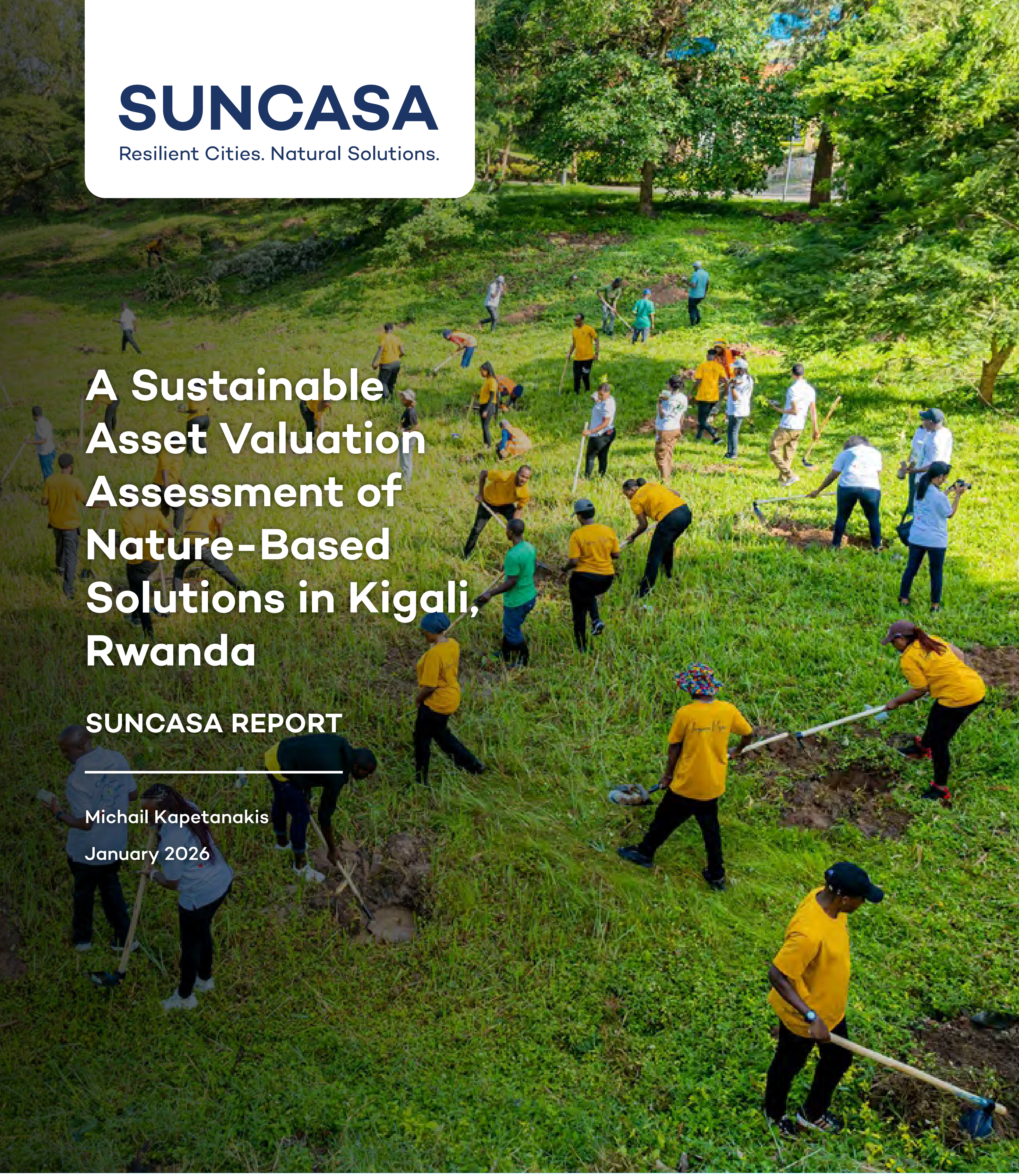

SUNCASA

Resilient Cities. Natural Solutions.

A Sustainable Asset Valuation Assessment of Nature-Based Solutions in Kigali, Rwanda

SUNCASA REPORT

Michail Kapetanakis

January 2026

Project partners

IISD International Institute for Sustainable Development

World Resources Institute

Funded by

In partnership with Canada

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A Sustainable Asset Valuation Assessment of Nature-Based Solutions in Kigali, Rwanda

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Written by Michail Kapetanakis

Photo: William Bidibura/ARCOS Network/SUNCASA

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SUNCASA Project Partners

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About SUNCASA

The SUNCASA initiative—Scaling Urban Nature-based Solutions for Climate Adaptation in Sub-Saharan Africa—is a 3-year project led by the International Institute for Sustainable Development and the World Resources Institute, with funding from Global Affairs Canada. It aims to enhance climate resilience, gender equality, social inclusion, and biodiversity protection in urban communities across Dire Dawa (Ethiopia), Kigali (Rwanda), and Johannesburg (South Africa).

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RYWP Rwanda Young Water Professional

Umujyi wa Kigali

ARCOS Network

AVEGA Association des Veuves du Génocide Agahozo

About the Nature-Based Infrastructure Global Resource Centre

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 the International Institute for Sustainable Development, with the financial support of the Global Environment Facility and the MAVA Foundation, in partnership with the United Nations Industrial Development Organization.

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Executive Summary

Kigali, Rwanda's largest urban centre, faces growing vulnerability to recurrent and destructive flash floods driven by rapid urbanization, climate change, and poor land-use practices. The city's steep terrain, combined with the proliferation of impervious surfaces and deforestation, has significantly reduced water infiltration, leading to increased surface runoff and soil erosion. Climate change is intensifying rainfall variability and extreme weather, placing additional pressure on Kigali's already degraded wetlands and natural flood buffers, resulting in water pollution and ecosystem loss. These overlapping risks undermine public health, urban resilience, and peri-urban livelihoods, disproportionately affecting informal, vulnerable, and marginalized communities and posing a serious threat to the city's sustainable development.

The Scaling Urban Nature-based Solutions (NbS) for Climate Adaptation in Sub-Saharan Africa (SUNCASA) project was designed to address these challenges. Through the implementation of NbS, the project aims to enhance climate adaptation, gender equality, and biodiversity protection in urban communities in Ethiopia, Rwanda, and South Africa by responding directly to locally identified needs and priorities in three cities: Dire Dawa (Ethiopia), Kigali (Rwanda), and Johannesburg (South Africa). The project's main objective is to support municipal governments, local communities, and other urban stakeholders to increase their resilience to climate-induced risks such as flooding, droughts, and other water-related risks by adopting and implementing gender-responsive NbS. The long-term success of these NbS interventions will depend on the ability of the government and local communities to maintain them over time. This report aims to provide information in support of the long-term budgeting and financing discussions on NbS in Kigali.

The SUNCASA initiative is being implemented by the International Institute for Sustainable Development in collaboration with the World Resources Institute and local partners, with funding support from Global Affairs Canada. Local partners include organizations and communities in the three cities, including traditionally marginalized groups, women, and local and national authorities.

Using the Sustainable Asset Valuation (SAVi) methodology, the International Institute for Sustainable Development developed an integrated cost-benefit analysis (CBA) to identify, value, and quantify the wider economic, social, and environmental impacts that the NbS implementation is projected to have in Kigali. The NbS interventions that are considered in this assessment include a combination of afforestation, reforestation, agroforestry, vegetated buffer zone development, and urban tree-planting activities. These activities aim to create natural flood protection that protects steep slopes and wetlands, preserve fertile agricultural lands for food security and improved land productivity, reduce the impacts of flooding, landslides, and heat in the city, and conserve and restore natural resources, in line with key priorities within strategic policy documents in Rwanda, such as the *Kigali City Master Plan 2050* and the *Revised Green Growth and Climate Resilience Strategy.* Further, the CBA assesses the multi-dimensional impacts of these NbS interventions in economic terms (such as flood damage to infrastructure; human health costs from floods, water pollution, and heat; carbon sequestration; and employment creation) and estimates their value in economic terms.

Key Results

The results in Table ES1 show that the NbS interventions in Kigali generate a wide range of economic, social, and environmental benefits, most of which are typically not considered in traditional infrastructure assessments. Overall, results show that the NbS interventions are projected to save costs related to flood damage to infrastructure, health costs from floods and landslides, water pollution, and heat and result in new value creation from carbon sequestration and employment benefits.

