NATURE-BASED INFRASTRUCTURE
GLOBAL RESOURCE CENTRE

Sustainable Asset Valuation of the Recovery of the Bogotá River, Colombia

Hybrid infrastructure to reduce flood risk and improve water quality in the Bogotá River

NBI REPORT

Supported by

Led by

IISD
International Institute for Sustainable Development

April 2026

Published by the International Institute for Sustainable Development

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

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

IISD
nbi.iisd.org

UNIDO
unido.org

GEF
thegef.org

MAVA
mava-foundation.org

Sustainable Asset Valuation of the Recovery of the Bogotá River, Colombia: Hybrid infrastructure to reduce flood risk and improve water quality in the Bogotá River

April 2026

Written by Andrea M. Bassi and Nathalia Niño

Photo: CAR

NATURE-BASED INFRASTRUCTURE
GLOBAL RESOURCE CENTRE

Supported by

Led by

Acknowledgements

We would like to thank the World Bank team for their collaboration and support throughout the development of this assessment. In particular, we acknowledge Daniela Villalba for coordinating interactions with stakeholders and facilitating access to information, Gonzalo Gutierrez for his contributions to data-related inputs and methodological review, and Klaas de Groot for his guidance in refining the scope of the analysis. We also acknowledge the Global Water Security and Sanitation Partnership for providing the means needed for the World Bank's support.

This work has been prepared with assistance from the World Bank with external contributions. Findings, interpretations, and conclusions expressed in this work do not necessarily reflect the views of the World Bank, its board of executive directors, or the governments they represent. The World Bank does not guarantee the accuracy of the data included in this work.

We also thank the valuable engagement and technical insights provided by the Regional Autonomous Corporation of Cundinamarca (in Spanish, Corporación Autónoma Regional de Cundinamarca), which were instrumental in shaping the analysis.

Liesbeth Casier reviewed the analysis and this report and provided valuable comments.

Author Contributions

The authors are listed in alphabetical order. Andrea M. Bassi reviewed the model, results, and report, and contributed to the interpretation of the results. Nathalia Niño coordinated communications with the World Bank, developed an Excel model based on systems thinking and integrated cost-benefit analysis, contributed to defining the scope of the analysis, and led the drafting of the report.

Executive Summary

Context

The Bogotá River basin has faced environmental and social challenges linked to urban growth, declining water quality, and recurring flood risks. Limited wastewater treatment capacity, the degradation of wetlands and riparian areas, and the occupation of floodplains have reduced the river's ability to support ecological functions and manage water flows. These pressures have been heightened by climate variability and episodes of heavy rainfall, as seen during the 2010–2011 La Niña event. Together, these factors point to the need for coordinated and sustainable approaches to water management and flood resilience at the basin scale.

This Sustainable Asset Valuation (SAVi) assessment examines the long-term economic, environmental, and social implications of the Bogotá River Environmental Recuperation and Flood Control Project, implemented with a loan from the World Bank. Carried out by the International Institute for Sustainable Development in collaboration with the World Bank, the assessment evaluates the performance of the interventions implemented in the middle basin. It also explores how hybrid infrastructure—combining conventional grey works and nature-based infrastructure (NBI)—adds value to the project. Beyond assessing the project impacts, the analysis seeks to inform future planning and emphasize the importance of basin-wide perspectives for effective river restoration.

The project consists of several complementary interventions aiming to improve water quality, strengthen hydraulic capacity, and restore ecological functions. These include the following:

- The expansion and optimization of the Salitre Wastewater Treatment Plant (WWTP).
- Hydraulic adaptation measures, such as dredging, channel expansion, and dike relocation.
- Ecological restoration actions, including rehabilitating wetland, riparian re-vegetation, and creating multifunctional areas that help buffer flood events and provide public space.

Together, these measures contribute to reducing pollutant loads, improving flow regulation, and enhancing environmental conditions for communities located throughout the basin.

Methodology

The SAVi assessment applies a multi-method approach that combines systems thinking and quantitative economic analysis. A causal loop diagram developed with the World Bank and the Regional Autonomous Corporation of Cundinamarca (Corporación Autónoma Regional de Cundinamarca, in Spanish) was used to identify key social, environmental, and economic indicators. These insights informed the definition of scenarios and the design of an Excel-based integrated cost-benefit analysis (CBA) for the period 2010–2060, applying a 9% discount rate.

The study compares a business as usual (BAU) scenario with a hybrid infrastructure scenario that reflects full implementation of the project. Within the hybrid scenario, two spatial variants are modelled: one that includes the upper and the middle basin, and another that restricts the analysis to the middle basin only.

The CBA quantifies investment costs, operation and maintenance (O&M) costs, added benefits from ecosystem services, property value, and carbon storage, as well as avoided costs related to flood damage. Several additional benefits identified in the systems thinking process—including health improvements, avoided agricultural losses, biodiversity gains, and recreational uses—remain unquantified due to data gaps, which makes the results conservative.

Results and Conclusions

The integrated CBA shows that the project's economic performance varies according to the geographic scope considered. When the analysis includes the upper basin and the middle basin, the total discounted costs amount to USD 1,299 million, while the combined added benefits and avoided costs reach USD 1,647 million. Under this broader scenario, the project achieves an internal rate of return (IRR) of 11.80% and a benefit-to-cost ratio (BCR) of 1.27. When the scope is limited to the middle basin, the benefits remain below the total costs, resulting in an IRR of 4.25% and a BCR of 0.72. The key factor explaining this difference is the higher level of avoided flood damage that is observed when the upstream impacts are included, which underscores the importance of evaluating river projects at the basin level.

Table ES1 summarizes the discounted CBA results for the two hybrid scenarios, expressed in USD million for 2010–2060 at a 9% discount rate.

Table ES1. Integrated CBA results in USD million (cumulative discounted between 2010 and 2060 at 9% discount rate)

CBA, cumulative undiscounted values from 2010 to 2060	**Hybrid infrastructure scenario**	
	Upper and middle basins	**Middle basin only**
Total costs	**1,299**	**1,299**
Capital cost	930	930
O&M costs	369	369
Total added benefits	**819**	**819**
Value of ecosystem services	554	554
Carbon storage	4	4
Property value	261	261
Total avoided costs	**828**	**110**
Flood damage	828	110

CBA, cumulative undiscounted values from 2010 to 2060	**Hybrid infrastructure scenario**	
	Upper and middle basins	**Middle basin only**
Net benefits	**349**	**(369)**
BCR	1.27	0.72
IRR	11.80%	4.25%

Source: Authors.

Hybrid interventions show stronger economic performance when assessed from a wider territorial perspective, as this captures upstream and downstream hydrological linkages as well as a more complete set of benefits. Improvements in ecosystem services represent the largest share of added benefits, reflecting the value that households place on cleaner waterways, greener environments, and improved environmental quality. It was not possible to quantify the following indicators identified during the systems thinking process: avoided agricultural losses, health improvements related to water quality, biodiversity gains, and recreational benefits. Therefore, the results presented here are likely to represent a conservative estimate of the project's full value.

The assessment also offers insights for climate resilience: the combination of grey works and NBI helps to strengthen the system's capacity to manage future hydrological changes by restoring natural floodplains, supporting infiltration, and reducing pollutant loads. These functions become increasingly relevant as climate scenarios project shifts in rainfall patterns and potential increases in extreme events.

The benefits of the project reach various groups. Communities in the middle basin experience improved environmental conditions, reduced exposure to flood risk, and gains in property value. Upstream communities benefit from reduced flood damage, linked to improved hydraulic performance downstream. The broader population of Bogotá benefits from enhanced wastewater treatment, better ecosystem services, and strengthened resilience to climate-related impacts. Ecological restoration also supports broader environmental improvements, such as carbon sequestration and healthier riparian habitats.

Overall, the SAVi assessment indicates that hybrid infrastructure can provide meaningful economic, environmental, and social benefits when evaluated across the full basin. The findings highlight the importance of integrating nature-based measures into the management of the Bogotá River and point to the value of coordinated planning to support long-term environmental recovery and resilience in the Bogotá River basin.

