NATURAL INFRASTRUCTURE IN CAMPINAS' WATER SYSTEM, SÃO PAULO STATE

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INTERACT-Bio
Integrated action on biodiversity
Cities4Forests

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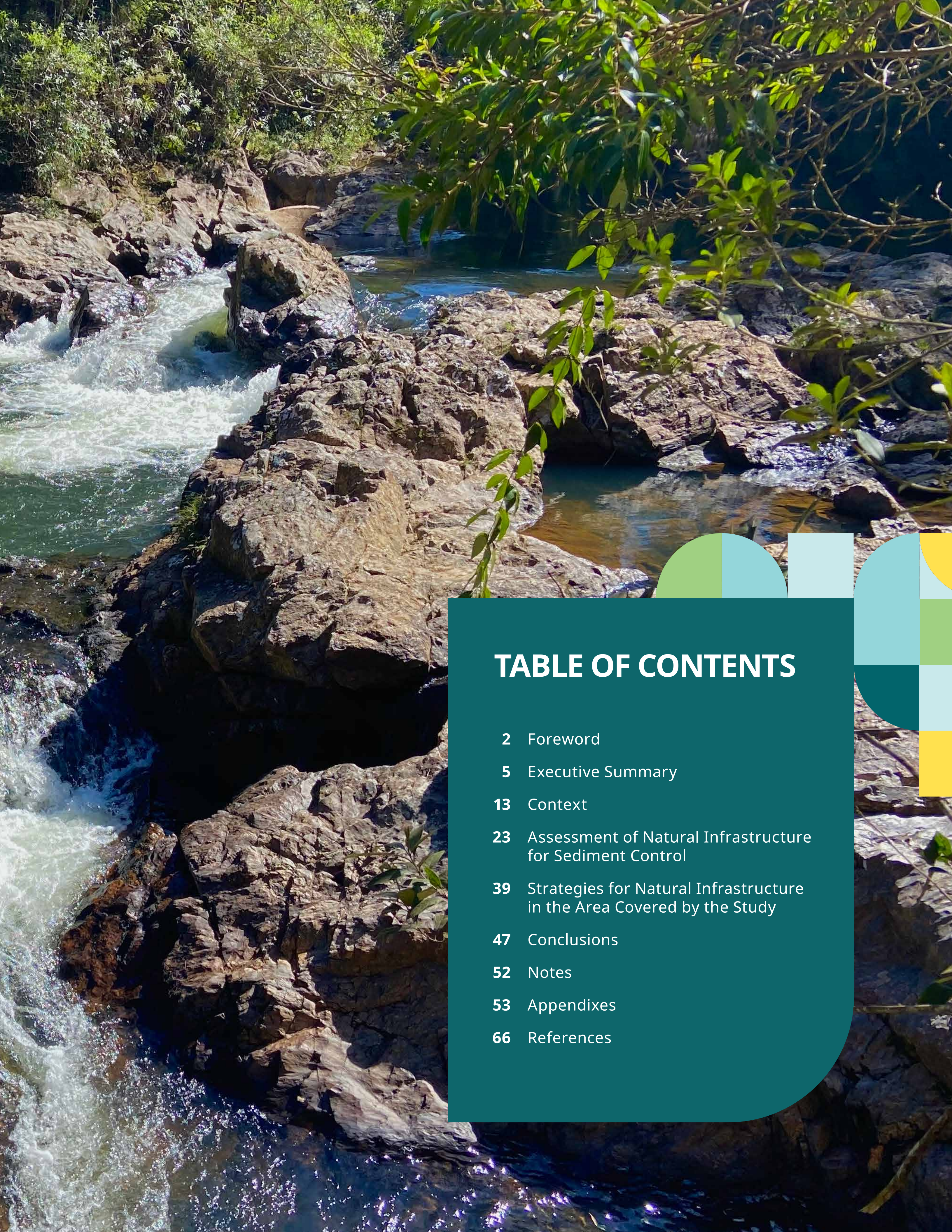
Suggested Citation
TRAMONTIN, Vitor et al. Natural Infrastructure in Campinas' Water System, São Paulo State. São Paulo, Brazil: WRI Brasil and ICLEI. 2022.

Cover photo
Rafael Berlandi/Shutterstock

July 2022



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FOREWORD

BY ICLEI SOUTH AMERICA

The year 2022 is the year in which the Post-2020 Biodiversity Framework will be discussed during the 15th Conference of the Parties (COP15) of the Convention on Biological Diversity (CBD). An ambitious agreement is expected to be signed, which reinforces the CBD's 2050 Vision that "by 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people".

In this sense, it is essential that subnational governments join forces to achieve these goals, given that the actions take place in their territory. The Campinas Metropolitan Region (RMC) was chosen as a model city for the INTERACT-Bio Project, which aims to integrate biodiversity and ecosystem services into urban planning, territorial management and urban infrastructure projects.

Since 2017, the RMC has been an ally in the preservation of biodiversity and launched, through the Reconecta RMC Program, the Local Biodiversity Strategy and Action Plan, whose goals include the implementation of ecological corridors, recovering and preserving springs and water bodies.

In this context, the present study on green infrastructure for water management provides an overview of the cost-benefit relationship and the potential of natural infrastructure in the urban environment. The study highlights the environmental and economic benefits brought to the water supply systems in the region through the preservation of ecosystems in priority strategic areas.

ICLEI's project development and implementation processes are based on five paths: low carbon, circular, resilient, equitable and people-centered and nature-based. The latter two paths are directly linked to the development of this report.