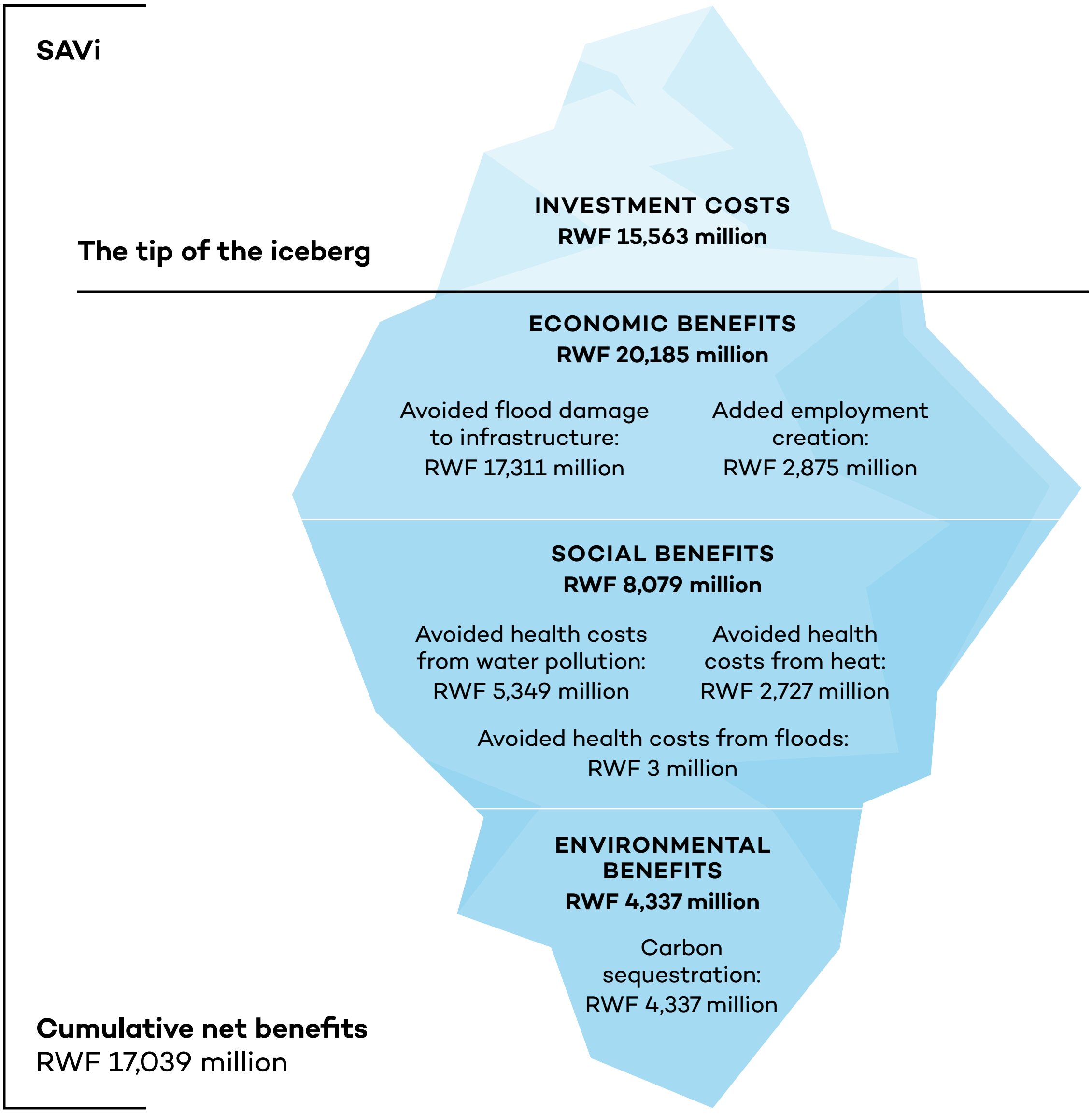
Table ES1. Integrated CBA of SUNCASA-implemented NbS interventions in Kigali (discounted at 10%)

		Sensitivity analysis (RWF million)		
Integrated CBA 2025–2050 (discounted at 10%)	**NbS scenario** (RWF million)	**High social cost of carbon**	**High cost of water pollution**	**High social cost of carbon and high cost of water pollution**
Total direct costs	**15,563**	**15,563**	**15,563**	**15,563**
Implementation costs	3,579	3,579	3,579	3,579
Operation and maintenance costs	11,984	11,984	11,984	11,984
Total added benefits	**32,602**	**40,409**	**37,951**	**45,758**
Avoided flood damage to infrastructure	17,311	17,311	17,311	17,311
Avoided health costs: floods and landslides	3	3	3	3
Avoided health costs: water pollution	5,349	5,349	10,699	10,699
Avoided health cost: heat	2,727	2,727	2,727	2,727
Added employment creation	2,875	2,875	2,875	2,875
Carbon sequestration	4,337	12,144	4,337	12,144
Total net benefits (undiscounted)	**91,590**	**133,866**	**114,127**	**136,404**
Total net benefits (discounted)	**17,039**	**24,846**	**22,388**	**30,195**
Benefit-to-cost ratio (BCR)	**2.09**	**2.60**	**2.44**	**2.94**

Source: Authors.

The NbS scenario will generate a cumulative net benefit of RWF 17,039 million (discounted at 10%), considering a project period of 25 years (2025 to 2050). The results of the project, when considering all economic, social, and environmental benefits, show an integrated BCR of 2.09. The payback period is 7 years from the beginning of the project. These results highlight the economic viability of the project, which generates a considerable amount of avoided costs (RWF 25,390 million), of which 68% are tangible, avoided infrastructure damage costs. The total added benefits reach RWF 7,212 million, 60% of which relate to carbon sequestration. The intangible societal value of the project is considerable, representing 38% of the total value generated via cost reductions and value creation. Further, the avoided costs and added benefits are shared across approximately 17,000 direct and 975,000 indirect beneficiaries in the city and its surroundings, as opposed to being accumulated by a few entities.

Figure ES1. Economic, social, and environmental benefits of NbS interventions in Kigali



Source: Authors.

The largest impact of the NbS scenario is the avoided cost of flood damage to infrastructure, valued at a cumulative, discounted RWF 17,311 million. This corresponds to a reduction in flood damage to approximately 687 buildings at risk in the city and surrounding areas. The second largest impact is instead intangible, relates to water pollution, and amounts to RWF 5,349 million over 25 years. In addition, carbon sequestration benefits are valued at RWF 4,337 million and income creation from employment amounts to RWF 2,875 million. This is another example of benefits that are shared across a large number of beneficiaries.

For the SUNCASA NbS interventions in Kigali, we considered three sensitivity analysis scenarios. The first one is related to the economic value of carbon sequestration benefits, which increases substantially when applying a higher shadow price for carbon, set at USD 40/ton in line with the World Bank's (2024) guidance. Under this higher carbon price assumption, cumulative carbon sequestration benefits are valued at RWF 12,144 million. Overall, the scenario yields cumulative net benefits of RWF 24,846 million and a BCR of 2.60, indicating stronger economic viability with a higher valuation of carbon.

In addition, the SAVi assessment found that under a higher water pollution cost scenario in Kigali, the project is also economically viable, with net benefits of RWF 22,388 million and a BCR of 2.44. When accounting for the higher shadow price of carbon, net benefits reach RWF 30,195 million and the BCR improves to 2.94, indicating that all scenarios show economic viability.

Integrated valuations, such as this SAVi assessment, provide a fuller picture of the medium- to long-term societal impacts of NbS projects, and complement and enhance traditional CBA analysis. This SAVi assessment demonstrates that implementing NbS investments in Kigali will both avoid potential costs and generate added benefits across a variety of indicators. This type of analysis enables government actors, planners, and developers to better assess the impacts of NbS implementation and to better plan financing strategies based on expected tangible and intangible impacts. This information is crucial to enable them to work in tandem with policy-makers to develop and implement policies and processes that turn the intangible value of externalities into tangible revenues for the municipality and its citizens.

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Glossary

Discounting
A financial 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 Programme [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, 2019).

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

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.

Nature-based solutions (NbS)
Actions to address societal challenges through the protection, sustainable management, and restoration of ecosystems, benefiting both biodiversity and human well-being (International Union for Conservation of Nature and Natural Resources, n.d.)

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 mimic a system's operation over time to analyze its behaviour and predict its performance. They are quantitative by nature and can be built using one or several methodologies (UNEP, 2014).

1.0 Introduction

Kigali is Rwanda's capital and largest urban centre, with a population of approximately 1.3 million (World Population Review, 2025). The city is increasingly vulnerable to recurrent and destructive flash floods, which are exacerbated by rapid urbanization and the proliferation of impervious surfaces that have reduced water infiltration, leading to surface runoff (Ministry of Disaster Management and Refugee Affairs, 2015). Informal settlements, many of which are located on steep and erosion-prone hillsides and often lack adequate drainage systems, such as those in the Rugunga sub-catchment area, are especially at risk of flood and landslide hazards. The annual intensity of flooding in Kigali is such that entire districts along the Nyabarongo river, including Kicukiro and Nyarugenge, experience extensive damage to public infrastructure, with negative health consequences, especially for vulnerable and marginalized communities (Rwanda Environment Management Authority [REMA], 2019).

Climate change is amplifying these risks by increasing rainfall variability and intensifying extreme weather events. While national-level assessments highlight both flooding and landslides in western Rwanda and drought in the east (Ministry of Environment, 2018), Kigali's unique topography, characterized by steep slopes and rapidly expanding built environments, renders the city highly susceptible to climate-induced hazards. Soil erosion, driven by deforestation and reduced vegetation cover, contributes to the degradation of natural flood-mitigating ecosystems. As a result, Kigali's remaining wetlands are under pressure, losing both ecological integrity and their capacity to regulate water flow. These environmental changes not only reduce urban resilience but also lead to declining water quality, increased pollution, and rising greenhouse gas emissions (REMA, 2021b).

The convergence of climate change, poor land-use practices, and insufficient urban planning in Kigali presents a systemic challenge that threatens sustainable development and long-term urban resilience. The impacts of flooding and landslides undermine water quality, affect public health, and reduce agricultural productivity in peri-urban areas, with informal and low-income communities bearing this burden disproportionately (REMA, 2019; Ministry of Environment, Republic of Rwanda, 2021).

