SAVi Sustainable Asset Valuation

Sustainable Asset Valuation (SAVi) of Senegal's Saloum Delta

An economic valuation of the contribution of the Saloum Delta to sustainable development, focussing on wetlands and mangroves

SUMMARY OF RESULTS

IISD International Institute for Sustainable Development

MAVA Fondation pour la Nature

SAVi Sustainable Asset Valuation

Wetlands International

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Written by Andrea M. Bassi, Liesbeth Casier, Georg Pallaske, Oshani Perera, and Ronja Bechau

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About SAVi

SAVi is a simulation service that helps governments and investors value the many risks and externalities that affect the performance of infrastructure projects.

The distinctive features of SAVi are:

- Valuation: SAVi values, in financial terms, the material environmental, social and economic risks and externalities of infrastructure projects. These variables are ignored in traditional financial analyses.
- Simulation: SAVi combines the results of systems thinking and system dynamics simulation with project finance modelling. We engage with asset owners to identify the risks material to their infrastructure projects and then design appropriate simulation scenarios.
- Customization: SAVi is customized to individual infrastructure projects.

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Executive Summary

This report provides the results and technical background of the Sustainable Asset Valuation (SAVi) assessment of the Saloum Delta. The assessment provides an economic valuation of the contribution of the Saloum Delta to local livelihoods and regional development. It assesses a range of scenarios and simulates how these scenarios affect the economic contribution of the delta.

Table E1 provides the summary results of the impacts of organic agriculture, mangrove restoration, road construction, solar cookstoves, and oil extraction. These scenarios demonstrate cumulative value over 40 years compared to business as usual.

Table E1. Summary integrated CBA, cumulative values 2020–2060 (1)

Integrated cost–benefit analysis (mn CFA)	Organic agriculture	Mangrove reforestation	Road construction	Solar cookstoves	Oil extraction
Total investment and operation and management (O&M) (1)	**951**	**10**	**19,625**	**2,758**	**0**
Avoided costs					
Social cost of carbon	18,033	12,986	-18,737	33,620	-15,038
Cost of fertilizers	12,671	-10	259	0	-1,602
Avoided fuelwood	0	0	0	33	0
Subtotal (2)	**30,704**	**12,976**	**-18,478**	**33,653**	**-16,640**
Added benefits					
Labour income	269,442	10,076	297,258	261	64,643
Value of ecosystem services provided	118,687	257,148	2,298	11,789	-297,112
Oil revenues	0	**0**	**0**	0	**554,586,209**
Subtotal (3)	**388,129**	**267,224**	**299,556**	**12,051**	**554,353,740**
Net result (2) + (3) - (1)	**417,883**	**280,190**	**261,453**	**42,946**	**554,337,101**

Table E1 shows that oil extraction leads to significant revenues, but also has a high negative impact on the ecosystem services that the wetland and mangrove area of the Saloum Delta provide. Organic agriculture leads to additional labour income in various sectors while enhancing the performance of the ecosystem services. Mangrove restoration leads to an increased performance of ecosystem services of more than CFA 257,000 million(EUR 391 million). Road construction has a strong impact on labour income in different economic sectors. Solar cookstoves are very effective in reducing greenhouse gas emissions, as is evidenced by an avoided social cost of carbon of more than CFA 33,000 million (EUR 50 million).

Given the economic importance of oil drilling off the coast of the Saloum Delta, stakeholders requested dedicated analyses on how oil extraction is impacting the costs and benefits. We included two additional scenarios to the analysis: one combination of all development interventions excluding, and one including oil extraction. Results are presented in Table E2.

Table E2. Summary integrated CBA, cumulative values 2020–2060 (2)

Integrated cost–benefit analysis (mn CFA)	Development scenarios without oil extraction	Development scenarios with oil extraction
Investment and O&M		
Subtotal (1)	**23,344**	**23,344**
Avoided costs		
Social cost of carbon	46,044	29,451
Cost of fertilizers	12,640	11,111
Avoided fuelwood	33	**33**
Subtotal (2)	**58,717**	**40,595**
Added benefits		
Labour income	587,036	656,356
Value of ES provided	392,527	68,430
Oil revenues	0	554,586,209
Subtotal (3)	**979,563**	**555,310,995**
Net result (2) + (3) - (1)	**1,014,936**	**555,328,246**

This assessment sheds light on the trade-offs for policy-makers and stakeholders when investing in economic development. Natural capital brings a host of long-term gains, some of which are calculated in this study; however, the promise of near-term revenues almost always takes precedence. Moreover, sourcing data to value the full spectrum of ecosystem services—provisioning, regulating, habitat, and cultural services—is always a challenge. The data gap further increases the differences between revenues from economic activity and the benefits from natural capital. The report details the ecosystem services that are valued in this instance.

Different stakeholders are using this study to identify and implement strategies that both protect the Saloum Delta ecosystem and increase revenues from the ecosystem services. The more revenues the ecosystem services can provide, the higher the incentive will be for stakeholders to prioritize its continued maintenance and upgrading.

This report informs this effort in several ways:

- First, it calculates the economic value of ecosystem services.
- Second, it compares the costs of maintaining these ecosystems services with the capital and operating costs of built alternatives. This helps stakeholders understand the infrastructure value of the wetlands and mangroves in financial terms.
- Thirdly, it provides scenario analyses of how the wetland's performance is affected by current development activities. Stakeholders can hence predict how the supply of ecosystem services could change if remedial action is not taken. Having predictability regarding these changes is critical when investigating ways and means to increase revenues from ecosystem services.

The results of the SAVi analysis highlight several potential financing strategies to increase ecosystem-based revenues and, in the same vein, increase the impetus for continued conservation. These strategies include carbon offsets, wider biodiversity credits (perhaps through the establishment of wetland banks), pay-for-performance financing, and pay-as-you-go initiatives. The latter, especially in relation to pay-as-you-go solar stoves and appliances, may be particularly effective in reducing fuelwood harvesting and mangrove deforestation.

How Can Decision-Makers Use This Analysis?

Stakeholders can use this analysis to make a multitude of decisions.

- Policy-makers can use it to make decisions on infrastructure planning, coastal conservation, sustainable agriculture, adaptation to changing climates, and economic development.
- Non-government organizations can use the economic valuations of ecosystem services to fine-tune mangrove restoration and conduct more targeted advocacy for continued conservation of the Saloum Delta.
- Project developers and sponsors of nature-based infrastructure can use the valuations to design conservation finance solutions, potentially raising capital from private investors.
- Public donors and private investors can also use this analysis as a baseline to perform due diligence for grants, concessional lending, and organizing "pay-for-performance" financing solutions.

Details are provided in the table below:

Stakeholder	How this analysis can be used in decision making	Example
Public budget holders **Public policy-makers**	1. Appreciate the economic value generated by the wetland ecosystems in the Saloum Delta. Compare the $ value of these ecosystem services with built alternatives. 2. Appreciate the extent to which revenues from local economic development—fisheries, agriculture, and tourism, for example—are dependent on the ecosystem services provided by the Saloum Delta. 3. Appreciate the $ value of lost ecosystem services due to offshore oil drilling, deforestation, unsustainable agriculture, and road expansion. 4. Make public investment decisions based on the trade-offs that increase the degradation of the Saloum Delta ecosystem. Of particular note is that these ecosystem services will be particularly cost-effective to mitigate the persisting drought, salinization of aquifers, and coastal erosion due to sea-level rise.	The Saloum Wetland generates cumulative ecosystem services worth CFA 964 billion between 2019 and 2029. Cumulative labour income from wetland-derived industrial activity including harvesting, fisheries, agriculture, and tourism amount to CFA 1,973 billion. Plan value-added trade-offs to combine upgrading and reforesting the Saloum wetland with sustainable harvesting, fisheries, and agriculture. In determining value-for-money across the wetland life cycle, note the 40-year cumulative costs of mangrove maintenance of CFA 20 million. Also note the 40-year cumulative total of the social cost of carbon, which is CFA 29,450 million. Note how the value of ecosystem services declines due to damage from oil spills. Consider the establishment of a conservation fund fuelled in part from revenues and royalties from oil extraction.
Nature-based Infrastructure project developers	1. Appreciate the economic value generated by wetland ecosystems in the Saloum Delta. Compare the $ value of these ecosystem services with built alternatives. 2. Appreciate the $ value of lost ecosystem services due to offshore oil drilling, deforestation, agriculture and investments in infrastructure such as roads. 3. Use the analysis as fundamental due diligence to prepare nature-based infrastructure projects and associated business plans. 4. Use the forecasts on the valuation of ecosystem services to improve predictability and compatibility on nature-based infrastructure. Develop financing solutions accordingly	The Saloum Wetland generates cumulative ecosystem services worth CFA 964 billion between 2019 and 2029. To generate the same services with built alternatives, the capital and cumulative operation costs over the next 10 years would be CFA 1,537 million. Determine the effectiveness of different mangrove conservation and exploitation options using the wetland quality index. Note the 40-year cumulative costs of mangrove maintenance, which are CFA 20 million. Also note the 40-year cumulative total of the social cost of carbon, which is CFA 29,450 million.

Stakeholder	How this analysis can be used in decision making	Example
Conservation NGOs	1. Make the economic case for continued and heightened mangrove restoration. 2. Given the high $ value of the ecosystem services provided by the Saloum Delta, increase advocacy for its long-term conservation.	Determine conservation strategies based on the value of the forecast of ecosystem services over 2019 to 2029. For example: Nitrogen removal: CFA 50 billion. Tourism: CFA 18 billion Water filtration: CFA 113.3 billion Carbon sequestration: CFA 72 billion Coastal erosion: CFA 113 billion. Edible plant harvesting: CFA 113 billion Biodiversity: CFA 84 billion
Public and private investors **Public donors**	1. Appreciate the economic value generated by wetland ecosystems in the Saloum Delta. Compare the $ value of these ecosystem services with built alternatives. 2. Appreciate the $ value of lost ecosystem services due to offshore oil drilling, deforestation, agriculture, and investments in infrastructure such as roads. 3. Assess the feasibility of investment opportunities using the scenarios and forecasts of this analysis as baseline due diligence. For example, the feasibility of "pay-for-performance" projects, carbon offsets, mitigation banks, and more. 4. Use as due diligence to make grant and concessional lending decisions. Note that climate change-induced drought, coastal erosion, and salinization of aquifers make the wetland ecosystem a very cost-effective service provider.	The Saloum Wetland generates cumulative ecosystem services worth CFA 964 billion between 2019 and 2029. To generate the same services with built alternatives, the capital and cumulative operation costs over the next 10 years would be CFA 1,537 billion. Determine the effectiveness of different mangrove conservation and exploitation options using the wetland quality index and the soil erosion index. The wetland quality index charts the symbiotic relationship between ecosystem health and reduced mangrove deforestation (through using solar cookstoves), augmented conservation and reforestation, use of more sustainable agriculture practices that reduce runoff from chemical fertilizers and pesticides and finally, the damage caused by oil spills.