We underline the importance of providing ecosystem services to improve human and environmental health, consequently increasing the well-being of citizens. Therefore, the value associated with the recovery and preservation of green areas and water sources must be seen as much larger than the economic value directly arising from such actions.

Rodrigo Perpétuo
Executive Secretary of ICLEI South America

BY WRI BRASIL

We are in the United Nations Decade on Ecosystem Restoration, a time when there is great interest and national and international commitments for the conservation and recovery of natural vegetation. It is at the scale of municipalities and metropolitan regions, however, that such initiatives get off the ground. In Brazil, the Campinas Metropolitan Region stands out for the great opportunities and benefits associated with the perception of forests as a form of investment in urban infrastructure.

Natural forests and vegetation can play an important role in water security for urban populations. They serve as a filter that reduces the amount of sediments caused by soil erosion that reach water bodies and reservoirs. WRI Brasil, through its Forests, Land Use and Agriculture program, has already produced studies and models showing the advantages of forests for water supply in São Paulo, Rio de Janeiro and Espírito Santo capital cities. Now, it brings this methodology to Campinas and its surrounding region.

You will see in these pages that the investment in forest conservation, management and restoration – which we refer to as green infrastructure for water management, precisely to reinforce its economic importance – pays for itself in the long term. In other words, in addition to bringing obvious benefits associated with improved water quality and increased water volume, it is an investment that positively impacts the financial health of municipalities and sanitation and water supply companies. It also contributes to the improvement of productivity and quality of life in rural areas.

Also, in addition to its economic benefits, green infrastructure plays a crucial role for biodiversity. Priority areas restored for water management purposes can serve as a connection between forest fragments. In this sense, the study shows strong synergies with the Local Biodiversity Strategy and Action Plan of the Campinas Metropolitan Region, produced by ICLEI under the INTERACT-Bio initiative.

WRI Brasil presents the results of this study to foster the recovery of degraded areas in Campinas and region, bringing benefits for society, and a step forward for the country towards the development of a sustainable, inclusive, and forest-based economy.

Fabiola Zerbini
Director of Forests, Land Use and Agriculture Program, WRI Brasil

EXECUTIVE SUMMARY

This study offers water resource managers in the municipality of Campinas and region – Campinas Metropolitan Region (RMC) and municipalities in the Atibaia river basin upstream of the RMC – an overview of the cost-benefit relationship and the potential of natural infrastructure to control sediments thrown into the water bodies that supply the region. It also aims to evaluate investment opportunities in green infrastructure to improve water quality and water flow through the collection of primary data and information, derived from consultations with local key actors and the use of financial, biophysical and geospatial analysis instruments.

HIGHLIGHTS

- This study demonstrates, with data and analysis, the importance of natural infrastructure in the recovery of springs and improvement of water quality in the municipality of Campinas and the surrounding region.
- The implementation of natural infrastructure actions in the Atibaia and Capivari river basins, responsible for supplying the population of Campinas and the surrounding region, has the potential to prevent soil erosion, reducing turbidity in water courses by up to 14%, and lowering water treatment costs for sanitation companies.
- Natural infrastructure decreases the costs of water treatment for sanitation companies (Browder et al. 2019; Feltran-Barbieri et al. 2018; Feltran-Barbieri et al 2021). The conservation of native vegetation remnants could save BRL 6.6 million per year, and the restoration of degraded lands could add BRL 335 thousand to BRL 1,5 millions per year, regarding the amount of hectares to be restored*.
- Among the priority areas for native vegetation restoration identified in this study, 130 hectares are common to the areas prioritized in the Local Biodiversity Strategy and Action Plan of the Campinas Metropolitan Region, within the scope of the Reconecta RMC program, which indicates that the implementation of natural infrastructure can be enhanced through articulation with existing programs and plans.
- Intersectoral involvement and coordination between current initiatives, such as the PCJ River Basins Plan (encompassing the watersheds of the Piracicaba, Capivari and Jundiaí rivers) and the Nascentes and ReflorestaSP programs (developed by the state of São Paulo's Secretariat for Infrastructure and the Environment), could accelerate the implementation of natural infrastructure in the region.

* All values in this report were estimated in Brazilian currency (R$), if converted into US at an average exchange rate would be of R$ 1 = $ 0,1957.

ABOUT THIS REPORT

The restoration of native vegetation in degraded areas stands out among natural infrastructure projects with the greatest potential for generating environmental services, mainly related to water resources. In 2021, the state of São Paulo made a new commitment to promote the restoration of 1.5 million hectares of native vegetation. Efforts to implement the scenarios presented in this study are in line with actions that aim to improve water quality, reduce climate vulnerability and increase water security in large metropolises.

Developed within the scope of the INTERACT-Bio project, this study presents a viable investment case to support the execution of the Action Plan for the Implementation of the Connectivity Area of the Campinas Metropolitan Region. It offers water resource managers in Campinas and region - Campinas Metropolitan Region (RMC) and municipalities in the Atibaia river basin upstream of the RMC - an overview of the cost-benefit relationship of natural infrastructure in the control of sediments and water quality, and also evaluates investment opportunities for the implementation of this infrastructure.

Through joint actions, such as the partnerships with ICLEI South America and WRI Brasil, the municipality of Campinas has been developing studies and public policies aimed at sustainable urban planning and the environmental recovery of its territory. The municipality has also made national and international commitments on the topics of biodiversity and climate resilience: in 2021, the city reached the climate leadership mark on the CDP Cities platform; in 2022, the city was recognized as the first Resilience Center in Brazil by the Global Coordinating Committee of the Making Cities Resilient Initiative (MCR2030) and the United Nations Office for Disaster Risk Reduction (UNDRR).

