand the impacts of reforested areas on soil retention.

DIRECT RUNOFF VOLUME

Model

The HEC-HMS model simulates runoff volume within a subset of the InVEST study area.

Inputs

- Digital elevation model raster: hydrologically conditioned elevation dataset
- Land use/land cover: with associated curve number values
- Precipitation

Outputs

- Direct runoff volume (1,000 m^3): total runoff for a single precipitation event
- Peak discharge (m^3/s): maximum discharge speed for a single precipitation event

Approach

Two land-use scenarios and 18 rainfall event sizes will be considered for a total of 36 simulations. The only variables that will change are land-use/land-change maps and precipitation.

7) **BAU**: loss of 22,336 ha of forest for 18 rainfall event sizes between 45.25 mm and 108 mm
8) **Reforestation**: reforestation of 3,697 ha with no forest loss for 18 rainfall event sizes between 45.25 mm and 108 mm

The goal is to understand the impacts of reforestation and retention wells on runoff.

Methods for Valuing Ecosystem Services

IMPACTS OF SOIL EROSION ON AGRICULTURAL PRODUCTION

Assumptions

- Baseline agricultural income is IDR 17.3 million/year/hectare.
- Erosion causes damage for 5 years after any year with 3,200 mm of rainfall.
- Reforestation reduces agricultural income loss by 6% in the first year after any year with 3,200 mm of rainfall. The annual avoided percent loss linearly decreases to 0% over 5 years.

Calculations

The annual benefit of avoided soil erosion is equal to the baseline agricultural income multiplied by the avoided agricultural income loss.

Scenarios

Two climate scenarios are considered (RCP 4.5 and RCP 8.5) for annual rainfall.

IMPACTS OF WATER RETENTION ON AGRICULTURAL PRODUCTION

Assumptions

- Additional water retention is available to meet irrigation requirements for maize and soybean.
- Additional water retention has no impact on rice production.
- Baseline maize income is IDR 350 billion/year.
- Baseline soybean income is IDR 13.8 billion /year/hectare.

Calculations

The CropWat model calculates percent yield reduction using rainfall and irrigation scenarios. The benefit of additional water retention is the change in yield reduction with more water available to meet irrigation requirements multiplied by the baseline agricultural income.

Scenarios

Three scenarios are considered: (i) current monthly rainfall, (ii) high future monthly rainfall, and (iii) low future monthly rainfall. Using the RCP 4.5 and RCP 8.5 climate scenarios, any year with less than the current annual rainfall is assumed to gain the benefit associated with the low future monthly rainfall scenario.

IMPACTS OF DIRECT RUNOFF VOLUME ON FLOODING

Assumptions

- Percent reduction in flood damage is equal to the average percent reduction in direct runoff volume.
- Rainfall that contributes to flooding is total monthly rainfall above 600 mm.
- Inundated area is calculated from monthly rainfall over 600 mm using the following equation: $\text{inundated area} = (0.012 \times \text{rainfall}^3 - 1.55 \times \text{rainfall}^2 + 76.25 \times \text{rainfall}) / 0.41$

Scenarios

Two climate scenarios are considered (RCP 4.5 and RCP 8.5) for monthly rainfall.

AGRICULTURE

Assumptions

- The agricultural area inundated is equal to 41% of the total area inundated.

- Agricultural productivity decreases by 10% on inundated land.
- Baseline agricultural income is IDR 17.3 million/year/hectare.

Calculations

Annual avoided agricultural damage is equal to the percent reduction in flood damage multiplied by the agricultural area inundated multiplied by the baseline agricultural income multiplied by the agricultural productivity decrease.

HOUSEHOLDS

Assumptions

- The number of inundated households is equal to 3.76 times the inundated area.
- The average damage per household per flood event is IDR 525,174.

Calculations

Annual avoided agricultural damage is equal to the percent reduction in flood damage multiplied by the number of households inundated multiplied by the average damage per household.

Scenarios

Two climate scenarios are considered (RCP 4.5 and RCP 8.5) for annual rainfall.

IMPACTS OF GROUNDWATER RECHARGE ON INDUSTRY

Assumptions

- 0.5% of water retention not used by crops is available to increase industrial production.
- Industrial activity benefits from additional water availability in any year with less than 30 mm of rainfall in August–October.

Scenarios

Two climate scenarios are considered (RCP 4.5 and RCP 8.5) for annual and monthly rainfall.

PRODUCTION VALUE

Assumptions

- Industrial production value increases by IDR 1,940,00 trillion for every additional m^3 of groundwater available.

Calculations

The value of additional water availability is water retention available to increase industrial production multiplied by industrial production value per m^3 of groundwater.

EMPLOYMENT

Assumptions

- Employment increases by 28.5 billion people for every additional m^3 of groundwater available.

Calculations

Employment due to additional water availability is water retention available to increase industrial production multiplied by employment per m^3 of groundwater.

VALUE OF CARBON STORAGE

ASSUMPTIONS

- The value of carbon storage is equal to USD 3.3/tonne (based on the historical REDD+ carbon price in Indonesia).

Calculations

The value of carbon storage is equal to additional carbon stored in the reforestation scenario compared to the BAU scenario multiplied by the REDD+ carbon price.

VALUE OF NUTRIENT RETENTION

Assumptions

- The value of nitrogen retention is equal to EUR 4,612/tonne (the avoided environmental costs and damages of nitrogen reaching a sea destination).
- The value of phosphorus retention is equal to EUR 7,533/tonne (the avoided environmental costs and damages of phosphorus reaching a sea destination).

Calculations

The value of nutrient retention is equal to additional nitrogen and phosphorus stored in a reforestation scenario compared to the BAU scenario multiplied by the avoided environmental costs and damages.