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List of Abbreviations

CAP	Common Agricultural Policy
BAU	business as usual
CBA	cost–benefit analysis
CLD	causal loop diagram
CO_2e	carbon dioxide equivalent
FTE	full-time equivalent
GHG	greenhouse gas
GDP	gross domestic product
mn	million
O&M	operation and management
PV	photovoltaic
SAVi	Sustainable Asset Valuation tool
SCC	social cost of carbon

Glossary

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

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

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

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

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

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

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

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

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

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

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

Stock and flow variables: "A *stock* variable represents accumulation and is measured at one specific time. A *flow* variable is the rate of change of the stock and is measured over an interval of time" (UNEP, 2014, p. 51).

System dynamics: A methodology developed by J. Forrester in the late 1950s (Forrester, 1961) to create descriptive models that represent the causal interconnections between key indicators and indicate their contribution to the dynamics exhibited by the system as well as to the issues being investigated. The core pillars of the system dynamics method are feedback loops, delays and non-linearity emerging from the explicit capturing of stocks and flows (UNEP, 2014).

Vertical/horizontal disaggregation of models: Vertically disaggregated models contain a high level of detail on the sectoral level (i.e., energy), while horizontally disaggregated models focus on capturing the interconnections between several sectors and contain less detail on the sectoral level (UNEP, 2014).

1.0 Introduction

This report discusses the results of the Sustainable Asset Valuation (SAVi) assessment of the Saloum Delta. It informs the work of local government, local communities, and civil society organizations in the delta by providing an integrated economic valuation of the ecosystem services and how these services are affected by different development scenarios.

The purpose of this SAVi assessment is to demonstrate the contribution of the Saloum Delta wetland in supporting livelihoods and local development in the region.

First, the analysis estimates the value of ecosystem services provided by the wetland.

Second, it simulates the impact of different development scenarios.

Third, the analysis brings all the information together in an integrated cost–benefit analysis (CBA) (Figure 1).

Fourth, the analysis informs a discussion on blended capital solutions to finance some of the development scenarios.

Figure 1. An integrated cost–benefit approach for the Saloum Delta

The Saloum Delta is a tropical mangrove ecosystem, rich in biodiversity, that provides livelihoods for more than 100,000 inhabitants. Its ecosystem is currently under pressure because of climate change and unsustainable use of the mangrove forests. This has led to coastal erosion and salination issues, threatening local development in the region (Wetlands International, 2019).

About the Saloum Delta

The delta largely falls under the administration of the Fatick region, which has a total of 841,298 inhabitants, about 5% of Senegal's total population in 2018 (République du Sénégal. Ministère, 2019). In the local departments of Fatick and Foundiougne, tourism and fisheries industries are among the key economic sectors. The indicators for the SAVi assessment are based on the area under the jurisdiction of the Foundiougne department (République du Sénégal, 2017).

The Sine-Saloum Delta has been designated as a UNESCO Biosphere Reserve since 1980 (UNESCO, n.d.) and as a World Heritage Site since 2011 (UNESCO, 2011).

IISD conducted this SAVi assessment in collaboration with Wetlands International–Africa, with the financial support of the MAVA Foundation.

2.0 The Economic Valuation of the Saloum Delta

Figure 2 illustrates the integrated approach to economic valuation of the Saloum Delta:

1. The Saloum Delta provides a set of services for local communities.
2. The delivery of those services depends on a certain level of maintenance or rehabilitation costs.
3. The services also serve a wider range of economic activities that create jobs and income for a larger share of the population.
4. Built infrastructure can replace some of the ecosystem services.

The SAVi assessment provides a customized monetary valuation of each of these components. The system dynamics model simulates the biophysical indicators of the ecosystem services of the wetland and uses scientific studies to attribute monetary values to the different services streams. We use local data where available. The economic valuation of the Saloum Delta serves as the business-as-usual (BAU) scenario for the SAVi assessment.

1 What are the services provided?

1. Water supply
2. Coastal erosion
3. Nitrogen uptake
4. Carbon sequestration
5. Economic activity

2 What are the economic activities enabled by these services?

1. Agriculture
2. Forestry
3. Fisheries
4. Industry
5. Services

3 What is the cost of providing these services?

1. Rehabilitation cost (e.g. reforestation)
2. Maintenance cost

4 What is the cost of built infrastructure to provide the same services?

1. Water (nutrient) treatment
2. Carbon sequestration
3. Flood protection

Figure 2. The economic value of the Saloum Delta as viewed through an integrated approach

Assumptions for the Calculation of the Economic Value of the Saloum Delta

Cost of Water (Nutrient) Treatment

The cost of nutrient treatment is based on the cost of built infrastructure for the removal of nitrogen from municipal wastewater. The average cost per kilogram (kg) of nitrogen (N) removed is based on different treatment technologies and amounts to USD 57.36/kg N (Tetratech, 2011).

Table 1. Cost of mangrove services

The cost of the following mangrove ecosystem services is based on Huxham et al., 2015.		
Protection against coastal erosion	USD/hectare (ha)/year	**395**
Protection against extreme weather	USD/ha/year	**35**
Carbon sequestration of mangroves	USD/ha/year	**251**
Tourism, education, and research	USD/ha/year	**41**

Table 2. Cost of wetland services

The cost of the following mangrove ecosystem services is based on Schuyt & Brander, 2004.		
Amenity/Recreation	USD/ha/year	**492**
Water filtering	USD/ha/year	**288**
Biodiversity	USD/ha/year	**214**
Habitat nursery	USD/ha/year	**201**
Water supply	USD/ha/year	**45**

Cost of Non-Timber Forest Products

Provision and revenues from non-timber forest products (NTFP) are based on République du Sénégal (2019). The total NTFP from the report was divided by total forest area to obtain ecosystem services provided per hectare. The value per tonne of NTFP was constant at CFA 15,000 per ton in 2014 and 2015.

Enabled Economic Activity/Labour Income

The additional labour income depends on the economic productivity of the sector and the respective "extra" revenue that is generated. Due to the very rural context of the delta, it is assumed that the total income of the population is equal to the revenues that are generated through economic productivity. The additional labour income for all sectors hence reflects the additional revenues generated over time.

3.0 Scenarios

The scenarios are based on the regional development plan (République du Sénégal, 2017) and were affirmed by the stakeholders at a workshop in Dangane in February 2020.

Table 3 provides an overview of the scenarios and underlying assumptions.

Across all scenarios, there are several key dynamics that the system dynamics model captures. They are explained in more detail in Section 6 of the report.

These key dynamics are:

- Population and economic development are key drivers of environmental degradation in the delta, and climate change exacerbates the impacts of these drivers.
- Population growth leads to increasing demand for land, food production, and fuelwood. This, in turn, increases pressure on the natural ecosystems, resulting in their continued degradation.
- The degradation of wetlands and mangroves reduces the level of ecosystem services provided. The greater the degradation, the lower the level of services that these natural assets can provide.

Table 3. Scenarios

Scenario	Assumptions
Sustainable agriculture	This scenario converts 20% of the land currently used for agriculture into organic agriculture (i.e., no use of chemical fertilizers, herbicides, or pesticides). The implementation of the scenario is foreseen over a period of 10 years (2020–2030). The capital cost for this investment is assumed at USD 476 per ha, and the maintenance cost USD 87.1 per ha. These are averages based on Karanja Ng'ang'a, et al., 2017. The implementation of organic agriculture increases production and employment and contributes to increased sectoral growth. The use of organic management practices reduces the total amount of chemical fertilizers applied, which benefits both farmers and the environment. Reducing fertilizer loads helps reduce soil erosion, improving soil quality and contributing to improved productivity.
Mangrove reforestation	This scenario implements 1,000 ha per year of mangrove reforestation over a period of 10 years (2020–2030). The cost per ha is assumed at USD 1,000 (Narayan, et al., 2016). The reforestation of mangroves leads to an increase in the total mangrove stock and maintaining ecosystem services. Increased soil cover from reforestation activities contributes to reducing soil erosion both on land and at the coast. Furthermore, the increase in mangrove area contributes to an increase in the area providing ecosystem services.

Scenario	Assumptions
Road construction	This scenario implements the construction of 50 km of road to expand the road network in the Fatick region. The timeline of implementation is 10 years (2020–2030). The project is estimated to cost CFA 19.6 billion. The estimate is based on the Regional Development Plan of the Foundiougne Department (République du Sénégal, Conseil départemental de Foundiougne, 2017) The expansion of the road network leads to improvements in total factor productivity and contributes to employment and income generation. However, the construction of roads also causes accelerated deforestation (in the proximity of the road), which increases the pressure on natural capital.
Solar cookstoves	This scenario foresees that 30% of households will replace fuelwood for cooking with solar-powered cookstoves by 2030. The cost assumption is USD 200 per stove (Solar Cooking Wiki, 2014). The lifetime of the stove is assumed to be eight years (Mendoza et al., 2019). In the Saloum Delta, fuelwood collection contributes to environmental degradation and the loss of the mangrove forest. The use of solar stoves leads to a reduction in fuelwood demand (Szulczewski, 2006) and hence contributes to maintaining forests and related ecosystem services.
Oil extraction	This scenario simulates the average impact of two oil spills (International Tanker Owners Pollution Federation Ltd [ITOPF], 2020) (ABS Consulting Inc., 2016), occurring at the beginning of production in 2023 and in 2028. This leads to a reduction in the stock of healthy mangroves and a corresponding loss of ecosystem services. This scenario was included because there are currently licences granted for offshore oil extraction at the level of the Saloum Delta. While the offshore oil drilling sites are outside the protected area, when oil spills occur, a larger zone including the delta will be affected. Other assumptions underlying this scenario are the following: the forecasted production is 100,000 barrels per day, at an average royalty revenue of USD 4.11/barrel. The first stage of production is assumed to take 10 years.
Development scenarios	The development scenario assumes the simultaneous implementation of all mentioned policy options, according to their respective time frames of implementation. This scenario is simulated to identify potential policy synergies and conflicts that may emerge over time. We make a distinction between the development scenarios with and without the Oil Extraction scenario.

4.0 Externalities

Table 4 reviews the externalities that were calculated for each of the scenarios. The calculation is based on a literature review and publicly available information.