Addressing the complex challenges in Kigali requires coordinated, cross-sectoral policy action that brings together sustainable land use, urban planning, water management, and environmental protection. Without timely intervention, these risks will continue to erode the city's resilience, public health, and socio-economic stability. Integrated water and landscape management, particularly through nature-based solutions (NbS), offers a critical pathway to strengthen urban resilience, safeguard ecosystems, and promote sustainable livelihoods across both urban and peri-urban areas of Kigali.

The Scaling Urban NbS for Climate Adaptation in Sub-Saharan Africa (SUNCASA) initiative was developed to tackle these challenges. SUNCASA is a 3-year project that aims to enhance climate adaptation, gender equality, and biodiversity protection in urban communities in Ethiopia, Rwanda, and South Africa by responding directly to locally identified needs and priorities in three cities: Dire Dawa (Ethiopia), Kigali (Rwanda), and Johannesburg (South Africa). The project is funded by Global Affairs Canada for the implementation of gender-responsive NbS in the three cities. In Rwanda, the SUNCASA project aims to increase the resilience of Kigali to climate- and water-related hazards by implementing NbS in the upstream areas of six critical micro-catchment areas in the city, identified as high-risk, flood-prone catchments by the Rwandan Ministry of Environment (Ministry of Environment, Republic of Rwanda, 2021). These catchments include Rugunga, Rwandex, Gisozi-Mukindo, Gisozi-Karuruma, Nyabisindu, and Kinyinya. SUNCASA focuses on interventions in critical upstream micro-catchments in the lower Nyabarongo River watershed to reduce flood risks, landslides, and soil erosion through gender-responsive NbS activities such as afforestation, reforestation, agroforestry, riparian restoration through vegetated buffer zone development, and urban tree planting.

SUNCASA seeks to increase the climate resilience of approximately 2,500 hectares (ha) of land in Kigali and its surrounding areas through the following interventions:

- developing natural buffer zones through afforestation and reforestation to protect steep slopes, wetlands, and ecologically fragile areas and reduce disaster risks from changing weather events caused by climate change;
- developing agroforestry systems to preserve fertile agricultural lands for food security;
- restoring degraded riparian zones and natural resources destroyed by disasters; and
- implementing urban green infrastructure, including the planting of 85,000 trees and making open space improvements, to reduce the impacts of flooding, landslides, and heat in urban settlements.

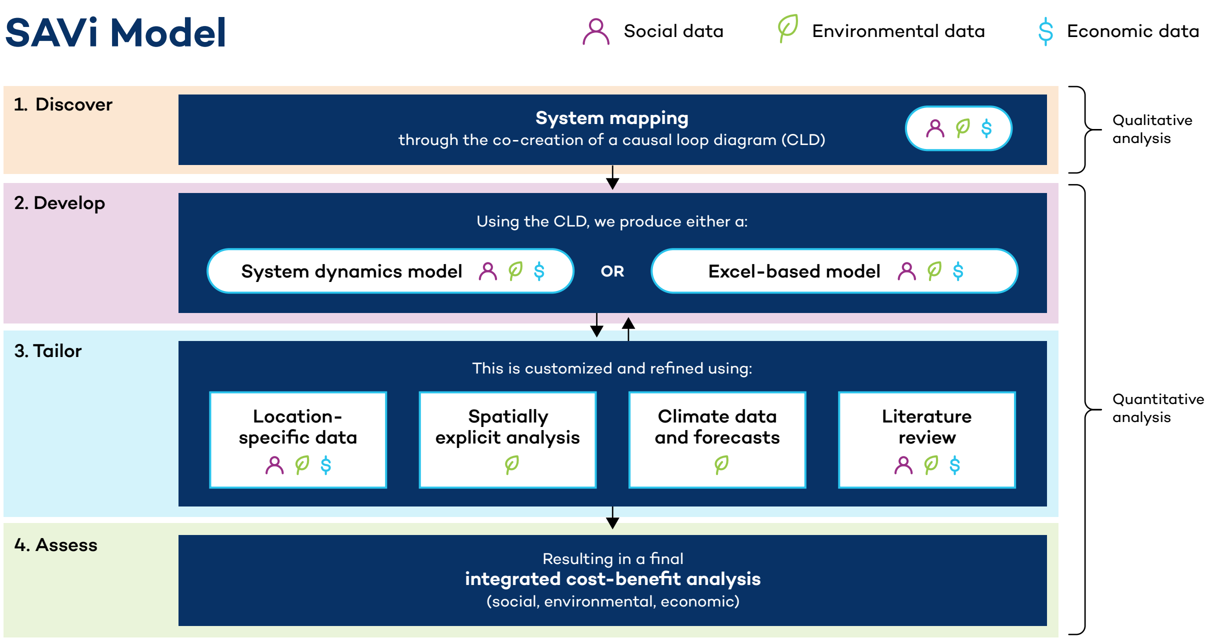
The NbS interventions align with key priorities in the *Kigali City Master Plan 2050* (City of Kigali, 2020), including promoting a green city by conserving natural resources and wetlands, expanding green public spaces, reducing greenhouse gas emissions, and supporting climate-resilient agriculture. The NbS interventions also support Rwanda's *Revised Green Growth and Climate Resilience Strategy* (2018) and key strategic objectives, including through their contributions to sustainable land and water management, improved food security, appropriate urban development, biodiversity preservation, enhanced social protection, and improved health and disaster risk reduction.

To promote a better understanding of the economic and financial viability of the SUNCASA project, and to support efforts for sustained funding and financing mechanisms for the NbS interventions, the International Institute for Sustainable Development developed an integrated cost-benefit analysis (CBA) using the Sustainable Asset Valuation (SAVi) methodology. SAVi allows for the identification, valuation, and quantification of the broad and often indirect socio-economic, environmental, and disaster risk benefits of NbS implementations. The SAVi assessment is complemented by capacity-building activities designed to raise awareness of NbS interventions, demonstrate their benefits, and encourage stakeholders to scale up these solutions in other regions. This report presents the methodology and results of the SAVi assessment of the SUNCASA NbS interventions in Kigali and concludes with recommendations on the use of the results by key stakeholders in the development, implementation, and financing of NbS. The long-term success of the NbS interventions will depend on the ability of the government and local communities to maintain them over time, so this report also aims to inform the long-term budgeting process.

2.0 SAVi

SAVi is an assessment methodology that provides policy-makers and investors with a comprehensive life-cycle analysis of infrastructure projects, considering often-overlooked impacts. Combining systems thinking and project-finance modelling, SAVi captures the full costs and benefits, including environmental, social, and economic risks. It calculates the monetary value of externalities, offering a nuanced evaluation. Integrated valuations such as the SAVi assessment basically provide a fuller picture of the long-term effects of infrastructure projects by integrating these externalities into traditional calculations of benefit-to-cost ratios (BCRs). This holistic approach enables investment decisions that align with regional development priorities, climate change adaptation, and the United Nations Sustainable Development Goals, ensuring a financially sound and sustainable outcome.

Figure 1. Steps in the SAVi model



Source: International Institute for Sustainable Development.

2.1 The Importance of Systems Thinking

The SAVi methodology is based on systems thinking. The methodology considers the intricate connections among various factors within a system and forms the first step of the SAVi methodology (see Figure 1). By employing this approach, our study explores how different indicators and variables within the system interact. The study delves into the complex relationships and interdependencies among key indicators, including rainfall patterns, agricultural practices, infrastructure, and socio-economic aspects. Understanding these interconnections provides a more nuanced perspective, enabling us to identify the fundamental drivers and dynamics influencing the livelihoods of local communities. These drivers might include deforestation, population growth, urbanization, and policy frameworks, while dynamics encompass interactions and feedback loops shaping the system's behaviours or outcomes.

By identifying these key drivers and dynamics, our study gains insights into the underlying causes and mechanisms shaping the current situation in Kigali. This method offers a more comprehensive view of how NbS projects interact within a wider context, recognizing that changes in one aspect of the system can trigger cascading effects on others. This improved understanding facilitates a more accurate assessment of potential impacts and the overall effectiveness and efficiency of NbS interventions.

Systems thinking also aids in identifying project or policy entry points—specific areas or aspects within the system where interventions or policies can yield the greatest impact. Policy-makers and project developers, armed with knowledge about these entry points, can prioritize and target their efforts, thereby maximizing the efficiency and effectiveness of investments.

In summary, by applying systems thinking, our study achieves several key objectives: gaining a comprehensive understanding of the climate resilience system, recognizing the interconnectedness of key indicators, uncovering key drivers and dynamics, and discerning the most impactful policy entry points.

