NATURE-BASED INFRASTRUCTURE
GLOBAL RESOURCE CENTRE

Sustainable Asset Valuation of Land Restoration and Climate-Smart Agriculture in Burkina Faso

NBI REPORT

Supported by

gef

UNIDO

MAVA
FONDATION POUR LA NATURE

Led by

IISD
International Institute for
Sustainable Development

In partnership with

NDC
PARTNERSHIP

June 2024

Published by the International Institute for Sustainable Development

The **Nature-Based Infrastructure (NBI) Global Resource Centre** aims to improve the track record of NBI to deliver infrastructure services and adapt to climate change while delivering other environmental, social, and economic benefits. We provide data, training, and customized valuations of NBI projects, based on the latest innovations in systems thinking and financial modelling.

The Centre is an initiative led by IISD, with the financial support of the Global Environment Facility (GEF) and the MAVA Foundation, in partnership with the United Nations Industrial Development Organization.

Sustainable Asset Valuation of Land Restoration and Climate-Smart Agriculture in Burkina Faso

June 2024

Written by Edoardo Carlucci and Marco Guzzetti

Photo: iStock.

IISD
nbi.iisd.org
@iisd_sustinfra

UNIDO
unido.org
@unido

GEF
thegef.org
@theGEF

MAVA
mava-foundation.org
@MavaFdn

NATURE-BASED INFRASTRUCTURE
GLOBAL RESOURCE CENTRE

Supported by

gef

UNIDO

MAVA
FONDATION POUR LA NATURE

Led by

IISD

In partnership with

NDC PARTNERSHIP

Acknowledgements

We would like to thank Ansiowor Gildas Constantin Some from Direction Générale des Aménagement Agro-pastoraux et du Développement de l'Irrigation for his engagement throughout this process, support in providing local data for the analysis, and review of the technical report. We would like to thank also David Vieira Ferreira Levy and colleagues from the NDC Partnership for their support throughout the process.

Andrea M. Bassi, Liesbeth Casier, David Uzsoki, and Benjamin Simmons reviewed this report and provided valuable feedback.

Author contributions: Edoardo Carlucci developed the Excel-based model and led writing of the report. Andrea Bassi reviewed the model and the cost-benefit analysis. Marco Guzzetti conducted the spatial analysis and wrote the related technical appendix.

Executive Summary

Burkina Faso is a landlocked country in West Africa that is already facing the impacts of climate change. In recent years, the country has been experiencing extreme rains and flooding events, as well as longer droughts that exacerbate land degradation and desertification. This has had a detrimental effect on agricultural land, with 46% of Burkina Faso's arable land being already degraded. Every year, an additional 105,000 to 250,000 ha become degraded and are less agriculturally productive, posing a serious threat to food security, health, and well-being of the country's rural communities.

The short- and long-term impacts of these climate change-related extreme weather events are devastating. In the short term, extreme precipitation can lead to crop losses and infrastructure damages. In the long term, flooding can cause far-reaching issues, including reduced soil quality due to land erosion, impacting public health, agriculture, and the economy. Both these long- and short-term impacts have resulted in the displacement of people, who are forced to leave their homes and livelihoods in search of security. Eighty per cent of the Burkinabè are employed in agriculture; therefore, this degraded land and agricultural decline—combined with the huge increase in conflict and food insecurity—mean that displacements in Burkina Faso have increased by over 7,000% since August 2018. This is one of the fastest-growing displacement rates in the world, alongside Mozambique and Ukraine.

To tackle the pervasive issue of land degradation and promote more sustainable agricultural livelihoods, the Ministry of Agriculture and the Ministry of Finance in Burkina Faso, in collaboration with the Nationally Determined Contributions (NDCs) Partnership, is implementing a comprehensive land restoration project. This initiative aims to encompass an extensive area of 100,270 km^2, equivalent to 37% of the nation's total territory. The project will primarily concentrate on the Sahel, the Boucle du Mouhoun, and the regions of the east and the Cascades. It is anticipated that this undertaking will directly benefit 26,071 households, with a specific focus on ensuring that at least 7,822 women (30% of the beneficiaries) are included. Additionally, it is estimated that the project will have an indirect positive impact on the lives of approximately 630,480 individuals.

This report presents a comprehensive analysis of the social, economic, and environmental impacts of this land restoration project in Burkina Faso. Our study employs a combination of spatial analysis, climate data, Excel-based modelling, and financial analysis to conduct an integrated cost-benefit analysis (CBA) comparing nature-based infrastructure (NBI) with a conventional infrastructure alternative. Specifically, our assessment focuses on three key areas: 6,000 ha of landscaped vegetation, 700 ha of lowland development completion, and 10,500 ha of assisted natural regeneration.

We assess the following scenarios:

- **NBI:** This scenario involves land restoration—consisting of tree planting, climate-smart agricultural practices and agro-silvo-pastoral (ASP) areas (which integrate agriculture, grasslands, and livestock production)—with a focus on reducing land erosion, increasing agricultural productivity, and retaining water in the soil. Qualitatively, this scenario includes the use of locally sourced biofertilizers and biopesticides.
- **hybrid infrastructure:** This scenario combines a solar-powered irrigation pumping system, soil restoration practices, and climate-smart agriculture to combat soil erosion, enhance water management, and increase agricultural yields and income. This integrated approach is committed to ensuring food and nutrition security while minimizing environmental impact. Qualitatively, the scenario includes the use of locally sourced biofertilizers and biopesticides.
- **grey infrastructure:** This scenario includes conventional water storage and irrigation. This involves engineered structures and systems designed to manage and utilize water resources for agricultural and other uses. It also includes the construction of reservoirs for storing water, which can then be released and distributed through a network of canals, pipes, and irrigation systems to agricultural fields. These systems are characterized by their reliance on human-engineered solutions, such as concrete and steel, to control and manipulate the water environment to meet human needs.

Our integrated CBA estimates the following costs, added benefits, and avoided costs:

- investment and maintenance costs for climate-smart agriculture and land restoration, solar pump system, plus the conventional water storage option
- ASP area revenues including fruit crop revenues (mango and citrus)
- crop revenue from climate-smart agriculture
- employment and income
- food security and nutrition
- carbon sequestration

Key Results

1. The NBI and the hybrid infrastructure prove to be economically sound investments, yielding a net integrated value of USD 869.57 million and USD 1.09 billion, respectively. These scenarios result in enhanced agricultural productivity, leading to higher crop and ASP area incomes, thereby fostering improved food security, nutrition, and health benefits.
2. By providing people with income and enough to eat while protecting them from floods, the NBI avoids the displacement of people from their homes, increases stability, and reduces the potential for conflicts and violence.

3. The use of NBI increases carbon storage, which mitigates climate change, generating an avoided cost of USD 28.1 million and offers financing opportunities through carbon credits.
4. The nature-based and hybrid interventions perform better than the grey infrastructure alternative of water storage and irrigation, while delivering valuable added benefits that the conventional infrastructure cannot provide.
5. The implementation of the nature-based infrastructure can be replicated across Burkina Faso and beyond to effectively combat desertification and sustain rural livelihoods by using NBI at scale.

Table ES1. Cost-benefit statement (undiscounted) – USD million

Indicators	NBI	Grey infrastructure	Hybrid infrastructure
Project costs			
Construction costs	21.0	14.5	31.2
Operating and maintenance costs	99.4	26.1	117.7
Total costs	**120.3**	**40.6**	**148.9**
Project benefits			
Food security and nutrition	754.3	244.2	1,242.6
ASP area income	900.0	0.0	900.0
Employment and income	39.3	1.8	17.1
Carbon sequestration	28.1	0.0	28.1
Crop income	54.3	0.0	54.3
Total benefits	**1,776.1**	**245.9**	**2,242.2**
Net benefit/(cost)			
Total benefits	1,776.1	245.9	2,242.2
Total costs	120.3	40.6	148.9
Net benefits/costs	**1,655.8**	**205.4**	**2,093.3**
Benefit/cost ratio	**14.8**	**6.1**	**15.1**

Source: Authors.

Table of Contents

List of Figures

List of Tables

Glossary

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

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

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

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

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

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

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

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

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

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

1.0 Introduction

Burkina Faso, a landlocked country in West Africa, is already grappling with the severe impacts of climate change. The nation experiences distinct wet and dry seasons, but the intensity of rainfall has escalated, leading to frequent floods. Conversely, the dry period has grown longer, intensifying land degradation and desertification, exacerbating the existing challenges.

This process has particularly affected agricultural land, with a staggering 46% of arable land in Burkina Faso already degraded. Disturbingly, each year, an additional 105,000 to 250,000 ha of land succumb to degradation, resulting in diminished agricultural productivity. This situation poses a critical threat to food security, as well as the health and well-being of rural communities in the country.

The short- and long-term impacts of climate change-related extreme weather events are profoundly devastating. In the short term, excessive precipitation leads to crop losses and infrastructure damage. Over the long term, flooding triggers far-reaching issues such as land erosion, which degrades soil quality and negatively affects public health, agriculture, and the economy. Both the immediate and lasting consequences have resulted in the displacement of people, turning them into climate refugees who are compelled to abandon their homes and livelihoods in search of security and jobs.

To combat this widespread land degradation, the Ministry of Agriculture and the Ministry of Finance for Burkina Faso, in collaboration with the NDC Partnership, have proposed a land restoration project. The project encompasses various components, including the establishment of 6,000 ha of landscaped vegetation, the development of 700 ha of lowlands, and the facilitation of 10,500 ha of assisted natural regeneration. Encompassing an area of 100,270 square kilometres (equivalent to 37% of the total national territory), the project focuses on the Sahel, the Boucle du Mouhoun, the east, and the Cascades regions.