Table 4. Externalities considered in the SAVi assessment

Externalities	• Avoided cost of greenhouse gas (GHG) emissions • Avoided cost of fertilizer • Avoided cost of fuelwood • Labour income • Value of ecosystem services • Oil revenues

Avoided Costs of GHG Emissions

The social cost of carbon (SCC) represents the economic cost caused by an additional tonne of carbon dioxide or its equivalent (CO_2e). It can be regarded as the discounted value of economic welfare from an additional unit of carbon dioxide emissions (Nordhaus, 2017). Life-cycle emissions are considered here in addition to CO_2e emissions during the operational phase of an asset. A life-cycle approach considers the carbon embedded both in capacity and carbon emissions from power generation. The SCC for renewable capacity hence stems from CO_2e emissions from the manufacturing of capacity. The SCC is estimated at USD 31 per tonne of CO_2e emissions. As indicated in Nordhaus (2017), we used a 3% increase in the cost of SCC annually.

Avoided Cost of Fertilizer

The avoided cost of fertilizer is estimated by comparing the total cost of chemical fertilizer in the BAU scenario to the total cost of chemical fertilizers in alternative scenarios. Changes in fertilizer use are caused by changes in agriculture productivity, land cover changes (soil erosion), and land management practices.

Avoided Cost of Fuelwood

The avoided cost of fuelwood is estimated by comparing the total cost of fuelwood in the BAU scenario to the cost of fuelwood in alternative scenarios. Changes in fuelwood are affected by the use of solar cooking stoves and other measures that aim at fuel switching or reducing deforestation. The cost of fuelwood is assumed at CFA 221.6/m3 (République du Sénégal, 2019).

Value of Ecosystem Services

For the assessment of the value of ecosystem services, see Section 2.

For nitrogen removal, the assumption for the calculation of the externality is based on Hernández-Sancho et al. (2010), not on the value of wastewater infrastructure.

The value of N removal is estimated based on the amount of N removed (40% of loadings assumed) by the wetland. A value of EUR 4.6 (USD 5.06) per kg N is applied based on Hernández-Sancho et al. (2010). This estimate is based on a shadow cost of pollutants if discharged into the environment, depending on the receiving waterbody. The value of EUR 4.6 per kg N represents the cost of disposing N into the open sea.

5.0 Results

5.1 Simulation of the Baseline Scenario

The following figures correspond to the four components of the integrated economic valuation of the Saloum Delta:

- Value of the ecosystem services (Figure 3)
- Value of the labour income enabled by the services the delta provides (Figure 4)
- Value of the maintenance and rehabilitation cost (no data available for this assessment)
- Value of the cost of built infrastructure that can replace certain ecosystem services (Figure 5)

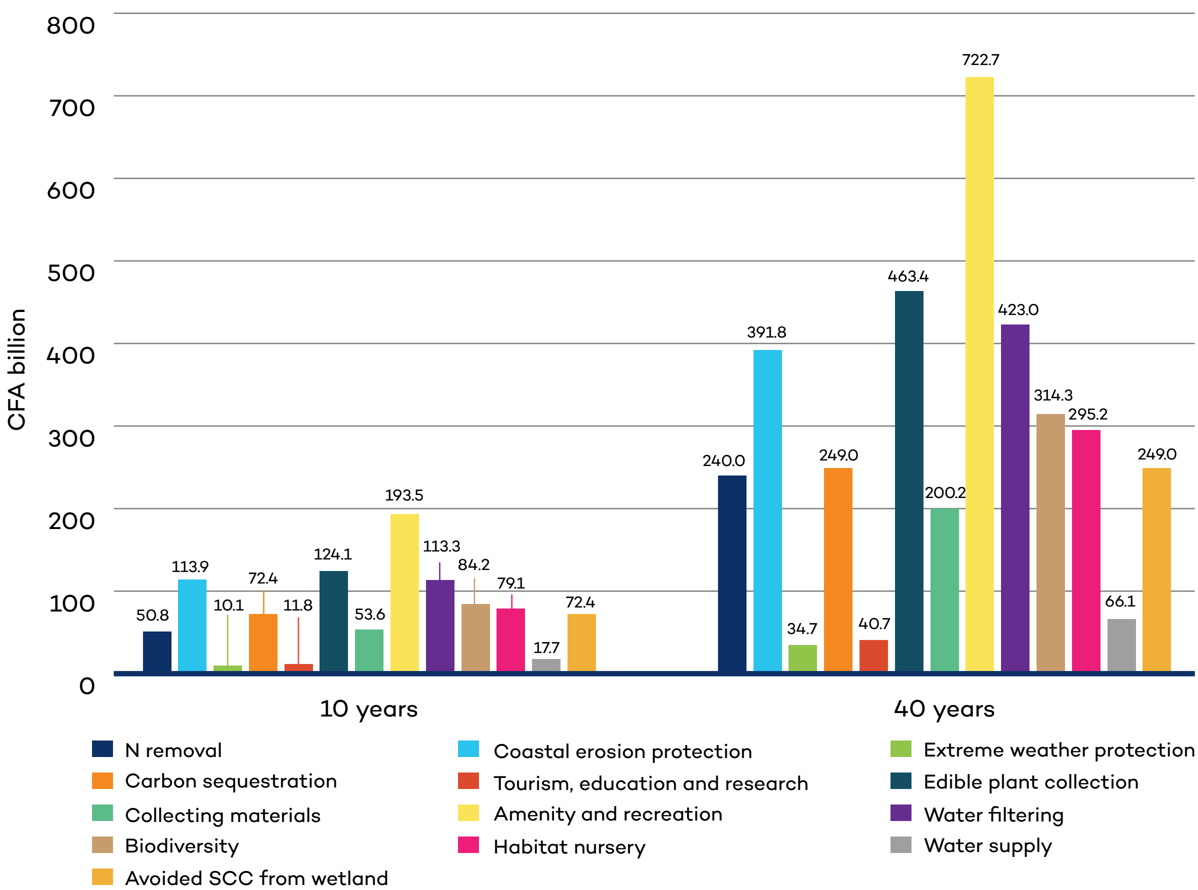

Figure 3. Value of ecosystem services (BAU)

Figure 3 shows the value of the ecosystem services over 10 years and over 40 years under a BAU scenario in CFA billion.

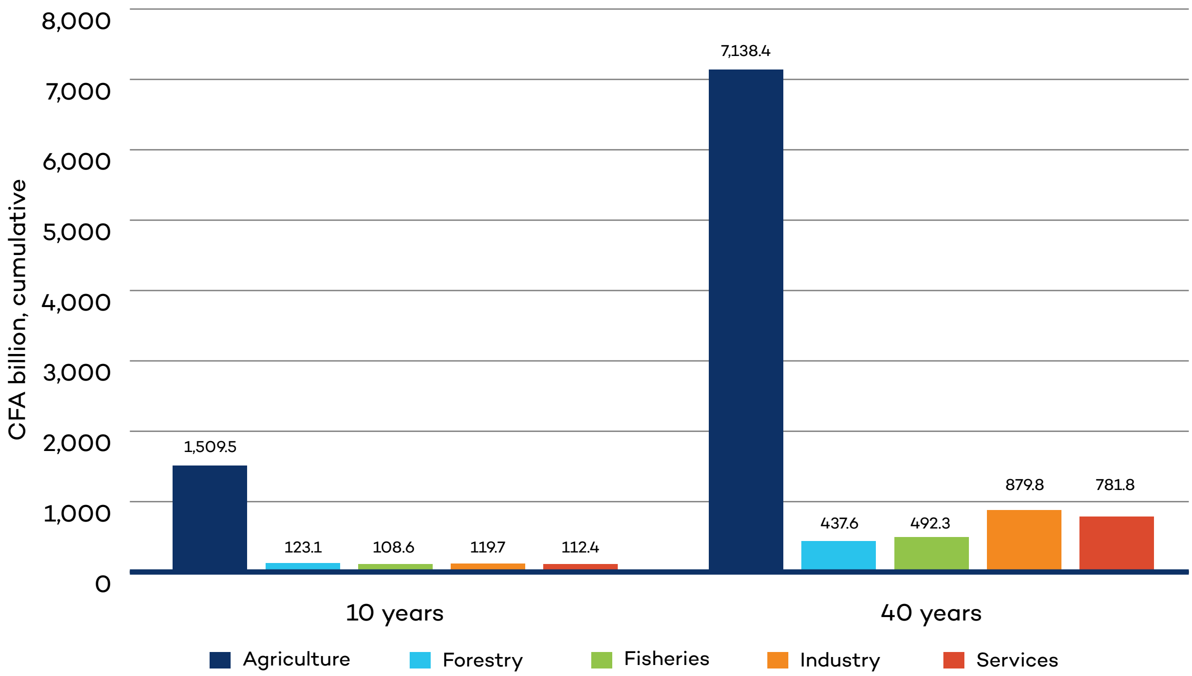

Figure 4. Labour income enabled by the services from the delta, CFA billion (BAU)

Figure 4 illustrates that especially the agriculture sector benefits from the ecosystem services of the delta.

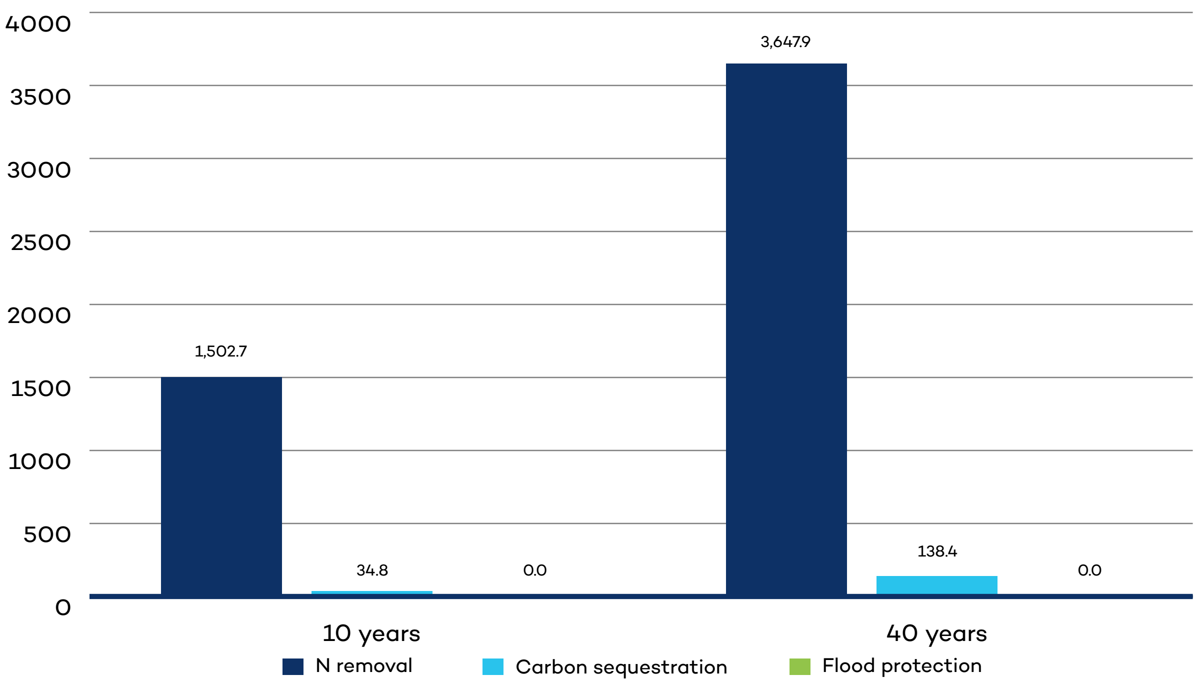

Figure 5. Cost of built infrastructure, CFA billion (BAU)

Figure 5 shows that the cost of wastewater treatment for nutrient removal amounts to CFA 1,503 billion over 10 years and CFA 3,648 billion over 40 years. This illustrates the magnitude of the value of the particular service the delta currently provides, and the investment needed if that service degrades or is lost. We could not obtain data for flood protection. For carbon sequestration, the cost of built infrastructure that saves the same level of GHG emissions is estimated at CFA 34.8 billion over 10 years, and CFA 138.4 billion over 40 years.