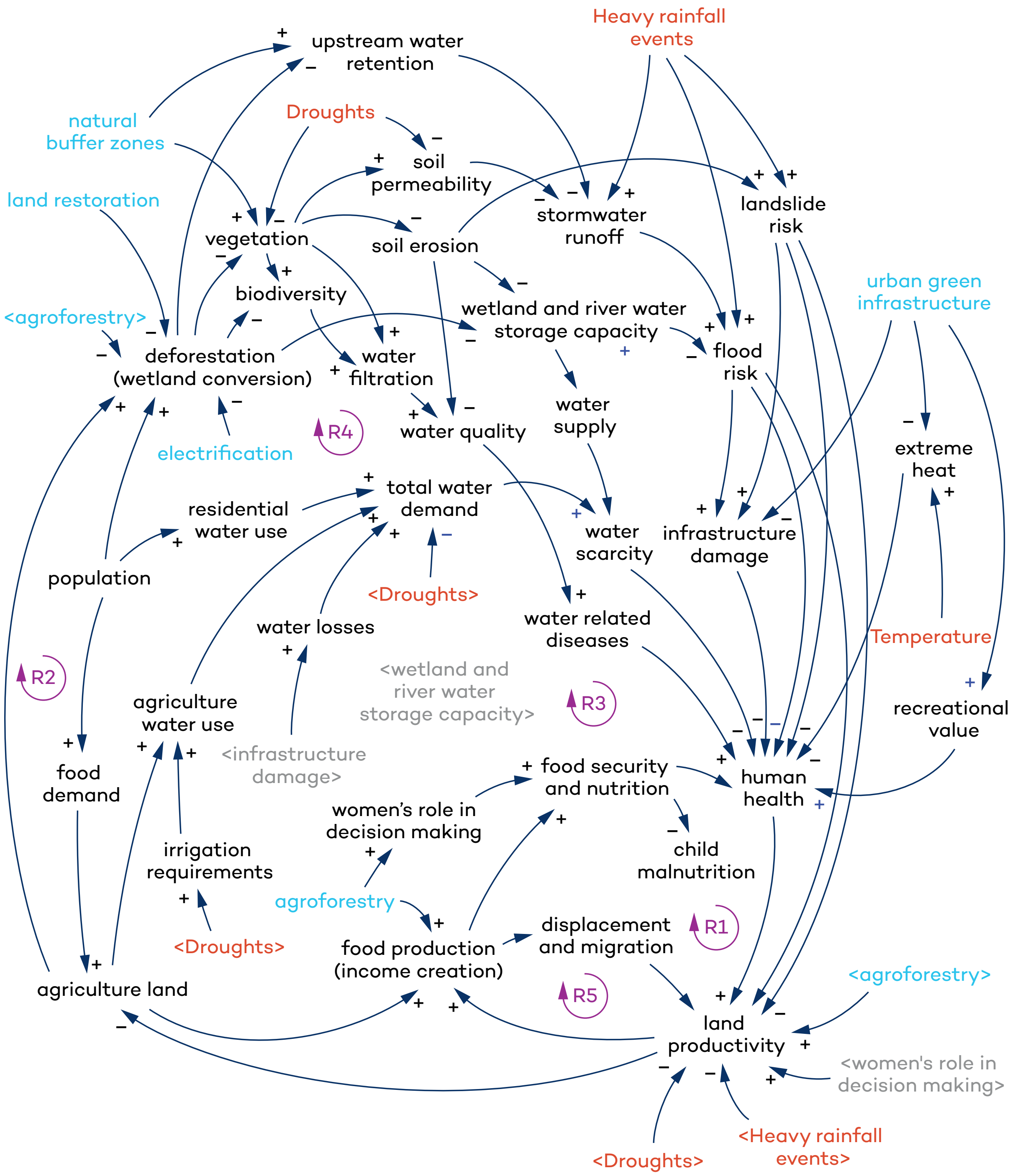
2.2 Causal Loop Diagram

The first step in the SAVi assessment is to identify the impacts and underlying dynamics of a project, including driving forces and key indicators and summarizing them in causal loop diagrams (CLDs). CLDs show the interconnections of social, economic, and environmental components of the system, highlighting key dynamics and potential trade-offs emerging from the different scenarios considered in the SAVi assessment. The CLD is the starting point for the development of the mathematical stock and flow model that will simulate the NbS scenario. The CLD was validated through engagement with local stakeholders in Kigali during a workshop that took place in June 2024. Feedback from the local stakeholders was incorporated into the CLD.

Box 1. Reading a CLD

A CLD 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 2. CLD representing the dynamics of the NbS interventions in Kigali



Source: Authors.

Over recent decades, rapid population growth in Kigali and its surrounding areas has triggered a combination of environmental degradation and human health challenges. One of the most critical outcomes of this growth has been the widespread deforestation and wetland conversion, which have diminished vegetative cover. The loss of vegetation directly reduces soil permeability and upstream water retention, intensifying the severity of hydrological responses to extreme weather events such as droughts and heavy rainfall. As stormwater runoff increases due to impermeable soils, the resulting erosion and sedimentation degrade wetland and riverine systems, reducing natural water storage capacity and elevating the risks of flooding and landslides. These hazards damage infrastructure and lead to direct human health costs, exacerbated by rising temperatures and heat stress, particularly in vulnerable communities.

Floods and landslide events diminish land productivity, a condition worsened by concurrent droughts and unpredictable rainfall. As agricultural productivity declines, food security deteriorates, undermining nutrition, particularly for children, and reducing household incomes. This disproportionately affects women, who often hold key roles in agricultural decision making (R1). The resulting food insecurity and loss of livelihoods can drive displacement and migration, which in turn further reduces the capacity of the land to recover, creating a self-reinforcing cycle of environmental and social vulnerability (R5). This cycle is further accelerated as declining land productivity increases the pressure on remaining arable land, leading to more deforestation and wetland conversion (R2). These land-use changes reduce biodiversity and impair natural water filtration, increasing the incidence of water-borne diseases and exacerbating the health risks associated with poor water quality (R4). Simultaneously, reduced wetland and river water storage capacity leads to widespread water scarcity, further deteriorating the public health impacts of limited access to clean water.

Population growth, urbanization, and the expansion of agricultural activities have also significantly increased the demand for water. This rising demand, combined with infrastructure losses caused by floods and landslides, puts further stress on already strained water systems. As droughts become more frequent and intense, the resulting imbalance between water supply and demand exacerbates both environmental degradation and the health challenges arising from water scarcity.

The application of NbS presents a strategic approach to mitigate key environmental pressures and address underlying drivers of land degradation and health-related challenges in Kigali, as illustrated in Figure 2. Through land restoration and the promotion of agroforestry practices, it is possible to curb deforestation, improve soil permeability, and enhance water retention, thereby moderating the intensity of flood and landslide events. These interventions also strengthen water filtration, reduce erosion, and improve water quality, yielding direct benefits for public health. The interventions responsive to gender equality and social inclusion in agroforestry can further boost agricultural productivity and food security, helping to diminish malnutrition and strengthen women's participation in decision-making processes within the agricultural sector, fostering economic resilience in rural communities. The establishment of natural buffer zones can stabilize hydrological systems by enhancing vegetative cover and restoring upstream catchments, thus reducing stormwater runoff and moderating flood risks. Lastly, integrating urban greening strategies in the city of Kigali would not only reduce infrastructure vulnerability to flooding but also help mitigate the urban heat island effect. This contributes to a reduction in heat-related health risks and simultaneously provides co-benefits such as improved urban liveability and recreational opportunities.

2.3 Spatially Explicit Analysis

Two Land-Use/Land-Cover (LULC) maps have been considered in this assessment: the Current LULC scenario (showing the land use of Kigali and surrounding areas prior to the beginning of the project) and the Restored LULC scenario (which considered the same study area but with the additional ha of the NbS interventions, including restored areas, tree planting, etc.). Table 1 shows the total number of ha of the additional land classes under the Restored LULC scenario (calculations made with QGIS). Figure 3 shows the specific location of the interventions.

Table 1. Total ha of interventions

Activity	ha
Agroforestry	1,200
Afforestation	215
Reforestation	650
Riparian zone restoration	395
Urban tree planting	59 (or 85,000 trees)

Source: Authors.

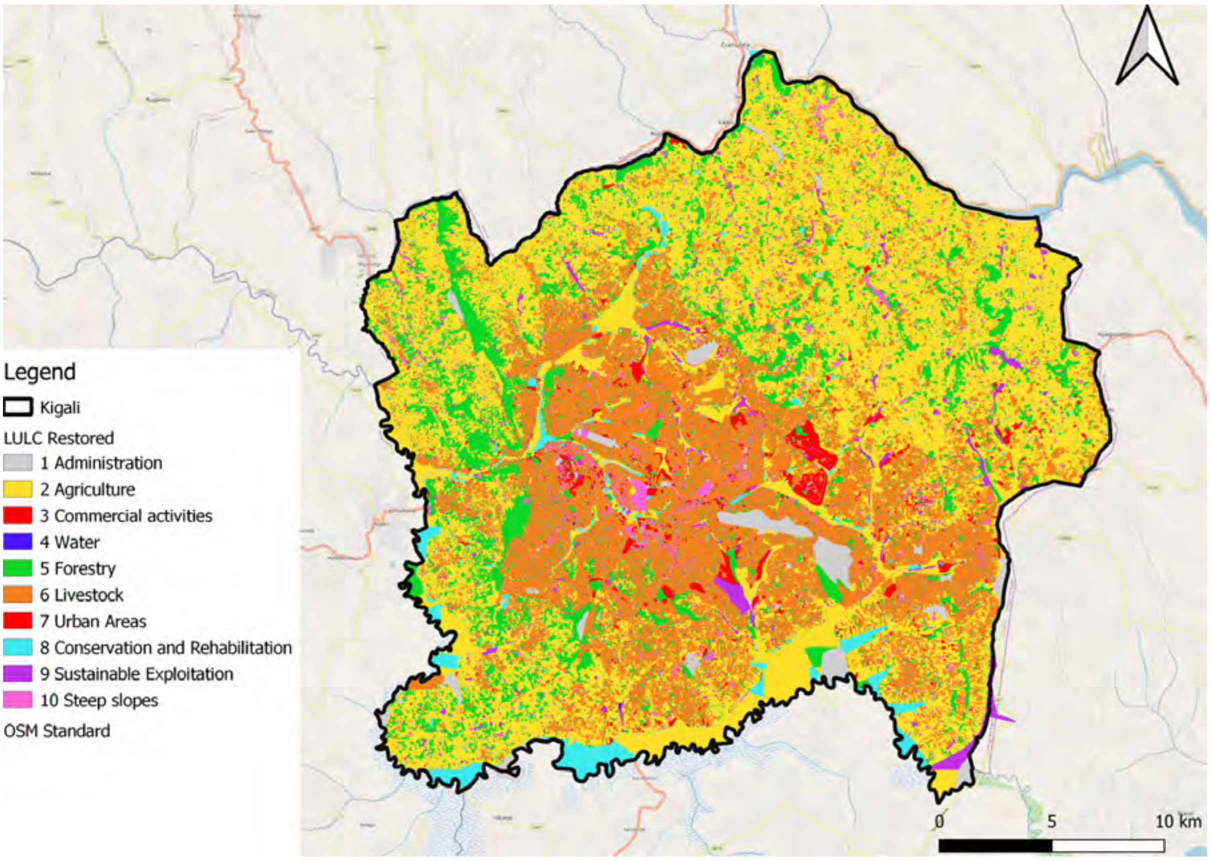
The spatially explicit analysis performed for this assessment relies on the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) suite of models. These models, developed by the Natural Capital Project (2019), use LULC maps as input and quantify a wide range of ecosystem services.[1]