The methodology for assessment of investments in natural infrastructure adopted in this report (known as Green-Gray Assessment – GGA/WRI) can support the region in meeting climate and environmental goals. The method is composed of six steps that help to incorporate natural infrastructure – more specifically forest restoration – into sanitation investment decisions. The GGA/WRI was applied in order to estimate costs and benefits that would be added to the sanitation system, based on the analysis of scenarios that include forest restoration strategies in priority areas, compared to a baseline scenario in which only built infrastructure is used.

The study was based on data from the municipality of Campinas and region, located in the PCJ river basins. In the water supply of the city of Campinas, the Atibaia river serves 94% of the population while the Capivari river serves the southern portion of the city, supplying 6% of the total volume needed for the entire municipality. The other municipalities to the south are also supplied by the Capivari river.

Data from Campinas were extrapolated to the entire region, which allowed a broad analysis of the RMC and the municipalities of the Atibaia river basin upstream of the RMC. Cost curves obtained for Campinas were weighted by volume (94% treated in the Atibaia river and 6% in the Capivari river) and applied to the entire region mentioned, in this study referred to as Campinas and region, assuming that the costs in the other Water Treatment Plants (WTPs) are the same as those reported by Sociedade de Abastecimento de Água e Saneamento S/A (SANASA).

All results were based on average monthly data, from January 2015 to December 2019. These data were discriminated between SANASA's five WTPs, four of them on the Atibaia river and one on the Capivari-Mirim river. The information on the volume of treated water (cubic meter – m^3), turbidity in the catchment point (nephelometric unit – NTU), quantity of chemical products used to treat turbidity (tons) and type of chemical used allowed the establishment of treatment cost curves in function of volume and turbidity of treated water. Primary data were provided by SANASA.

Chapter 1 presents the context of the area covered by this study, describes water management in Campinas and region and the main challenges faced by it, in addition to the mapping results regarding the main actors and strategies active in the region and related to Natural Infrastructure. Chapter 2 assesses the benefits of natural infrastructure and the costs incurred in projects for Campinas and region, and outlines the scenarios developed and the biophysical results estimated for each one. Chapter 3 discusses strategic management and financing needs for the implementation of the proposed scenarios, assessing the main actors, stakeholders and decision-making spaces related to the execution of actions. Chapter 4 concludes the study, presenting opportunities for optimizing strategic efforts and recommendations based on the results of the analyses conducted. In the appendices, it is possible to find details on the methodology used for stakeholder consultation, definition of investment assumptions and portfolios, biophysical models, mappings and financial analyses.

BENEFITS OF INTEGRATING NATURAL INFRASTRUCTURE INTO WATER MANAGEMENT

The study estimated that the existing native vegetation in Campinas and region currently provides a sediment retention service that generates savings of around BRL 6.6 million per year in the treatment of water turbidity. The RMC, together with the municipalities of the Atibaia river basin upstream, currently has 78 thousand hectares of native vegetation that prevent the discharge of 34 thousand tons of sediment per year. The loss of this vegetation would imply an increase in average turbidity of almost 70%, jumping from the current 44 to 75 NTU. This increase would have a significant impact on water treatment operations, which would require additional consumption of chemicals and energy equivalent to BRL 6.6 million per year, enough to supply treated water to 600 thousand people.

The forest restoration scenario targeting 14 thousand hectares of highly degraded pastures in the region would enable the generation of an additional benefit of BRL 1.7 million per year. The maintenance of the existing 78 thousand hectares of native vegetation and the restoration of the 14 thousand hectares of highly degraded pastures could potentially result in a 9% decrease in sediments exported to water courses, which would reduce the average turbidity in the Atibaia river by 14% and 17% in the Capivari river. Operationally, sanitation companies could achieve savings of BRL 1.7 million per year in avoided costs, equivalent to one more quarter per year with lower average turbidity levels, which are currently recorded in the dry season, between May and October.

Even in the scenario of mandatory restoration of 800 hectares arising from the construction of two reservoirs in the region, the infrastructure would generate significant net benefits of BRL 335 thousand in net present value. The construction of the Pedreira and Duas Pontes reservoirs requires the restoration of 427 hectares of vegetation to be implanted as Permanent Preservation Areas (PPAs), obligatorily located around the dams in 100-meter strips. Another 373 hectares to compensate for the current vegetation that will be submerged could be implemented in areas with the highest level of degradation. In real cases such as this one, restoration is often seen as a cost of legal compliance, where benefits are rarely evidenced. This study shows that restoration should be seen as an investment, with the potential to reduce water turbidity from the current 44 to 42 NTU, and consequently generating potential savings of BRL 35 million in 50 years. During this period, a total of BRL 23 million would be spent on investments in planting and maintaining the restored areas. Applying a discount rate of 5% per year, the net present value of benefits would amount to BRL 335 thousand.

The economic performance of natural infrastructure varies by type and location of investments and depends on the intended benefits. Concentrating restoration on priority areas results in greater cost-effectiveness, but in many situations, restoration needs to follow other guidelines, as in the case of the mandatory restoration of PPAs around reservoirs addressed in the 800-hectare scenario (R800). It is worth noting that the performance of natural infrastructure is highly dependent on the type of ecosystem service provided (sediment retention, water flow, thermal comfort, pollination), the type of intervention (conservation or restoration), the scale (landscape or specific infrastructure) and motivation (priority areas, areas made available by rural landowners, legally required areas). Nevertheless, natural infrastructure is a great ally of strategies for the conservation and rehabilitation of water sources, enhancing benefits for the management of watersheds and their users.

