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A Sustainable Asset Valuation Assessment of Nature-Based Solutions in the Jukskei River Catchment in Johannesburg, South Africa

SUNCASA REPORT

Michail Kapetanakis

March 2026

Project partners

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Written by Michail Kapetanakis

Photo: Cesar Henrique Arrais/IISD

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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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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

Johannesburg, South Africa's largest city and home to more than 4.8 million people, is facing increasing water scarcity due to mounting pressure on its water resources. The Jukskei River, with a catchment area of 772 km^2, is among the most degraded river systems in the city. Rapid urban growth without sufficient infrastructure, informal settlement expansion into riparian zones, frequent flooding, and widespread pollution have severely impacted river and wetland health. Soil erosion, sedimentation, and deteriorating water infrastructure exacerbate pressure on the river system. Open space fragmentation and poor land-use planning contribute to a decline in ecosystem services and environmental quality, reducing social and recreational value across the city.

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 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.

Through the use of 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 implementations are projected to have in Johannesburg. The NbS interventions that are considered in this assessment include a combination of removal of invasive alien vegetation, strategic reforestation, wetland rehabilitation, and the development of multifunctional urban green infrastructure. These activities aim to enhance ecosystem services, reduce the risks of water contamination and erosion, reduce the impacts of flooding and heat in the city, and improve the adaptive capacity of urban populations. Further, the CBA assesses the multi-dimensional impacts of these NbS interventions (such as flood damages to infrastructure, human health costs from floods, water pollution and heat, alien invasive plant management costs, carbon sequestration and employment creation benefits) and estimates their value in economic terms.

Key Results

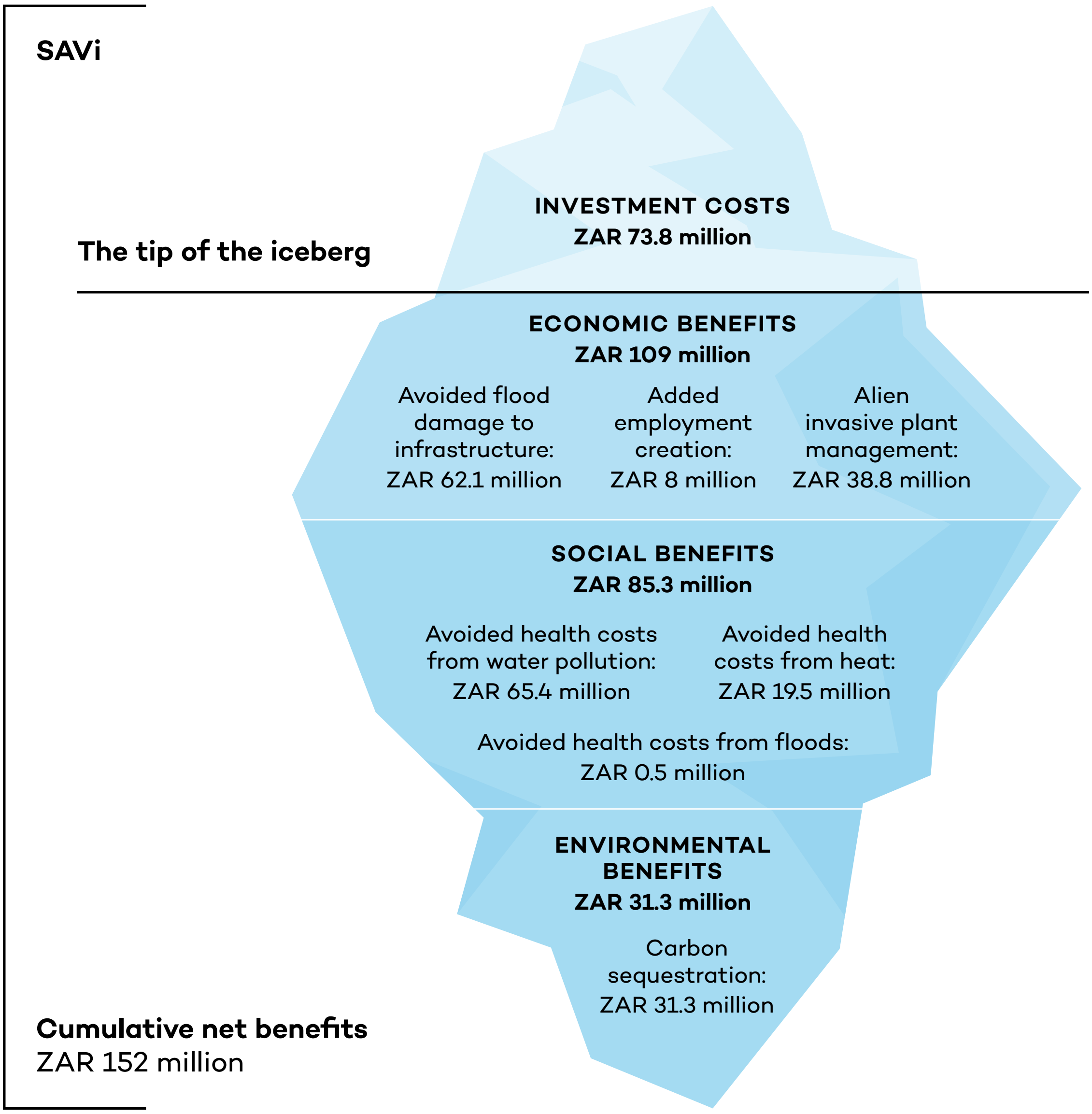
The results in Table ES1 show that the NbS interventions in Johannesburg generate a wide range of economic, social, and environmental benefits, most of which are typically not considered in traditional infrastructure assessments. Overall, results show that the NbS interventions are projected to save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

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

		Sensitivity analysis (ZAR million)	
Integrated CBA 2025–2050 (discounted at 10%)	**NbS scenario** (ZAR million)	**High cost of carbon**	**Low damages to infrastructure**
Total direct costs	**73.8**	**73.8**	**73.8**
Implementation costs	22.0	22.0	22.0
Operation and maintenance costs	51.9	51.9	51.9
Total added benefits	**225.8**	**282.6**	**175.9**
Avoided flood damage to infrastructure	62.1	62.1	12.4
Avoided health costs: floods and landslides	0.5	0.5	0.5
Avoided health costs: water pollution	65.4	65.4	65.4
Avoided health cost: heat	19.5	19.5	19.5
Avoided alien invasive plant management costs	38.8	38.8	38.8
Added employment creation	8.3	8.3	8.3
Carbon sequestration	31.3	88.0	31.3
Total net benefits (undiscounted)	**737.1**	**898.9**	**448.6**
Total net benefits (discounted)	**152.0**	**208.7**	**102.1**
Benefit-to-cost ratio (BCR)	**3.06**	**3.83**	**2.38**

Source: Authors.