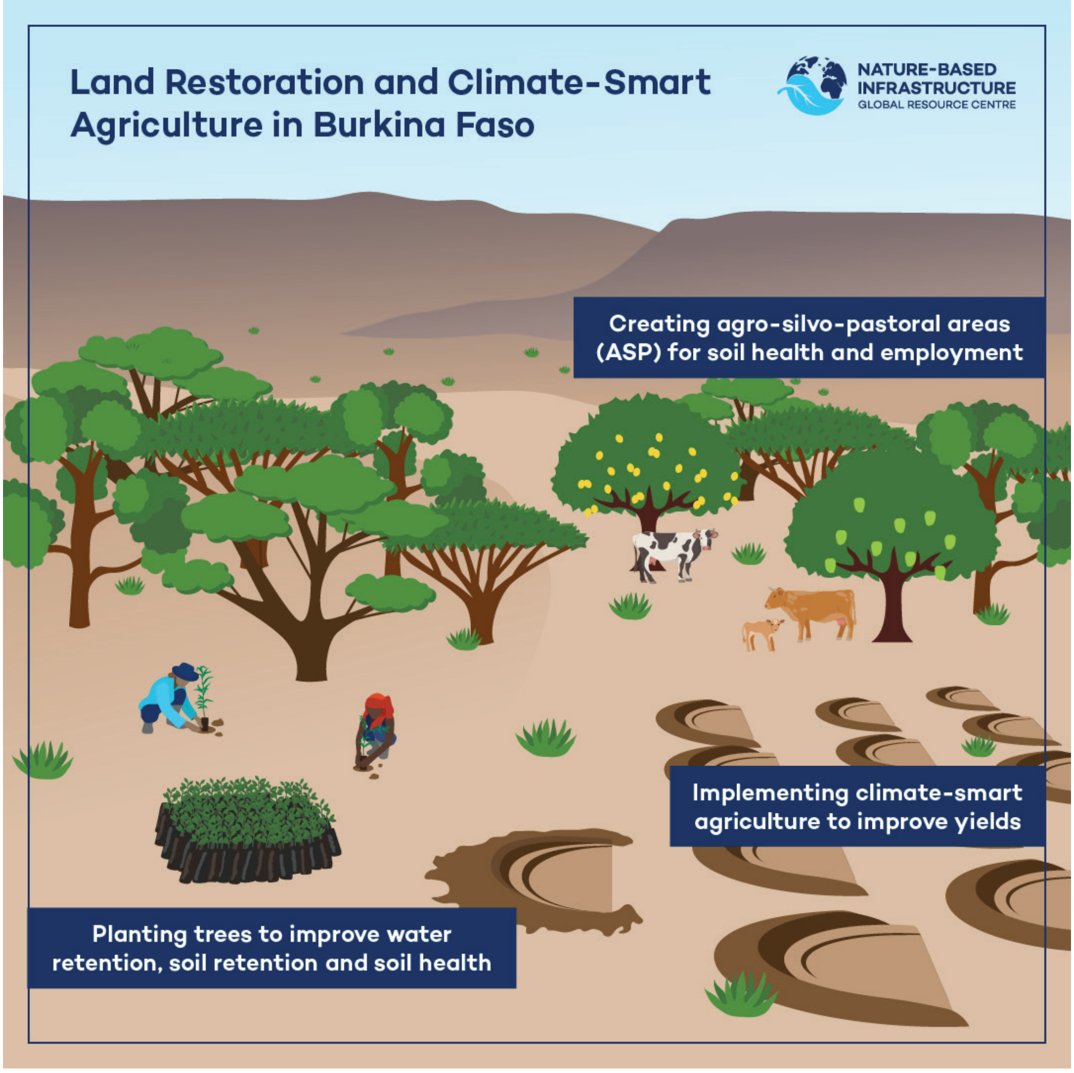
It is estimated that the project will directly benefit approximately 26,071 households, with a specific emphasis on ensuring that at least 7,822 women (30% of the beneficiaries) receive support. Additionally, the project is expected to have an indirect positive impact on approximately 630,480 individuals. Based on the outcomes of this initiative, the government will consider replicating similar efforts in other areas of the country.

We conducted an assessment of two project scenarios for land restoration: an NBI approach and a hybrid solution that combines the nature-based approach with a solar-powered irrigation pumping system. The NBI scenario involves tree planting, climate-smart agricultural practices, and the establishment of combined ASP areas that integrate agriculture, grasslands, fruit crops (mango and citrus), and livestock production. The primary focus is on reducing land erosion, increasing agricultural productivity, and improving water retention in the soil.

In addition, the hybrid solution incorporates soil restoration practices and climate-smart agriculture, along with the solar-powered irrigation pumping system. This integrated approach aims to combat soil erosion, enhance water management, and achieve higher agricultural yields and income. Also, we compare these two scenarios with a conventional infrastructure approach that includes water storage and irrigation. All three scenarios take into account the utilization of non-chemical pesticides, specifically ecological pesticides and biological matter that are already being used in the area. These ecological pesticides offer an environmentally friendly alternative to conventional chemical pesticides, aligning with the nature-based and hybrid approaches. Incorporating these non-chemical pest control methods supports sustainable agricultural practices and minimizes the potential negative impacts on ecosystems and human health.

This report serves as a valuable resource for evaluating potential financial support for the project. It assists in determining the optimal financial structure for the work and calculating the expected return on investment across various scenarios. The analysis combines financial forecasting methods based on projected cash flows, economic valuations of natural ecosystem services, and consideration of other co-benefits offered by the project. The assessment is fully customized to the local context and has been developed in close collaboration with the NDC Partnership and government stakeholders in Burkina Faso.

Furthermore, the report aims to facilitate the replication and expansion of the nature-based infrastructure (NBI) approach, serving as a case study for the widespread adoption of NBI throughout the country. The assessment process also contributes to capacity-building efforts at the national and regional levels in Burkina Faso, promoting more informed policy design and implementation of nature-based approaches to address sustainability challenges.



Source: Authors.

2.0 Sustainable Asset Valuation

2.1 Importance of Systems Thinking

Systems thinking is a holistic approach to understanding complex systems by analyzing the relationships between their various components. It involves considering the interdependence of different factors within a system to understand how it functions as a whole. In this approach, the focus is not only on isolated components but rather on understanding the underlying structure and dynamics that produce specific events and patterns (Goodman, n.d.).

Three key elements are involved in system thinking:

- **events:** These are specific occurrences or happenings that can be observed and recorded. Events provide basic information about what took place, where, when, and who was involved.
- **patterns:** Patterns are recurring themes or trends that emerge from the events. They are like the threads that weave the events together, offering a more comprehensive view of the system's behaviour and dynamics.
- **systemic structures:** Systemic structures represent the underlying relationships and interactions between the various components of the system. They illustrate how factors within the system are interconnected and influence one another, leading to the observed patterns and events. By describing these systemic structures, we can gain insight into why specific events occur and better comprehend the overall behaviour of the system.

By employing systems thinking, we can identify points of intervention that can lead to meaningful changes and improvements. Understanding the interplay between events, patterns, and systemic structures enables us to approach complex problems more effectively and develop strategies that address the root causes of issues.

2.2 Introduction to Sustainable Asset Valuation

The Sustainable Asset Valuation (SAVi) methodology incorporates various analytical and modelling approaches to provide a comprehensive assessment of infrastructure projects. By using system dynamics models, SAVi supports the development of integrated investment assessments and policies, enabling the exploration of "what-if" scenarios for long-term system stability. These models inform policy formulation, evaluation, and monitoring. By combining system dynamics and project finance modelling, SAVi considers a wide range of environmental, social, economic, and governance risks. Moreover, SAVi quantifies the monetary value of added benefits and avoided costs resulting from infrastructure development.

A key aspect of the SAVi approach is the collaborative co-creation of knowledge. Through engagement with diverse local stakeholders and decision-makers, SAVi assessments are developed, starting with a participatory exercise to gather information and collaboratively create causal loop diagrams (CLDs) that shape the assessment process.

We leverage climate data and projections from the Copernicus Climate Change Service in integrated infrastructure valuations, enabling explicit representation of climate impacts and a more comprehensive assessment of related risks and externalities.

Spatial modelling informs the economic valuation of environmental indicators by quantifying ecosystem services and showing where an impact takes place, which is essential for economic valuation.

Complementing these assessments, CBAs estimate the amount and value of environmental services provided in the current landscape and under future scenarios. To evaluate the viability and societal value of nature-based solutions, SAVi relies on key performance indicators such as benefit-to-cost ratio (BCR), internal rate of return (IRR), and the net integrated value (net present value, or NPV).

2.3 Causal Loop Diagram

The main goal of the project is to improve agriculture land productivity, and hence revenues and profitability for farmers and nutrition for the population. The growing frequency of extreme climatic events is already posing challenges, especially in relation to droughts and floods, and climate projections highlight that precipitation, and especially extreme rainfall events, will increase in the future, along with an increased concentration of rainfall in the months of July and August, leaving the first part of the year with lower precipitation and higher risk of desertification.

Overall, we observe two main impacts of climate change on agriculture production in the study area. The first impact, soil erosion, builds and increases over time and poses a systemic, long-term challenge. The second impact, extreme weather events, is more immediate and either prevents the yield (extended droughts) or causes pre-harvest losses (extreme precipitation and floods). Both climate-related challenges can be addressed by investing in land restoration, e.g., to prevent desertification (challenge 1), and by investing in climate-smart practices, e.g., half-moons to minimize the impacts of extreme weather events (challenge 2). Half-moons are semi-circular ponds designed to enhance water retention, thereby boosting agricultural productivity in West Africa. This agricultural method is primarily employed to prevent further degradation by effectively retaining rainfall water (Issa, 2024).

The CLD presented in Figure 1 summarizes these dynamics in three main circular relations or feedback loops. First, R1 indicates that increased soil erosion leads to lower soil quality. A decline in soil quality results in lower agriculture land productivity, a known challenge that is expected to worsen. To avoid negative impacts on income and nutrition, an expansion of agriculture land is often considered. However, this would result in a further reduction of vegetation and in the possible increase of soil erosion and desertification. In fact, feedback loop R2 highlights that a reduction of vegetation has a direct impact on runoff retention, which results in higher floods and soil erosion. Finally, R3 indicates that when soil erosion increases and soil quality declines, runoff retention also declines, resulting in a higher flood risk. This shows that there is a direct link between soil erosion and runoff retention, and hence floods, via land cover change and the impoverishment of soil. These two factors, combined with the forecasted higher frequency of extreme rainfall events and prolonged periods of droughts, highlight the presence of a systemic issue that is bound to grow in importance over time.