Table of Contents

List of Figures

List of Tables

Abbreviations and Acronyms

BAU	business as usual
BCR	benefit-to-cost ratio
CapEx	capital expenditure
CAR	Corporación Autónoma Regional de Cundinamarca
CBA	cost-benefit analysis
CO_2	carbon dioxide
COP	Colombian peso
CPI	Consumer Price Index, Bogotá
dmnl	dimensionless
IRR	internal rate of return
NBI	nature-based infrastructure
O&M	operation and maintenance
SAVi	Sustainable Asset Valuation
USD	United States dollar
WWTP	Wastewater Treatment Plant

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).
Internal rate of return (IRR)	An indicator of the profitability prospects of a potential investment. The IRR is the discount rate that makes the net present value of all cash flows from a particular project equal to zero. Cash flow net of financing gives us the equity IRR.
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).
Nature-based infrastructure (NBI)	A subset of nature-based solutions with a focus on nature-provided infrastructure services. The NBI Global Resource Centre defines NBI as follows: "natural ecosystems or functional landscapes that can be conserved, rehabilitated, and maintained to enhance capacities and reduce the need for grey infrastructure, as well as hybrid infrastructure that combines engineered and Nature based Solutions (NbS)" (Bechauf et al., 2022).
Net benefits	The cumulative number of monetary benefits accrued across all sectors and actors over the lifetime of investments compared to the baseline, reported by the intervention scenario.
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 that these future paths may have on our system (e.g., a country or a business).
Simulation model	Models are simplifications of reality that help to reduce complexity and describe, at their core, how a system works. Simulation models are quantitative by nature and can be built using one or several methodologies (UNEP, 2014).

1.0 Introduction

The Bogotá River basin spans approximately 6,000 km^2 across the department of Cundinamarca and the city of Bogotá. The main river channel flows through 46 municipalities, including the capital city. The river plays a central role in the region, serving as a source of drinking water in its upper basin and supporting a wide range of economic activities, such as agriculture, producing livestock, and generating electricity. Despite its importance, the basin faces persistent challenges related to water pollution, environmental degradation, and flood risk, with implications that extend across its upper, middle, and lower reaches.

Over several decades, rapid urbanization, industrial growth, and insufficient wastewater treatment infrastructure have contributed to a marked deterioration in the river's water quality. By 2010, Bogotá, then home to approximately 7.3 million people, was discharging nearly all of its waste water into the Bogotá River through the river's three main tributaries: the Salitre, Fucha, and Tunjuelo rivers (World Bank, 2023). As a result, untreated urban effluents became the dominant source of organic and chemical pollution in the middle basin, affecting downstream ecological conditions and human uses of the river (World Bank, 2023).

The middle basin of the Bogotá River is also characterized by the presence of extensive wetland systems, which historically provided habitat for biodiversity, recreational opportunities, and natural regulation of water quality and flows. However, these wetlands have experienced severe decline, shrinking from an estimated 50,000 hectares in 1950 to approximately 1,000 hectares by 2009 (World Bank, 2010). This loss has significantly weakened the river's natural capacity to buffer floods, filter pollutants, and sustain ecological functions.

Flood risk in the river basin arises from a combination of hydrological and geomorphological factors, including high rainfall, elevated groundwater tables, and constrained runoff conditions. At the time of the project's initial appraisal (see Figure 1), flood protection standards along the river were limited, with most sections designed for a 25-year return period and some offering protection of only 10 years—well below the 100-year standard adopted for the city of Bogotá (World Bank, 2010). These conditions left large areas and populations exposed to recurrent flooding.

Climate variability has further intensified these pressures. Extreme rainfall events, such as those experienced during the 2010–2011 La Niña episode, demonstrated how existing vulnerabilities can be amplified when precipitation exceeds historical norms. During this event, approximately 785,573 homes were affected nationwide, including 957 households in Bogotá alone (Econometría S.A., 2023). Such episodes illustrate how, under more intense rainfall conditions, flood risk is increased by constrained hydraulic capacity and the loss of natural buffers.

These environmental and physical pressures have translated into tangible social and economic impacts. Extremely high pollution levels in the Bogotá River have affected the health of populations relying on its water, increased costs for water-dependent economic activities, influenced land use patterns and property value along the river corridor, and limited opportunities for recreation and other beneficial uses. Rapid urban expansion has also contributed to channelization, the destruction of wetlands, and the occupation of flood-prone areas by low-income communities. Public concern over these trends has been longstanding: a 2008 survey indicated that nearly half of Bogotá's population identified pollution of the Bogotá River as one of the city's main environmental problems (World Bank, 2023).

The Bogotá River Environmental Recuperation and Flood Control Project was developed with financing and technical support from the World Bank to improve water quality, enhance hydraulic performance, and restore ecological areas along the middle basin of the river. Its design combines conventional grey infrastructure with nature-based infrastructure (NBI), seeking to reduce pollutant loads, increase flow capacity, and reintroduce ecological functions that help mitigate flood risk and improve the quality of the environment.

A central component of the project is the expansion and upgrading of the Salitre Wastewater Treatment Plant (WWTP). As one of the main wastewater facilities serving Bogotá, its improved treatment capacity reduces the amount of pollution entering the river. Complementing this, the project's hydraulic adaptation measures—including channel expansion, dredging, and the relocation of dikes—are allowing the river to manage larger flows and reduce flood risks. Alongside these grey works, restoring wetlands and creating multifunctional ecological areas is helping to recover natural filtration processes, provide habitats for local biodiversity, and create accessible public spaces.

Figure 1. Map of the Río Bogotá project at the initial appraisal phase

Source: World Bank, 2010.

The integration of NBI within these interventions provides a valuable complement to traditional grey infrastructure. Restored wetlands, meanders, and multifunctional areas improve water quality, enhance flood buffering, and contribute to broader environmental and social benefits that would be more limited in a grey-only approach. These nature-based components also support long-term climate resilience by restoring functions that help regulate water flow and improve riparian ecosystems.

The project has now been fully implemented, with completion in 2023, although continued efforts toward ecosystem restoration are being carried out in the area by the local authorities. The results of the project provide an opportunity to evaluate the combined performance of grey and green infrastructure, assess the co-benefits, and inform future planning in upstream areas of the Bogotá River basin. This is the purpose of the Sustainable Asset Valuation (SAVi) assessment carried out by the International Institute for Sustainable Development in collaboration with the World Bank, which aims to quantify the social, environmental, and economic impacts of the interventions and evaluate their economic performance under different scenarios. The assessment also helps to identify effective balances between nature-based and grey infrastructure, which can support decision making for future investment strategies and river restoration planning.

The development and implementation of the Bogotá River recovery efforts have involved a broad range of institutions. The project's formal structuring began in June 2007 with the signing of Convenio 171: an agreement between the Regional Autonomous Corporation of Cundinamarca (Corporación Autónoma Regional de Cundinamarca [CAR]), the District Secretariat of Environment (Secretaría Distrital de Ambiente), and the Bogotá Water and Sewerage Company (Empresa de Acueducto y Alcantarillado de Bogotá [EAAB]), which established a framework for joint planning and coordinated investment in the middle basin. During the project's implementation, the World Bank provided financing and technical assistance, working closely with CAR (as the executing entity) alongside Empresa de Acueducto y Alcantarillado de Bogotá, municipal governments, community groups, and environmental organizations.

By valuing the environmental and social benefits associated with hybrid infrastructure, the SAVi assessment aims to strengthen the evidence base for nature-based solutions in river basin management. Beyond the Bogotá River, the results offer insights for other regions in Colombia that are seeking to integrate ecological restoration with flood protection and improved water quality through coordinated, basin-scale approaches.