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



Source: Authors.

The NbS scenario will generate a cumulative net benefit of ZAR 152.0 million (discounted at 10%), considering a 25-year project period (2025 to 2050). The results of the project, when considering all economic, social, and environmental benefits, show an integrated BCR of 3.06. The payback period is 7 years from the project's start. Undiscounted values of the NbS scenario amount to a cumulative net benefit of ZAR 737.1 million and a BCR of 4.00. These results highlight the project's economic viability, which generates a considerable amount of avoided costs (ZAR 186.3 million), of which 54% are tangible, i.e., avoided infrastructure damage costs and avoided alien invasive plant management costs. The total added benefits reach ZAR 39.6 million, 79% of which relate to carbon sequestration. The intangible societal value of the project is considerable, representing 52% of the total value generated via cost reductions and value creation. Further, the avoided costs and added benefits are shared across 2,000 direct and 1.045 million indirect citywide beneficiaries, as opposed to being accumulated by a few entities. The largest impact of the NbS scenario relates to avoided health costs of water pollution, amounting to a cumulative discounted ZAR 65.4 million over 25 years. This is an intangible avoided cost that affects people in the city. This is closely followed by the tangible impact related to avoided costs of flood damage to infrastructure, valued at a cumulative discounted ZAR 62.1 million. In addition, the avoided costs of alien invasive plant management amount to ZAR 38.8 million by 2050. The added benefits related to carbon sequestration are valued at ZAR 31.3 million. This is another example of a benefit that is shared across a large number of beneficiaries.

For the SUNCASA NbS interventions in Johannesburg, we considered two sensitivity analysis scenarios. The first relates 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 ZAR 88 million. Overall, the scenario yields cumulative net benefits of ZAR 208.7 million and a BCR of 3.83, indicating stronger economic viability with a higher valuation of carbon.

The SAVi assessment also considers a sensitivity analysis scenario of lower flood damages based on Royal HaskoningDHV (2021). According to this scenario, the avoided costs of flood damages to infrastructure decline from ZAR 65.1 million to ZAR 12.4 million. However, the NbS interventions are still economically viable with cumulative, discounted net benefits of ZAR 102.1 million and a BCR of 2.38.

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 Johannesburg will generate both avoided costs and 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 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

Johannesburg, South Africa's rapidly expanding metropolitan hub with a population of more than 4.8 million inhabitants (City of Johannesburg, 2025), faces growing pressure on its water resources, exacerbating water scarcity. The city's river systems, particularly the Jukskei River, which drains a catchment area of approximately 772 km² over a 50 km reach, are among the most severely degraded. The ecological health of Johannesburg's rivers and wetlands has been critically compromised due to the combined impacts of rapid urbanization without adequate infrastructure, informal settlement expansion into riparian zones, frequent flooding, and widespread pollution from solid waste and illegal dumping. Additional pressures stem from soil erosion, sedimentation, aging water and stormwater infrastructure, and the fragmentation of open spaces. These factors collectively contribute to declining ecosystem services, inefficient land-use patterns, and the significant loss of both environmental quality and social amenity across the urban landscape (City of Johannesburg, 2022b).

Urban stormwater pollution in Johannesburg presents a significant and escalating threat to water resources, aquatic ecosystems, public health, and property values. The Jukskei River is heavily impacted by elevated levels of sewage contamination, gross pollutants such as litter, and relatively high concentrations of *Escherichia coli* (E. coli). These challenges are intensified by a sewerage system that is increasingly unable to accommodate rising housing densities associated with rapid urban development. Additional pressures to the Jukskei river include widespread littering and diffusion of sediment runoff, which contribute to riverbank erosion, channel incision, bed modification, and further sedimentation. Industrial activities in the catchment have also resulted in increased concentrations of minerals in the water, while historical and ongoing mining operations are associated with elevated pH levels, high sulphate concentrations, and acid mine drainage. Landfill leachate further exacerbates contamination, leading to both environmental and human health risks (City of Johannesburg, 2022b). At the same time, invasive alien species in wetlands and urban forests are undermining the resilience of these ecosystems, diminishing their capacity to absorb floodwaters, regulate microclimates, and provide essential ecological services (Henderson, 2020). The degradation of biodiversity and ecosystem health further exacerbates climate vulnerability across the Jukskei catchment (City of Johannesburg, 2022b).

The Jukskei River catchment plays a critical role in the region's water security, traversing a complex urban landscape that includes high-income residential zones, informal settlements, commercial hubs, and light industrial areas. This diversity of land use places considerable pressure on water resources and ecosystem functioning. Urban informal settlements, often densely populated and located along riverbanks, face heightened exposure to flooding, waterborne pollution, and associated health risks. Vulnerable communities in these areas are disproportionately affected by deteriorating water quality and climate-related hazards (City of Johannesburg, 2022b).

Addressing these interconnected challenges in Johannesburg requires coordinated, cross-sectoral policy action that brings together sustainable land use, urban planning, water management, and environmental protection. Without timely intervention, these impacts threaten to undermine Johannesburg's long-term resilience, public health, and socio-economic stability. Integrated water and landscape management, including investment in gender-responsive nature-based approaches, offers a critical pathway to strengthen urban resilience, protect ecosystems, and promote sustainable livelihoods across Johannesburg (Acreman et al., 2021).

The Scaling Urban Nature-based Solutions (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.

The SUNCASA project aims to restore and revitalize the Jukskei River catchment to address key urban climate and environmental challenges. The program aims to mitigate flooding, improve urban heat regulation, enhance water security, support biodiversity, and strengthen local livelihoods, particularly for vulnerable and historically underserved local communities. SUNCASA prioritizes gender-responsive NbS, integrating ecological restoration with social inclusion. The interventions include the removal of invasive alien vegetation, strategic reforestation, wetland rehabilitation, and the development of multifunctional urban green infrastructure. These actions will enhance ecosystem services, reduce the risks of water contamination, erosion, and flooding, and improve the adaptive capacity of urban populations.

Gender-responsive NbS refer to approaches that aim to strengthen environmental resilience while empowering marginalized groups by embedding gender equality and inclusion into climate adaptation efforts. These approaches actively address and integrate gender considerations, ensuring that women and other underrepresented groups have equitable access to resources, meaningful participation, and fair distribution of benefits. Such groups are often more vulnerable to the negative impacts mentioned above, including water-related challenges, adverse effects on human health, and the consequences of floods and landslides. Addressing these disparities and empowering women and vulnerable communities is a critical component of this initiative.