Conventional infrastructure managers, such as water utility companies, can derive operational benefits from investing in natural infrastructure. The reduction of water treatment costs, stability in supply, reduced risk of flooding and, consequently, of wear and tear, depreciation or losses caused by damage to the infrastructure are measurable benefits resulting from the performance of natural infrastructure. Mandatory forest restoration in PPAs and forest restoration for compensation purposes, still considered as mere costs, need to be seen as viable investments that are an integral part of the business.

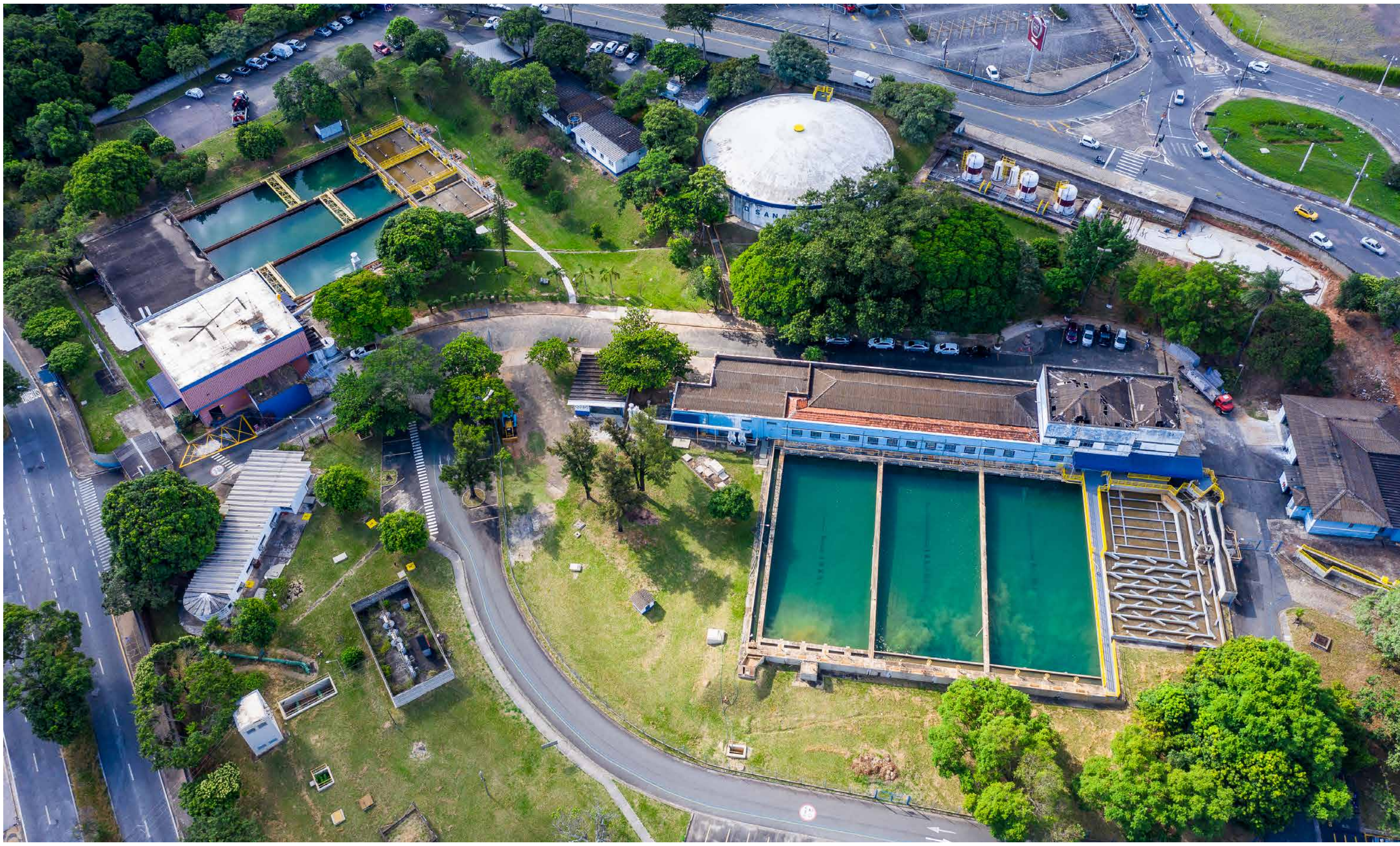


Table 1 SE | Financial performance of natural infrastructure with restoration of 800 ha (R800 scenario) for sediment and water turbidity management

NATURAL INFRASTRUCTURE BENEFITS (VALUES IN BRL THOUSAND)	
TOTAL	**34,640**
Avoided costs with chemical products	17,203
Avoided costs with filtering substances	6,559
Avoided wear and tear and depreciation	10,878
NATURAL INFRASTRUCTURE COSTS (VALUES IN BRL THOUSAND)	
TOTAL	**11,461**
Investment in planting	6,340
Operational costs with maintenance	840
Transaction costs	761
Land use opportunity costs	3,520
NET BENEFITS (VALUES IN BRL THOUSAND)	
TOTAL	**23,179**
FINANCIAL PERFORMANCE (DISCOUNT RATE = 5% P.Y.)	
Net present value (NVP – values in BRL thousand)	**335**
Internal rate of return (IRR)	**5,2%**
Payback	**45,5 years**

Source: Authors.

RECOMMENDATIONS

Campinas and region have the opportunity to meet their water needs by combining conventional and natural infrastructure strategies, including the other municipalities in the RMC and belonging to the Piracicaba, Capivari and Jundiaí river basins (PCJ River Basins). A crucial step towards achieving this goal is incorporating natural infrastructure considerations into water resources management planning processes and sharing them with local actors, such as rural landowners, who are the main actors in the process of implementing natural infrastructure, thus enabling all parties to achieve shared goals.