2.0 Methodology and Assumptions

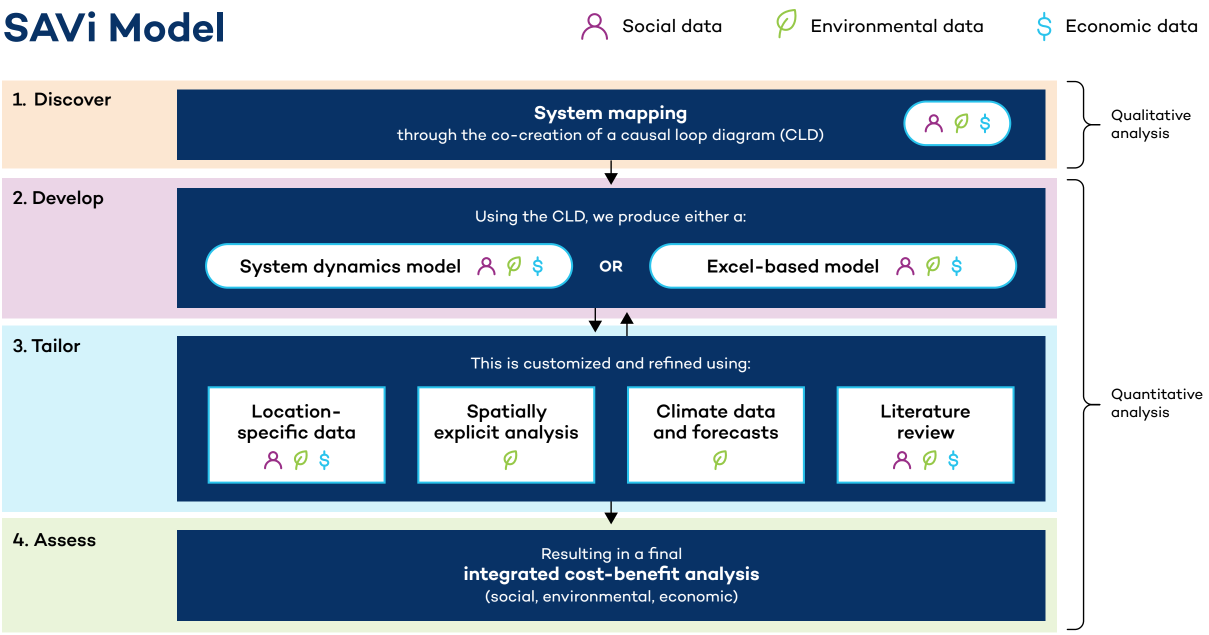
The analysis was conducted using the SAVi methodology, which applies a multi-method approach. The process began with the creation of a system map that would allow us to understand the interrelations among social, environmental, and economic variables of the system; this map was validated by the World Bank Group team and the CAR team. This was followed by a literature review of the observed impacts and use as a basis of the economic analysis developed by Econometría S.A. in 2023. These insights informed the development of scenarios and the quantification of impacts, which was done in an Excel-based model using an approach grounded in local data. Further details on the SAVi methodology are provided in the following sections.

2.1 Sustainable Asset Valuation

SAVi is an assessment methodology that provides policy-makers and investors with a comprehensive life-cycle analysis of infrastructure projects (see Figure 2). It considers impacts that are often overlooked. Combining systems thinking and project finance modelling, SAVi captures the full costs of infrastructure projects, including the environmental, social, economic, and governance risks. By calculating the monetary value of externalities, it assesses an investment's economic value in addition to its financial performance.

The SAVi methodology combines qualitative and quantitative tools to develop an integrated cost-benefit analysis (CBA) of NBI assessments. This holistic approach enables investment decisions to align with regional development priorities, climate change adaptation, and the UN Sustainable Development Goals, ensuring a financially sound and sustainable outcome.

Figure 2. The SAVi methodology



Source: International Institute for Sustainable Development.

2.2 The Importance of Systems Thinking

The SAVi approach relies on systems thinking, a holistic methodology that considers the intricate connections among various factors within a system. It forms the first step of the SAVi methodology (see Figure 2). 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 and across social, economic, and environmental dynamics. Understanding these interconnections provides a more nuanced perspective, which makes it possible to identify the fundamental drivers and dynamics influencing the livelihoods of local communities.

Systems thinking also aids in identifying policy entry points: specific areas or aspects within the system where interventions or policies can yield the greatest impacts. A systemic understanding allows for a strategic approach to policy formulation by revealing leverage points and areas where interventions can be most effective. Policy-makers who are equipped with knowledge about these entry points can prioritize and target their efforts, thereby maximizing the efficiency and effectiveness of policy interventions.

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

2.3 Causal Loop Diagram

A causal loop diagram is a systems thinking tool used to visualize how different factors within a complex system interact through cause-and-effect relationships. By mapping these connections, a causal loop diagram makes it possible to identify feedback loops—both reinforcing and balancing—that shape system behaviour over time.

For the Bogotá River Environmental Recuperation and Flood Control Project, the causal loop diagram (see Figure 3) was co-created with the World Bank and CAR to capture systemic interactions among social, environmental, and economic indicators that influence the river and its surrounding communities. Its purpose is to (a) reveal the underlying dynamics that have contributed to declining water quality and rising flood risk, and (b) support a more integrated understanding of how NBI interventions can shift these dynamics toward more sustainable outcomes. The diagram illustrates how urban development around the river has intensified the identified pressures through strengthening “reinforcing loops.” It also depicts the environmental, social, and economic consequences in “balancing loops.”

Two reinforcing loops, marked with an “R,” represent self-reinforcing processes that amplify change; once triggered, these processes grow stronger over time. Loop R1 depicts how the city’s expansion around the river has unfolded. As the urban population increases, urban expansion intensifies, which in turn attracts additional residents and fuels further growth, reinforcing the cycle. Loop R2 captures the rise of economic activities along the Bogotá River. Urban expansion stimulates agricultural activity near the riverbanks, which contributes to regional economic growth. This growing economic activity then encourages additional urban expansion, reinforcing the loop. Historically, this dynamic has also driven the occupation of the riverbanks for agriculture, shaping land use patterns across the region.

Balancing loops, identified with the letter "B," work toward restoring equilibrium in the system by counteracting pressures. In the case of Bogotá, the side effects of urban development act as balancing forces that eventually limit urban expansion near to the river. One of the most significant side effects is the increased flood risk. In loop B1, growing urban expansion leads to greater occupation of flood-prone areas, raising the flood risk for nearby communities. Higher flood risk results in increased reconstruction costs, which then reduce incentives for further urban development in these areas. Flood risk can also be amplified by factors external to the system (shown in red in Figure 3), such as climate change and informal settlements along the riverbanks. This heightened risk affects property value, as shown in loop B2, where greater exposure to flooding reduces the value of land and properties near the river. Flooding also affects the agricultural sector, as illustrated in loop B3: more frequent or more severe flood events worsen agricultural losses and drive up recovery costs, ultimately lowering agricultural productivity in areas close to the river.

Another important side effect of urban expansion is the degradation of wetlands. This degradation is directly linked to development pressures on the river system. Loop B5 shows that the loss of wetlands reduces their natural capacity to absorb excess water, thereby increasing the flood risk and reinforcing the dynamics previously described.