Four InVEST models, used to map and quantify specific ecosystem services based on LULC data, were used. First, the Carbon Storage model calculates the amount of carbon stored in the landscape. The results, illustrated in Figure 4, demonstrate that relative to the Current LULC scenario, carbon storage is expected to increase by around 30% (approximately 600,000 tons). Second, the Habitat Quality model estimates changes in disturbances to habitat, defined using a unitless index that ranges from 0 to 1, in which 0 represents no habitat and 1 is the highest quality habitat. The results indicate that the mean of habitat quality in the study area will increase by almost 19%. This is because trees and other interventions replace land classes with lower potential for habitat quality, such as agriculture. Third, the Urban Cooling model estimates the temperature reduction by vegetation based on shade, evapotranspiration, and albedo, as well as distance from cooling islands (e.g., parks). The results indicate that the temperature in Kigali will decrease by 0.14% or 0.04°C in the whole study area as a result of the NbS interventions, with potentially larger benefits at the local

[1] The spatially explicit analysis was conducted in June 2024 at the start of the economic assessment of the SUNCASA project in Kigali. Its purpose was to provide a high-level estimate of the potential ecosystem services offered by the assessed NbS interventions. These initial estimates were later refined during the project design phase, resulting in some variations in the values and metrics used in the final economic analysis.

level. Fourth, the Urban Flood Risk mitigation calculates the runoff reduction, which is the amount of runoff retained per pixel compared to the storm volume, when land cover changes (i.e., in this case, when trees are planted) during a precipitation event of 100 mm. The results, illustrated in Figure 5, indicate that retention volume will increase by roughly 5% (or around 1,700,000 m^3). If vegetated land cover increases, then the runoff retention is higher than in the areas covered by other land classes, because trees and other plants can retain larger volumes of water in the soil. Lastly, flooded areas and infrastructure are also calculated using global river flood hazard maps, which are a gridded data set representing inundation along the river network, for seven different flood return periods (from 1-in-10-years to 1-in-500-years). A 100-year flood period was considered, and Geofabrik spatial data of the buildings and roads found in Kigali were downloaded to extract the number of buildings and metres of roads that are at risk of flooding. The results are shown in Table 3.

Figure 3. Location of the interventions



Source: Authors.
Note: OSM standard is that of the OpenStreetMap project.

Compared to the Current LULC scenario, carbon storage, habitat quality, and runoff retention are estimated to be higher in the Restored LULC scenario, as shown in Table 2, while the average temperature is expected to decrease. Overall, the results of the InVEST analysis show an increase in benefits from selected ecosystem services thanks to the implementation of SUNCASA's NbS activities in Kigali.

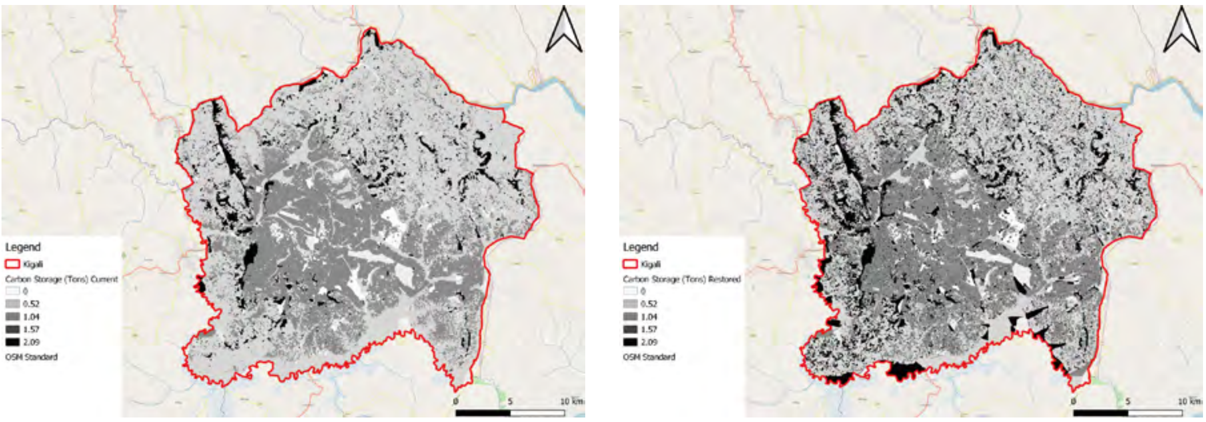
Table 2. Spatial analysis results summary

LULC scenario	Carbon storage (tons)	Habitat quality (mean)	Average temperature value (°C)	Runoff retention (m^3)
Business as usual (Current)	2,005,161	0.067	30.289	32,823,933
Restored	2,624,008	0.080	30.247	34,563,120
Change from the current scenario	30.86%	18.90%	-0.140%	5.30%

Source: Authors.

Figure 4. Carbon storage in tons: Current and Restored LULC scenarios

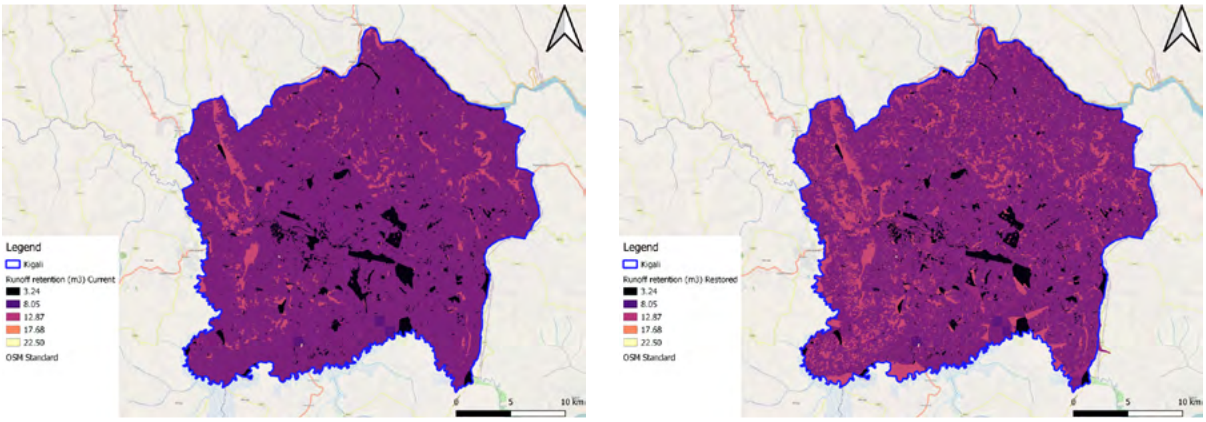
Current scenario **Restored scenario**



Source: Authors.

Figure 5. Runoff retention in m^3: Current and Restored LULC scenarios

Current scenario **Restored scenario**



Source: Authors.

Table 3. Total number of buildings and metres of roads in Kigali and the number that are at risk of flooding

Total metres of road	3,804,650
Metres of roads at risk	167,561
% of metres of roads at risk	4%
Total number of buildings	229,094
Number of buildings at risk	687
% of buildings at risk	0.3%

Source: Authors.

3.0 Integrated CBA

3.1 Methodology

The integrated CBA builds upon all elements of the SAVi methodology that were detailed previously: the CLD, systems thinking, and spatial analysis. For example, the CLD identified carbon sequestration as an important outcome of the NbS, the spatial analysis quantified how many additional tons of carbon will be stored, and the CBA assigned a monetary value to this carbon storage.

The CBA is the outcome of a customized Excel-based model that integrates the results of these assessments. This user-friendly tool is designed to enhance accessibility and facilitate comprehensive assessments. Our Excel-based model considers not only the financial implications of NbS measures but also their broader ecological and socio-economic impacts. Through the inclusion of key indicators such as investment costs, ecosystem service valuation, and employment/income generation, the model provides a nuanced understanding of the overall effectiveness and sustainability of NbS strategies.