Natural infrastructure actions demand the involvement of different actors. The analyses conducted in this study demonstrate that the expansion of technical-scientific knowledge on the subject and the scaling of investments are essential for the implementation of forest restoration focused on improving water quality. **This study shows that initiatives committed to retaining sediments and improving water quality through natural infrastructure bring important and economically viable benefits.**

Intersectoral involvement and coordination between existing initiatives, such as the PCJ River Basins Plan and the Nascentes and ReflorestaSP programs (developed by the state of São Paulo's Secretariat for Infrastructure and the Environment)

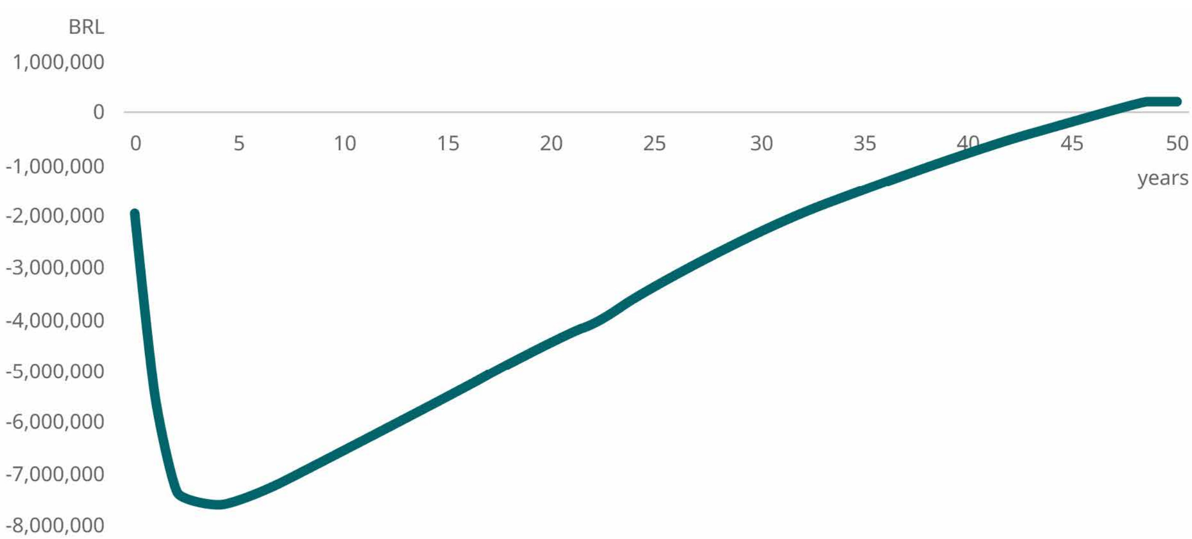
- the initiatives can technically collaborate and accelerate the implementation of natural infrastructure actions. Within the area covered by the study, 130 hectares are common to the areas prioritized in the Local Biodiversity Strategy and Action Plan of the Campinas Metropolitan Region, developed within the scope of the Reconecta RMC program and the INTERACT-Bio project, by ICLEI South America and by the 20 municipalities of the RMC, with the participation of 80 different actors from the state and federal public sectors, the private sector, academia, organized civil society and non-profit organizations.

Forest restoration is common to several official planning instruments, which means that the articulation, planning, execution and communication between initiatives and projects are essential pillars to ensure the continuity of technical collaboration and to accelerate the implementation of restoration at scale. Forest restoration is part of projects and programs at different levels of government and territorial management, such as: Master Plans, Integrated Urban Development Plans, Municipal and State Plans for the Implementation of Green Areas, in addition to River Basin Plans. Planning demands the articulation and integration of institutions, and the topic of restoration can be one of the elements that make this integration possible.

Campinas and region will gain efficiency in restoration if there is a strong alignment of priorities among the actors involved. A joint effort of the Local Biodiversity Strategy and Action Plan of the Campinas Metropolitan Region and the Reconecta RMC program with sanitation companies, such as SANASA, can lead to the identification of common high value areas for erosion contention and biodiversity. These initiatives would strengthen actions of the Payments for Environmental Services Program of the PCJ River Basins Committee.

It is essential that river basins management and planning bodies, executive and legislative bodies, the private initiative and users acknowledge, in their decisions and deliberations, the causal link between forest restoration and water quality improvement. This acknowledgement allows recovery and restoration plans to overcome administrative constraints, justifying investments in natural infrastructure that coincide with the most appropriate sphere of management. Improving water quality in a given municipality may require actions in upstream municipalities, and it is therefore necessary that decision-making and mediation spheres allow integrated solutions that go beyond local jurisdictions.