The NbS interventions are implemented across 469 hectares of riparian zone, while 46,000 trees are planned to be planted as part of urban greening strategies. The NbS interventions include the following:

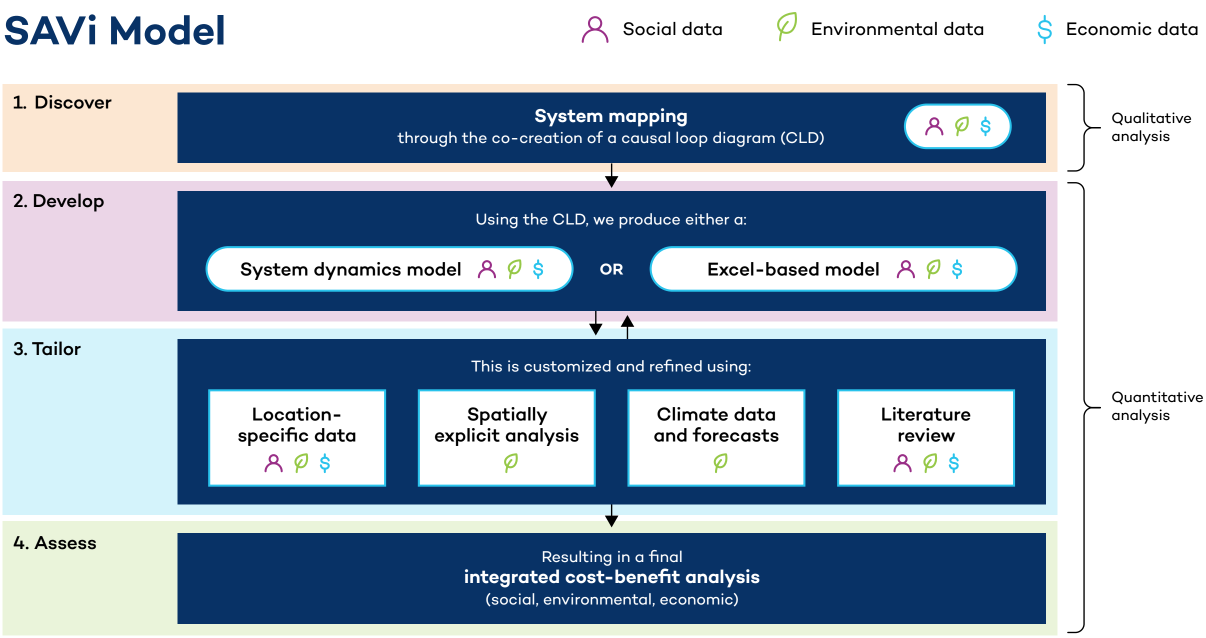
- **afforestation and reforestation** to strategically rehabilitate riverbanks and prevent ongoing erosion and sedimentation;
- **removal of solid waste, debris, and invasive species from riverine systems and wetlands,** including invasive alien vegetation;
- **urban green infrastructure,** including tree planting and open space improvements, to reduce impacts of stormwater and extreme heat and increase biodiversity;
- **development of usable parkland and green corridors** alongside watercourses to improve residents' access to the city's rivers and wetlands.

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 Johannesburg and concludes with recommendations on the use of the results by key stakeholders in the development, implementation, and financing of NbS.

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 SAVi assessments, basically provide a fuller picture of the long-term effects of infrastructure projects by integrating these externalities into traditional calculations of BCRs. This holistic approach enables investment decisions that align with regional development priorities, climate change adaptation, and the UN 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 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. It 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 Johannesburg. 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 system in which the SUNCASA NbS interventions operate, recognizing the interconnectedness of key indicators, uncovering key drivers and dynamics, and discerning the most impactful policy entry points.

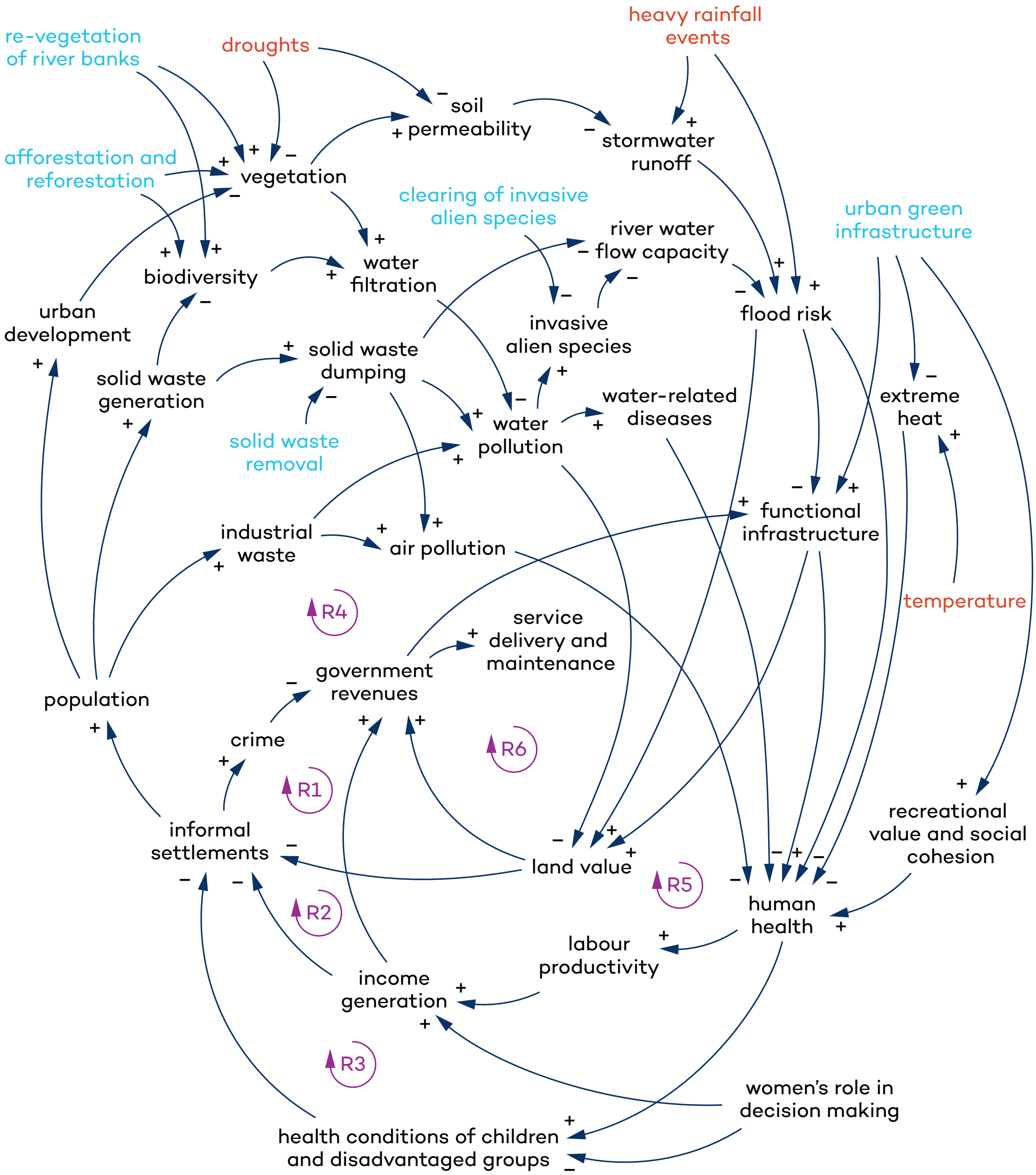
2.2 Causal Loop Diagram

The first step in the SAVi assessment is to identify the impacts and underlying dynamics of a project, including driving forces and key indicators, 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 Johannesburg 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 Johannesburg



Source: Authors.