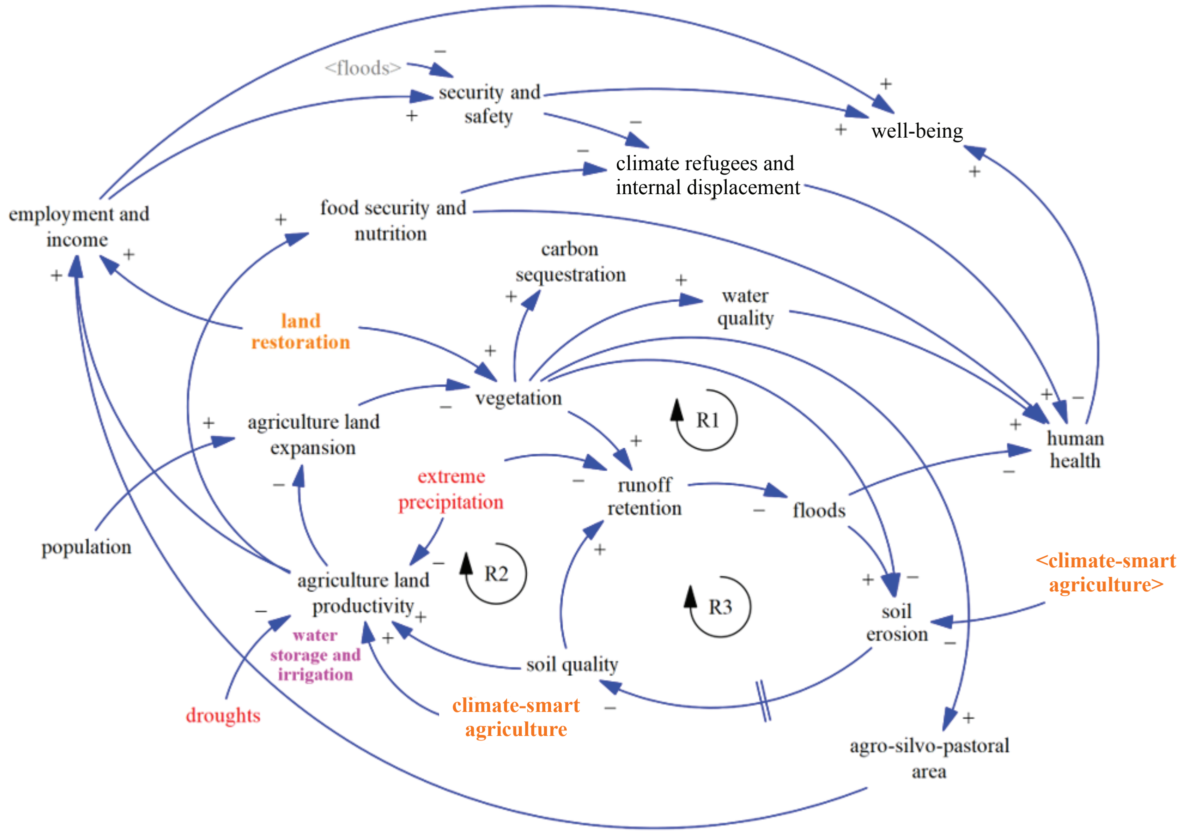
Investments in land restoration and climate-smart agriculture (CSA), as presented in Figure 1, can improve adaptive capacity, and hence reduce climate vulnerability. Land restoration results in higher runoff retention and reduced soil erosion, reversing the vicious cycles represented by R1, R2, and R3, and increase revenue generation potential from ASP systems. Climate-smart agriculture (CSA) practices, such as the use of half-moons, increases water retention, improves agriculture land productivity, and improves water quality by reinforcing the natural vegetation and its water filtration services, already in the short term. As a result, agriculture production will increase, along with production from ASP systems, and so will income for farmers and food security. With positive outcomes for income and nutrition, security and safety are expected to increase, reducing the risk of internal displacement (i.e., climate-induced migration and climate refugees). Well-being is expected to increase, with improved nutrition, higher income, improved water quality, increased security and safety, and reduced impact of floods.

The construction of water storage facilities, as a built infrastructure option, will generate similar benefits on land productivity. On the other hand, this infrastructure will not improve climate resilience to the same extent (i.e., it offers improved resilience to drought but not to extreme rainfall events). Additionally, it lacks synergies with ASP systems and does not enhance water quality.

Box 1. Reading a causal loop diagram

A causal loop diagram is a tool that supports systems thinking. It shows relations between components of a system. Arrows indicate causality and plus and minus signs are used to show the direction of causality. A plus sign means that two variables change in the same direction (a positive correlation), while a negative sign means that they change in opposite directions (a negative correlation). Feedback loops are labelled as either reinforcing (R) or balancing (B). A reinforcing loop indicates that a change in one variable will lead to further change in the same direction, whereas a balancing loop dampens change.

Figure 1. CLD representing the main dynamics of climate vulnerability in the case studies assessed in Burkina Faso



Source: Authors.

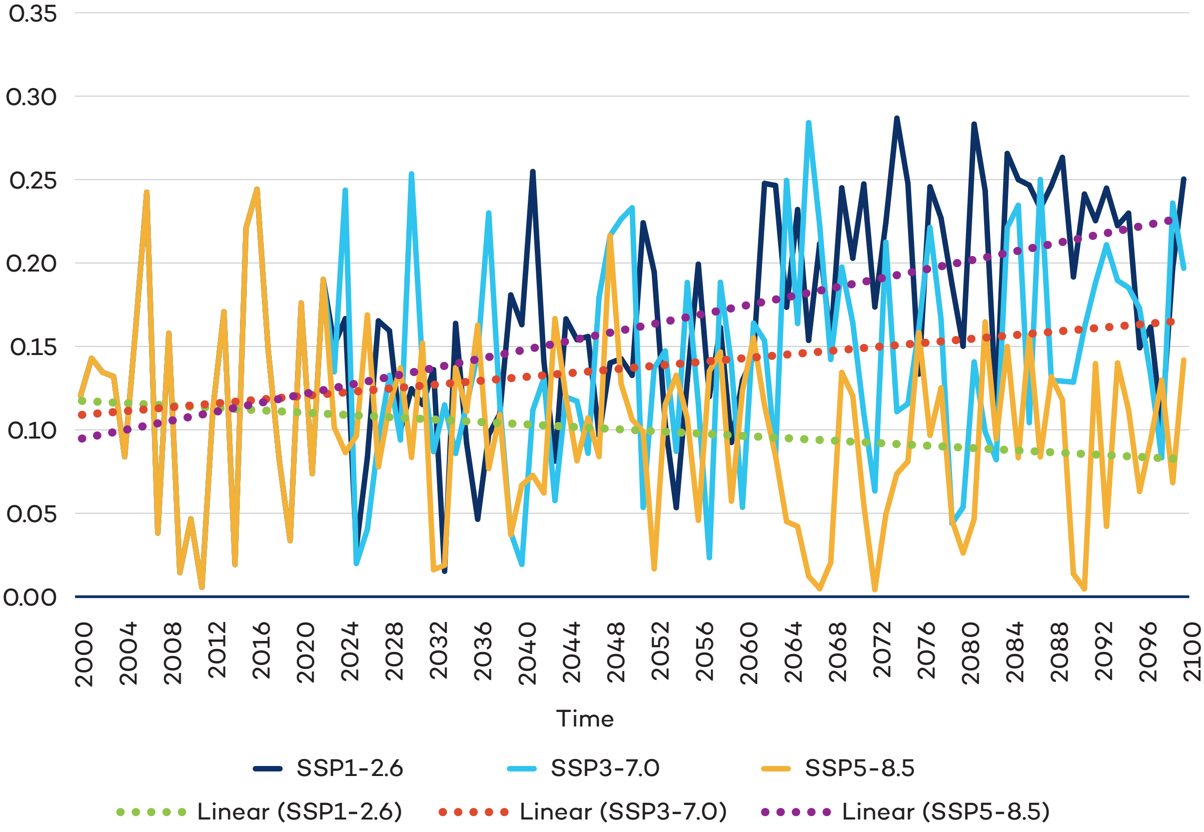
2.4 Climate Data Analysis

Climate data considered in this analysis are based on the shared socio-economic pathways (SSPs) scenarios. The SSPs define different baselines that might occur based on various underlying factors like population, technological, and economic growth, which may lead to different future greenhouse gas (GHG) emissions and warming outcomes (Carbon Brief, 2018). The SSPs are based on various narratives describing broad socio-economic trends that can shape future societies. Specifically, this study considers the following SSPs, as described by Meinshausen et al. (2020):

- SSP1-2.6, where global temperatures are expected to increase by 2°C by 2100
- SSP3-7.0 is a medium-high reference scenario
- SSP5-8.5 correspond to a high reference scenario in a high-fossil fuel use world throughout the 21st century

Figure 2 shows the extreme wet percentile from 2000 to 2100 under different SSP scenarios from 2000 to 2100. Climate data suggest that the incidence of extreme wet climate abnormalities in the SSP1-2.6 scenario slightly declines between 2000 and 2100. In the SSP3-7.0 and SSP5-8.5 scenarios, we find that the incidence of extreme wet abnormalities in Boucle du Mouhoun increases over time. In the SSP3-7.0 scenario, it reaches 0.17 in the year 2100 (+70%) and in the SSP5-8.5 scenario the incidence doubles to 0.2 (+100%), compared to 0.1 in 2020. This increase indicates that the frequency and intensity of the already relentless rainfall events will increase in the future.

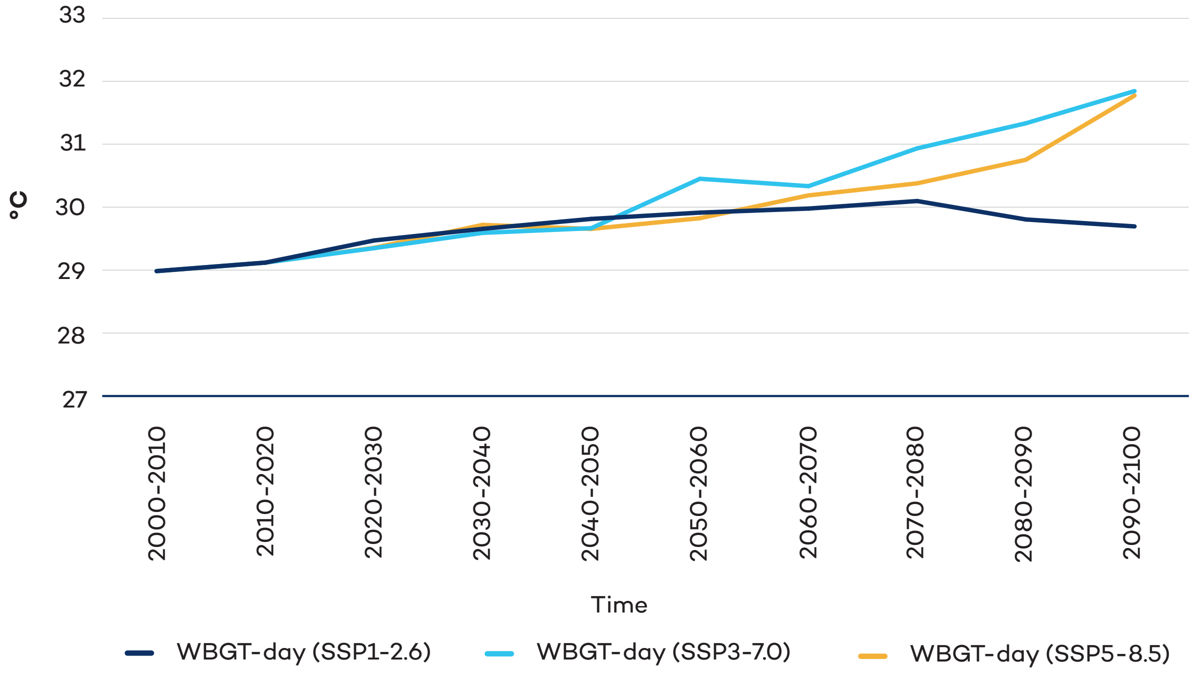
Figure 2. Extreme wet percentile (Boucle du Mouhoun)



Source: Authors.