Figure 1 SE | Evolution of the net present value of natural infrastructure in the R800 scenario



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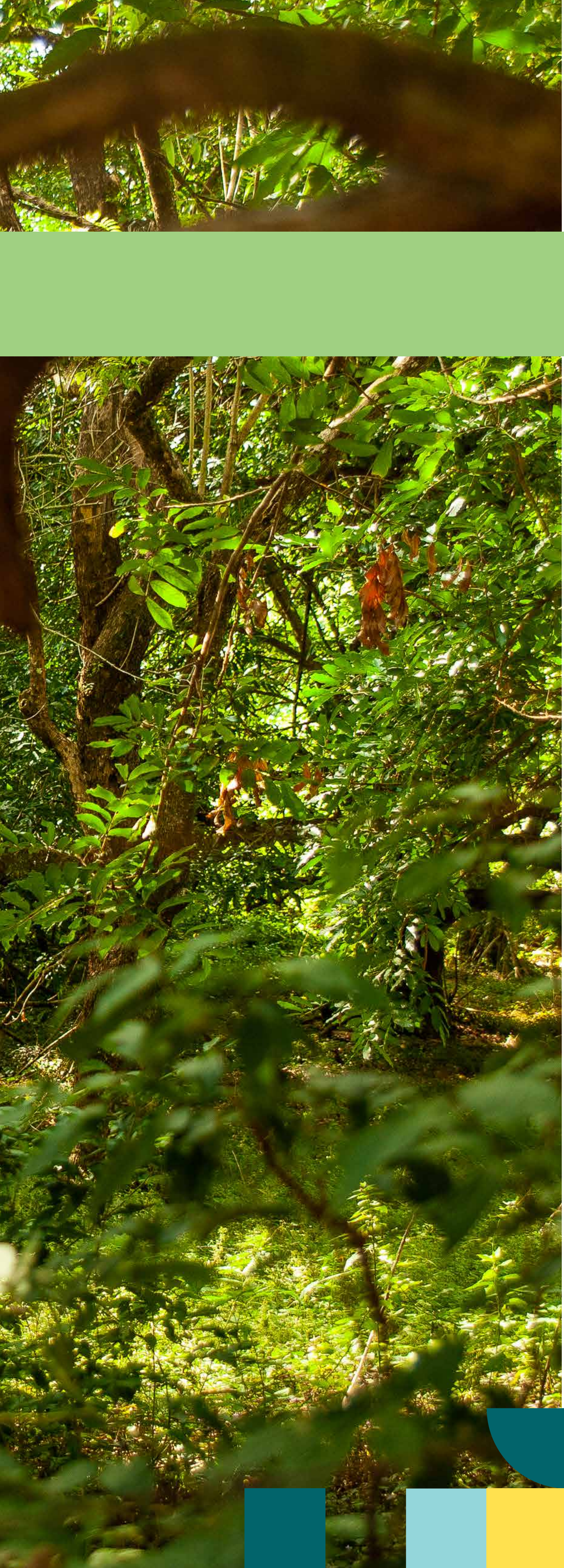


CONTEXT

Developed within the scope of the INTERACT-Bio[1] project and with the support of the Cities4Forests[2] iniciative, the study seeks to present a viable investment case in order to support the Local Biodiversity Strategy and Action Plan of the Campinas Metropolitan Region, within the scope of the Reconecta RMC program[4].

WATER MANAGEMENT CHALLENGES IN THE PIRACICABA, CAPIVARI AND JUNDIAÍ RIVER BASINS (PCJ)

Campinas and region are located in the PCJ River Basins, with the Atibaia river responsible for supplying water to 94% of the Campinas population and the Capivari river for supplying the southern portion of the city, accounting for 6% of the total volume needed for the municipality. The other municipalities are also supplied by the Capivari river.

The water supply systems comprise 16 supply companies and have been severely affected by recent water crises, such as the one faced in 2014 and 2015, which affected the Cantareira System and the water supply to the São Paulo Metropolitan Region. Campinas and region, despite being part of the Cantareira System, make little use of the reservoirs, being very vulnerable to water shortages because they crucially depend on direct water collection from rivers, whose flows result from the rainfall regime, the quality of the soil and the vegetation cover in the region, as well as the demand volumes of various productive sectors. The deterioration of ecosystems and climate change have worsened this situation (Thornton and Herrero, 2010).