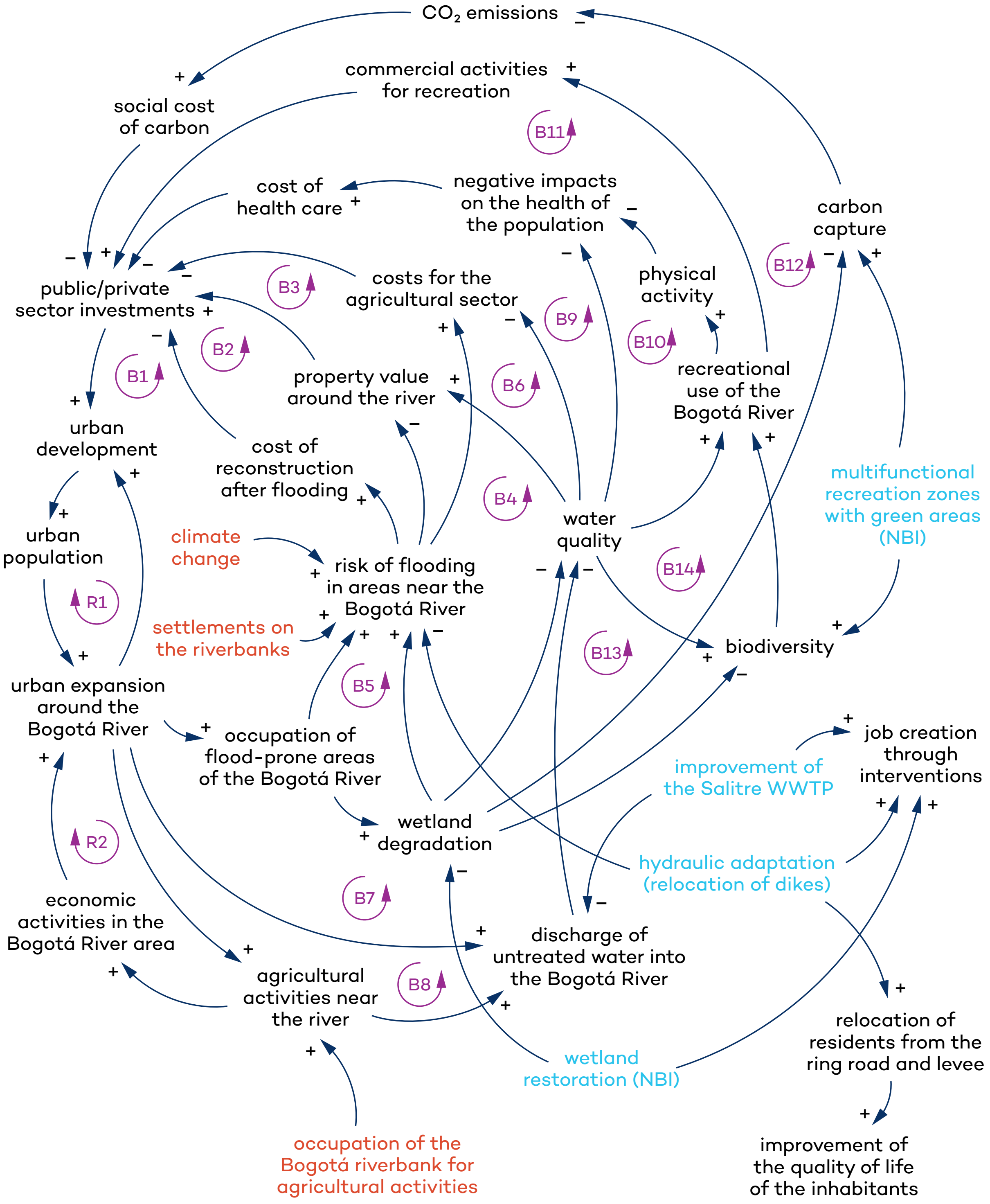
Wetland degradation also affects water quality, biodiversity, and carbon storage—key environmental variables in the system. Regarding water quality, the causal loop diagram illustrates several effects. Declining water quality reduces the value of property near the river, as shown in loop B4. It also increases production costs for agriculture, as represented by loop B6, because farmers who irrigate with contaminated water face additional challenges and expenses associated with reduced land productivity and increased pest infestations.

Reduced water quality also has direct consequences for health. As illustrated in loop B9, poor water quality increases the incidence of water-related illnesses, leading to higher healthcare costs for affected populations. It also diminishes recreational opportunities along the Bogotá River. Loop B10 shows that as water quality deteriorates, activities including enjoying riverfront spaces, exercising near the river, or participating in water-based recreation become less feasible, which reduces active mobility and physical activity, affecting public health. In addition, as depicted in loop B11, declining water quality negatively impacts commercial and recreational activities, such as fishing and swimming, which depend on a healthy aquatic ecosystem.

Further environmental impacts linked to wetland degradation appear in loop B12. As wetlands and green spaces shrink, the landscape's ability to store carbon declines, increasing carbon dioxide (CO_2) emissions and the social cost of carbon. The loss of biodiversity is another consequence. With fewer species and habitats, the attractiveness of the river for tourism and nature-based activities declines, as shown in loop B13. Biodiversity is also directly affected by water quality, as depicted in loop B14.

Another major driver of declining water quality is the discharge of untreated waste water into the Bogotá River—a practice that is closely tied to ongoing urban expansion. As noted in loop B7, untreated discharges negatively impact water quality, further degrading the ecosystem and exacerbating the environmental impacts of socio-economic expansion. The agricultural sector also contributes to wastewater discharge, as represented in loop B8, which puts more pressure on water quality.

Figure 3. Causal loop diagram of the main dynamics affecting water quality and flood control (Bogotá River middle basin)



Source: Authors.

The Bogotá River Environmental Recuperation and Flood Control Project introduces multiple interventions aimed at reducing flood risk, improving water quality, and increasing the ecological and recreational value of the riverbed, as represented by the orange variables in the diagram. The project combines grey and green infrastructure measures.

On the grey infrastructure side, a key intervention is the upgrade of the Salitre WWTP. This upgrade is expected to substantially reduce the discharge of untreated waste water from the 30% of Bogotá's population that the plant serves. This reduction in pollutant loads will improve water quality and generate positive effects across multiple variables, including property value, agricultural costs, public health, and recreational use of the river. The second grey intervention is the hydraulic adaptation, which includes widening the river section and relocating dikes. These measures will directly reduce flood risk, especially in historically vulnerable areas.

Among the green infrastructure solutions, wetland restoration is central and closely linked to the hydraulic adaptation efforts. Restoring wetlands will help to reverse degradation, strengthen ecological functions, and contribute to improving water quality while reducing flood risk. Creating multifunctional areas, designed to temporarily work as river meanders during flood events, will provide additional ecosystem benefits. These include increased carbon sequestration, enhanced biodiversity, and further reductions in flood risk. Finally, the interventions will generate broader co-benefits, such as employment during their implementation and improvements in quality of life for households who are relocated from high-risk areas and were previously living in inadequate conditions.

2.4 Scenarios Modelled

The analysis in this report compares two different scenarios: a no-action scenario, which serves as the baseline, and a hybrid infrastructure scenario for the Bogotá River Environmental Recuperation and Flood Control Project. The results for each scenario are presented in relative terms, indicating the net change generated by the hybrid infrastructure scenario for the analysis of the investment case (i.e., capturing only what is additional due to the project).

Business as Usual (BAU) Scenario: The BAU scenario represents a "no-action" approach, in which existing trends continue without any new interventions. Under this scenario, ecosystems and water quality continue to deteriorate and flood risk remains high, because there are no targeted interventions to tackle the problems.

Hybrid Infrastructure Scenario: This scenario reflects the full implementation of the Bogotá River Environmental Recuperation and Flood Control Project. It integrates grey wastewater treatment and hydraulic works with nature-based restoration measures. The key components include:

- **Optimization and expansion of the Salitre WWTP:** Increasing treatment capacity and implementing a secondary treatment to improve pollutant removal; and reducing organic loads and contaminants entering the river (see Figure 4).
- **Hydraulic adequacy and ecological restoration:** Implementing a package of interventions designed to reduce flood risk and restore riverine ecosystems. These

include (a) expanding channels, dredging, and relocating dikes to increase flow capacity and improve flood protection; (b) establishing multifunctional ecological zones (see Figure 5) designed to provide natural filtration, flood buffering, and recreational opportunities; (c) making environmental improvements, such as widening and protecting the riparian corridor (see Figure 6) to restore river meanders and wetlands, and landscape design and riparian habitat restoration (including planting native species); and (d) resettling and compensating 188 households living in high-risk flood areas.