Finally, Figure 6 provides an integrated overview. We did not obtain data that would allow the calculation of maintenance or rehabilitation costs.

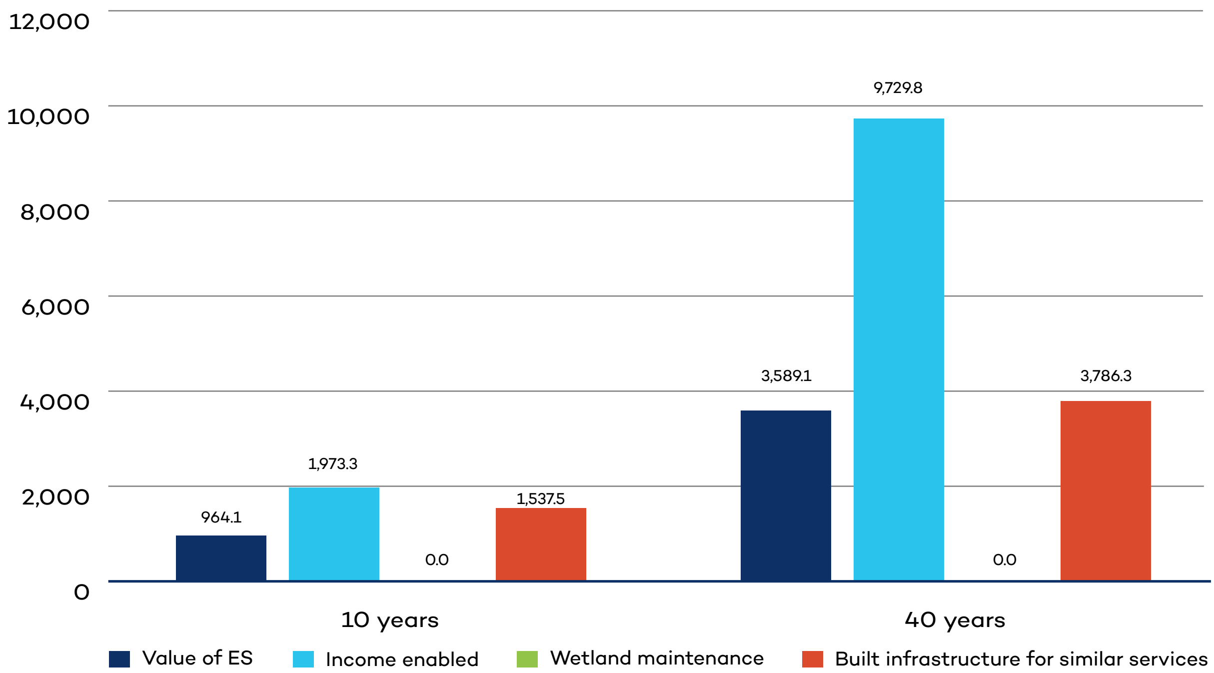

Figure 6. Integrated assessment of the Saloum Delta, CFA billion (BAU)

5.2 Wetland Quality and Soil Erosion Index

The wetland quality index and the soil erosion index indicate trends of further degradation of the Saloum Delta that will take place under BAU if no intervention takes place.

Figure 7 shows the wetland quality index under the BAU scenario. The underlying drivers of the wetland quality index are the size of the land covered by forests and mangroves, the size of the wetland, and chemical fertilizer use.

In the simulation model, the index is used as a multiplier that we use to forecast the impact of the different scenarios on the quality of the wetland and soil erosion (see Figures 9 and 10).

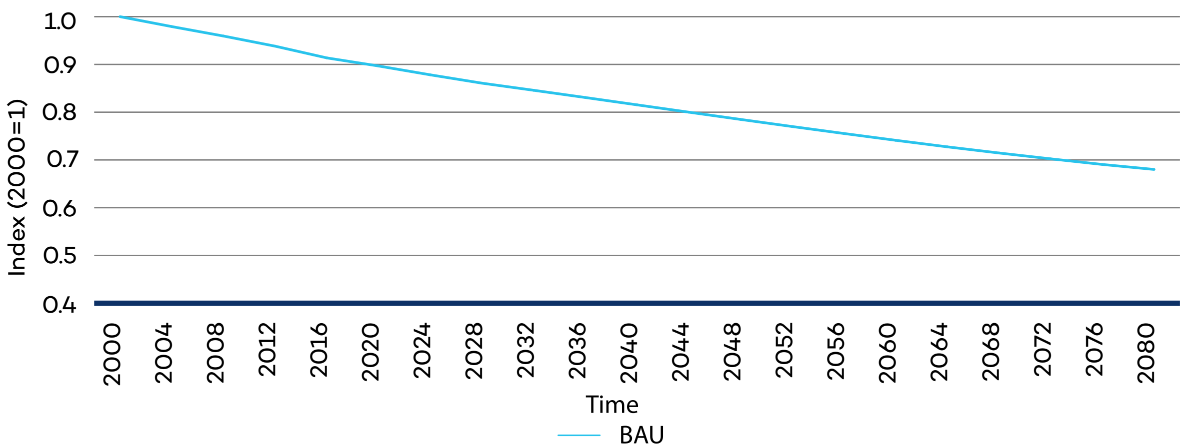

Figure 7. Wetland quality index (BAU)

Figure 8 shows the soil erosion index. The underlying drivers of the soil erosion index are the land covered by forest and mangroves, chemical fertilizer use, and seasonal rainfall.

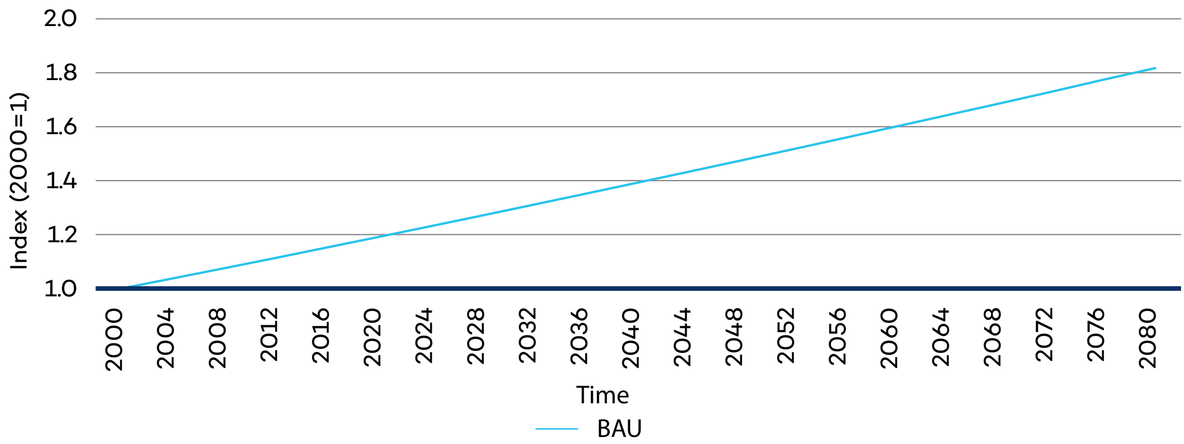

Figure 8. Soil erosion index (BAU)

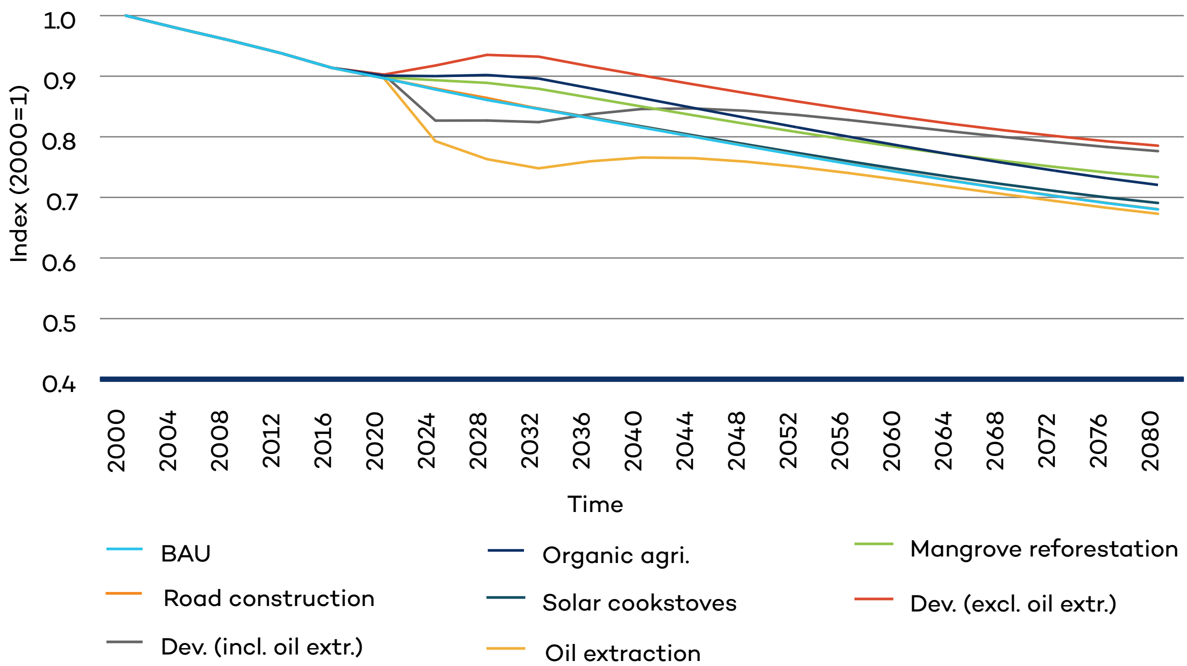

Figure 9. Wetland quality index under different scenarios

Figure 9 shows that solar cookstoves and road construction have little to no effect on the degradation of the wetland taking place under the BAU scenario. Interventions such as organic agriculture, mangrove reforestation, or a combination of the development scenarios (excluding oil extraction) reduce the overall degradation of wetland quality, but none reverses the curve of decrease in quality. The oil extraction scenario that simulates the impact of two oil spills decreased the quality more than under a BAU scenario, but after 2040 the wetland quality recovers. The development scenario (including oil extraction) has a less negative impact, as the oil extraction consequences are mitigated due to the positive impact of the other scenarios.