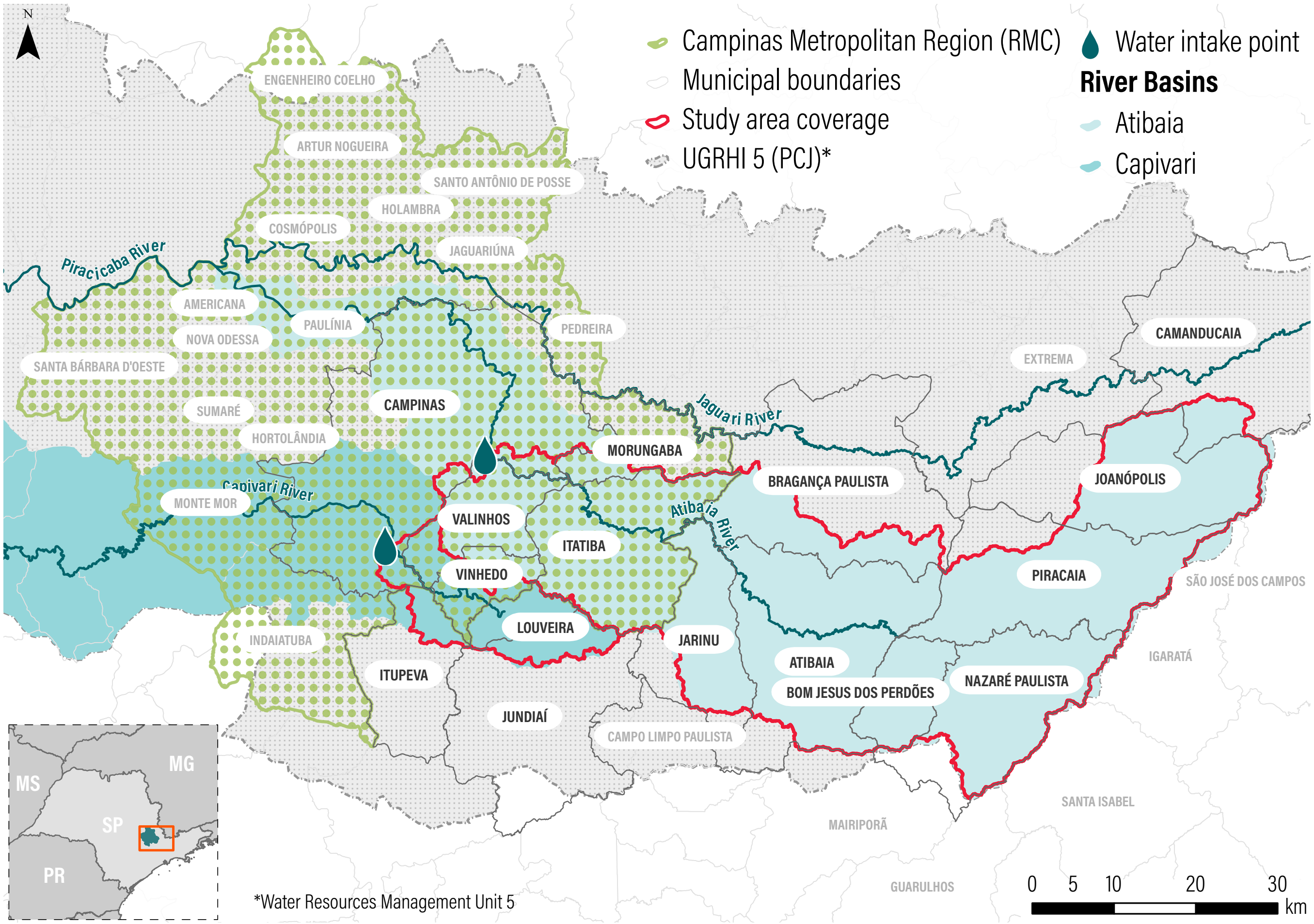
Another major source of pressure for water management in Campinas and region stems from urban and economic growth, which has seen a major transformation over the past three decades. Gross Domestic Product (GDP) and population grew by 160% and 70%, respectively, between 1990 and 2018 (IBGE, 2019). In the same period, the urban area increased by 380 square kilometers, a 72% growth (MapBiomas, 2021).

The expansion of the urban sprawl, based on land-use and territorial planning that requires integration, has been compromising the water supply capacity. An expansion of 1.7 square kilometers has been observed in the surface occupied by water bodies, resulting from the damming of rivers in small lakes and dams (MapBiomas, 2021). Considering the importance of conserving forests and restoring degraded areas as part of the natural infrastructure approach, 20 thousand hectares of native vegetation have been deforested over the past three decades (MapBiomas, 2021). In addition, there is a very high level of fragmentation and degradation of the landscape, with more than 14 thousand hectares of areas showing a moderate to severe degree of degradation (LAPIG, 2021).

In the Brazilian legal system, the management of water resources – considered a public role of common interest – must be carried out in a shared manner between the state and neighboring municipalities (Brazil, 2015). In administrative terms, the RMC comprises 20 municipalities, all located in the PCJ River Basins. Since 1973, water and sanitation services in the municipality of Campinas have been provided by SANASA, which services a population of over 1.2 million inhabitants, 87% for residential purposes, 10% for commercial purposes, 2% for public use and 1% for industrial purposes (SANASA, 2019).

Despite the municipal water abstraction and treatment management, it is also necessary to consider the ten municipalities of the Atibaia and Capivari rivers sub-basins, located upstream of these abstractions, beyond the limits of the RMC (namely: Camanducaia, Joanópolis, Piracaia, Nazaré Paulista, Atibaia, Bragança Paulista and Jarinu, in the Atibaia river basin; Louveira, Itupeva and Jundiaí, in the Capivari river basin) (Figure 1). Given the large number of actors that provide water supply services, the identification of actors to be involved and priority areas for investment in natural infrastructure, as well as the benefits of the natural infrastructure approach, often go beyond municipal administrative boundaries, which requires an integrated strategy.

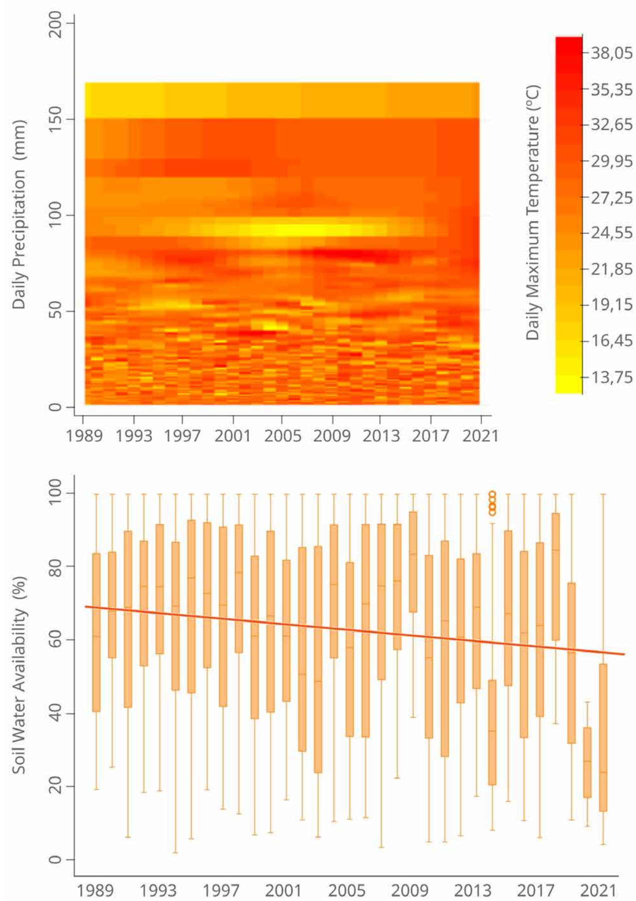
Figure 1 | Schematic representation of catchment basins and integrated municipalities



Source: Authors.