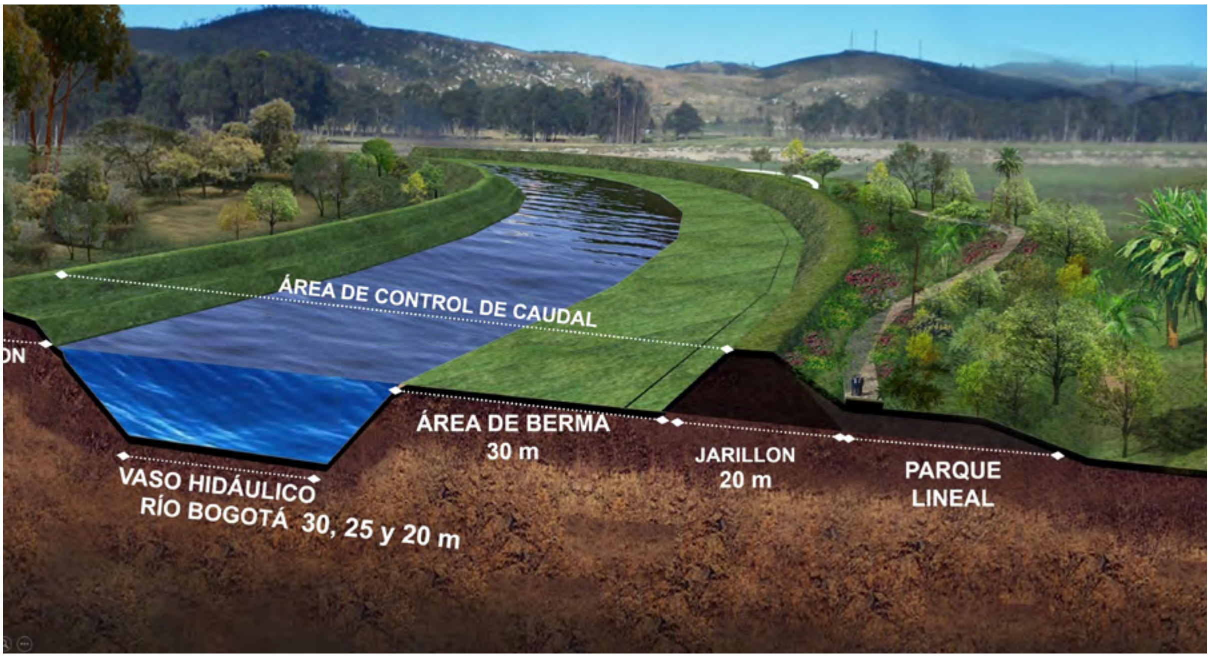
Figure 4. Progress at the Salitre WWTP in 2021

Source: Regional Autonomous Corporation of Cundinamarca, as cited in World Bank Group, 2021.

Figure 5. A multifunctional area in the dry season, October 2022 (left) and in the rainy season, November 2022 (right)

Source: Regional Autonomous Corporation of Cundinamarca, as cited in World Bank Group, 2021.

Figure 6. Bogotá River Environmental Recuperation and Flood Control: Project concept



Source: Corporación Autónoma Regional de Cundinamarca, as cited in World Bank Group, 2021.

Within the hybrid infrastructure scenario, two sub-scenarios were modelled to illustrate the effects of the interventions in: (a) the upper basin and the middle basin; and (b) the middle basin only.

This distinction is important: although the project's interventions are physically located in the middle basin, they increase the general river's water transport capacity. By increasing conveyance and lowering flood peaks, the hydraulic improvements in the middle basin were expected to reduce future flood-related losses for these upstream communities as well as for those in the middle reach, where the interventions are located.

Evidence from the 2010–2011 La Niña "Winter Wave" flood event illustrates the scale of this upstream exposure: while only 957 households were affected in Bogotá, approximately 2,458 households were affected if all the upper basin is considered (Econometría S.A., 2023).

To capture and compare this extended benefit, the economic analysis considers two variants of the hybrid infrastructure scenario:

- **Hybrid Infrastructure Scenario – Upper and Middle Basin:** This option includes both the upper and middle basins in the analysis. This broader perspective captures the indirect but meaningful benefits for upstream communities.
- **Hybrid Infrastructure Scenario – Middle Basin Only:** This option restricts the analysis to impacts occurring solely within the middle basin. It captures avoided flood damage and added benefits for the directly intervened area only, excluding the upstream impacts.

These two sub-scenarios of the hybrid infrastructure investment allow the analysis to compare the value of a narrower, intervention-only scope against a broader system perspective. Expanding the assessment area highlights the importance of upstream–downstream interactions and reveals additional benefits, especially avoided flood damage, that would otherwise remain unaccounted for.

2.5 Integrated CBA

A spreadsheet model was developed to estimate the required investment, avoided costs, and aggregate benefits resulting from the project implementation. The indicators measured are listed and described in Table 1. Details of the approach used for calculating each indicator are provided in Appendix A.

Some of the indicators identified in the causal loop diagram could not be quantified due to data gaps, and these indicators are not included in Table 1. This does not imply that these indicators are less relevant; in fact, their exclusion means that the SAVi analysis underestimates the avoided costs and added benefits of the NBI investment. Among these unquantified indicators are avoided agricultural losses linked to improved water quality; recreational benefits (such as fishing and the use of riverside walking paths); health impacts associated with water quality; biodiversity gains; and improvements in the quality of life of households relocated from high-risk areas.

Table 1. Indicators included in the CBA

Indicator	Description
Investment and costs The financial resources required to implement and maintain the project.	
Capital cost	The initial expenditure required for project implementation, including investments in infrastructure, equipment, and technology.

Indicator	Description
Operation and maintenance (O&M) costs	The ongoing expenses needed to sustain project activities, such as labour, equipment maintenance, and system upgrades.
Added benefits The positive economic, environmental, and social impacts generated by the project or intervention. The added benefits reflect how the project creates value beyond its direct costs.	
Value of ecosystem services	The perceived benefits that communities along the river—and the broader Bogotá population—derive from the project. This indicator captures how people value improvements in water quality, green areas, recreation, biodiversity, and the overall quality of the environment.
Carbon storage	The monetary valuation of the CO_2 sequestered by new trees planted in various areas of the middle and upper basins of the Bogotá River, contributing to climate change mitigation efforts.
Value of properties	How property prices are influenced by improvements to public space and reduced flood risk in the surrounding areas. This indicator measures the economic appreciation of land and housing attributable to the project's investments.
Avoided costs Expenses that are reduced or eliminated by the project by preventing or reducing negative outcomes	
Flood damage	The costs associated with flood events along the Bogotá River. This indicator measures the economic losses incurred during flooding, including damage to infrastructure, property, and community assets.

Source: Authors.

2.6 Limitations and Interpretation of the Results

The methodology and data used in this assessment inevitably involve assumptions and simplifications, as is common in long-term integrated economic analyses of complex river systems. These elements provide important context for interpreting the results, and they highlight areas where future analysis and monitoring could further strengthen the evidence base. Overall, the results should be understood as solid, transparent, and indicative estimates of the project's economic performance, rather than as precise forecasts.

For some indicators—in particular, property value and households' willingness to pay—the analysis relies on secondary data and valuation parameters derived from comparable studies or broader contexts. This approach is consistent with established practice in applied CBA, and it allows the assessment to approximate impacts where local primary data are not available. Although this introduces uncertainty around specific point estimates, the assumptions used are conservative and clearly documented, ensuring that the resulting values remain plausible and relevant to policy-making.

Various relevant benefits identified through the systems thinking process could not be monetized due to current data limitations or uncertainty about their magnitude over time. These include the following: health improvements associated with better water quality; avoided agricultural losses; biodiversity gains; and benefits related to recreation and quality of life. Their exclusion does not imply that these effects are negligible; on the contrary, it suggests that the quantified results are likely to understate the full range of social and environmental benefits generated by the project. As monitoring systems mature and additional empirical evidence becomes available, these dimensions could be progressively incorporated into future valuations.

The modelling framework simplifies complex hydrological and socio-economic processes. Relationships—such as flood depth-damage functions, changes in exposure and vulnerability, and behavioural responses to improved environmental conditions—are represented through scenario-based assumptions, rather than by fully dynamic or spatially explicit models. This approach supports clarity and transparency at the basin scale, while acknowledging that local variations and site-specific dynamics are not captured in detail.

Finally, the results are conditioned by the chosen temporal and spatial scope, including the analysis period, the discount rate, the basin boundaries, and the information available at the time of the study. Long-term changes in land use, population patterns, infrastructure development, and climate conditions could influence future costs and benefits in ways that differ from those modelled here. Nonetheless, the scenarios presented provide a consistent and credible basis for comparing alternative perspectives and for illustrating how basin-wide approaches can reveal additional value that would otherwise remain unaccounted for.