Over recent decades, urban growth and population expansion in Johannesburg have triggered a combination of negative environmental, social, and economic impacts, resulting in the degradation of ecosystem services, increased vulnerability to climate hazards, and deteriorating public health in the city, especially for low-income, marginalized communities. A critical driver in this system is the decline in vegetation cover, intensified by extreme weather events, such as droughts. Reduced vegetation leads to lower soil permeability, which in turn accelerates stormwater runoff and raises the risk of flooding, particularly under heavy rainfall conditions. These floods, both through immediate damage and long-term pressure on critical infrastructure, contribute to declining land values. As land values drop, the development of informal settlements accelerates, reinforcing the cycle of urban expansion and ecological degradation (R1).

Simultaneously, the reduction in vegetation diminishes biodiversity and weakens natural water filtration processes, thereby increasing water pollution. This further degrades land value and facilitates the spread of invasive alien species that reduce river flow capacity, intensifying flood risks. Water pollution also increases the likelihood of waterborne diseases, leading to negative public health impacts that are exacerbated by climate-induced extremes, such as flooding and rising urban temperatures. The resulting health pressures reduce labour productivity, limiting income-generating opportunities and driving further informal settlement expansion (R2). This cycle disproportionately impacts women and disadvantaged groups, exacerbating existing socio-economic inequalities and contributing to poor nutritional outcomes, particularly among children (R3).

Informal settlements, often emerging in ecologically vulnerable and low-value areas, fuel the growth of the informal economy. In combination with reduced land value, this undermines municipal revenue collection, which in turn constrains public investment in essential infrastructure. This fiscal weakening impairs service delivery and infrastructure maintenance, further lowering land value (R6). Population growth and urbanization also lead to increased solid waste generation and informal dumping. This practice not only erodes biodiversity but also increases water and air pollution, leading to negative health outcomes (R4). Industrial waste discharge exacerbates these impacts, contributing to a deteriorating urban environment and putting additional pressures on health systems.

The application of NbS presents a strategic systems-level approach capable of disrupting some negative feedback loops by mitigating key environmental pressures and addressing root causes. Strategic afforestation, reforestation, riverbank re-vegetation and urban green infrastructure initiatives can reverse vegetation loss, restore biodiversity, and improve soil permeability, directly reducing stormwater runoff and associated flood risks. Enhanced water filtration through restored ecosystems would mitigate water pollution, offering direct public health benefits by lowering disease burdens and indirectly enhancing labour productivity and economic participation. Complementary interventions, such as the removal of solid waste, would alleviate pressures on water and air quality, improving public health while potentially enhancing land value. The targeted removal of invasive alien species would improve river flow and reduce infrastructure vulnerability to floods. Finally, integrating urban green infrastructure could moderate the urban heat island effect, particularly in informal settlements, thus reducing heat-related health impacts while also providing spaces that foster recreation and social cohesion. Collectively, these interventions not only restore ecological balance but also realign urban development pathways toward a more resilient, inclusive, and healthy Johannesburg.

2.3 Spatially Explicit Analysis

Two land-use/land-cover (LULC) maps were developed in support of this assessment: the Current LULC scenario (showing the land use of selected neighbourhoods in Johannesburg prior to the beginning of the project) and the Restored LULC scenario (which considered the same study area but also with the additional hectares (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).

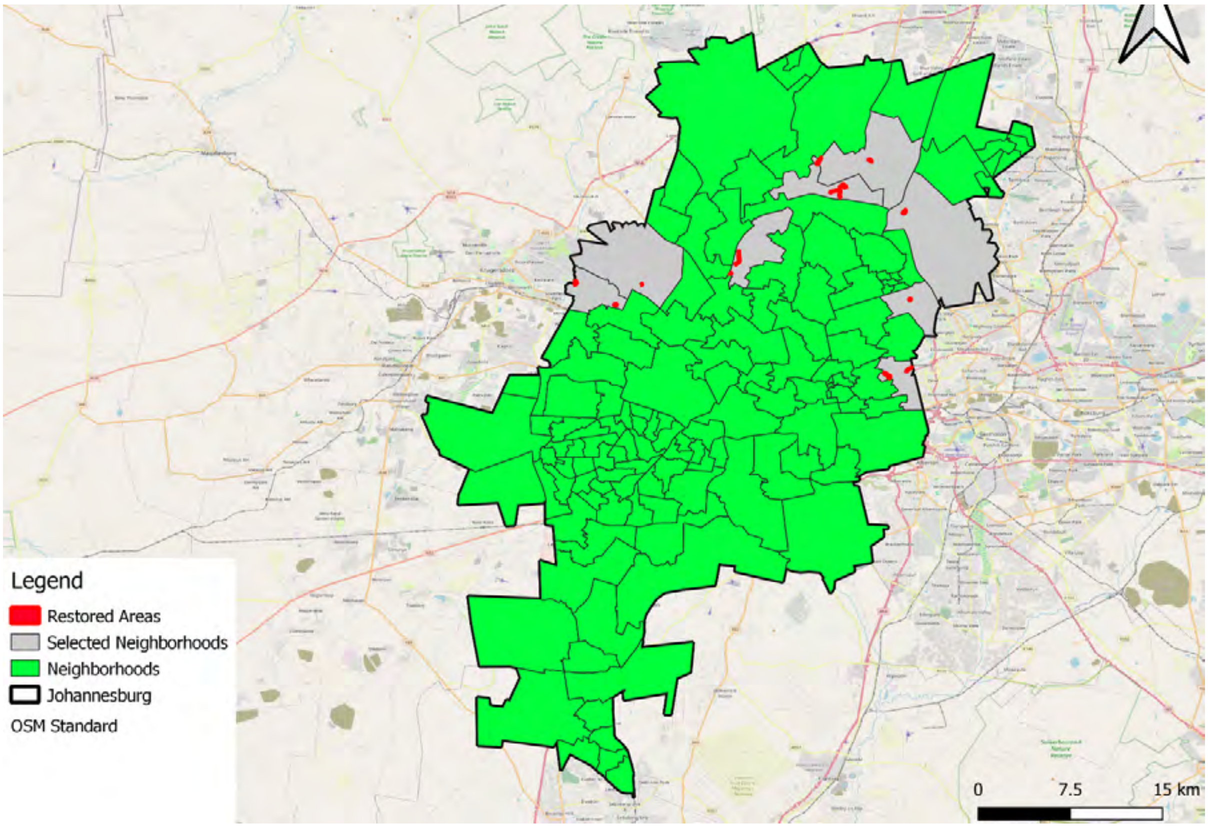
Since the interventions are localized, we considered as study areas both the city of Johannesburg and the neighbourhoods where the interventions will be located. Figure 3 shows the specific location of the interventions considered for this assessment.