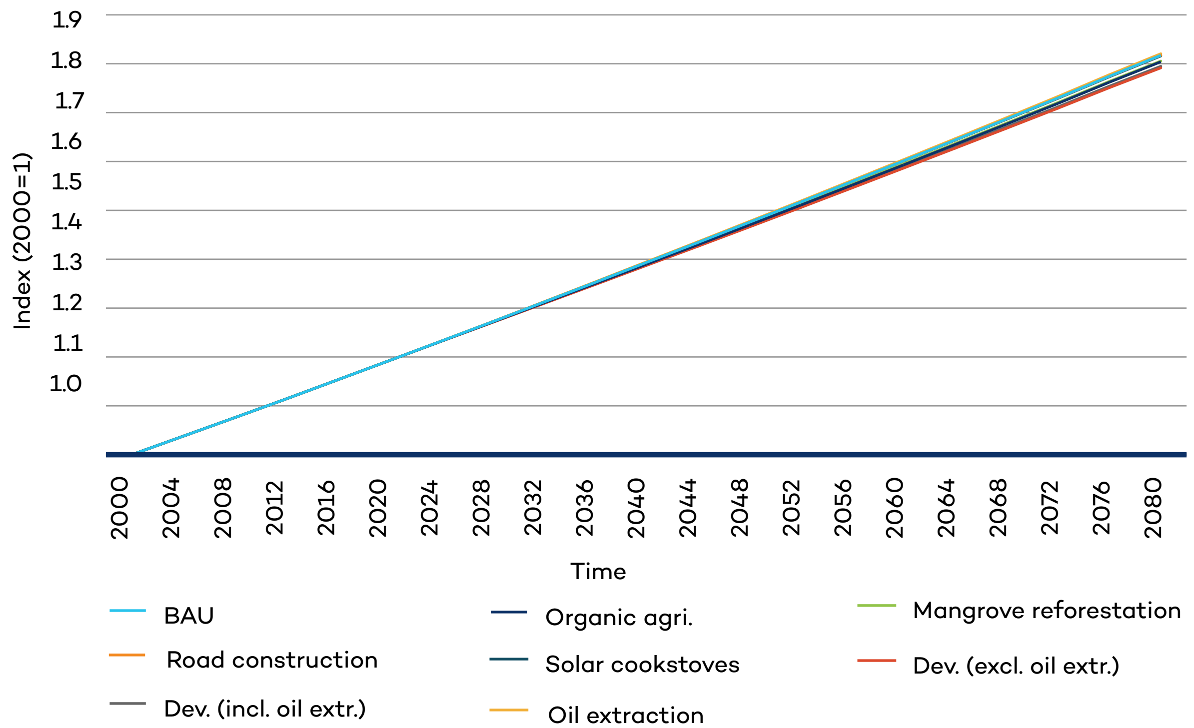

Figure 10. Soil erosion index under different scenarios

Figure 10 shows that no intervention scenario affects the soil erosion index significantly.

5.3 Integrated Cost–Benefit Analysis

Table 5 provides an overview of the integrated CBA with cumulative values over 40 years. All the scenarios generate positive net results.

Avoided costs:

- Organic agriculture, mangrove reforestation, and solar cookstoves have significant avoided costs in relation to a reduction in GHG emissions compared to BAU.
- Road construction and oil extraction have the opposite effect and generate more costs related to GHG emissions due to the nature of their activity.
- Road construction improves market access, enhancing revenues and profits of farmers. This leads to lower fertilizer use as farmers do not need to use as much fertilizer to generate a similar amount of revenue and profit. This is likely only a short-term effect.
- Oil extraction has a negative impact on ecosystem services, requiring more fertilizer to maintain a sufficient level of production.

Added benefits:

- Every scenario generates added benefits, with the revenue from oil extraction being very significant. The impact on the value of the ecosystem services of oil extraction, is, however, very negative and lowers labour income from industry.

- Mangrove restoration enhances the performance of the ecosystem for protection against coastal erosion and extreme weather events while also offering carbon sequestration. When including the value of tourism, education, and research benefits, its value accumulates to CFA 154,031 million compared to a situation where no action would be taken to restore the mangroves.
- Organic agriculture enhances the performance of the wetland ecosystem services with about CFA 128,530 million.

Table 5. Integrated CBA (1)[1]

Integrated CBA (mn CFA)	Organic agriculture	Mangrove reforestation	Road construction	Solar cookstoves	Oil extraction
Investment and O&M					
Organic agriculture	951	0	0	0	0
Capital	633	0	0	0	0
O&M cost	318	0	0	0	0
Mangrove restoration	0	10	0	0	0
Capital	0	10	0	0	0
O&M cost	0	0	0	0	0
Road construction	0	0	19,625	0	0
Capital	0	0	19,625	0	0
O&M cost	0	0	0	0	0
Efficient stoves	0	0	0	2,758	0
Capital	0	0	0	330	0
O&M cost	0	0	0	2,429	0
Total Investment and O&M (1)	**951**	**10**	**19,625**	**2,758**	**0**
Avoided Costs					
Social cost of carbon	18,033	12,986	-18,737	33,620	-15,038
From wood fuel use	0	0	0	31,091	0

[1] 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.

Integrated CBA (mn CFA)	**Organic agriculture**	**Mangrove reforestation**	**Road construction**	**Solar cookstoves**	**Oil extraction**
From sequestration in the wetland	7,655	5,753	149	363	-14,886
From tractors	0	0	0	0	0
From land-based emissions	10,379	7,232	0	2,166	-152
From road construction and maintenance	0	0	-18,886	0	0
Cost of fertilizers	12,671	-10	259	0	-1,602
Avoided fuelwood	0	**0**	**0**	33	**0**
Subtotal (2)	**30,705**	**12,976**	**-18,478**	**33,653**	**-16,640**
Added Benefits					
Labour income	269,442	10,076	297,258	261	64,643
Labour income agriculture	230,869	1,552	111,936	70	68,444
Labour income from forestry (excluding NTFP)	0	0	0	-33	-1
Labour income fisheries	0	0	0	0	0
Labour income industry	26,534	1,428	113,636	156	-30,069
Labour income services	12,039	690	71,687	69	26,269
Labour income from interventions	0	6,406	0	0	0
Value of ES provided	118,687	257,148	2,298	11,789	-297,112
N removal	-9,842	7	-200	0	-8,960
From mangroves	0	154,031	0	4,483	-38,158
Coastal erosion protection	0	84,269	0	2,452	-20,876
Extreme weather protection	0	7,467	0	217	-1,850

Integrated CBA (mn CFA)	Organic agriculture	Mangrove reforestation	Road construction	Solar cookstoves	Oil extraction
Carbon sequestration	0	53,548	0	1,559	-13,265
Tourism, education, and research	0	8,747	0	255	-2,167
From wetland	128,530	96,606	2,499	6,087	-249,951
Edible plant collection	23,967	18,015	466	1,135	-46,608
Collecting materials	10,353	7,782	201	491	-20,133
Amenity and recreation	37,378	28,094	725	1,769	-72,693
Water filtering	21,881	16,446	426	1,037	-42,551
Biodiversity	16,259	12,221	316	770	-31,618
Habitat nursery	15,271	11,478	297	723	-29,698
Water supply	3,419	2,570	67	162	-6,649
From non-timber forest products	0	6,504	0	1,219	-43
Oil revenues	0	0	0	0	554,586,209
Subtotal (3)	**388,129**	**267,224**	**299,556**	**12,051**	**554,353,740**
Net result (2) + (3) - (1)	**417,883**	**280,190**	**261,453**	**42,946**	**554,337,101**

Table 6 discusses the results of the two additional scenarios that capture:

1. All above scenarios but exclude oil extraction
2. All above scenarios but include oil extraction.

Table 6 exemplifies the trade-offs that policy-makers and stakeholders are required to evaluate when investing in economic development. While the ecosystem services bring a host of longer-term benefits, the potential for much higher near-term revenues (oil extraction) always takes precedence.

Oil extraction projects are of national interest. Their negative impacts are mostly felt locally, as in the case of the Saloum Delta. Under this simulation model, it is expected that the benefits outweigh the costs, as it does not include the costs of emissions of transporting or burning the oil, nor the costs of additional infrastructure impacts such as deforestation for the construction of pipelines.