Figure 3 shows the average monthly temperature (°C) in Boucle du Mouhoun from 2000 to 2100 under the three different SSP scenarios. The trends are similar under all three SSP scenarios until 2050, after which they bifurcate. In the SSP1-2.6, monthly temperature remains constant throughout the decades between 2050 and 2100. In the SSP3-7.0 and SSP5-8.5 scenarios, the average monthly temperature increases by roughly 2°C compared to 2050, or 3°C compared to 2000. The SSP3-7.0 scenario hereby projects the soonest increase in temperature, followed by the SSP5-8.5 scenario. The increase in temperature after 2050 will cause an additional decline in crop yields, given that air temperatures will increase further above the optimal temperature range for many crops.

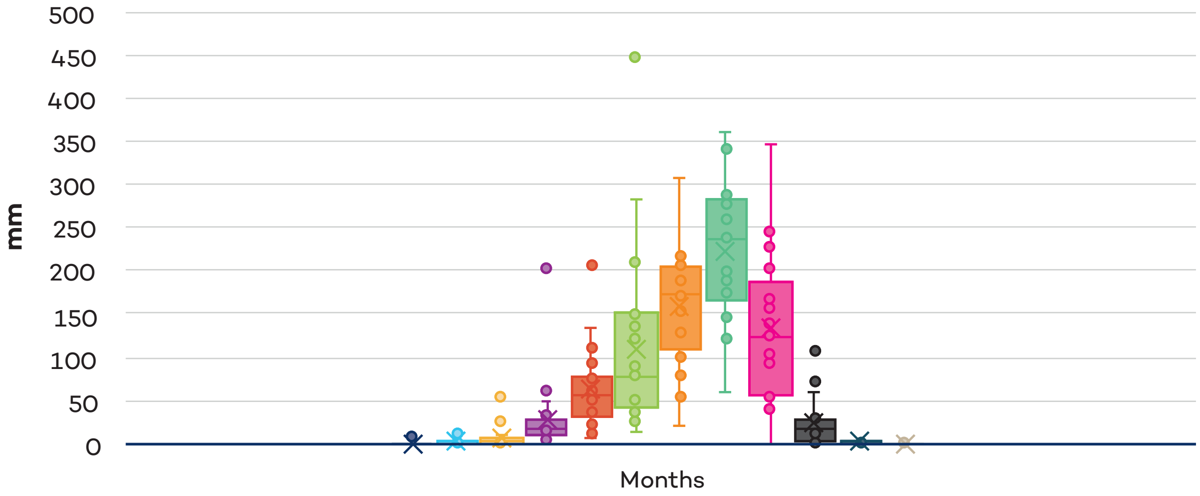
Figure 3. Average monthly temperature (Boucle du Mouhoun)



Source: Authors.

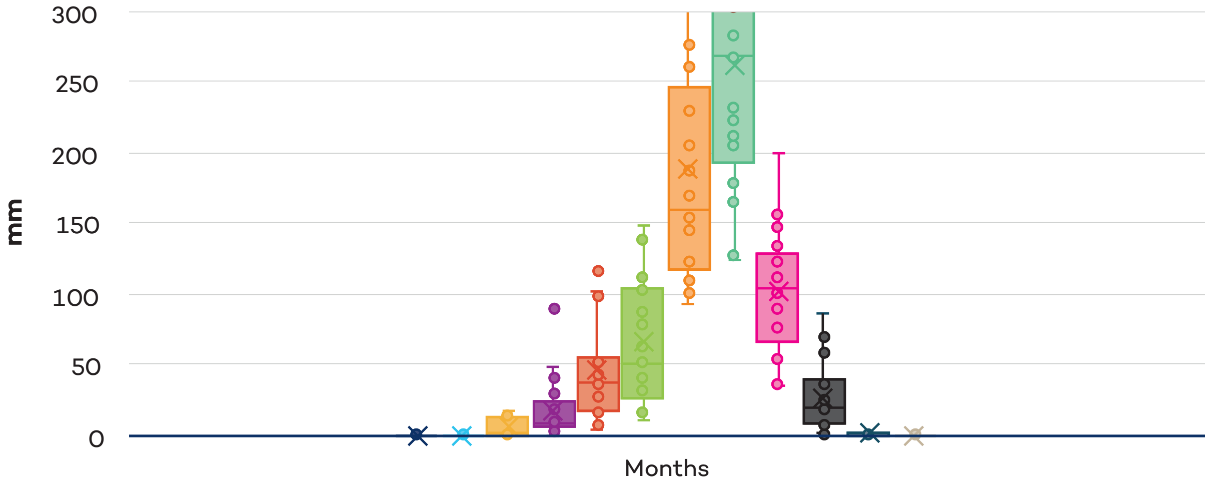
Figure 4 shows in a box plot the average precipitation (mm/month) in Boucle du Mouhoun for the period 2000 to 2020 under the SSP5-8.5 scenario, while Figure 5 shows the same variables but for the period 2040–2060. The results suggest that from 2000 to 2020, most months of the wet season (from June to September) received an equal amount of rainfall. In the average precipitation estimated for the period 2040 to 2060, a concentration of rainfall to July and August, while the average rainfall for June and September declines considerably. This is consistent with the increased incidence of extreme wet abnormalities described above.

Figure 4. Average precipitation (2000–2020)



Source: Authors.

Figure 5. Average precipitation (2040–2060)



Source: Authors.

2.5 Spatially Explicit Analysis

2.5.1 Methodology

The spatially explicit analysis performed for this assessment relies on the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) suite of models.[1] These models, developed by the Natural Capital Project, use land-use/land cover (LULC) maps as inputs and quantify a wide range of ecosystem services.

For this assessment, we used the LULC map created by the Climate Change Initiative (CCI) Land Cover team.[2] This is a prototype high-resolution LULC map at 20m over Africa based on 1 year of Sentinel-2A observations from December 2015 to December 2016. The area of interest was extracted from this map, and its resolution was increased to 1 m in QGIS 3.8.0.[3] Increasing the resolution of a raster in QGIS means increasing the level of detail or granularity of the raster dataset. This process involves dividing each cell of the raster into smaller cells, resulting in more cells covering the same area and thus increasing the overall resolution of the raster.

The legend of this map includes 10 generic land cover classes that appropriately describe the land surface at 20 m: "tree-covered areas (1)," "shrub-covered areas (2)," "grassland (3)," "cropland (4)," "vegetation aquatic or regularly flooded (5)," "lichen and mosses/sparse vegetation (6)," "bare areas (7)," "built-up areas (8), and "open water (10)."

---

[1] https://naturalcapitalproject.stanford.edu/software/invest

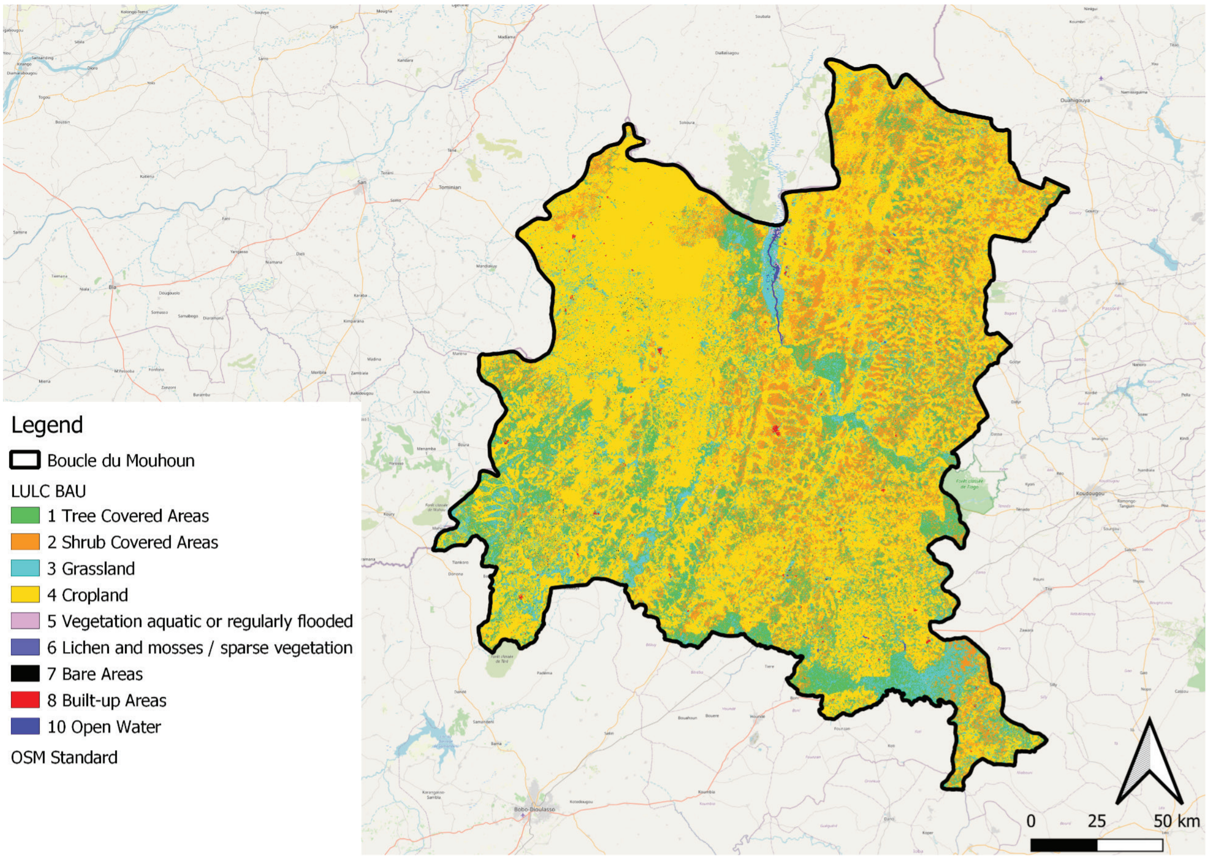
[2] http://2016africalandcover20m.esrin.esa.int/

[3] QGIS, which stands for Quantum Geographic Information System, is a free and open-source geographic information system (GIS) software that allows users to create, edit, visualize, analyze, and publish geospatial information. It is widely used by professionals and enthusiasts in various fields such as geography, cartography, environmental science, urban planning, and many others.