Table 1. Total hectares of interventions

Activity	ha
Riparian zone restoration	469
Urban tree planting	460 (or 46,000 trees)

Source: Authors.

Figure 3. Location of the interventions



Source: Authors.

Note: OSM standard is that of the OpenStreetMap project.

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, use LULC maps as input and quantify a wide range of ecosystem services.

Flooded areas and infrastructure were 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 return period was considered, and Geofabrik spatial data for buildings and roads in Johannesburg were downloaded to determine the number of buildings and the total length of roads at risk of flooding. The results are shown in Table 2.

Table 2. Total number of buildings and metres of roads in Johannesburg, and the number that are at risk of flooding[1]

Total metres of road	7,482,197
Metres of roads at risk	11,704
% of metres of roads at risk	0.2%
Total number of buildings	36,307
Number of buildings at risk	–
% of buildings at risk	0.0%

Source: Authors.

[1] The number of buildings at risk of flooding in the SAVi assessment was estimated using City of Johannesburg (2022a, 2022b), as it yielded more accurate and location-specific data for the project context.

3.0 Integrated CBA

3.1 Methodology

The integrated CBA builds upon all elements of the SAVi methodology that were detailed previously: CLD, systems thinking, and spatial analysis. For example, the CLD identified costs of flood damages to infrastructure as an important outcome of the NbS, the spatial analysis quantified how many metres of road will be at risk of flooding, and the CBA assigns a monetary value to this parameter.

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. By including 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 are applied to ensure continuity and coherence in the analysis. Specific values, sources, and assumptions that were used for this assessment are included in Appendix A. 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 and 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, along with avoided alien invasive plant management costs and 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 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 and the restoration of the Jukskei River catchment in Johannesburg. As part of the same scenario, two sensitivity analysis scenarios[2] are included:

1. NbS Scenario

This scenario proposes the introduction of gender-responsive NbS measures, including afforestation and reforestation of the Jukskei riverbanks, riparian restoration such as removal of solid waste, debris, and invasive species and urban tree planting to reduce flooding and heat impacts, as well as enhance water security. These measures aim to enhance ecosystem services and strengthen local livelihoods while reducing the risks of flooding, erosion, and water pollution.

- **1.1. High cost of carbon:** This scenario assumes a higher cost of carbon (USD 40/ ton), based on the World Bank (2024) shadow price of carbon.
- **1.2. Low cost of flood damages:** This scenario assumes lower avoided flood damages to infrastructure based on Royal HaskoningDHV (2021).

[2] Given the inherent uncertainty in several key assumptions underlying the CBA, including the monetary value assigned to carbon emissions, discount rates, or the magnitude of certain indicators, a sensitivity analysis is conducted to test the robustness of the results. The sensitivity analysis allows for assessing 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 shown in Table 3, showing discounted values at 10%. The analysis shows that the NbS scenario is economically viable and that the SUNCASA implemented NbS interventions in Johannesburg 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 damages to infrastructure, avoided health costs from floods, water pollution, and heat, avoided alien invasive plant management costs, and carbon sequestration and employment benefits.

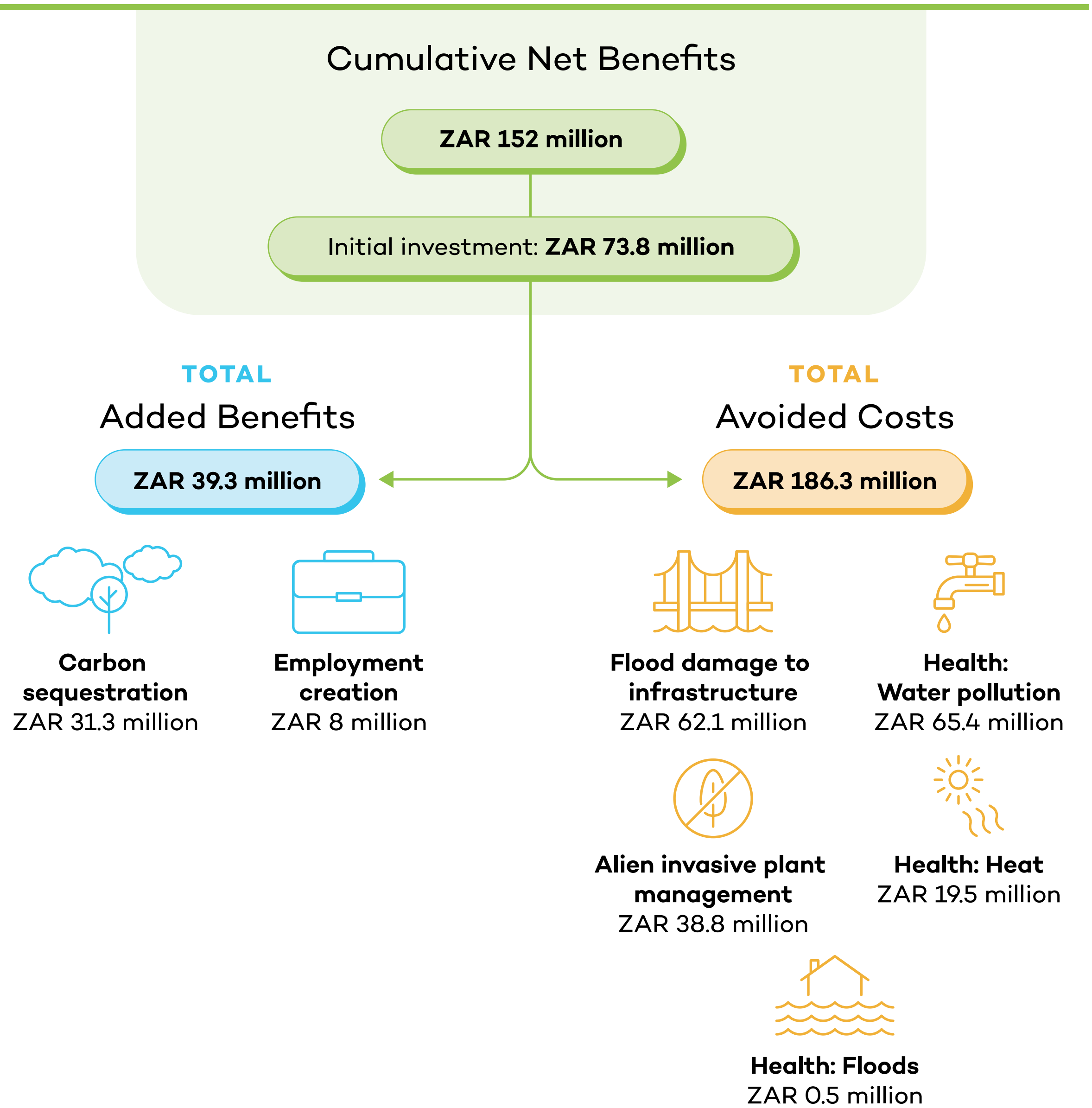
Table 3. Integrated CBA of SUNCASA-implemented NbS interventions in Johannesburg (Discounted at 10%)[3]