The model's initial structure benefits from the cumulative and collective knowledge that the NBI Centre has built over the years. We tailored the model to the specific needs of the project and its partners through an iterative process involving data collection, equation formulation, and results validation. In the case of data gaps in the development of the model simulations, informed assumptions were applied to ensure continuity and coherence in the analysis. Specific values, sources, and assumptions that were used for this assessment are included in the Appendix. Following this iteration, we finalized the use of the following key indicators:

1. **Construction/implementation and maintenance costs:** The model incorporates a detailed assessment of the investment and maintenance costs associated with the various NbS interventions considered. This includes expenses related to tree planting, restoration, and operation management.
2. **Value of ecosystem services:** An integral component of the model involves a robust evaluation of the value of ecosystem services (expressed in monetary terms). This encompasses a thorough analysis of avoided infrastructure damage costs, avoided human health costs from floods, water pollution, and heat, for instance, through healthcare cost savings, as well as the quantification of carbon sequestration within the ecosystem.
3. **Employment and income generation:** To capture the socio-economic benefits of the NbS project, the model accounts for both permanent and temporary employment opportunities generated through the implementation of interventions. Furthermore, it assesses the additional income generation stemming from the operation and management activities needed.

3.2 Scenarios

One NbS scenario was simulated for the SAVi assessment using a timeline from 2025 to 2050. The NbS scenario considers the proposed NbS interventions in Kigali. As part of the same scenario, three sensitivity analysis scenarios[2] are included:

1. NbS scenario

This scenario proposes the introduction of NbS measures, including afforestation, reforestation, agroforestry, riparian restoration through vegetated buffer zones development and urban tree planting to reduce flooding, landslides, and heat impacts. These measures aim to reduce soil erosion, improve water quality and land productivity, and mitigate negative public health impacts.

- **1.1 High cost of carbon:** This sensitivity analysis scenario assumes a higher cost of carbon (USD 40/ton), based on the World Bank (2024) shadow price of carbon.
- **1.2 High cost of water pollution:** This sensitivity analysis scenario assumes a higher cost of water pollution (double the current cost) based on studies on the price per kg of nitrogen and phosphorus removal from NbS from Denmark and the United States.
- **1.3 High cost of carbon and high cost of water pollution:** This sensitivity analysis scenario assumes both a higher cost of carbon value (USD 40/ton), based on the World Bank (2024) shadow price of carbon and a higher (double) cost of water pollution.

[2] Given the inherent uncertainty in several key assumptions underlying the CBA, including the monetary value assigned to carbon emissions, discount rates, and the magnitude of certain indicators, a sensitivity analysis is conducted to test the robustness of the results. The sensitivity analysis allows for an assessment of how variations in these parameters affect net benefits, the BCR, and overall outcomes of the interventions. By systematically varying critical assumptions, the sensitivity analysis identifies which variables most influence the results and highlights the range of potential outcomes under alternative scenarios. This approach ensures that decision-makers are informed not only about the central estimates but also about the degree of confidence and risk associated with them, thereby strengthening the credibility and transparency of the CBA.

4.0 Results

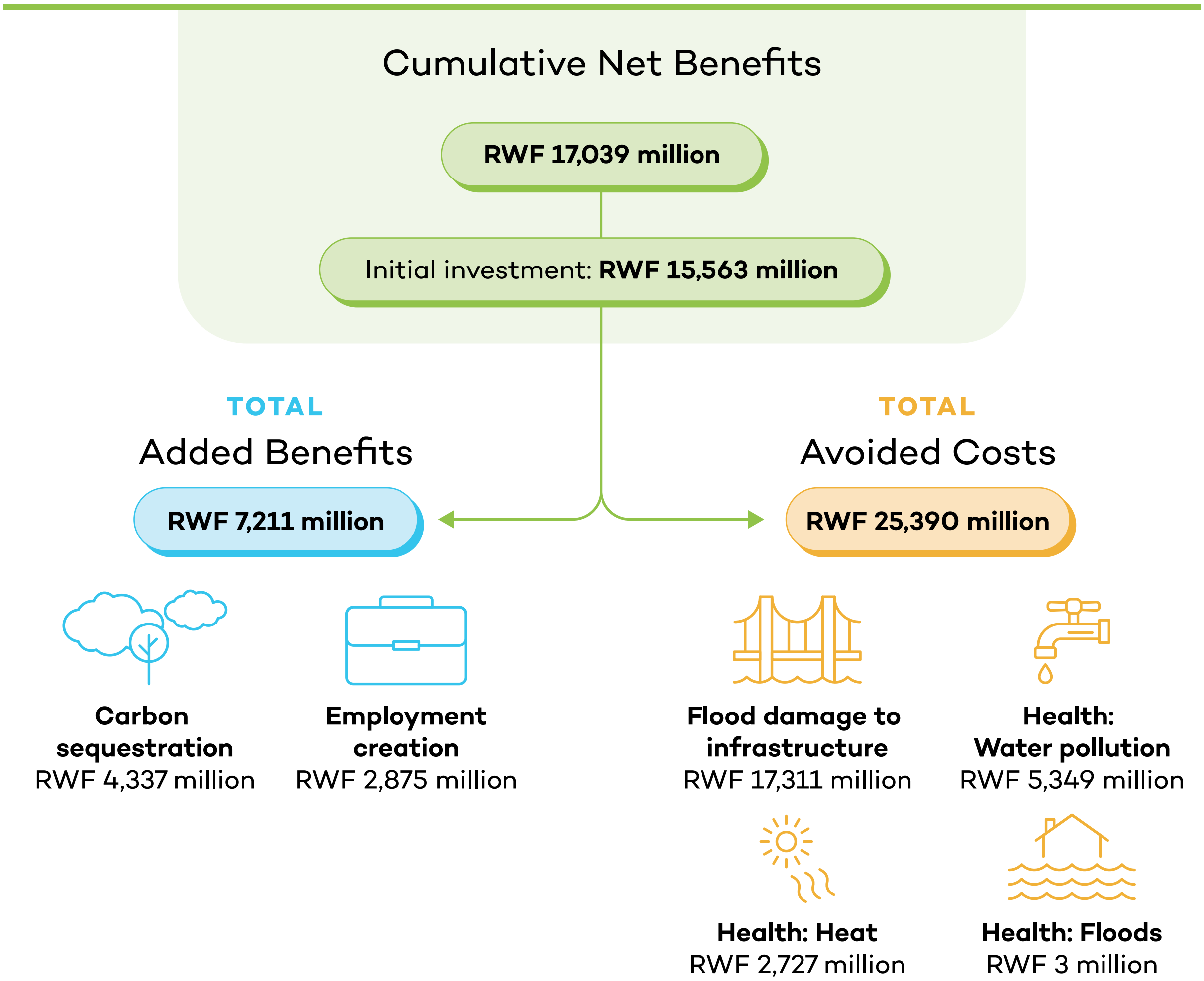
The integrated CBA is demonstrated in Table 4, showing discounted values at 10%. The analysis shows that the NbS scenario is economically viable and that the SUNCASA-implemented NbS interventions in Kigali would have a wide range of economic, social, and environmental benefits that are additional to the initial infrastructure costs. The NbS interventions will have benefits related to avoided costs connected to flood damage to infrastructure; avoided health costs from floods, landslides, water pollution, and heat; and carbon sequestration and employment benefits.

Table 4. Integrated CBA of SUNCASA-implemented NbS interventions in Kigali (discounted at 10%)

		Sensitivity analysis (RWF million)		
Integrated CBA 2025–2050 (discounted at 10%)	**NbS scenario** (RWF million)	**High social cost of carbon**	**High cost of water pollution**	**High social cost of carbon and high cost of water pollution**
Total direct costs	**15,563**	**15,563**	**15,563**	**15,563**
Implementation costs	3,579	3,579	3,579	3,579
Operation and maintenance costs	11,984	11,984	11,984	11,984
Total added benefits	**32,602**	**40,409**	**37,951**	**45,758**
Avoided flood damage to infrastructure	17,311	17,311	17,311	17,311
Avoided health costs: floods and landslides	3	3	3	3
Avoided health costs: water pollution	5,349	5,349	10,699	10,699
Avoided health cost: heat	2,727	2,727	2,727	2,727
Added employment creation	2,875	2,875	2,875	2,875
Carbon sequestration	4,337	12,144	4,337	12,144
Total net benefits (undiscounted)	**91,590**	**133,866**	**114,127**	**136,404**
Total net benefits (discounted)	**17,039**	**24,846**	**22,388**	**30,195**
Benefit-to-cost ratio (BCR)	**2.09**	**2.60**	**2.44**	**2.94**

Source: Authors.