Table 6. Integrated CBA (2)

Integrated CBA (mn CFA)	Development scenarios without oil extraction	Development scenarios with oil extraction
Costs		
Organic agriculture	951	951
Capital	633	633
O&M cost	318	318
Mangrove restoration	10	10
Capital	10	10
O&M cost	0	0
Road construction	19,625	19,625
Capital	19,625	19,625
O&M cost	0	0
Efficient stoves	2,758	2,758
Capital	330	330
O&M cost	2,429	2,429
Subtotal (1)	**23,344**	**23,344**
Avoided Costs		
Social cost of carbon	46,044	29,451
From wood fuel use	31,091	31,091
From sequestration in the wetland	14,061	-2,359
From tractors	0	0
From land-based emissions	19,777	19,605
From road construction and maintenance	-18,886	-18,886
Cost of fertilizers	12,640	11,111
Avoided fuelwood	33	**33**
Subtotal (2)	**58,717**	**40,596**

Integrated CBA (mn CFA)	Development scenarios without oil extraction	Development scenarios with oil extraction
Added Benefits		
Labour income	587,036	656,356
Labour income agriculture	349,133	419,984
Labour income from forestry (excluding NTFP)	-33	-33
Labour income fisheries	0	0
Labour income industry	145,594	114,462
Labour income services	85,802	115,208
Labour income from interventions	6,541	6,736
Value of ES provided	392,527	68,430
N removal	-9,817	-18,400
From mangroves	158,516	115,586
Coastal erosion protection	86,723	63,236
Extreme weather protection	7,684	5,603
Carbon sequestration	55,107	40,183
Tourism, education, and research	9,002	6,564
From wetland	236,106	-36,430
Edible plant collection	44,027	-7,388
Collecting materials	19,019	
Amenity and recreation	68,664	-11,524
Water filtering	40,195	-6,745
Biodiversity	29,867	-5,012
Habitat nursery	28,053	-4,708
Water supply	6,280	-1,054
From non-timber forest products	7,723	7,674
Oil revenues	0	554,586,209
Subtotal (3)	**979,563**	**555,310,996**
Net result (2) + (3) - (1)	**1,014,936**	**555,328,247**

6.0 Preliminary Ideas on Blended Finance

The preceding chapters of this report make a strong case for stakeholders to improve the Saloum Delta's provision of ecosystem services. Additional impetus comes from the fact that global warming and changing climate will continue to exacerbate the prevailing drought in and around the delta, and its importance as a natural, low-cost source of water must not be overlooked. Stakeholders also voice concern that sea-level rise (again exacerbated by global warming) is increasing coastal erosion and the salinization of groundwater reserves. The delta's ecosystem services are particularly significant because the administrative area of Foundiougne is perhaps the country's largest source of agricultural produce. The importance of the Saloum Delta in ensuring hydrological cycles and water availability for irrigation and municipal use is undisputed.

However, maintaining the productivity of the delta requires funds—but identifying opportunities to secure and maintain financing is often challenging. This section explores a range of opportunities in light of the economic valuation of the wetland's ecosystem services we have calculated. These opportunities are carbon offsets, pay-for-performance instruments, mitigation banks, natural asset inventories, and community-based financing schemes.

6.1 Carbon Offsets

A carbon offset refers to a reduction in greenhouse gas emissions or an increase in carbon storage that is used to compensate for emissions made elsewhere. Offsets are measured in tonnes of carbon dioxide-equivalent (CO_2e): One tonne of carbon offset represents the reduction of one tonne of carbon dioxide or its equivalent of other greenhouse gases such as methane.

Offsets are provided through on-the-ground projects and activities that reduce carbon emissions, such as renewable energy projects (e.g., wind farms, biogas plants), energy-efficiency projects (e.g., improved cookstoves) or projects that increase the storage of carbon (e.g., reforestation). The impact of such emission reduction projects is typically calculated, measured, and usually verified by a third party (Broekhoff et al., 2019).

There are two markets for carbon offsets: the larger compliance and the smaller voluntary market. In the compliance market, companies or governments buy carbon offsets in order to comply with regulations on the total amount of carbon dioxide they are allowed to emit. Such emission caps can, for instance, apply to companies under the EU Emission Trading Scheme (ETS). In 2018, about USD 44 billion worth of carbon offsets was purchased in the compliance market, representing about 11 billion tonnes of CO_2e reductions (World Bank, 2019). In the voluntary market, companies, individuals, or governments can buy carbon offsets to compensate for their greenhouse gas emissions. For example, they might compensate for their emissions from air travel or electricity use. In 2016, carbon offsets worth about USD 190 million were traded, representing an emissions reduction of about 60 million tonnes of CO_2e (Hamrick & Gallant, 2017).

One concept that is critical to understanding how carbon offsets work is called "additionality." A project can only be used for carbon offsets if it is additional, meaning that its implementation is bound to receiving funds through the selling of offsets. For example, one cannot sell offsets for a forest that is already existing and sequestrating carbon, as this is not additional. Only additional measures such as reforestation qualify for carbon offsets.

Carbon offsets can be a viable way of raising funds to upgrade and maintain the ecosystem services of the Saloum Delta. Stakeholders will need to identify the conservation activities that will increase the wetlands' carbon sequestration. Measures enabling such "additional sequestration" can then be financed through the sale of offsets. To make this work, it is critical to verify that the projects will indeed be carried out and lead to the promised additional sequestration. The credibility of emission reduction projects can be verified through a standard on carbon performance. Programs administering such standards fulfill three functions: "(1) they develop and approve standards that set criteria for the quality of carbon offset credits; (2) they review offset projects against these standards (generally with the help of third-party verifiers); and (3) they operate registry systems that issue, transfer, and retire offset credits" (Broekhoff et al., 2019).

We recommend that stakeholders approach the two major standards, the Verified Carbon Standard (Verra, n.d.) or the Gold Standard (Gold Standard, n.d.), to explore further. Both standards enable certified projects to turn their GHG emission reductions and removals into tradeable carbon offsets. Both standards also report that they each have certified over 1,500 projects that have reduced or removed more than 200 million tonnes of CO_2e from the atmosphere.

This report provides estimates of the present and future carbon sequestration potential of the Saloum Delta. These estimates can provide a starting point for exploring the design of a carbon offset program. A special purpose entity may need to be established to administer the undertaking. This special purpose entity would then be responsible for administering the sale of offsets, supervising the disbursement of funds, and providing audited accounts on carbon sequestration.

6.2 Pay-for-Performance Instruments

These instruments are also known as results-based finance, outcome-based finance, or impact bonds. The financing is connected to measurable social or environmental benefits. An impact bond usually includes five stakeholders (Instiglio, 2020), see Figure 11:

1. An outcome payer (e.g., a foundation or government agency) who enters into a contract to pay for specific, measurable social outputs and outcomes.
2. A service provider who works to deliver these outcomes in a flexible manner.
3. One or several investors (e.g., individuals, foundations, or investment firms) who provide service providers with upfront working capital.
4. An independent evaluator, who assesses the outcomes of the program.
5. An organization (e.g., special purpose vehicle or trust) managing the project.

In an impact bond model, an investor provides upfront financing for the operations of a service provider and receives a return from the outcome payer once results have been achieved. If the program was successful and the targets were met, the outcome payer pays back the working capital plus a return on investment to the investor. If the targets are not met, the investors lose their money or are only partially refunded their investments and do not receive interest payments. In addition, the service provider may be required to refund all or a part of the working capital. On the other hand, if the outcomes are achieved, the service provider can be entitled to a bonus. The theory behind impact bonds is that stakeholders have a strong financial interest in the outcomes being delivered, and risks are transferred from outcome payers to private investors (Ecorys UK, n.d.; Instiglio, 2020).

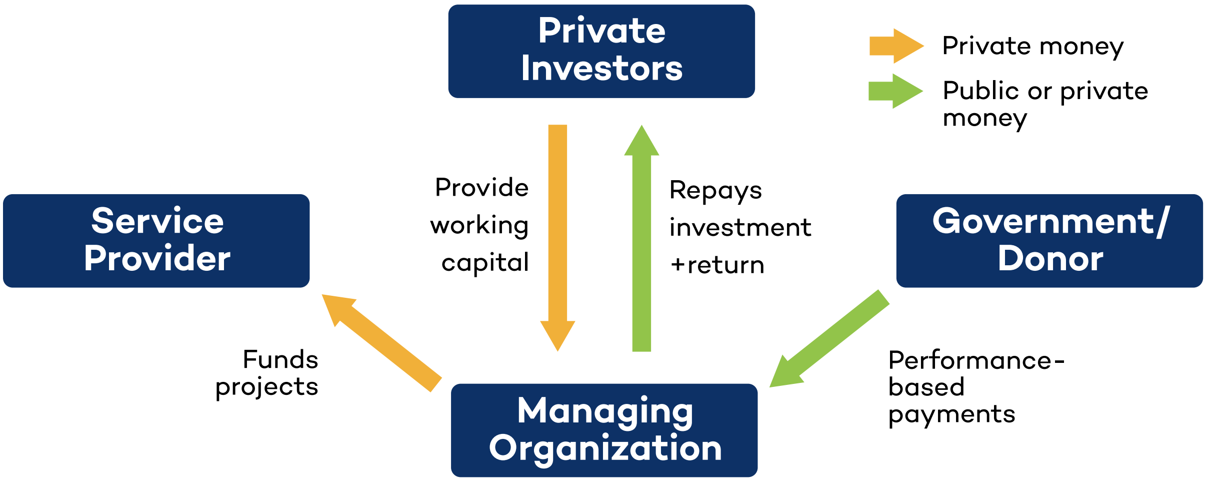

Figure 11. Performance-based instruments

Source: Author figure, based on Roy et al., 2018.

Performance-based instruments such as impact bonds require a strong evidence base and an even stronger track record to build from. Firstly, the service provider needs to demonstrate that they have the capabilities to deliver the required service on time and on budget. Secondly, impact bond due diligence also requires that all stakeholders have verified and comparable information on how much it will cost to deliver the service and how these costs may change in the future. Thirdly, targeted outcomes must be quantified and verifiable. Fourthly, a special purpose vehicle with the capabilities to launch and administer the scheme, liaise with all parties, disburse funds, and monitor and report on performance needs to be established.

In the case of the Saloum Delta it would (for instance) be necessary to know:

- What ecosystem services are provided today, and at what cost? (e.g., in relation to carbon sequestration or flood protection)
- Can they be provided in the future and at what costs?
- How will these services increase/decrease with climate change and other foreseeable risks?

The results of the SAVi assessment provide a starting point for outcome-based finance instruments. Because the assessment quantifies the baseline ecosystem services currently provided by the Saloum Delta and forecasts the development of these services for future scenarios, it can serve as the basis for approaching outcome funds and service providers. Further due diligence would, however, be required on land tenure, beneficiaries, definition of auditable outcomes, and much more. There is also the very real risk regarding the extent to which preservation and restoration measures could be severely hampered by climate change and offshore oil drilling.

Impact bonds and other performance-based instruments are increasingly being tried and tested in many sectors, including conservation, health care, education, and climate adaptation. The box below provides an example of the use of Rhino Impact Bonds in the conservation sector.

RHINO IMPACT BOND

In 2019, a coalition of civil society organizations launched a Rhino Impact Bond with the goal of protecting the rhino population, which is being severely decimated through poaching. Because current financial resources are insufficient to protect the rhinos, and the protection measures need to react dynamically to the poaching developments, the Rhino Bond seeks to boost the financial means and provide the necessary flexibility. It aims at boosting the black rhino population by 10% globally (United for Wildlife, n.d.; Srivastava, 2019).