		Sensitivity analysis (ZAR million)	
Integrated CBA 2025–2050 (discounted at 10%)	**NbS scenario** (ZAR million)	**High cost of carbon**	**Low damages to infrastructure**
Total direct costs	**73.8**	**73.8**	**73.8**
Implementation costs	22.0	22.0	22.0
Operation and maintenance costs	51.9	51.9	51.9
Total added benefits	**225.8**	**282.6**	**175.9**
Avoided flood damage to infrastructure	62.1	62.1	12.4
Avoided health costs: floods and landslides	0.5	0.5	0.5
Avoided health costs: water pollution	65.4	65.4	65.4
Avoided health cost: heat	19.5	19.5	19.5
Avoided alien invasive plant management costs	38.8	38.8	38.8
Added employment creation	8.3	8.3	8.3
Carbon sequestration	31.3	88.0	31.3
Total net benefits (undiscounted)	**737.1**	**898.9**	**448.6**
Total net benefits (discounted)	**152.0**	**208.7**	**102.1**
Benefit-to-cost ratio (BCR)	**3.06**	**3.83**	**2.38**

Source: Authors.

[3] Disaggregated data by gender or social group was not available. It is recommended to track benefits by gender and vulnerability in future assessments.

Figure 4. Added benefits and avoided costs of the NbS interventions in Johannesburg



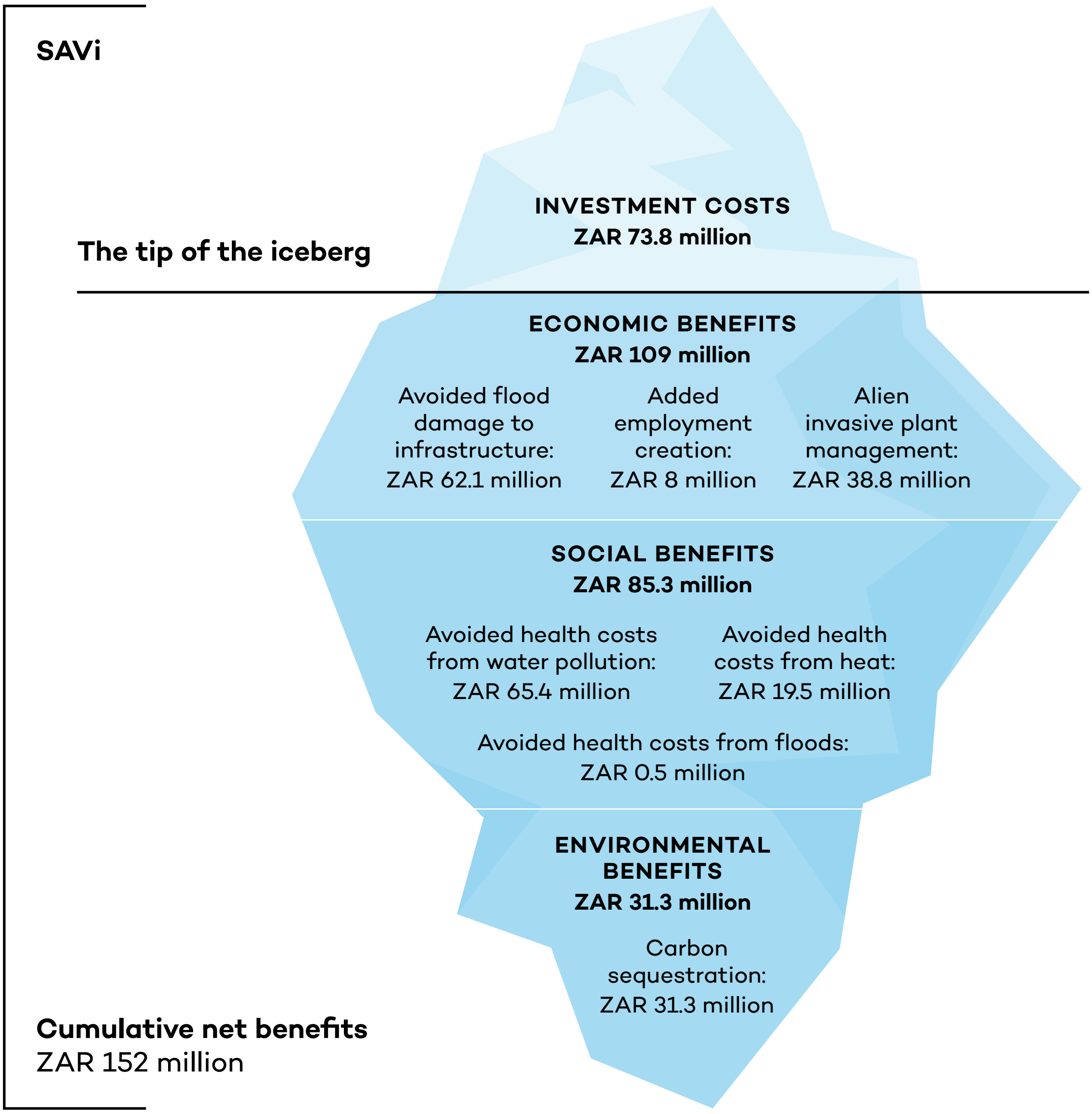
Source: Authors.