For each LULC, we considered the current landscape (business-as-usual [BAU] scenario) and a second option that assumed the implementation of restoration activities (restored scenario). The restoration activities set in this NBI project (the development of 6,000 ha of landscaped vegetation, 700 ha of lowland development completion, and 10,500 ha of assisted natural regeneration) have been applied to create the LULC under the restored scenario. Please note that the 6,000 ha of landscaped vegetation have been considered as a new land cover, since these could be considered new trees (code 12), while the 700 ha of lowland have been considered as grassland, and the 10,500 ha of assisted natural vegetation as shrubs. Figure 6 and Figure 7 show the LULC under both the BAU and the restored scenario, respectively.

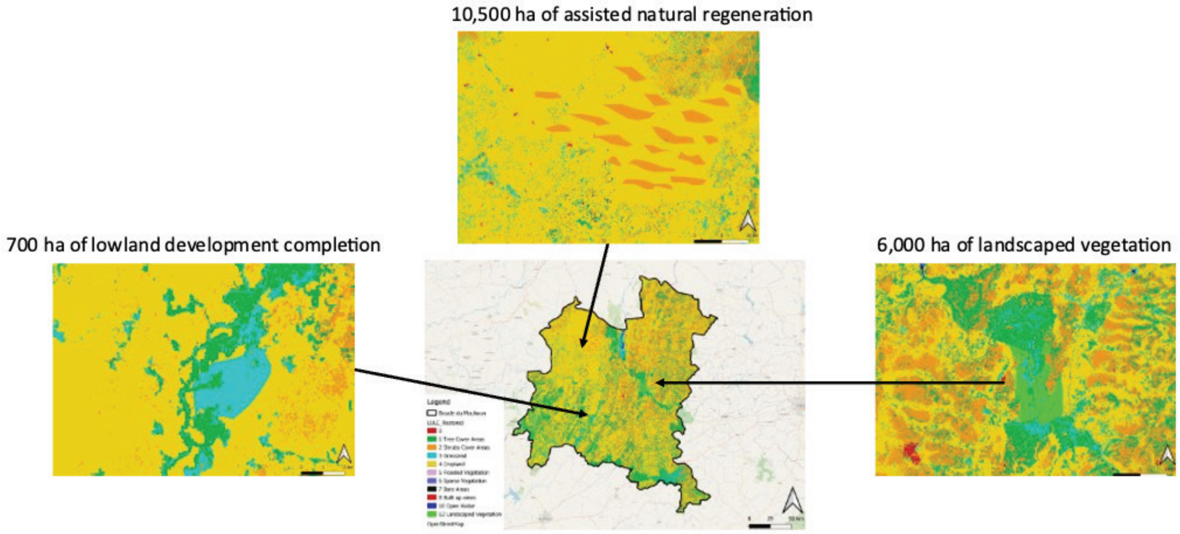
For additional information on the methodology please see Technical Appendix on Spatial Analysis.

Figure 6. LULC BAU scenario



Source: Authors.

Figure 7. LULC Restored scenario (zoom in on the restored areas)



Source: Authors.

2.5.2 Results

The results of four InVEST models are presented. First, the carbon storage model calculates the amount of carbon stored in the landscape. Second, the water yield model estimates the annual average quantity of water produced by one or more watersheds found in the study area. Third, the Nutrient Delivery model allows to map nutrient sources (nitrogen and phosphorus) from watersheds and their transport to the stream. Lastly, the Sediment Delivery Ratio model quantifies the avoided erosion in the landscape.

Compared to the BAU scenario, carbon storage is estimated to be higher in the restored scenarios in all the study areas, as shown in Table 1, while water yield volume, nutrients export, and sediment export are expected to decrease.

Table 1. Spatial analysis results

LULC scenario	Carbon storage (tons)	Water yield volume (m^3)	Nitrogen export (kg)	Phosphorus export (kg)	Sediment export (tons)
BAU	349,970,071	686,314,179	6,914,646	1,800,808	26,742,438
Restored	350,533,009 (Change 0.16%)	683,682,599 (Change -0.38%)	6,861,781 (Change -0.76%)	1,785,960 (Change -0.82%)	26,675,547 (Change -0.25%)

Source: Authors.

These results suggest that landscape restoration not only increases carbon storage but also reduces nutrient and sediment exports, potentially improving water quality and agricultural production, respectively. The decrease in water yield is caused by the increase in forest land and other land classes replacing cropland. The yield decreases because natural vegetation can, in fact, intercept precipitation and retain large amounts of water (Manashi, 2016). The decline in water yield (thanks to an increase in forest land, grassland, and shrubs) indicates that more water is retained in the landscape, which would constrain water availability for productive purposes (e.g., agriculture).

2.6 Integrated Cost-Benefit Analysis

2.6.1 Methodology

We use an Excel-based model relying on multiple data sources and assumptions to calculate each indicator included in the CBA. When possible, we used local data provided by local stakeholders. Data gaps were filled using international peer-reviewed literature and other assumptions validated by local stakeholders.

We report the cumulative value of these indicators over time, both undiscounted and discounted. For the undiscounted results, we present the net benefits and BCR. The discounted analysis consists of three elements: the cash flow statement, the impact statement, and the integrated value statement. The cash flow statement includes only the costs and revenues that are actual cash flows from the interventions. The impact statement includes all other benefits generated by the implementation of the interventions. The integrated value statement combines the two.

At the integrated value statement level, we calculate the following three indicators:

- BCR in present value (PV) terms
- IRR
- PV of the net integrated value

Collectively, these indicators provide a comprehensive view of the economic impact of our proposed interventions, helping stakeholders make informed decisions.

Assumptions

Table 2. Cost-benefit analysis indicators, assumptions, and data

Indicator	Assumptions
Costs	
Construction cost	Construction costs for the **NBI scenario** are based on three interventions: land restoration, CSA, and ASP systems. Land restoration construction costs are estimated by multiplying the area of 17,200 ha with USD 800 average cost per hectare (Ansiowor Gildas Constantin Some, assumption validated via personal communication, June 21, 2023). The total construction costs for land restoration amount to USD 13,760,000. For CSA, the construction costs are estimated by multiplying the area covering 6,000 ha with an average cost for implementing CSA practices, as found in the literature (USD 175 per hectare) (Douxchamps et al., 2012). The total construction costs for CSA are USD 1,050,000. Similarly, for ASP systems, the construction costs are estimated by multiplying the area (5,500 ha) with an average cost of USD 1,120 per hectare implementing these systems (Ansiowor Gildas Constantin Some, data validation via personal communication, June 21, 2023). The total construction costs for ASP systems are USD 6,160,000. The overall construction costs for the NBI are determined by totalling the three interventions (land restoration, CSA, and ASP systems), which amount to USD 20,970,000. The construction costs of the **hybrid infrastructure scenario** are determined by the sum of the three interventions of the NBI scenario (land restoration, CSA and ASP systems) plus the construction costs of solar pumps. For solar pumps, construction costs are estimated by multiplying the area supported (6,000 ha) by the average construction cost for solar pumps, based on literature (USD 1,700 per hectare, Agrawal & Jain, 2018). The total construction costs incurred for solar pumps amount to USD 10,200,000. The total construction cost for the hybrid summing all four interventions mentioned above amounts to USD 31,170,000. For the **water storage scenario**, construction costs are estimated by multiplying the area supported (6,000 ha) with an average construction cost for water storage, based on literature (USD 2,416 per hectare, Min. of Agriculture, Govt. of India, n.d.). The total construction costs of the water storage amounts to USD 14,496,000.

Indicator	Assumptions
Operation and maintenance (O&M)	The O&M costs of the **NBI** are calculated as the sum of two interventions (land restoration and CSA). Each of the two interventions is calculated as the multiplication of the number of ha by a fixed annual O&M unit cost. Specifically: • Land restoration: 17,200 ha * USD 150/ha/year (Ansiowor Gildas Constantin Some, data validation via personal communication, June 21, 2023). The overall O&M cost for land restoration is USD 2,580,000 per year. • CSA: 600 ha * USD 30/ha/year (Douxchamps et al., 2012). The overall O&M cost for CSA is USD 180,000 per year. Therefore, the sum of O&M costs for land restoration and CSA is USD 2,760,000 per year. The O&M costs for the **hybrid infrastructure** are determined by the sum of O&M costs of land restoration and CSA calculated above in the NBI scenario, plus the O&M costs of solar pumps. The O&M costs of solar pumps are calculated at 5% of the total construction costs of the solar pumps (USD 10,200,000), equating to USD 510,000 per year. (Ansiowor Gildas Constantin Some, data validation via personal communication, June 21, 2023). The overall total O&M costs for the hybrid infrastructure, including land restoration, CSA, and solar pumps, amount to USD 3,700,000 per year. For **grey infrastructure**, annual O&M costs are calculated by multiplying 6,000 ha with an average cost of USD 2,416 per ha (Ansiowor Gildas Constantin Some, assumption validated via personal communication, June 21, 2023).
Added benefits	
ASP revenue	The revenue generated by the ASP system includes three sources of revenue: revenue from agro-sylvo activities, revenue generated by fruit cultures, and pastoral revenue. **Agro-sylvo revenue** is calculated by multiplying the area (5,500 ha) with the average agro-sylvo revenue (USD 1,500 per hectare per year, Ansiowor Gildas Constantin Some, assumption validated via personal communication, June 21, 2023). The total revenue for agro-sylvo activities amounts to USD 8,250,000 per year. Furthermore, the revenue from **pastoral activities** consists of income generated from pine sales (USD 50 per ha per year) plus the revenue from cattle sales (USD 1,200 per ha per year) (Rade et al., 2017) multiplied by the area (5,500 ha) (Rade et al., 2017). The total revenue generated from pastoral activities amount to USD 6,875,000 per year. **Revenue from fruit crops** is calculated on the total annual production of mangoes in Burkina Faso (200,000 tons) (World Bank, 2007) and citrus fruits (75,000 tons) (World Bank, 2017), resulting in a combined fruit production of 275,000 tons per year.