VALUE OF AGROFORESTRY PRODUCTION

Assumptions

- Agroforestry revenue is IDR 3.82 million/ha.
- Agroforestry is established on 3,697 ha.

Calculations

The value of agroforestry revenue is equal to revenue per hectare multiplied by agroforestry area.

THE VALUE OF BAMBOO PRODUCTS

Assumptions

- The export value of bamboo is IDR 1.34 million/year/ha.
- Bamboo plantations are established on 130 ha.

Calculations

The value of bamboo plantations is equal to the export value per hectare multiplied by the bamboo forest area.

ADDITIONAL EMPLOYMENT

Assumptions

- Agroforestry creates 0.25 jobs/ha.
- Average agroforestry wages are IDR 15.5 million/person/year.
- Average industrial wages are IDR 35.2 million /person/year.
- The personal income tax rate is 5%.
- The discretionary spending rate is 22.6%.

Calculations

Total additional wages are equal to additional industrial employment multiplied by industrial wages plus total agroforestry jobs multiplied by agroforestry wages. Additional income tax is equal to total additional wages multiplied by the personal income tax rate. Additional discretionary spending is equal to total additional wages multiplied by discretionary spending rate.

Scenarios

Two climate scenarios are considered (RCP4.5 and RCP8.5) for industrial employment from water retention.

Annex B. Method and Data Requirement for SAVi Mangrove Restoration

This annex illustrates the method and data requirement for a SAVi mangrove restoration model in Indonesia.

Overview

Mangroves provide many services, including flood protection, carbon sequestration, water purification, erosion control, timber and non-timber forest products, fisheries maintenance, and tourism and recreation. There are a variety of methods for quantifying these benefits. Below, we summarize the results of some studies from the global literature on mangrove co-benefits. These indicators can be customized for a specific location.

Co-Benefits of Mangroves

FLOOD PROTECTION

- Globally, mangroves can reduce flood property damage by 7.8%–9.9% (Menéndez et al., 2020).
- Globally, mangroves can reduce area flooded by 25.6%–29.8% (Menéndez et al., 2020).
- In Indonesia, mangroves between settlements and the coast were found to have reduced casualties from the 2004 tsunami by 8% (Laso Bayas et al., 2011).
- In Thailand, mangroves were shown to reduce tsunami inundation flow velocity by up to 50% (Kaiser et al., 2011).
- In Indonesia, a 10-year-old, 500-metre wide mangrove forest can reduce the hydrodynamic force of a 3-metre-deep tsunami by 70% and reduce the inundation depth by 38%. The percent reductions are much lower for a tsunami inundation depth greater than 4 m (Yanagisawa et al., 2010).

CARBON SEQUESTRATION

- Mangroves store an average of 856.1 mg C/ha (Kauffman et al., 2020).
- In Brazil, mangrove carbon sequestration values ranged from USD 19 to USD 82/ha using REDD+ and Clean Development Mechanism valuations (Estrada et al., 2015).
- In the Philippines, Rhizophora mangrove forests store 15 t C/ha/year in biomass and 1.5 t C/ha/year in soil (Walton et al., 2006).

WATER QUALITY

- In China, it was estimated that mangroves could trap 90.5 g nitrogen/m^2/year and 2.2 g phosphorus/m^2/year (Wang et al., 2010).
- Wastewater from 1 hectare of intensive shrimp farming can be filtered by 22 ha of mangroves (Kuenzer & Vo, 2013).

COASTAL EROSION

- In Thailand, the annualized cost of using grey infrastructure to replace the erosion control services of mangroves is estimated to be USD 3,679 per hectare per year (Barbier et al., 2011).
- The average erosion control value of mangroves is USD 11,690/ha/year (Kuenzer & Vo, 2013).

RAW MATERIALS AND FOOD

- In Thailand, products collected from mangroves have been estimated to have a value of USD 484–585/ha/year (Barbier et al., 2011).
- In Vietnam, the average value of timber products collected from the Can Gio mangrove was USD 1,457/household/year (Kuenzer & Vo, 2013).

FISHERIES MAINTENANCE

- The value of mangroves to fisheries has been estimated at between USD 70 and USD 13,223/ha. The wide variation is due to the differences between mangrove systems, difficulties with attributing the proportion of coastal fisheries that benefit from mangroves, and difficulties with monitoring fisheries landings (Walton et al., 2006).
- In Mexico, mangroves in the Gulf of California contribute USD 25,149 per km of mangrove fringe per year (Aburto-Oropeza et al., 2008).

TOURISM AND RECREATION

- The Har Biosphere Reserve in Iran was estimated to attract 154,943 visitors every year, giving the mangrove forest a recreation value of USD 97 per hectare per year (Dehghani et al., 20110).
- In Vietnam, the tourism value of Can Gio mangroves was estimated to be USD 104.4 million/year (Kuenzer & Vo, 2013).

Data Requirements

QUANTIFICATION OF ECOSYSTEM SERVICES (BIOPHYSICAL VALUE)

- Land-cover map
- Watershed and subwatershed delineation
- Precipitation and scenarios to use for future precipitation
- Parameters (e.g., for each land-cover class) to estimate soil erosion, carbon sequestration (blue carbon in this case)

ECONOMIC VALUATION OF ECOSYSTEM SERVICES AND CO-BENEFITS (POSITIVE EXTERNALITIES)

- The farm price of crop production, including costs of production input (for the estimation of foregone revenue if productive land is to be used for mangrove restoration)

- The average income per person per year for agricultural and non-agricultural activities (potentially including fisheries, likely increasing in the case of mangrove restoration)
- Flood damage to agriculture and households based on case studies (expected to decline due to improve coastal resilience)
- The carbon price related to mangrove restoration projects
- The environmental cost of nutrient export

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