Taken together, these considerations underscore that the SAVi assessment offers a solid and conservative representation of project value, while also identifying clear pathways for refinement and expansion as new data and insights emerge.

3.0 Results

This section presents the results of the integrated CBA for the Bogotá River Environmental Recuperation and Flood Control Project. The assessment evaluates the economic, social, and environmental performance of the hybrid interventions implemented along the river. The analysis spans a 50-year period (2010–2060) and applies a 9%[1] discount rate. It complements the indicators and assumptions used in previous studies by the consulting firm Econometría S.A. with new indicators and updated economic valuations.

Table 2 presents the discounted results for the two hybrid infrastructure scenarios: the first of which considers the benefits across the upper and middle basins, and the second limiting the assessment to the middle basin only. The undiscounted results are presented in Appendix B. The results are expressed in terms of total investment and O&M costs, added benefits, avoided costs, and net benefits (all relative to the BAU scenario), as well as in terms of the benefit-to-cost ratio (BCR) and the internal rate of return (IRR).

Overall, the findings indicate that the economic performance of the project depends on the geographical scope of the analysis. **When both the upper basin and the middle basin are included, the project yields benefits that exceed the total discounted costs, with a BCR of 1.27 and an IRR of 11.80%, which is above the discount rate.** When the assessment is limited to the middle basin, the BCR decreases to 0.72 and the IRR declines to 4.25%, remaining below the discount rate. This difference is explained by the higher avoided flood damage that is captured when the upper basin is included.

Table 2. Integrated CBA results in USD million, cumulative discounted between 2010 and 2060 (9% discount rate)

CBA, cumulative undiscounted values from 2010 to 2060	**Hybrid infrastructure scenario**	
	Upper and middle basins	**Middle basin only**
Total costs	**1,299**	**1,299**
Capital cost	930	930
O&M costs	369	369
Total added benefits	**819**	**819**
Value of ecosystem services	554	554
Carbon storage	4	4
Property value	261	261
Total avoided costs	**828**	**110**

---

[1] A social discount rate of 9% was applied. This was consistent with the recommendation of Colombia's Department of National Planning for economic evaluations of public investment projects, as suggested by the consultancy of Econometría S.A. (2023).

CBA, cumulative undiscounted values from 2010 to 2060	**Hybrid infrastructure scenario**	
	Upper and middle basins	**Middle basin only**
Flood damage	828	110
Net benefits	**349**	**(369)**
BCR	1.27	0.72
IRR	11.80%	4.25%

Source: Authors.

In relation to the costs, the total discounted costs are the same for both scenarios, amounting to USD 1,299 million, of which USD 930 million corresponds to capital expenditure and USD 369 million corresponds to O&M.

The added benefits also remain constant at USD 819 million across both scenarios. These benefits include USD 554 million associated with ecosystem services, USD 4 million from carbon storage, and USD 261 million resulting from increased property value driven by reduced flood risk and improved recreational areas along the river. The value of ecosystem services makes up the largest share of added benefits, illustrating that improved water quality, restored wetlands, and healthier riparian environments are the principal sources of long-term societal gains.

Regarding the avoided costs, avoided flood damage is the only element that differentiates the two scenarios. When the upper and middle basins are both included in the analysis, the total avoided costs reach USD 828 million. This reflects the fact that hydrological improvements in the middle basin, such as increased flow capacity and restored natural flood buffers, generate substantial benefits upstream too. Conversely, when the analysis is restricted solely to the middle basin, the avoided flood damage reaches only USD 110 million.

These variations in avoided flood damage drive the differences in overall economic performance. When the upper and middle basins are considered together, the project generates positive net benefits of USD 349 million, a BCR of 1.27, and an IRR of 11.80%, which is above the 9% discount rate and therefore economically viable. In contrast, when the analysis is limited to the middle basin, the scenario produces negative net benefits of −USD 369 million, a BCR of 0.72, and an IRR of 4.25%.

Overall, the findings demonstrate that the scenario that includes the upper and middle basins generates positive economic returns, with the benefits exceeding the total discounted costs. The scenario that is restricted to the middle basin does not reach economic viability because it excludes the upstream benefits related to avoided flood damage, which constitute a substantial share of the total value generated by the project.

On the other hand, as indicated above, the quantitative analysis performed could be more comprehensive. The systems thinking process used to develop the causal loop diagram revealed a more extensive list of indicators that are relevant for the CBA. These include the following: avoided costs in the agricultural sector due to improved water quality; the long-term health gains associated with cleaner waterways and biodiversity improvements; and the future potential of recreational and cultural uses along the river. Currently, due to data gaps, none of these indicators are fully quantified. As these gaps are addressed through monitoring and evaluation or new research, a more comprehensive set of indicators could be incorporated in the CBA. The inclusion of these indicators will improve economic viability, which could make the middle basin analysis also economically viable.

It can be concluded that the results presented here reflect a conservative estimate, grounded in the indicators that it was possible to quantify using the information presently available. It is also recognized that a broader set of systemic impacts from the Bogotá River project can be captured as more information becomes available. As monitoring systems are strengthened and more environmental and social outcomes become measurable, the economic value of the project is likely to increase further.

4.0 Conclusions and Recommendations

The SAVi assessment of the Bogotá River Environmental Recuperation and Flood Control Project shows that **the economic performance of the hybrid interventions depends strongly on the geographic scope used in the evaluation.** When the upper and middle basins are considered together, the project generates benefits that exceed the total discounted costs, with a BCR of 1.27 and an IRR above the 9% discount rate. This result is mainly driven by the substantial reduction in flood damage that occurs beyond the area with direct interventions, highlighting the upstream–downstream hydrological linkages that shape the basin's behaviour. By contrast, when the analysis is limited to the middle basin alone, the results fall below economic viability. This underscores that a narrow spatial assessment fails to capture important benefits generated by the interventions, illustrating the importance of adopting a basin-wide perspective when assessing river infrastructure.

The analysis also indicates that improved ecosystem services account for the largest share of added benefits, reflecting the high value that society places on cleaner waterways, restored wetlands, and overall environmental quality. Additional gains from increased property value and carbon storage strengthen the long-term value of the investment. Taken together, these results reinforce that nature-based and hybrid solutions are inherently multi-benefit and multi-stakeholder approaches: their value is not limited to reducing flood risk but also includes improvements in ecosystem services, land and property value, and climate regulation. Accurately reflecting this value proposition in economic assessments therefore requires systematically accounting for risk reduction as well as a broader set of social, environmental, and economic co-benefits.

At the same time, these results represent a conservative estimate. Several indicators identified in the systems thinking process—including avoided agricultural losses, health improvements linked to better water quality, biodiversity gains, and benefits from recreational uses—remain unquantified due to data limitations. Their exclusion suggests that the project's total benefits are likely to be greater than those captured in the CBA.

Overall, the findings show that hybrid infrastructure—combining grey and green measures—can be a cost-effective way to deliver joint economic, environmental, and social benefits in a dense, urbanized river basin, such as Bogotá. The project contributes to improved water quality, reduced flood risk, and enhanced resilience, while offering opportunities for broader ecological restoration and community well-being as monitoring and data availability continue to expand. Although multi-objective, integrated projects like this one often require higher upfront investments and more complex implementation arrangements than traditional single-purpose grey works, the CBA indicates that these additional efforts are outweighed by the larger and more diverse benefits they generate over time, especially when assessed from a basin-wide perspective. Hybrid solutions make use of the predictable performance and rapid effectiveness of grey infrastructure, while nature-based components add adaptability, aesthetic improvements, and multiple co-benefits, together mitigating the weaknesses that each approach would present if applied in isolation.

Based on these insights, several practical recommendations emerge:

- Future assessments and planning processes should adopt a basin-scale approach, since many hydrological and economic benefits extend beyond the immediate intervention area.
- It is important to embed integrated, systemic CBAs into the preliminary and the final phases of infrastructure planning. Such assessments help quantify the full range of project outcomes; test the economic viability of alternative options; and provide a transparent basis for engaging stakeholders around multi-dimensional impacts across social, environmental, and economic indicators.
- Efforts should be made to strengthen monitoring and data collection, especially for health, agriculture, biodiversity, and recreational indicators, so that future CBAs to incorporate a more complete set of project outcomes.
- Continued integration of NBI into river and urban water management strategies can help to sustain and amplify the long-term benefits observed in this analysis, providing a replicable model for other river basins and urban regions seeking to combine risk reduction with broader environmental and social gains.