The NbS scenario will generate a cumulative (discounted at 10%)[4] net benefit of ZAR 152.0 million, considering a 25-year project period, from 2025 to 2050. The results of the assessment, which consider all economic, social and environmental benefits, also show that SUNCASA's gender-responsive NbS interventions in Johannesburg will lead to a discounted,

[4] A 10% discount rate was considered for the assessment for the following reasons: (i) the central bank lending rate for South Africa is currently set at 10.50%, in line with an average of 11.43% from 1950 until 2025 (South African Reserve Bank, Trading Economics 2025b) (ii) the central bank rate may slightly decline in the future, especially when considering the 25-year timeframe for the analysis (the central bank interest rate was 7% in 2025) (South African Reserve Bank, Trading Economics 2025a); (iii) 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% as chosen for the analysis.

integrated BCR of 3.06, highlighting the societal returns on investment. As a reminder, the BCR determines the overall value for money of a project and illustrates the return for every unit (ZAR invested) by comparing the project's total benefits with the total costs. The payback period is 7 years from the beginning of the project. Importantly, inclusive approaches that target women and other underrepresented groups and communities can further increase the societal return on investment. Lastly, undiscounted values of the NbS scenario amount to a cumulative net benefit of ZAR 737.1 million and a BCR of 4.00.

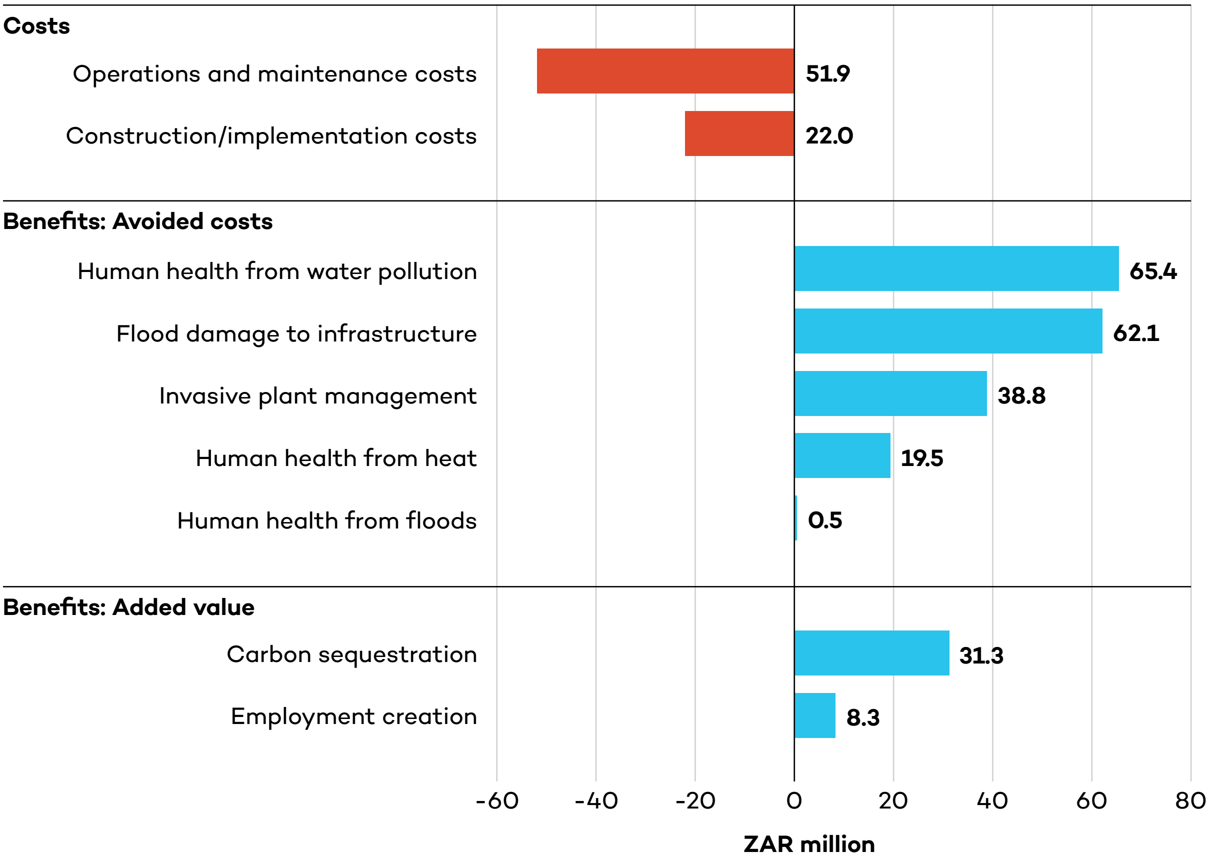
Figure 5. Economic, social, and environmental benefits of the NbS interventions in Johannesburg



Source: Authors.

The greatest impact of the NbS scenario relates to avoided health costs of water pollution, valued at a cumulative, discounted ZAR 65.4 million. This is an intangible avoided cost that affects people in the city. This is closely followed by the avoided costs of flood damage to infrastructure amounting to a cumulative ZAR 62.1 million. In addition, the avoided costs of alien invasive plant management amount to ZAR 38.8 million by 2050. The added benefits related to carbon sequestration are valued at ZAR 31.3 million. The above impacts are shown in Figure 6.

Figure 6. 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 shadow price for carbon, set at USD 40/ton, in line with World Bank's (2024) guidance. Under this higher carbon price assumption, cumulative carbon sequestration benefits are valued at ZAR 88 million. Overall, the scenario yields cumulative net benefits of ZAR 208.7 million and a BCR of 3.83, indicating stronger economic viability with a higher valuation of carbon.

The SAVi assessment also considers a sensitivity analysis scenario of lower flood damages based on Royal HaskoningDHV (2021). According to this scenario, the avoided costs of flood damages to infrastructure decrease from ZAR 65.1 million to ZAR 12.4 million. However, the NbS interventions are still economically viable with cumulative discounted net benefits of ZAR 102.1 million and a BCR of 2.38.

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 health costs from water pollution and avoided infrastructure damage costs. When carbon pricing is excluded, the payback period is 7 years, in line with the payback period when the values of all impacts are integrated into the analysis.

Table 4. Net benefits and BCRs of the NbS interventions in Johannesburg across scenarios

	NbS scenario	**High cost of carbon**	**Low damages to infrastructure**
Undiscounted net benefits	737.1	898.9	448.6
Discounted (at 10%) net benefits	152.0	208.7	102.1
BCR (discounted)	3.06	3.83	2.38

Source: Authors.

5.0 Conclusions

The SAVi assessment combines international expertise and local knowledge, using a systemic, model-based approach. This work builds on the collaborative efforts of the World Resources Institute and a wide range of local partners in Johannesburg that reviewed and validated the sources used in this assessment to ensure a comprehensive and collective perspective.

The NbS interventions in Johannesburg are a multifaceted solution with strong potential to advance climate adaptation efforts across the city and surrounding areas. The results of the SAVi assessment represent not only the implementation costs but also demonstrate that a range of economic, social, and environmental added benefits and avoided costs can be generated over time. SUNCASA's extensive riparian restoration and urban tree planting efforts have the potential to reduce risks related to floods, water pollution, extreme heat, and invasive alien species while creating jobs and providing multiple economic, social, and environmental benefits for the city's wider population.