Indicator	Assumptions
ASP revenue (continued)	The estimated revenue from fruit cultivation is USD 2,100 per ton per year (Ansiowor Gildas Constantin Some, personal communication, June 21, 2023). Here, it is multiplied by the total production of mango and citrus in Burkina Faso (275,000 tons per year) providing an estimation of the total revenue from mangoes and citrus productions in Burkina Faso (USD 577,500,000). To estimate the total revenue from mangoes and citrus production for the specific region of Boucle du Mouhoun, the total revenue of mangoes and citrus production (USD 577,500,000) is multiplied by 1.71%, which is the share of fruit production for the Boucle du Mouhoun region (Carrico et al., 2021). The projected total fruit revenue for the region being studied is USD 9,875,250 per year. The total revenue generated by ASP activities is calculated by summing the total revenue from agro-sylvo activities, pastoral activities and fruit crops amounting to USD 25,000,250 per year. These calculations are used for both the NBI scenario and the hybrid scenario, generating the same monetary values. On the contrary, grey infrastructure scenario does not generate any additional revenue from agro-sylvo pastoral activities.
Employment and income	Employment and income in the **NBI scenario** consider the income from sylvo-pastoral activities and the income generated by construction and O&M of land restoration. The average salary per person is calculated on the average salary per person in CFA francs (XOF 1,004,500 per year) (World Salaries, 2023) multiplied by an exchange rate of 599 (XOF per USD).[4] The result gives the average salary per person in USD in Burkina Faso, which is USD 1,677 per year. Income from **sylvo-pastoral activities** is calculated on the area (5,500 ha), multiplied by the jobs per hectare (0.05 jobs per hectare per year) multiplied by the average salary (USD 1,677). The results are multiplied by 30%, representing the percentage of income creation based on the total salary. The total income generated for sylvo-pastoral activities is USD 143,951 per year. Income from **land restoration (construction)** is calculated on the area (17,200 ha), multiplied by the jobs per hectare (0.12 jobs per hectare per year) multiplied by the average salary (USD 1,677). The results are multiplied by 30%, which represents the percentage of income creation based on the total salary. The total income generated for sylvo-pastoral activities amount to USD 1,064,838 per year. Income from **land restoration (O&M)** is calculated on the area (17,200 ha), multiplied by the jobs per hectare (0.11 jobs per hectare per year) multiplied by the average salary (USD 1,677). The results are multiplied by 30% which represents the percentage of income creation based on total salary. The total income generated for sylvo-pastoral activities is USD 917,666 per year.

---

[4] Exchange rate date: November 20, 2023.

Indicator	Assumptions
Employment and income (continued)	For the **hybrid infrastructure** scenario, the calculations for employment and income follow the same methodology as the NBI scenario, with one significant difference. While the NBI scenario bases the calculation on 17,000 ha, the calculations for the hybrid infrastructure are based on 6,000 ha for land restoration (construction and O&M). The overall employment and income benefit generated for the hybrid infrastructure amounts to USD 835,523. For the **water storage scenario**, the employment and income benefit is calculated by first multiplying 6,000 ha by the number of jobs estimated per hectare per year (0.02 persons per hectare per year). This gives an estimate of 120 jobs created. Next, this is multiplied by the average salary per person per year (USD 1,677 per person per year, based on validation via personal communication with Ansiowor Gildas Constantin Some on June 21, 2023). The resulting total salary amount is then multiplied by 30% to represent the estimated percentage of income creation out of the total salary amount. The final total employment and income benefit for the water storage scenario amounts to USD 2,126,456 per year.
Crop revenue	Crop production is estimated by multiplying the area (6,000 ha) by the land productivity for maize. The productivity is estimated by the difference between investment and business as usual (BAU). Land productivity depends on climate change. Specifically, we include the following impacts on yield: • Temperature – 2°C results in -20% of yield (United States Agency for International Development, n.d.), so we assume that a 1°C change results in a yield loss of -10%, and 0.5°C, -5% yield loss. • Number of consecutive dry days – if the length of the drought doubles (i.e., number of consecutive dry days), you have a 20% reduction in yield (Deutsche Gesellschaft für Internationale Zusammenarbeit, n.d.). Data series (2023–2060) of those two impacts in Burkina Faso were downloaded from the Climate Change Knowledge Portal (World Bank, 2021) for the SSP3 and SSP5 climate scenarios. In the absence of climate change, we project that productivity would follow the historical average annual increase of 1.28% (Food and Agriculture Organization of the United Nations, n.d.), starting with a productivity of 1.65 tons per hectare in 2018. However, with the impact of climate change factored in, the total percentage change in productivity, relative to the scenario with no climate change, is determined by summing the percentage change attributed to increased temperatures and the percentage change caused by the number of consecutive dry days.

Indicator	Assumptions
Avoided costs	
Food security and nutrition	To calculate the avoided cost of malnutrition for the **NBI scenario**, first we estimate the number of undernourished people in Burkina Faso by multiplying the total population of Burkina Faso (21,522,626 people as of 2022) (World Bank, 2022) by the percentage of the population that is undernourished (18%) (Macrotrends, 2020). As a result, we find that approximately 3.874 million people are undernourished. Next, we calculate the cost of malnutrition per person by multiplying the number of undernourished people in Burkina Faso (3,874,073 people) by the total cost of malnutrition (USD 800 million) (Lemeke & Stulman, 2015). We then estimate the additional kilocalories (Kcal) produced from land restoration and CSA by multiplying the tons of additional crop production (previously estimated as part of the crop revenue calculation) by an average Kcal per ton (2.7 million Kcal per ton) (Lukmanji et al., 2008). Then, we determine the number of people supported by this additional production by dividing the total additional Kcal produced by the average deficiency per person. The deficiency per person is estimated at 365,000 Kcal per person per year, based on daily requirement of 1,000 Kcal per person per day (validated via personal communication with Ansiowor Gildas Constantin Some on June 21, 2023). Finally, the number of people supported is multiplied by the cost of malnutrition per person. The same methodology is used to calculate the avoided cost of food security and nutrition for the **grey infrastructure scenario** with an estimated lower crop productivity compared to the NBI scenario. In the **hybrid infrastructure scenario**, the calculations for the avoided cost of malnutrition are based on the same methodology, but also include the additional avoided costs generated by solar pumps. These costs are calculated by multiplying the cost of malnutrition per person (207 USD) by the number of people supported by the additional production generated by solar pumps, which amounts to 65,688 people per year. The number of people supported by the additional production generated by solar pumps is calculated by multiplying the added productivity achieved through solar pump irrigation (1.48 tons per hectare per year, Van Der Wijngaart, et al.) by the area (6,000 ha). As a result, the additional production in tons (8,800 tons per year) is then multiplied by the average Kcal per ton (2.7 million Kcal per ton, Lukmanji et al., 2008) and by the average deficit of Kcal per person (365,000 Kcal per person per year).
Carbon sequestration	Carbon sequestration is estimated with the spatial analysis, using land cover classes and a specific carbon pool (i.e., carbon sequestration potential). When land is restored, the InVEST model estimated the amount of additional carbon sequestration by multiplying the extent of land by the carbon sequestration potential per hectare. This increase in sequestration (562,938 tons of CO^2) is multiplied by the CO^2 shadow price (USD 50 per ton).

Source: Authors.

2.6.2 Scenarios

We assess and compare the impacts of three types of interventions: an NBI, a hybrid solution, and a grey infrastructure. The grey infrastructure serves as a point of comparison for evaluating the differences between a conventional intervention and one that incorporates NBI.

The scenarios include the following:

NBI

- involves tree planting, climate-smart agricultural practices, and the establishment of combined ASP areas;
- integrates agriculture, grasslands, fruit crops (mango and citrus), and livestock production;
- focuses on reducing land erosion, increasing agricultural productivity, and improving water retention in the soil.

HYBRID INFRASTRUCTURE

- incorporates soil restoration practices and CSA;
- uses a solar-powered irrigation pumping system;
- aims to combat soil erosion, improve water management, and achieve higher agricultural yields and income.

CONVENTIONAL (GREY) INFRASTRUCTURE

- includes water storage and irrigation.

In all three scenarios, we consider the implementation of non-chemical pest control methods, including ecological pesticides and biological matter, which are already in use in the area. These eco-friendly alternatives align with the nature-based and hybrid approaches, supporting sustainable agricultural practices while mitigating potential negative impacts on ecosystems and human health.

2.6.3 Results

As depicted in Table 3 (undiscounted values), all three scenarios exhibit positive net benefits and positive BCRs. The most significant benefits observed are the ASP income and the improvements in food security and nutrition. For the hybrid and NBI scenarios, these two benefits substantially outweigh the cumulative construction and maintenance costs.

On the contrary, the grey infrastructure lacks the capacity to generate any supplementary benefits in terms of ASP income. Moreover, the grey infrastructure generates lower avoided costs for food security and nutrition when compared to the NBI and hybrid infrastructure. Additionally, the grey infrastructure does not contribute to additional benefits in the form of crop income from CSA or carbon sequestration.

The CBA shows the potential advantages of the NBI and hybrid infrastructure scenarios, which exhibit higher net benefits and more favourable BCRs. Despite having lower costs, the grey infrastructure lags in generating certain benefits, underscoring the importance of nature-based approaches to maximize the overall value and sustainability of the project.