References

Bank of the Republic. (2025a). *Tasa de cambio del peso colombiano.* https://suameca.banrep.gov.co/estadisticas-economicas/informacionSerie/1/tasa_cambio_peso_colombiano_trm_dolar_usd

Bank of the Republic. (2025b). *Índice de Precios al Consumidor.* https://suameca.banrep.gov.co/estadisticas-economicas/informacionSerie/100002/indice_de_precios_al_consumidor_ipc

Bechauf, R., Cutler, E., Bassi, A. M., Casier, L., Kapetanakis, M., Pallaske, G., & Simmons, B. (2022). *The value of incorporating nature in urban infrastructure planning* (IISD report). International Institute for Sustainable Development. https://nbi.iisd.org/report/nature-in-urban-infrastructure-planning/

Bechauf, R., Guzzetti, M., & Niño, N. (2024). *Sustainable asset valuation of Parques del Río Norte in Medellín, Colombia.* International Institute for Sustainable Development. https://www.iisd.org/publications/report/savi-nbi-centre-medellin

Centre for Green Mobility. (2015). *Bicycle share system for Dwarka sub-city: Detailed project report.* https://shaktifoundation.in/wp-content/uploads/2017/06/Public-Bicycle-Sharing-DPR-Dwarka.pdf

Econometría S.A. (2023). *Evaluación económica de la adecuación hidráulica y recuperación ambiental de la cuenca media del Rio Bogotá.* Bogotá: Banco Mundial.

Guzzetti, M., Niño, N., & Bechauf, R. (2024). *Climate-resilient infrastructure for urban flood risk management in San Salvador de Jujuy, Argentina.* International Institute for Sustainable Development. https://nbi.iisd.org/report/restoring-the-alvarado-canal-in-san-salvador-de-jujuy-argentina/

United Nations Environment Programme. (2014). *Using indicators for green economy policymaking.* https://wedocs.unep.org/bitstream/handle/20.500.11822/9532/-Using%20indicators%20for%20Green%20Economy%20policymaking-2014IndicatorsWorkingPaper.pdf

World Bank. (2010). *Colombia – Río Bogotá Environmental Recuperation and Flood Control Project.* https://documents.worldbank.org/en/publication/documents-reports/documentdetail/346111468026366389

World Bank Group. (2021). *Restoring a Long-Lost Relationship with Rio Bogotá.* https://www.worldbank.org/en/results/2021/04/09/restoring-a-long-lost-relationship-with-rio-bogota

World Bank. (2023). *Implementation completion and results report: CO Río Bogotá environmental recuperation and flood control project.*

World Bank. (2024). *Guidance note on shadow price of carbon in economic analysis.* http://documents.worldbank.org/curated/en/099553203142424068

Appendix A. Data Inputs, Methods, and Assumptions

This appendix outlines the methodology used to calculate the indicators for the integrated cost-benefit analysis (CBA), translating biophysical impacts—such as hectares restored, jobs created, and people impacted—into economic terms. By expressing these impacts in monetary values, the analysis facilitates a direct comparison between costs and benefits across diverse indicators, including capital costs, operation and maintenance (O&M) costs, the value of ecosystem services, carbon storage benefits, increases in property value, and avoided flood damage. The section details the sources of data, assumptions, and formulas used to estimate each indicator, ensuring transparency and consistency in the valuation process.

Investment and Costs

Indicator: Capital cost

The capital cost represents the total investment and costs required to implement the project's components: the expansion and optimization of the Salitre Wastewater Treatment Plant (WWTP); the hydraulic adaptation works (grey infrastructure); environmental improvements (green infrastructure); administration and management; technical assistance; and land acquisition. To estimate the capital cost, first all market prices were converted into economic prices by using the accounting price ratios recommended for this project (Econometría S.A., 2023). Two different ratios were applied depending on the type of cost: ratio 1, equal to 0.8244, was used for components such as infrastructure and materials; ratio 2, equal to 0.7083, was applied to administration and technical assistance items (Table A1).

Once converted into economic terms, each cost component was distributed across its corresponding implementation period, according to the project phases and implementation milestones (Table A1). For example, the Salitre WWTP expansion was implemented between 2016 and 2023, so the cumulative cost was assigned in equal portions of 12.5% every year, during the 8 years of implementation to reach 100% of usage. The hydraulic adaptation works were implemented between 2013 and 2019 at an annual implementation pace of 14.29%, while the environmental improvement activities occurred between 2022 and 2024 with an annual pace of implementation between 20% and 40%, depending on the year. Administration and management costs were distributed from 2010 to 2022, land acquisition was assigned entirely to 2020, and technical assistance was distributed between 2013 and 2019.

Table A1. Capital costs: summary of calculations by indicator

Component	Market cost (USD)	Accounting ratio	CapEx (USD)	Implementation period	Annual pace
Salitre WWTP	433,100,000	0.8244	357,047,640	2016–2023	12.5%
Hydraulic adaptation	149,400,000	0.8244	123,165,360	2013–2019	14.29%
Environmental improvement	18,000,000	0.8244	14,839,200	2022–2024	20%–40%
Administration and management	9,800,000	0.7083	6,941,340	2010–2022	7.69%
Land purchase	26,300,000	1.0	26,300,000	2020	100%
Technical assistance	4,000,000	0.7083	2,833,200	2013–2019	14.29%

Source: Authors.

Administration and technical assistance costs benefited both the Salitre WWTP and the hydraulic adaptation works. To allocate these shared costs consistently, the analysis applied the ratio derived from the relative size of each component's capital expenditure (CapEx). This resulted in 68.48% of these costs being attributed to the WWTP and 31.52% to hydraulic adaptation. Table A1 synthesizes the CapEx estimation and the associated parameters.

Indicator: O&M costs

The operational expenditures include the annual O&M costs associated with each major component of the project. These expenditures were estimated by applying a fixed share of the respective CapEx, as recommended by Econometría. For the Salitre WWTP, the annual O&M costs are equal to 7.1% of the CapEx (Econometría S.A., 2023), while the hydraulic adaptation works, which include both grey and green infrastructure, require 0.82% of their CapEx in annual O&M costs (Econometría S.A., 2023). The annual operational expenditure for each component was therefore computed by multiplying the economic cost by the corresponding O&M coefficient. Table A2 presents the resulting calculations.

Table A2. O&M costs: summary of calculations by indicator

Component	Economic CapEx (USD)	O&M costs share (%/year)	Annual O&M costs (USD/year)
Salitre WWTP	357,047,640	7.1%	25,350,382
Hydraulic adaptation and environmental improvement	138,004,560	0.82%	1,131,637

Source: Authors.

Added Benefits

Indicator: Value of ecosystem services

The value of ecosystem services was derived from households' willingness to pay for improvements associated with the project. The willingness to pay was originally estimated by Econometría S.A. in 2010 and was updated in 2021 (Econometría S.A., 2023). Since the project does not include the implementation of recreational parks (as initially envisioned), and because the avoided impacts of flooding are already included under a separate indicator, the corresponding components of the study by Econometría S.A. on the value of ecosystem services were excluded to prevent double counting. Therefore, the analysis retains only the ecosystem protection and wastewater treatment components, which together constitute 58.8% of the total willingness to pay (Econometría S.A., 2023).

The value of ecosystem services for the Bogotá River project provided by Econometría S.A. (2023) were expressed in 2009 prices. These values were updated to current prices by applying an inflation adjustment based on the Bogotá Consumer Price Index (CPI) for each year (National Administrative Department of Statistics, as cited in Bank of the Republic, 2025b). The updated values were then converted into USD by applying the annual average exchange rate (Financial Superintendency of Colombia, as cited in Bank of the Republic, 2025a). Finally, the total value of ecosystem services in each year was obtained by multiplying the updated per-household willingness to pay by the number of households in Bogotá in that year (from 2010 onward). The numbers of households were derived by dividing the projections for the total population by the average household size, which was projected to decline gradually from 4.2 to around 2 people per household during the period. The main parameters used are summarized in Table A3.