Investors will provide USD 50 million as capital for rhino protection projects in Kenya and South Africa. If the service providers meet the target of increasing the African black rhino populations in these sites, the investors will be paid back their capital plus interest yields by the outcome payers. The interest yield will depend on changes in the number of rhinos. If the projects are not successful and the rhino populations continue to shrink, the investors will take financial losses, depending on the drop in rhinos and their terms of investment (Aglionby, 2019). The instrument can only work because there is a good evidence base for rhino protection: rhino numbers are well-known, which makes it possible to measure the impact of investment. Also, because rhino conservation methods are well-established, there is general trust in how they perform.

6.3 Mitigation Banking

Mitigation banking is a system created to ensure that ecological loss caused by development projects is compensated in other areas so that there is no net loss to the environment. Typically, damages to wetlands and streams are compensated by the preservation and restoration of wetlands, natural habitats, and streams elsewhere (Jhawar, 2020; USEPA, n.d.).

Mitigation banks are being established in the EU but have a greater track record in the United States. The National Mitigation Banking Association (NMBA) defines mitigation banking as "the restoration, creation, enhancement, or preservation of a wetland, stream, or other habitat area undertaken expressly for the purpose of compensating for unavoidable resource losses in advance of development actions, when such compensation cannot be achieved at the development site or would not be as environmentally beneficial" (Jhawar, 2020). The feasibility of setting one up in Senegal would need to be assessed.

A mitigation bank has mitigation credits that it can sell to customers to compensate for the impact of their development projects. A bank offering credits to offset ecological damages to wetlands is called a "wetland mitigation bank" (Jhawar, 2020). Mitigation banks have four components (USEPA, 2019) (see Figure 12):

- Bank site: The land restored, established, enhanced, or preserved
- Bank instrument: The formal agreement between the bank owners and regulators that establishes liabilities, performance standards, management and monitoring requirements, and the terms of bank credit approval
- Interagency Review Team (IRT): This team provides reviews, oversees and approves of the bank
- Service area: The geographic area in which impacts can be compensated.

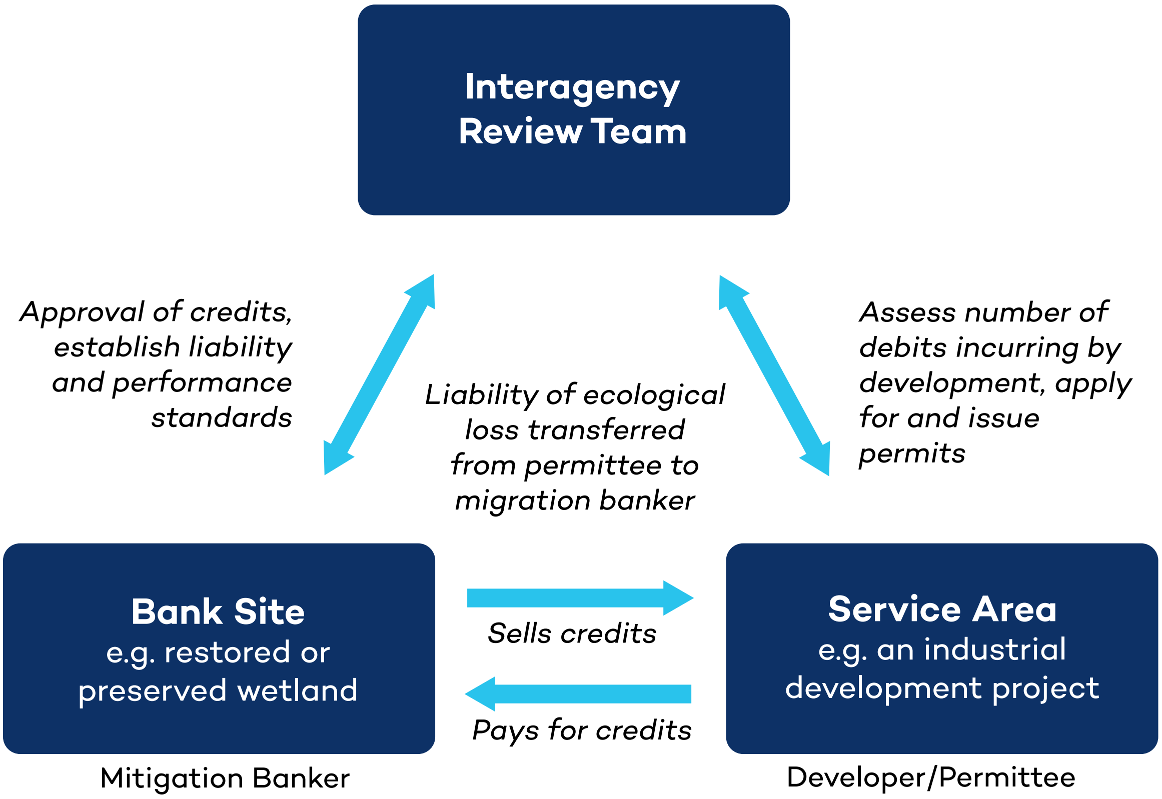

Figure 12. Mitigation banking structure

Source: Based on Jhawar, 2020; Hook & Shadle, 2013.

Mitigation banking can have several benefits compared to mitigation measures carried out by the party responsible for the negative impact. These benefits include an improved certainty that the mitigation measures will successfully offset project impacts, the greater availability of financial resources and expertise, as well as better cost-efficiency of compensation measures (USEPA, 2019)

Developers in the United States need to apply (through a mitigation bank) to the Environmental Protection Agency (EPA) for a permit to compensate for the unavoidable impacts of development. U.S. authorities have published a checklist for the information to be included in the application (USEPA & U.S. Army Corps of Engineers, 2003). Of course, this is not directly transferable to Senegal but can be useful to get a sense of what information could be important to consider for a mitigation bank in Saloum. The checklist includes:

- Description of functions lost at the impact site and functions gained at the mitigation site.
- Basic information on the sites, e.g., related to vegetation, hydrology, and land uses.
- Mitigation work plan describing the mitigation measures, e.g., what would be constructed.
- Description of performance standards and success criteria.
- Proof of site protection, maintenance, monitoring and management, including responsibilities, legal measures, a maintenance plan, and a monitoring plan.
- Financial assurances, identifying responsible parties and their assurances.

More information about compensatory mitigation in the United States is available at the EPA website (USEPA, 2019).

6.4 Natural Asset Inventories

Recording natural assets as tangible capital assets provides a strong incentive for public authorities to protect and preserve natural capital, based on the assumption that when the monetary value of an ecosystem service is recorded, one is less likely to destroy it. Traditionally, public sector accounting frameworks do not mandate the recording of nature as an asset based on the value provided by its ecosystem services. If, however, natural assets are valued based on their provision of ecosystem services, there is an incentive for protecting this value, which is recorded as a tangible capital asset on their financial statement.

Early practice on natural asset inventories is emerging in Canada, where public sector accounting frameworks are being reformed to enable municipalities to record natural assets as tangible capital assets on their financial statements. These much-welcomed reforms are in their early days, and a range of accounting, and governance challenges still need to be addressed and resolved. Examples can be found in British Columbia (Canada) (Asset Management BC, 2019a, 2019b).

6.5 Pay-as-You-Go Community-Based Financing

Pay-as-you-go (or community-based) financing schemes allow local community entrepreneurs to set up "workshops" to sell and service accredited solar, wind, and biogas appliances to local communities. Local communities "pay as they go," and there is no upfront investment required.

To help communities switch from wood-fuel based cookstoves to solar cookstoves, or switch to clean energy and advance up the energy and technology ladder, these schemes can provide low-cost credit to help local communities purchase new technology on an as-needed basis. For example, the MWEZI network (https://mwezi.org/network/) offers pay-as-you-go solar solutions that include solar cookstoves. This assessment shows that affordable solar cookstoves will reduce demand for fuelwood and contribute to a decrease in deforestation.

7.0 How SAVi for the Saloum Delta Assessment Was Built

7.1 Systems Thinking and System Dynamics

The underlying dynamics of the local development in the Saloum Delta, including driving forces and key indicators, are summarized in the causal loop diagram (CLD) displayed in Figure 12. The CLD includes the main indicators analyzed during this SAVi assessment, their interconnections with other relevant variables, and the feedback loops they form.

The CLD illustrates the interconnections of the economy and natural resources while highlighting key dynamics and potential trade-offs emerging from different development strategies envisaged for the Saloum Delta. The CLD was developed and customized to the local context in collaboration with Wetlands International–Africa and validated during a stakeholder workshop in Dangane in February 2020. The CLD is the starting point for the development of the mathematical stock and flow model.

7.2 Reading a CLD

To design solution-oriented and effective interventions, CLDs need to capture the causal relations of a system correctly. Therefore, CLDs establish causal links between variables by linking them with arrows and attributing a sign to the arrow (either + or −) that indicates whether a change in one variable generates a positive or negative change in the other.

As noted by Bassi et al. (2016):

- A causal link from variable A to variable B is positive if a change in A produces a change in B in the same direction.
- A causal link from variable A to variable B is negative if a change in A produces a change in B in the opposite direction" (Bassi et al., 2016).

Table 7. Causal relations and polarity

Variable A	Variable B	Sign
↑	↑	+
↓	↓	+
↑	↓	-
↓	↑	-

Moreover, these causal interactions can form what is known as a positive or negative "feedback loop" (Forrester, 1961). In other words, an intervention made in that system can support the tendency toward an equilibrium within the overarching system, in which case this negative feedback loop is called a balancing loop. Alternatively, an intervention can reinforce the intervention's impact and hence create a positive feedback loop, which is called a reinforcing loop (Bassi, 2009; Forrester, 1961). What makes CLDs useful for decision-makers and other stakeholders is this feedback component, showing how the different elements within a system interact with each other and either exacerbate or ameliorate a given situation (TEEB, 2018). These mapped relationships may not necessarily indicate linear behaviour, and potential impacts may occur delayed, which is why a CLD that captures the extent and complexity of this system is important. The interaction of feedback loops may also be where the source of a given policy problem lies, and therefore where decision-makers will need to direct their efforts for finding a solution—along with being aware of how this solution will affect the rest of the system (WWF, 2014).

7.3 Model Overview

We have applied the SAVi nature-based infrastructure model to inform decision-makers about the potential risks and externalities in relation to different interventions in the Saloum Delta. The assessment monetizes risks and externalities and provides information about social and environmental impacts on top of the conventional economic assessment.

Figure 13 presents the CLD of the basic dynamics that underlie the analysis, showing the key variables that drive the local development and its impact on the environment in the delta. This CLD was completed and validated at the February 2020 workshop and resulted in Figure 13.