Table 3. Cost-benefit statement (undiscounted) – USD million

Indicators	**NBI**	**Grey infrastructure**	**Hybrid infrastructure**
Project costs			
Construction costs	21.0	14.5	31.2
Operating and maintenance costs	99.4	26.1	117.7
Total costs	**120.3**	**40.6**	**148.9**
Project benefits			
Food security and nutrition	754.3	244.2	1,242.6
ASP area income	900.0	0.0	900.0
Employment and income	39.3	1.8	17.1
Carbon sequestration	28.1	0.0	28.1
Crop income	54.3	0.0	54.3
Total benefits	**1,776.1**	**245.9**	**2,242.2**
Net benefit/(cost)			
Total benefits	1,776.1	245.9	2,242.2
Total costs	120.3	40.6	148.9
Net benefits/costs	**1,655.8**	**205.4**	**2,093.3**
Benefit/cost ratio	**14.8**	**6.1**	**15.1**

Source: Authors.

Table 4 shows the performance of the NBI, hybrid infrastructure, and the grey infrastructure scenarios in discounted real terms (discount rate of 3.5%) (HM Treasury, 2022),[5] excluding inflation to match the uninflated format of the cost and benefit values. In all scenarios, the net integrated values (in PVs) demonstrates that the NBI and the hybrid infrastructure delivers better value for money compared to the grey infrastructure. Additionally, it is important to mention that the discounted PVs and BCRs tend to be lower than the undiscounted net benefits and BCRs presented in Table 3. The reason for this difference is the application of a discount rate which reduces the PV of future benefits over time.

---

[5] All the values are discounted to April 2023

Despite having the highest construction and maintenance costs, the hybrid infrastructure scenario generates the largest value for money in terms of net integrated value. The hybrid infrastructure scenario yields a net integrated value of USD 1.09 billion, closely followed by the NBI with 869.6 million USD. The higher net integrated value for the hybrid infrastructure is primarily attributed to its larger irrigation capacity, facilitated by solar pumps, which enables the irrigation of more fields across greater distances. As a result, the hybrid infrastructure scenario yields substantial avoided costs in terms of food security and nutrition. In contrast, the grey infrastructure scenario shows the lowest net integrated value, totalling USD 103.3 million.

Table 4. Discounted analysis (3.5% discount rate) – USD million

Indicators	NBI	Grey infrastructure	Hybrid infrastructure
Net cash flow (PV)			
Construction costs	-19.8	-13.7	-29.4
O&M	-52.9	-13.9	-62.6
Pre-financing net cash flow	**-72.7**	**-17.1**	**-92.1**
Impact statement (PV)			
Food security and nutrition	391.6	129.9	651.5
Agro-sylvo-pastoral income	478.9	0.0	478.9
Employment and income	21.3	1.0	9.2
Carbon sequestration	22.1	0.0	22.1
Crop income	28.2	0.0	28.2
Net impact	**942.2**	**123.9**	**1,190.0**
Integrated value statement (PV)			
Pre-financing net cash flow	-72.7	-20.6	-92.1
Net impact	942.2	123.9	1,190.0
Net integrated value	**869.6**	**103.3**	**1,097.9**
BCR – PV	**12.97**	**4.75**	**12.92**

Source: Authors.

In conclusion, the NBI and hybrid scenarios stand out for their evident societal and economic benefits, offering invaluable advantages that conventional infrastructure cannot provide. As a result, these interventions emerge as more sustainable and viable options from a societal perspective in the long term, outweighing the higher initial investment and maintenance costs.

3.0 Financial Analysis

3.1 Methodology

To conduct the financing analysis, we considered two funding approaches for the NBI, hybrid, and grey infrastructure scenarios. The first approach involves a combination of debt and a non-repayable grant, with 50% debt and 50% grant. The second approach relies entirely on a 100% grant, without any debt. These two financing options resulted in a total of six scenarios, taking into account the three infrastructure projects. The assumption underlying our financial model is that the grant component is sourced from international funding agencies, such as multilateral development banks.

To calculate debt repayment, we use specific assumptions, including a 0.25% front-end fee rate, a commitment fee of 0.25%, and an interest rate of 2.20%. These assumptions were derived from the financial terms applied in the International Bank for Reconstruction and Development (IBRD) flexible loans for Burkina Faso. The interest rate is comprised of a 1.56% real rate of interest based on the 10-year Treasury Inflation Protected Securities yield from U.S. bonds (Trading Economics, 2023) along with a 0.64% lending margin based on IBRD flexible loans for Burkina Faso (IBRD, n.d.). Furthermore, we considered a 3-year maturity period, taking into account the relatively short construction period for the project.

Throughout the analysis of various financing options and scenarios, the primary objective is to determine the portion of indirect benefits and avoided costs that need be monetized to fund the project. Understanding the proportion of added benefits and avoided costs that can be converted into revenue streams allows the gauging of the overall financial feasibility of the project. By doing so, the financing analysis contributes to the establishment of a well-informed financing plan that aligns with the project's goals and objectives.

The concept of internalizing benefits and avoided costs can be applied in various financial mechanisms, including outcome-based financing. In this approach, these benefits and costs are converted into revenue streams to fund projects and yield returns for investors (Brand et al., 2021). The specific methods for generating revenue from these indirect benefits and costs may vary depending on the context, but the goal remains to showcase how monetizing them can enhance the financial viability of a nature-based project. For instance, the savings derived from reduced carbon emissions can be transformed into an alternative revenue stream by selling carbon credits, thereby generating additional income (Twidale & Evans, 2022).

3.2 Results

This analysis considers the monetization of the following benefits and avoided costs:

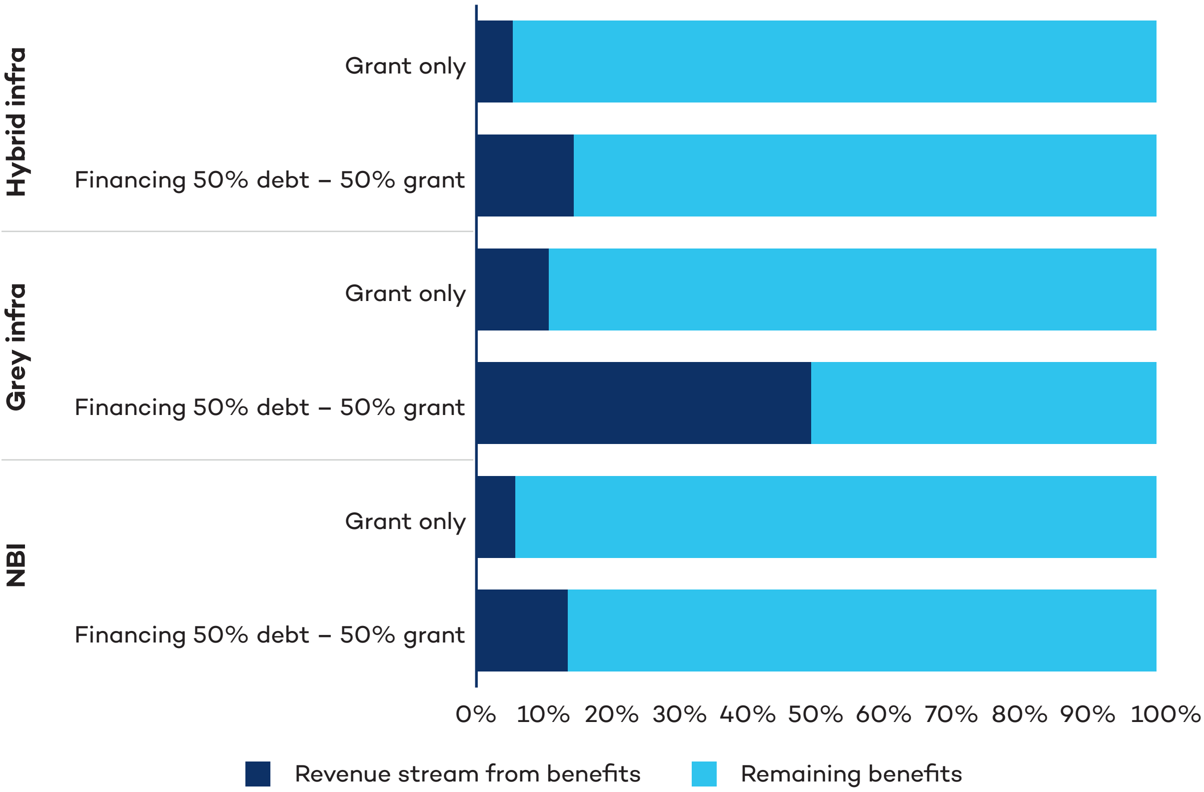
- food security and nutrition
- ASP income
- employment and income
- carbon sequestration
- crop income.

Figure 8 shows the portion of avoided costs and benefits that need to be converted into revenue streams to fund the project according to the two types of financing. If the portion of avoided costs and benefits is relatively small, it means that there are better chances to generate revenue stream from the ecosystem services.

When examining the financing options with a 50:50 debt–grant ratio, we find that the NBI project needs 13.4% of monetized added benefits and avoided costs to secure funding for the project and cover debt costs. The hybrid infrastructure requires a slightly higher percentage of monetized benefits and avoided costs (14.3% internalization) due to higher implementation expenses. In contrast, the grey infrastructure requires a significantly higher portion of benefits to be monetized (49.2% internalization) during the debt repayment period due to lower benefits and avoided costs generated by the infrastructure (Figure 8).

As expected, the grant-only financing option requires a lower monetization of added benefits and avoided costs for the project to achieve financial equilibrium. Under this financing option, the required percentage of indirect benefits and avoided costs results in 5.7% for the NBI, 5.3% for the hybrid infrastructure, and 10.6% for the grey infrastructure (Figure 8).

Figure 8. Required benefits to achieve financial viability



Source: Authors.

Table 5 shows both the required percentage of benefits and avoided costs that need to be monetized and the corresponding monetary value generated by that percentage. Consequently, the hybrid infrastructure (USD 170.5 million with 50% debt and 50% grant) and NBI options (USD 126.3 million with 50% debt and 50% grant) generate the highest monetary value while requiring a smaller portion of their total benefits and avoided costs to be converted into revenue streams.

In contrast, the grey infrastructure option generates a smaller monetary value despite requiring a higher portion of its total benefits and avoided costs to be monetized.

Table 5. Avoided costs and benefits internalization under financing scenarios (50:50 debt–grant ratio and 100% grant)

	NBI		**Grey infrastructure**		**Hybrid infrastructure**	
	Financing 50% debt – 50% grant	**Grant only**	**Financing 50% debt – 50% grant**	**Grant only**	**Financing 50% debt – 50% grant**	**Grant only**
Construction costs	19.8	19.8	13.7	13.7	29.4	29.4
O&M	52.9	52.9	13.9	13.9	62.6	62.6
Internalization requirement	126.31	53.33	64.42	13.89	170.54	63.07
Internalization %	13.4%	5.7%	49.2%	10.6%	14.3%	5.3%

Source: Authors.