Table A3. Value of ecosystem services: calculations by indicator

	2009 CPI dmnl	**Annual CPI (average)** dmnl	**Inflation factor (base year 2009)** dmnl	**Exchange rate** COP to USD	**Bogotá population**	**People per home in Bogotá**	**Number of homes in Bogotá**
2010	71.15	72.8	1.02	1,899	6,793,855	4.2	1,632,117
2011	71.15	75.2	1.06	1,847	6,889,826	4.0	1,719,420
2012	71.15	77.6	1.09	1,798	6,985,354	3.9	1,810,927
2013	71.15	79.2	1.11	1,869	7,080,401	3.7	1,906,818
2014	71.15	81.5	1.15	2,000	7,174,949	3.6	2,007,285
2015	71.15	85.6	1.20	2,743	7,268,997	3.4	2,112,533
2016	71.15	92.0	1.29	3,051	7,362,381	3.3	2,222,727
2017	71.15	96.0	1.35	2,951	7,455,318	3.2	2,338,152
2018	71.15	99.1	1.39	2,956	7,547,867	3.1	2,459,063
2019	71.15	102.6	1.44	3,281	7,640,112	3.0	2,585,734
2020	71.15	105.1	1.48	3,693	7,732,161	2.9	2,640,915
2021	71.15	108.8	1.53	3,743	7,823,334	2.9	2,696,589
2022	71.15	119.9	1.69	4,255	7,873,316	2.9	2,738,734
2023	71.15	134.0	1.88	4,325	7,907,281	2.8	2,775,803
2024	71.15	142.8	2.01	4,071	7,929,539	2.8	2,809,174
2025	71.15	149.8	2.11	4,074	7,937,898	2.8	2,837,956
2060	71.15	149.8	2.10	4,074	6,946,612	2.0	3,419,787

Note: dmnl = dimensionless[2]; COP = Colombian peso.

Source: Authors.

---

[2] Dimensionless (dmnl) refers to variables or parameters that have no physical units, as they represent ratios, indices, or normalized values derived from quantities with the same units.

Indicator: Carbon storage

Carbon storage benefits arise from planting 140,000 trees along the river corridor. Of these, 90,000 were established as part of the hydraulic adaptation works and 50,000 were planted in multifunctional areas. The trees were planted in two phases: between 2013 and 2016 (for the hydraulic component) and between 2013 and 2015 (in multifunctional areas) in the first phase; and between 2024 and 2025 in the second phase. The analysis assumed that trees require 10 years to reach maturity, after which each tree sequesters 0.02 tonnes of carbon dioxide (tCO_2) a year. Annual sequestration before this point was scaled according to age.

To determine its monetary value, the stored carbon was multiplied by the World Bank's recommended shadow price of carbon (World Bank, 2024). The analysis used an average price that began at USD 56 per tonne in 2017, was set to USD 60 per tonne in 2020, and increases to USD 146 per tonne by 2060, growing at a constant annual rate of 2.25%.

Indicator: Property value

The project is expected to generate an increase in property value due to the following improvements to ecosystem services: an increase in green spaces around the river; reduced flood risk; and improved water quality.

The additional property value was estimated by applying a percentage increase to the baseline value of the affected housing stock. The baseline was derived using the average property value for middle-income households in Bogotá, calculated as COP 4.8 million per square metre multiplied by an average dwelling size of 70 m^2, resulting in COP 336 million per house (Table A4). This value was then multiplied by the total number of homes exposed to different levels of flood risk within the project area.

The percentage increase in property value was differentiated according to the degree of flood risk reduction. Four categories were considered: very high, high, medium, and low. Homes in very high-risk areas were assigned a 7% increase in value, those in high-risk areas 5%, those in medium-risk areas 3%, and those in low-risk areas 1%. These values fall within a conservative range of 1% to 7%, consistent with estimates reported in the literature for projects that enhance green areas and urban ecosystem services (Centre for Green Mobility, 2015), as well as previous SAVi assessments, which applied increases of 5% (Bechauf et al., 2024) and 15% (Guzzetti et al., 2024).

The final property value used for the CBA were obtained by summing up the increase for houses in each flood risk category and converting them to USD using the data series presented in the section on the "value of ecosystem services" indicator. Table A4 outlines the number of houses and the percentage increases used for houses in each flood risk level.

Table A4. Property value: summary of calculations by indicator

Indicator	Value	Unit
Homes in very high-risk flood areas	957	homes
Homes in high-risk flood areas	10,208	homes
Homes in medium-risk flood areas	88,255	homes
Homes in low-risk flood areas	25,239	homes
Average property value in Bogotá	336,000,000	COP/home
Total value of homes in very high-risk flood areas	321,552,000,000	COP
Total value of homes in high-risk flood areas	3,429,888,000,000	COP
Total value of homes in medium-risk flood areas	29,653,680,000,000	COP
Total value of homes in low-risk flood areas	8,480,304,000,000	COP
Percentage increase in property value in very high-risk flood areas	0.07	%
Percentage increase in property value in high-risk flood areas	0.05	%
Percentage increase in property value in medium-risk flood areas	0.03	%
Percentage increase in property value in low-risk flood areas	0.01	%
Total additional property value	**1,168,416,480,000**	**COP**

Source: Authors.

Avoided Costs

Indicator: Flood Damage

Avoided flood damage is a measure of how far improved flood protection reduces expected annual flood-related losses. Figures for the baseline damage was obtained from Econometría (2023), which provided average annual damage costs for the four categories of flood risk in 2009 prices. These values were updated to current prices using a CPI-based inflation factor, calculated as the ratio between the CPI of the relevant year and that of 2009 (National Administrative Department of Statistics, as cited in Bank of the Republic, 2025b). After adjusting for inflation, damage costs were converted into USD using the corresponding annual exchange rate (Financial Superintendency of Colombia, as cited in Bank of the Republic, 2025a).

The total avoided damage costs were calculated by multiplying the updated annual damage estimates by the number of homes classified under each risk category. When the analysis includes the upper basin, the total avoided damage costs for the middle basin were multiplied by 6.54, a factor derived from Econometría's (2023) study to account for the additional flood impacts of the upper basin. Table A5 summarizes the steps involved.

Table A5. Flood damage: summary of calculations by indicator

Parameter	Value	Unit
Homes in very high-risk flood areas	957	homes
Homes in high-risk flood areas	10,208	homes
Homes in medium-risk flood areas	88,255	homes
Homes in low-risk flood areas	25,239	homes
Avoided flood damage costs in very high-risk homes	1,264,929	2009 COP/home/year
Avoided flood damage costs in high-risk homes	480,017	2009 COP/home/year
Avoided flood damage costs in medium-risk homes	66,807	2009 COP/home/year
Avoided flood damage costs in low-risk homes	26,195	2009 COP/home/year
Total annual avoided flood damage – middle basin	**12,667,737,979**	**2009 COP/home/year**
Relative increase in the avoided flood damage costs when including the upper basin	6.54	
Total annual avoided flood damage – upper basin	**82,819,824,799**	**2009 COP/home/year**

Source: Authors.

Appendix B. Undiscounted Results

The undiscounted results of the integrated cost-benefit analysis (CBA) for hybrid scenarios are presented in Table B1.

Table B1. Integrated CBA results in USD million, cumulative and undiscounted, between 2010 and 2060

CBA, cumulative undiscounted values from 2010 to 2060	Upper and middle basins	Middle basin only
Total costs	**1,541**	**1,541**
Capital cost	531	531
Operation and maintenance costs	1,010	1,010
Total added benefits	**2,013**	**2,013**
Value of ecosystem services	1,716	1,716
Carbon storage	11	11
Property value	287	287
Total avoided costs	**1,980**	**263**
Flood damage	1,980	263
Net benefits	**2,452**	**735**
Benefit-to-cost ratio	2.59	1.48
Internal rate of return	11.80%	4.25%

Source: Authors.

NATURE-BASED INFRASTRUCTURE
GLOBAL RESOURCE CENTRE