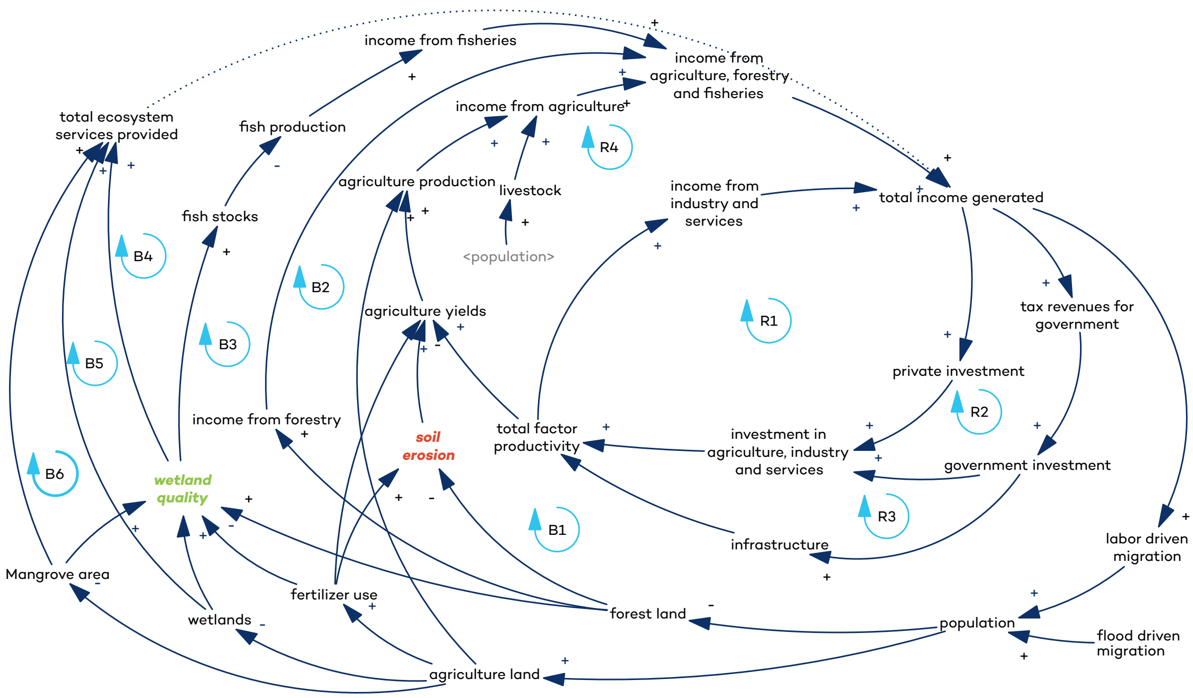

Figure 13. CLD for the Saloum Delta

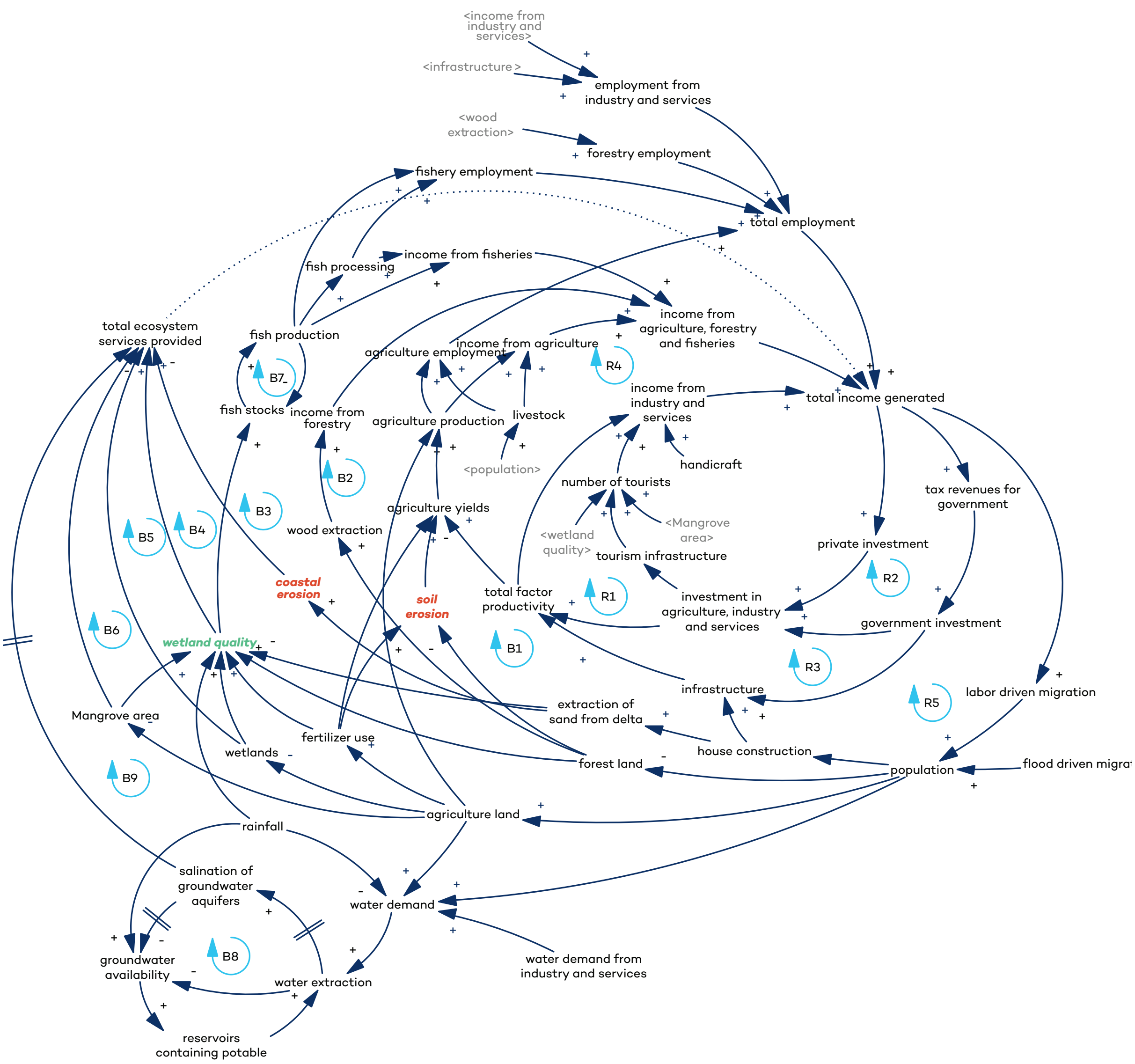

Figure 14. CLD for the Saloum Delta, after the stakeholder workshop (February 2020)

The reinforcing loops (Rs) highlight the potential for growth and economic development, driven by sectoral income and public and private investments (loops R1 through R5). Income generation results in tax revenues and capital for private investments, which leads to the construction of infrastructure (roads, houses, etc.) (loops R3 and R5). It also leads to higher total factor productivity (R1). Improvements in total factor productivity further benefit agricultural production and contribute to employment and income generation (R4).

The reinforcing loops highlight the dynamics that have contributed to the economic development, ensuring the area's significance as the breadbasket of Senegal. Moving forward, these dynamics also have the potential to undermine the integrity of natural resources and curb economic development prospects in the future.

The balancing loops (Bs) illustrate processes that counteract growth and highlight potential trade-offs emerging from various development interventions. In the context of the Saloum Delta, land use and water availability determine the demand for new land (B1 through B6) and the exploitation of water resources (B8). For example, B1 illustrates how demand for food and fuelwood reduces natural forest cover, which in turn exacerbates soil erosion and wetland degradation. Potential consequences of this accelerated deforestation are (i) reduced production potential of the forestry sector, (ii) lower levels of ecosystem services, and (iii) non-timber forest products. It also, in turn, impacts fish reproduction. This highlights critical interconnections between economic development stimuli and the availability of natural capital to sustain the outlined ambitions in the long run. In other words, the balancing loops in the CLD constitute the limits to growth, based on the availability of resources.

The CLD presented in Figures 13 and 14 show the interconnectedness of socioeconomic and environmental key indicators. It allows for a greater understanding of the potential impacts of policy implementation and how these impacts would unfold through the system. By illustrating potential policy impacts, the CLD can inform about the potential success of policy interventions on the spectrum between development and conservation. With regards to the Saloum Delta, and given existing pressures on land and water, the CLD indicates that economic development should be aligned with the availability of natural resources to maintain the integrity of the delta, or even with a conservation approach to mitigate current and abate future pressures.

7.4 Indicators Concerning Expenditure, Avoided Costs, and Added Benefits

We have assessed three cost categories for each scenario: investment and O&M expenditure, avoided costs, and added benefits as a valuation of externalities (economic, social, and environmental costs and benefits for society at large).

7.4.1 Direct Expenditure

This category covers the investment and O&M expenditure for the implementation of each scenario.

From a private sector perspective, expenditures refer to the monetary costs of project implementation, such as investment, O&M costs, and extrabudgetary expenditure. From a public sector point of view, expenditures refer to the allocation and/or reallocation of financial resources with the aim of reaching a stated policy target—for example, providing subsidies for investments in organic agriculture or mangrove restoration projects.

7.4.2 Avoided Costs

The estimation of potential avoided costs considers the results of the successful implementation of an investment or policy. In this case, avoided costs refer to savings in relation to the SCC, which monetizes GHG emissions, or the avoided cost of having to purchase chemical fertilizer. It also included the avoided cost of harvesting wood from the mangroves for cooking.

7.4.3 Added Benefits

Among the added benefits are the monetary value of economic, social, and environmental outcomes obtained from investment or policy implementation. Added benefits are assessed by comparing the investment scenario against the baseline scenario, focusing on short-, medium-, and long-term impacts across sectors and actors. In this assessment, the added benefits consist of the revenues from oil production, the restored (or lost in certain scenarios) value of ecosystem services related to the wetland and mangrove area, and the labour income in different economic sectors, which would not be affected in the BAU scenario.

8.0 Conclusion

This SAVi assessment demonstrated the contribution of the Saloum Delta in supporting livelihoods and local development in the region. It provided an estimation of the current value of the ecosystem service provided by the wetland and mangrove area. This value has been degrading over time and, without interventions, will continue doing so. A range of policies and projects are currently rolled out in the delta to combat the degradation of the ecosystem. The SAVi assessment sheds light on the costs and benefits of these interventions in an integrated way.

The results show that any development ambition should focus on supplementary strategies that combat further degradation of the wetland and continued deforestation of the mangrove area. Further degradation of the natural capital of the delta will have ripple effects across all economic sectors.

The report concludes with ideas and suggestions on financing strategies for continued conservation, which at the same time increase revenues from ecosystem services.

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