In this context, the internalization of monetized benefits and avoided costs can leverage various financial or incentive-based mechanisms to generate revenue streams. For example, the carbon sequestration can be used to sell carbon credits and integrate them into the project overall structure as a potential revenue stream.

The same considerations can be applied to other benefits and avoided costs beyond carbon sequestration. For example, additional benefits generated by employment and income could yield extra tax revenue that can be leveraged by local or national authorities.

Payment for ecosystem services (PES) schemes can be a useful incentive-based mechanism for generating alternative revenue streams from crop income. These schemes can encourage farmers and landowners to adopt regenerative and sustainable practices in exchange for regular payments (Fripp, 2014). For instance, farmers can contribute by investing a portion of the increased income generated from crops (USD 28.2 million) into a PES fund. In return the PES scheme redistributes payments to farmers to implement and maintain the land restoration and improve specific sustainable practices, such as ASP and CSA activities (Jack et al., 2008).

These are only few examples of how to internalize the value of the ecosystem services and generate potential cash flow to fund the NBI project.

4.0 Conclusions

Key findings from the assessment include the following:

1. **Nature-based interventions foster climate adaptation by enhancing land productivity.** By elevating agricultural output, these interventions generate higher incomes from crops and ASP zones, thereby contributing to improved food security, enhanced nutrition, and better overall health. The significance becomes even more pronounced in areas prone to substantial climate-induced damages, and so they amplify the climate resilience of the project. This effect is primarily attributed to the flood mitigation facilitated by NBI.
2. **Nature-based interventions increase carbon storage.** The land restoration project mitigates climate change and reduces nutrient and sediment exports, improving water quality and agricultural production, respectively. The reduction in GHG emissions provides opportunities to generate revenue through carbon credits. This additional revenue stream can support and enhance the financial sustainability of the nature-based intervention.
3. **The NBI and the hybrid infrastructure options outperform grey water storage and irrigation infrastructure.** Notably, the grey infrastructure lacks the capability to generate additional revenue from ASP activities and crop production through CSA and can't provide carbon sequestration. As a result, nature-based and hybrid approaches are more sustainable and attractive options for achieving broader environmental and socio-economic benefits.
4. **Hybrid infrastructure generates higher net integrated value.** The higher net integrated value can be attributed to the larger irrigation capacity generated by the solar pumps. This results in larger avoided costs in terms of malnutrition and food security. Additionally, solar pump systems have the advantage of transporting water over long distances, offering a more climate-resilient solution compared to water reservoirs for local communities.
5. **NBI and hybrid infrastructure need a smaller portion of avoided costs and benefits to make the project break even.** NBI and hybrid infrastructure require a smaller portion of monetized benefits and avoided costs to secure funding and cover debt costs compared to the grey infrastructure. Additionally, the grant-only financing option proves to be a more viable approach, requiring less monetization of added benefits and avoided costs to achieve financial equilibrium.

5.0 References

Agrawal, S., & Jain, A. (2018, September 5). Sustainable deployment of solar irrigation pumps: Key determinants and strategies. *Wiley Interdisciplinary Reviews, 8*(2). https://wires.onlinelibrary.wiley.com/doi/abs/10.1002/wene.325

Brand, M. W., Seipp, K. Q., P Saksa, N. U., Bomblies, A., L Mandle, M. A., O Wing, J. T.-d., & Parker, E. A. (2021). *Environmental Impact Bonds: a common framework and looking ahead. Environmental Research: Infrastructure and Sustainability, 1*(2). https://iopscience.iop.org/article/10.1088/2634-4505/ac0b2c

Carbon Brief. (2018). *Explainer: How 'Shared Socioeconomic Pathways' explore future climate change*. https://www.carbonbrief.org/explainer-how-shared-socioeconomic-pathways-explore-future-climate-change/

Carrico, C., Okoko, E., & Klaver, D. C. (2021, November). *Scoping study on fruits and vegetables: Results from Burkina Faso*. Wageningen Economic Research. https://edepot.wur.nl/556783

Deutsche Gesellschaft für Internationale Zusammenarbeit. (n.d.). *Climate risk profile: Burkina Faso*. https://www.pik-potsdam.de/en/institute/departments/climate-resilience/projects/project-pages/agrica/giz_climate-risk-profile_burkina-faso_en

Douxchamps, S. A., Ayantunde, A., & Barron, J. (2012). *Evolution of agricultural water management in rainfed crop-livestock systems of the Volta Basin. Colombo, Sri Lanka*. CGIAR Challenge Program on Water and Food. https://cgspace.cgiar.org/bitstream/handle/10568/21721/AWM%20Volta%20review%20final%20rv%20sm.pdf?sequence=3&isAllowed=y

Food and Agriculture Organization of the United Nations. (n.d.). *FAOSTAT*. https://www.fao.org/faostat/en/#data/

Fripp, E. (2014). *Payments for Ecosystem Services (PES): A practical guide to assessing the feasibility of PES projects*. Center for International Forestry Research. https://www.cifor.org/publications/pdf_files/Books/BFripp1401.pdf

Goodman, M. (n.d.). *Systems thinking: What, why, when, where and how?* The System Thinker. https://thesystemsthinker.com/systems-thinking-what-why-when-where-and-how/

HM Treasury. (2022, November 18). *The green book*. https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent/the-green-book-2020

International Bank for Reconstruction and Development Financial Products. (n.d.). *IBRD financial products: Lending rates & fees*. World Bank. https://treasury.worldbank.org/en/about/unit/treasury/ibrd-financial-products/lending-rates-and-fees

Issa, N. M. (2024). *Assessing the impact of agroecological interventions in Niger through remotely sensed changes in vegetation*. USAID.GOV. https://fscluster.org/sites/default/files/documents/tr_resilience_niger.pdf

Jack, B. K., Kousky, C., & Sims, K. (2008). Designing payments for ecosystem services: Lessons from previous experience with incentive-based mechanisms. *Proceedings of the National Academy of Sciences of United States of America*. https://www.researchgate.net/publication/5230210_Designing_Payments_for_Ecosystem_Services_Lessons_from_Previous_Experience_with_Incentive-Based_Mechanisms

Lemeke, R. K., & Stulman, M. (2015). *The costs of hunger in Burkina Faso*. Catholic Relief Services. https://www.crs.org/stories/cost-hunger-burkina-faso

Lukmanji, Z., Hertzmark, E., Mlingi, N., Assey, V., Ndossi, G., & Fawzi, W. (2008, November). *Tanzania food composition tables*. Muhimbili University of Health and Allied Sciences, Tanzania Food and Nutrition Centre, & Harvard School of Public Health. https://www.researchgate.net/publication/265627809_Tanzania_Food_CompositTion_Tables_Compiled_by

Macrotrends. (2020). *Burkina Faso hunger statistics*. https://www.macrotrends.net/countries/BFA/burkina-faso/hunger-statistics

Meinshausen, M., Nicholls, Z. R., Lewis, J., Gidden, M. J., Vogel, E., Freund, M., & Wang, R. H. (2020). The shared socio-economic pathway (SSP) greenhouse gas concentrations and their extensions to 2500. *Geoscientific Model Development, 13*(8), 3571-3605. https://gmd.copernicus.org/articles/13/3571/2020/

Ministry of Agriculture, Government of India. (n.d.). *Pattern of assistance in various schemes of Dept. of Agriculture & Cooperation, Min. of Agriculture, Govt. of India*. https://rkvy.nic.in/static/schemes/WaterHarvestingIrrigation.html

Natural Capital Project. (n.d.). *What is InVEST?* Stanford University. https://naturalcapitalproject.stanford.edu/software/invest

Paul, M. (2016). *Impacts of land use and climate changes on hydrological processes in South Dakota Watersheds* [Master's thesis]. Open Prairie. https://openprairie.sdstate.edu/etd/1018/

Rade, D., Cañadas, Á. L., Zambrano, C. Z., Molina, C. H., Ormaza, A. M., & Wehenkel, C. (2017). Silvopastoral system economical and Financial feasibility with Jatropha curcas L. in Manabí, Ecuador. *Revista MVZ Córdoba*. https://www.researchgate.net/publication/321919820_Silvopastoral_System_Economical_and_Financial_feasibility_with_Jatropha_curcas_L_in_Manabi_Ecuador

Trading Economics. (2023). *United States 10 year TIPS yield*. https://tradingeconomics.com/united-states/10-year-tips-yield

Twidale, S., & Evans, D. (2022). *ICE launches nature-based carbon credit futures contract*. Reuters. https://www.reuters.com/business/sustainable-business/ice-launches-nature-based-carbon-credit-futures-contract-2022-05-09/

United Nations Environment Program (UNEP). (2014). *Using models for green economy policymaking*. https://www.un-page.org/files/public/content-page/unep_models_ge_for_web.pdf

United States Agency for International Development. (n.d.). *Climate change risk profile: West Africa Sahel*. https://www.climatelinks.org/sites/default/files/asset/document/2017%20April_USAID%20ATLAS_Climate%20Change%20Risk%20Profile%20-%20Sahel.pdf

Van Der Wijngaart, R., Helming, J., Jacobs, C., Garzon Delvaux, P., Hoek, S., & Gomez Y Paloma, S. (2019). *Irrigation and irrigated agriculture potential in the Sahel: The case of the Niger river basin*. Publications Office of the European Union. https://publications.jrc.ec.europa.eu/repository/handle/JRC108657

World Bank. (2007, September). *Burkina Faso: The challenge of export diversification for a landlocked country*. Diagnostic Trade Integration Study for the Integrated Framework Program. https://documents1.worldbank.org/curated/en/654001468236983561/pdf/431340SR0White1ete0Report1eng1rev00.pdf

World Bank. (2021). *Climate change knowledge portal*. https://climateknowledgeportal.worldbank.org/

World Bank. (2022). *Total population in Burkina Faso*. https://data.worldbank.org/indicator/SP.POP.TOTL?locations=BF

World Salaries. (2023). *Average salary in Burkina Faso for 2023*. https://worldsalaries.com/average-salary-in-burkina-faso/

NATURE-BASED INFRASTRUCTURE
GLOBAL RESOURCE CENTRE