Integrated valuations using the SAVi methodology provide a fuller picture of the long-term effects of infrastructure projects by integrating these values into the traditional calculations of BCRs. BCRs determine the overall value for money of a project. In this case, they illustrate the return for every unit (ZAR invested) by comparing the SUNCASA project's total benefits with the total costs. The analysis demonstrates that SUNCASA's NbS interventions in Johannesburg will lead to a discounted (at 10%) BCR of 3.06, highlighting the societal returns on investment. In addition, the NbS interventions will lead to estimated discounted net benefits of ZAR 152.0 million for the population of Johannesburg and its surroundings, cumulatively, from 2025 to 2050. Importantly, inclusive approaches that target women and other underrepresented groups can further increase the societal return or investment.

The greatest impacts over the timeline (2025–2050) that was considered in the analysis are the avoided costs of harms to human health from water pollution, (ZAR 65.4 million), the avoided costs of flood damages to infrastructure (ZAR 62.1 million), the avoided alien invasive plane management costs (ZAR 38.8 million), and the avoided costs of human health from heat (ZAR 19.5 million).

The SAVi assessment also demonstrates that advancing NbS investments, such as the activities in Johannesburg, delivers strong economic, social, and environmental outcomes that outweigh the upfront implementation and 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 Johannesburg:

- **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 investment- worthy while 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 A. Key Data Sources

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

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

	Indicator	Value	Data source
Construction/implementation costs			
	Area and number of trees for NbS interventions	Riparian zone: 469 ha for tree planting, urban greening: 16,000 public open space trees and 30,000 household trees	Internal SUNCASA project documents reviewed by Johannesburg Inner City Partnership (JICP).
	Cost of strategic rehabilitation and litternet trap installation	ZAR 6,161,469 for strategic rehabilitation, ZAR 5,500 for litternet trap installation	Internal SUNCASA project documents reviewed by JICP.
	Planting cost per tree	ZAR 360 per tree for riparian zone, and public open space trees, ZAR 180 per tree for household trees	Assumption based on feedback from participants during the August 2025 workshop in Johannesburg.
	Trees per hectare	100	Assumption based on the Johannesburg urban landscape and tree density. Reviewed by JICP.
	Time of construction/ implementation in years	5 years	Assumption
Operation and maintenance (O&M) costs			
	Area and number of trees for NbS interventions	Riparian zone: 469 ha for tree planting, 2.38 ha for debris management (per month), urban greening: 16,000 public open space trees	Internal SUNCASA project documents reviewed by JICP.
	Average cost of debris management per ha	ZAR 28,668	JICP (2024)
	Planting cost per tree	ZAR 133 per tree for riparian zone and public open space trees	JICP (2024)

	Indicator	Value	Data source
	Trees per hectare	100	Assumption based on Johannesburg urban landscape and tree density. Reviewed by JICP.
	Time of O&M costs in years	23 years (starting after 3 years of implementation until 2050)	Assumption based on feedback from participants during the August 2025 workshop in Johannesburg.
Avoided flood damage to infrastructure (starting after 5 years of initial NbS implementation)			
	Number of houses/ buildings damaged (2016 flood)	650 houses	City of Johannesburg (2022b)
	Cost to infrastructure loss (water, roads, stormwater and culverts, energy), (2016 flood)	ZAR 75,000,000	City of Johannesburg (2022b)
	Total number of houses/ buildings at risk	135	City of Johannesburg (2022b)
	Road damage when flood occurs	11,704 m	Johannesburg spatial analysis
	Average replacement cost per km of road	ZAR 18,000,000	Assumption based on feedback from participants during the August 2025 workshop in Johannesburg
	Direct flood damages	ZAR 44,500,000 for Alexandra (10-to-100-year return flood events), ZAR 3,600,000 for Kaalfontein (5-to-100-year return flood events), ZAR 19,000,000 for Diepsloot (10-to-100-year return flood events)	Royal HaskoningDHV (2021)
	Future frequency of floods	Every 2 years	Assumption
	Percentage increase in water retention (as a result of the NbS interventions)	20%	Assumption
	Time for NbS to mature	8 years	Assumption

	Indicator	Value	Data source
Avoided human health costs from floods (starting after 5 years of initial NbS implementation)			
	Number of people impacted per flood	339 persons	City of Johannesburg (2022a)
	Average cost of health care treatment in South Africa	USD 584/person	Macrotrends (2025)
	Future frequency of flood	Every 2 years	Assumption
	Percentage of people impacted needing health care	50%	Assumption
	Percentage increase in water retention (as a result of the NbS interventions)	20%	Assumption
	Time for NbS to mature	8 years	Assumption
Avoided human health costs from water pollution (starting after 5 years of initial NbS implementation)			
	Nitrogen uptake per ha	126 kg/ha/year	Kim & Issac (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 of origin	50%	Assumption
	Percentage of water pollution budget avoided (as a result of the NbS interventions)	40%	Assumption
	Time for NbS to mature	8 years	Assumption

	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	USD 200/tree	Akbari (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
Avoided cost of alien invasive plant management (starting after 5 years of initial NbS implementation)			
	Total cost of alien invasive plant removal	ZAR 6,161,439 for half of the total hectares (234.5 ha)	Internal SUNCASA project documents reviewed by JICP.
	Percentage of alien invasive plant management budget avoided (as a result of the NbS interventions)	50%	Assumption
	Time for NbS to mature	8 years	Assumption
Employment creation (construction/implementation employment in the first 5 years, O&M employment after 5 years and until 2050)			
	Total number of jobs	200 full-time jobs, 56 seasonal jobs, 800 transient jobs	Internal SUNCASA project documents
	Hourly salary	ZAR 27.58/hour	Internal SUNCASA project documents
	Working days per week	4 working days/week	Internal SUNCASA project documents
	Working hours per day	8 hours/day	Assumption
	Working weeks per month	4 weeks/month	Assumption
	Working months per year	12 working months/year	Assumption
	Working hours per day	6 hours/day	Assumption

	Indicator	Value	Data source
	Percentage of discretionary spending	20%	Assumption
	Time of construction/ implementation employment and O&M employment	5 years and 23 years	Assumptions based on feedback from participants during the August 2025 workshop in Johannesburg.
	Percentage of employment creation for construction to O&M	10%	Assumption
Carbon sequestration (starting after 5 years of initial NbS implementation)			
	Trees planted in 200,000	200,000 trees	Van Staden (2018)
	Carbon sequestration of the Greening Soweto project (for 25 years)	729,271 tons of CO_2	Van Staden (2018)
	Price of carbon in South Africa	EUR 13.78 per ton of CO_2	Organisation for Economic Co-operation and Development (2023)
	Social cost of carbon	USD 40 per ton of CO_2	World Bank (2024)
	Time for NbS to mature	8 years	Assumption

Source: Authors.

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