Figure 6. Added benefits and avoided costs of the NbS interventions in Kigali



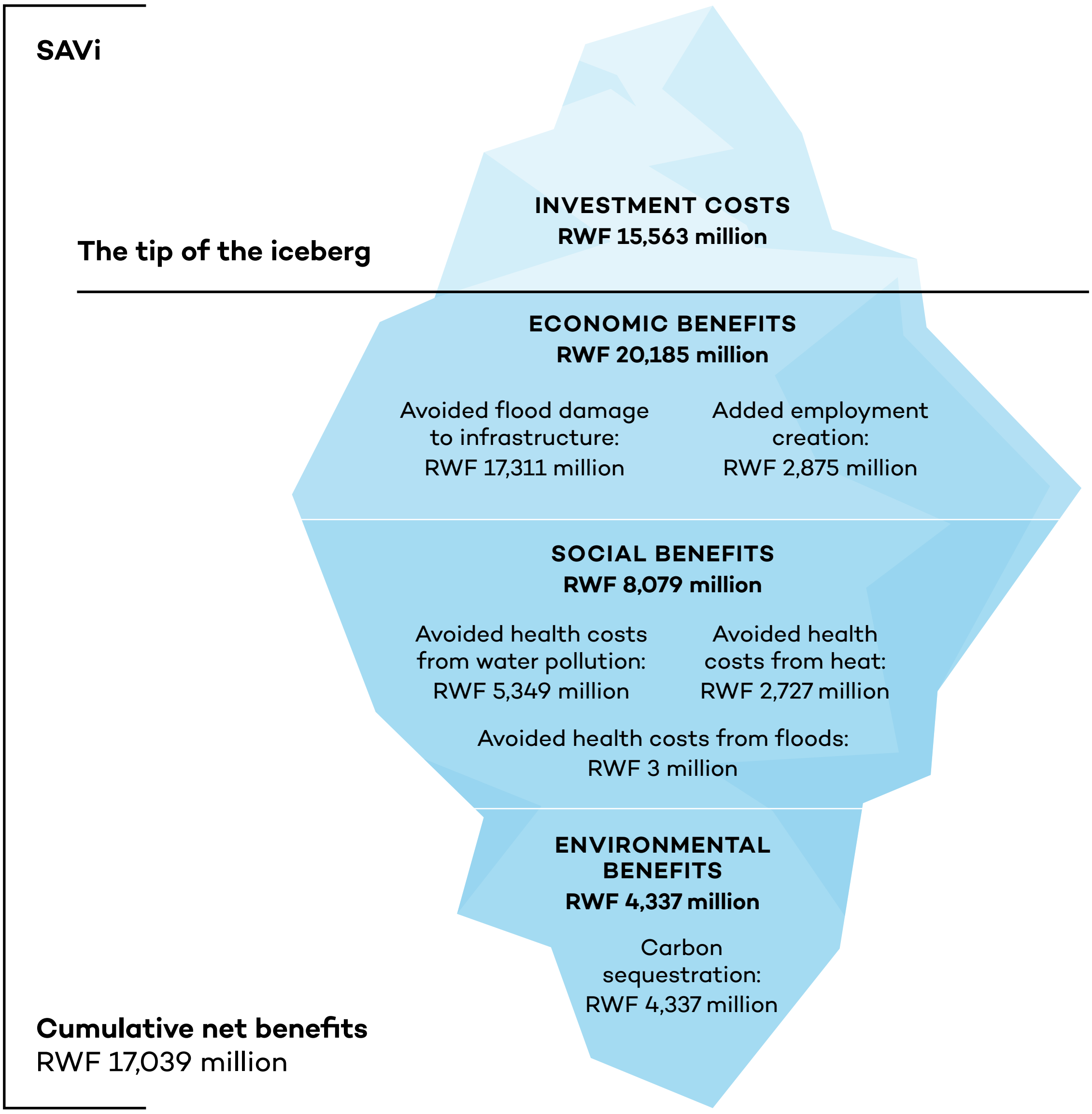
Source: Authors.

The NbS scenario will generate a cumulative (discounted at 10%)[3] net benefit of RWF 17,039 million, considering a project period of 25 years, from 2025 to 2050. The results of the assessment that consider all economic, social, and environmental benefits also show that SUNCASA's gender-responsive NbS interventions in Kigali will lead to a discounted, integrated BCR of 2.09, highlighting the societal returns on investment. Importantly, recall that the BCR determines the overall value for money of a project and illustrates the return for every unit (RWF invested) by comparing the project's total benefits with the total costs. The payback period is seven years from the beginning of the project. Importantly, inclusive approaches that target women and other underrepresented groups and communities can

[3] A 10% discount rate was considered for the assessment for the following reasons: 1) the Central Bank lending rate for Rwanda is currently set at 15.8% (National Bank of Rwanda); 2) the Central Bank rate may well decline in the future, especially when considering the 25-year timeframe for the analysis (the Central Bank interest rate was 6.5% in 2025); 3) we assume that projects that support climate adaptation and mitigation can be eligible for conditional loans, either via preferential rates or risk reduction related to the provision of collateral or a grant portion for the project. As a result, a rate of 10% was chosen for the analysis, consistent with the other two SUNCASA projects in Dire Dawa and Johannesburg.

further increase the societal return on investment. Lastly, the undiscounted values of the NbS scenario amount to a cumulative net benefit of RWF 91,590 million and a BCR of 2.50.

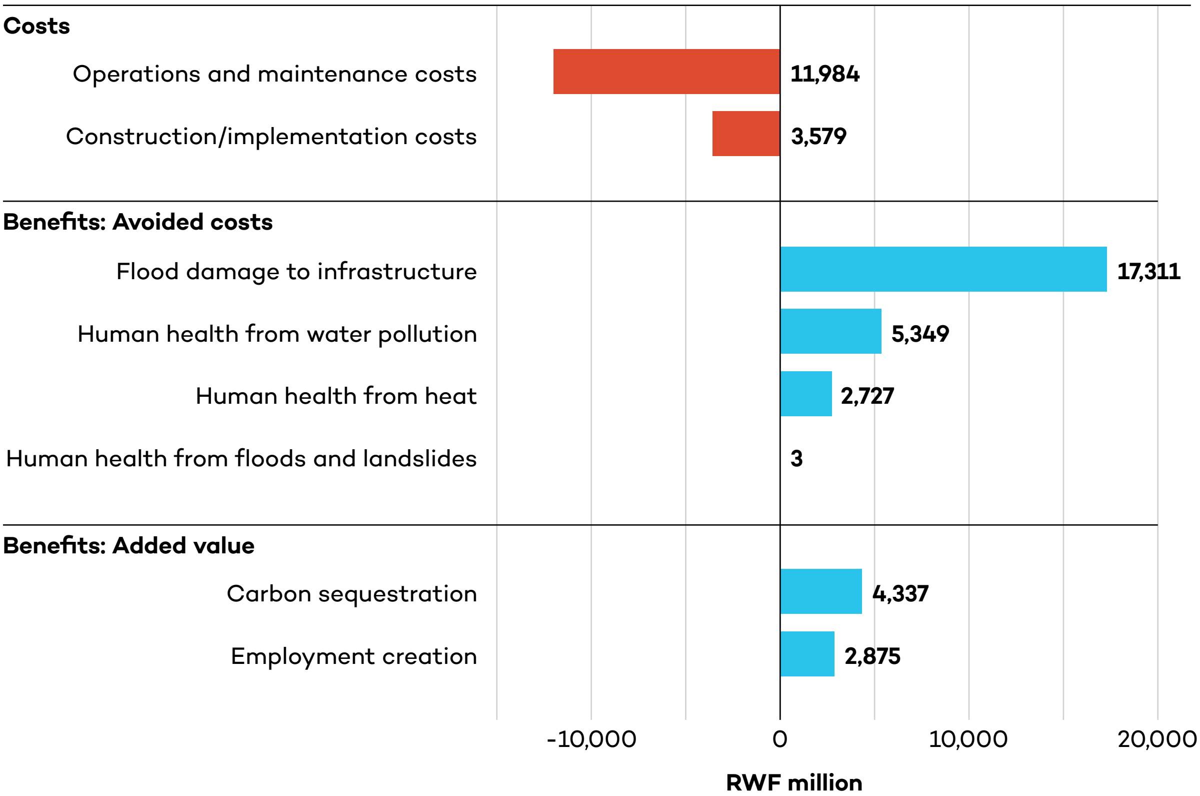
Figure 7. Economic, social, and environmental benefits of the NbS interventions in Kigali



Source: Authors.

The greatest impact of the NbS scenario is the avoided cost of flood damage to infrastructure, valued at a cumulative, discounted RWF 17,311 million. This is a tangible avoided cost that affects people in the city and surrounding areas. The second largest impact is instead intangible, relates to water pollution, and amounts to a cumulative RWF 5,349 million. In addition, carbon sequestration benefits are valued at RWF 4,337 million, and income creation from employment amounts to RWF 2,875 million. The above impacts are shown in Figure 8.

Figure 8. Monetary values of the NbS scenario (discounted at 10%, cumulative 2025–2050)



Source: Authors.

When considering the sensitivity analysis scenarios, the economic value of carbon sequestration benefits increases substantially when applying a higher social cost of carbon, set at USD 40/ton in line with the World Bank's (2024) shadow price of carbon. Under this high social cost of carbon sensitivity scenario, cumulative carbon sequestration benefits are valued at RWF 12,144 million. Overall, the scenario yields cumulative net benefits of RWF 24,846 million and a BCR of 2.60, indicating strong economic viability.

In addition, the SAVi assessment found that under a higher water pollution cost scenario in Kigali, based on studies on the price per kg of nitrogen and phosphorus removal from NbS from Denmark and the United States, the project is still economically viable, with net benefits of RWF 22,388 million and a BCR of 2.44. When accounting for the higher shadow price of carbon, net benefits reach RWF 30,195 million, and the BCR improves to 2.94, indicating that all scenarios show economic viability.

Importantly, even without accounting for the value of carbon pricing, the investment in NbS interventions remains economically viable due to the significant contribution to savings such as avoided infrastructure damage costs. When carbon pricing and health benefits are excluded, the payback period extends to 11 years instead of 7. When only carbon pricing is excluded, the payback period is 9 years. Incorporating the value of carbon pricing further shortens the payback period from 9 to 7 years.

Table 5. Net benefits and BCRs of the NbS interventions in Kigali across scenarios (RWF million)

	NbS scenario	High social cost of carbon	High cost of water pollution	High social cost of carbon and high cost of water pollution
Undiscounted net benefits	91,590	133,866	114,127	136,404
Discounted (at 10%) net benefits	17,039	24,846	22,388	30,195
BCR (discounted)	2.09	2.60	2.44	2.94

Source: Authors.

5.0 Conclusions

The NbS project in Kigali stands out as a multifaceted solution with strong potential to advance climate adaptation efforts across the city and surrounding areas. The results represent not only implementation costs but also a variety of economic, social, and environmental added benefits and avoided costs that show the societal value of NbS interventions. SUNCASA's extensive reforestation, afforestation, agroforestry, riparian restoration, and urban tree-planting efforts have the potential to reduce risks related to floods, water pollution, and extreme heat while creating jobs and providing multiple economic, social, and environmental benefits for the city's wider population. These impacts also align with key priorities within strategic policy documents in Rwanda, such as the *Kigali City Master Plan 2050* (City of Kigali, 2020) and the *Revised Green Growth and Climate Resilience Strategy* (2018).

Integrated valuations, such as this SAVi assessment, provide a fuller picture of the long-term effects of infrastructure projects by integrating these values into the traditional calculations of BCRs. Recall that BCRs determine the overall value for money of a project. In this case, they illustrate the return for every unit (RWF invested) by comparing the SUNCASA project's total benefits with the total costs. The analysis demonstrates that SUNCASA's NbS interventions in Kigali will lead to a discounted (at 10%) BCR of 2.09, highlighting the societal returns on investment. In addition, the NbS interventions will lead to estimated discounted net benefits of RWF 17,039 million for the population of Kigali and its surroundings, cumulatively, from 2025 until 2050. Importantly, inclusive approaches that target women and other underrepresented groups can further increase the societal return on investment.

The greatest impacts over the timeline (2025–2050) that was considered in the analysis are the avoided cost of flood damage to infrastructure (RWF 17,311 million), the avoided costs on human health from water pollution (RWF 5,349 million), the benefits of carbon sequestration (RWF 4,337 million), and the benefits from additional income creation from employment (RWF 2,875 million).

The SAVi assessment also demonstrates that advancing NbS investments, such as the activities in Kigali, delivers strong economic, social, and environmental outcomes that outweigh the upfront implementation (as well as operation and maintenance) costs in the long term. The following recommendations are intended to support future efforts in identifying, assessing, and maximizing the value of NbS initiatives in Kigali.

- The analysis presents a positive case for implementing NbS interventions; therefore, policy-makers, city planners, and project developers should actively plan for, finance, and implement NbS. Systematically identifying and quantifying the broader economic, social, and environmental added benefits and avoided costs of NbS and subsequently incorporating these wider values into decision-making processes is essential to ensure that NbS investments are worth the costs, delivering maximum societal benefits.
- Policy-makers should collect and use data that is disaggregated by gender or social group to better measure and understand the benefits of climate adaptation efforts. Embedding this data into decision making ensures equitable access, participation, and benefit-sharing for women and other underrepresented groups.

- The analysis shows that there are substantial economic gains in investing in NbS; therefore, governments should consider putting in place economic incentives for the promotion of NbS.

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Appendix. Key Data Sources

Table A1. Data sources used in the Sustainable Asset Valuation assessment of the NbS interventions in Kigali

	Indicator	Value	Data source
Construction/implementation costs			
	Area and number of trees for nature-based solutions (NbS) interventions	Agroforestry: 1,200 ha; afforestation: 215 ha; reforestation: 650 ha; riparian zone: 395 ha; urban tree planting: 85,000 trees	Internal SUNCASA project documents
	Planting costs per tree	USD 1.10/tree (average of 2, 1, and 0.3)	Feedback from participants during the August 2025 workshop in Kigali
	Trees per ha	1,433 trees/ha (average of 1,100, 1,600, and 1,600)	Assumption based on feedback from participants during the August 2025 workshop in Kigali
	Time of construction/ implementation in years	5 years	Assumption
Operation and maintenance (O&M) costs			
	Area for NbS interventions	Agroforestry: 1,200 ha; afforestation: 215 ha; reforestation: 650 ha; riparian zone: 395 ha; urban tree planting: 85,000 trees	Internal SUNCASA project documents
	O&M costs per tree	USD 0.52/tree (average of 1, 0.5, and 0.06)	Feedback from participants during the August 2025 workshop in Kigali
	Trees per ha	1,433 trees/ha (average of 1,100, 1,600, and 1,600)	Assumption based on feedback from participants during the August 2025 workshop in Kigali
	Time of O&M costs in years	21 years	Assumption

	Indicator	Value	Data source
Avoided flood damage to infrastructure (starting after 5 years of initial NbS implementation)			
	Total number of buildings at risk	229,094 buildings	Kigali spatial analysis
	Percentage of buildings damaged when flood occurs	0.30%	Kigali spatial analysis
	Average flood area of residential buildings	38 m^2	Rwanda Environmental Management Authority (REMA), 2013.
	Average replacement cost of new residential house	RWF 78,500/m^2	REMA (2013)
	Future frequency of floods	Every two years	Assumption
	Percentage increase in water retention (as a result of the NbS interventions)	36%	REMA (2021a)
	Road damage when flood (total)	167,561 m	Kigali Spatial Analysis
	Average replacement cost of road	RWF 196,666,667/km (average of gravel road, stone road, and tarmac road)	REMA (2013)
	Percentage increase in water retention (as a result of the NbS interventions)	36%	REMA (2021a)
	Time for NbS to mature	8 years	Assumption based on feedback from participants during the August 2025 workshop in Kigali
Avoided human health costs from floods and landslides (starting after 5 years of initial NbS implementation)			
	Number of people impacted per flood	131 persons	Reliefweb (2023)
	Average cost of healthcare treatment in Rwanda	USD 60/person	Macrotrends (2024)

	Indicator	Value	Data source
	Future frequency of flood	Every two years	Assumption
	Percentage of people impacted needing healthcare	56%	Assumption based on feedback from participants during the August 2025 workshop in Kigali
	Percentage increase in water retention (as a result of the NbS interventions)	36%	REMA (2021)
	Time for NbS to mature	8 years	Assumption based on feedback from participants during the August 2025 workshop in Kigali
Avoided human health costs from water pollution (starting after 5 years of initial NbS implementation)			
	Nitrogen uptake per ha	126 kg/ha/year	Kim & Isaac (2022)
	Phosphorus update per ha	14 kg/ha/year	European Soil Data Centre (2022)
	Price per kg of nitrogen removed	USD 50/kg	Plauborg et al. (2023)
	Price per kg of phosphorus removed	USD 177/kg	Dunne et al., 2013.
	Percentage reduction in nitrogen and phosphorus uptake per ha and price per kg based on size of trees and country source	50%	Assumption
	Percentage of water pollution budget avoided (as a result of the NbS interventions)	40%	Assumption based on feedback from participants during the August 2025 workshop in Kigali
	Time for NbS to mature	8 years	Assumption based on feedback from participants during the August 2025 workshop in Kigali

	Indicator	Value	Data source
Avoided human health costs from heat (starting after 5 years of initial NbS implementation)			
	Reduction in energy use (air conditioning) and air pollution from urban shade trees	200 USD/tree	Akbar (2022)
	Duration of tree benefits	30 years	Assumption
	Percentage of heat mitigation budget avoided (as a result of the NbS interventions)	40%	Assumption
	Time for NbS to mature	8 years	Assumption based on feedback from participants during the August 2025 workshop in Kigali
Employment creation (construction/implementation employment in the first 5 years, O&M employment after 5 years and until 2050)			
	Total number of jobs (project staff, seedling production and maintenance, urban tree and fruit workers, tree planting, preparation, tree nursery managers and guards, field technicians/supervisors)	3,062 total jobs for construction/ implementation and 1,895 total jobs for O&M	Internal SUNCASA project documents
	Average daily salary	RWF 2,500/day	Internal SUNCASA project documents
	Average working days per month	24	Internal SUNCASA project documents
	Percentage of discretionary spending	20%	Assumption
	Time of construction/ implementation employment and O&M employment	5 years and 21 years	Assumption

	Indicator	Value	Data source
Carbon sequestration (starting after 5 years of initial NbS implementation)			
	Price of carbon in Rwanda	EUR 13.68/tCO_2	Organisation for Economic Co-operation and Development (2024)
	Shadow price of carbon	40 USD/tCO_2	World Bank (2024)
	Carbon stored	2,005,151 tCO_2 in Current scenario; 2,624,008 tCO_2 in Restored scenario	Kigali spatial analysis
	Time for NbS to mature	8 years	Assumption based on feedback from participants during the August 2025 workshop in Kigali

Source: Authors.

Note: All assumptions and data sources were validated by stakeholders during the August 2025 workshop in Kigali.

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