Water supply challenge: the climate in the city of Campinas has undergone changes, with increasing temperatures and decreasing availability of water in the soil. Although climate change is a phenomenon whose observation crucially depends on long time series, it is possible to note (Figure 2) that, in the last 35 years, there has been a consistent increase in daily maximum temperatures accompanied by a decrease in rainfall and also a decrease of 0.5% per year on average in the availability of water in the soil. Up to the completion of this study in May 2022, rainfall levels were 15% lower than the historical average (Agritempo, 2021).

Figure 2 | Evolution of temperature and soil water availability in Campinas, from 1989 to 2021



Source: Authors.
Note: "Counter Plot" and "Box Plot" chart models based on daily precipitation (mm), maximum temperature (°C) and soil water availability (%) data from the Cepagri/Unicamp meteorological station (Agritempo, 2021). Chart 1 (Counter Plot) shows the relationship between maximum temperatures and daily precipitation, while Chart 2 (Box Plot) shows soil water availability and trend line in the historical series (R^2=0.26, p< 0.05).

Sediment pollution challenge: Like most water supply systems, watersheds in Campinas and region are constantly suffering from sediment pollution. Between 2004 and 2019, the concentration of suspended solids measured by SANASA at the Atibaia river catchment points ranged from 151 to a maximum of 1,180 milligrams per liter on November 16, 2004, when turbidity reached 774 nephelometric units (NTU[5]). The monthly averages of raw water turbidity recorded by SANASA over the past six years were 38 NTU in the Atibaia river and 87 NTU in the Capivari river, which is equivalent to a turbidity 5 to 9 times higher than the monthly average observed in the Cantareira System, which means that these rivers have higher levels of sediment concentration when compared to the average of the whole system to which they belong, which is mainly a consequence of direct collection without the support of reservoirs and the high level of soil degradation.

Data on the volume of chemical products used, provided by SANASA for this study, allow an estimation of the company's turbidity treatment costs at approximately BRL 14 million per year. Turbidity and sediment management have at least three impacts on the cost of providing water:

1. **Turbidity treatment costs:** sediments are the main cause of water turbidity (water turbidity due to the presence of particles). Soil erosion causes sediments to be carried into waterways, increasing levels of suspended solids. Removing them requires the use of chemical products, energy, labor, equipment washing and replacement of filtering materials.

2. **Dredging costs:** sediments carried and saturated in water settle in reservoirs, reducing storage capacity or requiring them to be dredged so that the sludge can be removed. While the material removed can be sold to recoup costs, dredging can be an expensive process – especially for the construction industry, which causes environmental degradation.

3. **Depreciation of equipment:** sediment pollution can lead to the wear and tear of water infrastructure, requiring greater frequency of maintenance and replacement of equipment used in the turbidity removal process. This wear and tear tend to increase the depreciation rate of equipment, which increases the expenses of companies responsible for maintenance.

Other costs, such as the temporary interruption in water supply due to turbidity, can be significant, but, as they are usually treated as contingency or emergency costs, are not considered in this study.

DEMANDS FOR THE EXPANSION OF CONVENTIONAL INFRASTRUCTURE IN CAMPINAS AND REGION

The management of water resources aims to guarantee sustainable access to adequate amounts of water, in satisfactory quality conditions for human well-being, economic development and the maintenance of water sources and the environment (UN, 2013). Participatory, multisectoral management is required, with broad investment strategies; additionally, the combination of conventional civil engineering infrastructures with natural/green infrastructures, such as forest conservation and restoration, is also increasingly relevant.

A large set of investments in conventional infrastructure for water management, in particular for water reservation6 and water treatment, has been mapped for the region. This mapping was carried out through a review of technical documents and consultations with river basin managers, sanitation companies, municipalities and the public prosecutor's office, through the GAEMA, a specialized action group on the environment, housing and urbanism of the São Paulo state prosecutor's office, and specialists in the area.

Most of the investments comprise the expansion or improvement of sewage collection and treatment networks and expansion of water distribution. Out of the investment projects, two projects focus on the construction of reservoirs and significantly change the landscape and the management of water resources: the first one, on the border of the municipalities of Campinas and Pedreira (Pedreira reservoir), and the second one in Amparo (Duas Pontes reservoir). Both will help to reduce the exposure of the population and the economy to risks of scarcity, as they increase the water reserve capacity by around 85 million cubic meters, which is equivalent to the annual consumption of a population of one million inhabitants. The main characteristics of these reservoirs are shown in Table 1.

Conventional infrastructure projects are important to manage water supply, but do not change the production dynamics and the water flow of the landscape. To achieve this, the recovery of springs through conservation and restoration of natural infrastructure – native vegetation – is essential, protecting and enhancing the efficiency of engineering works. Natural infrastructure policies and strategies must be analyzed vis-à-vis those aimed at conventional infrastructure.

Table 1 | Conventional infrastructure planned for water supply in Campinas and region

	PEDREIRA RESERVOIR	DUAS PONTES RESERVOIR
Municipalities	**Campinas and Pedreira**	**Amparo**
Useful volume (m^3 million)	31.9	53.4
Water mirror (ha)	202	486
Cost with expropriations (BRL million)	28	85
Total investment (BRL million)	370	390
Permanent Preservation Area – PPA (ha)	214	391
PPA to be restored (ha)	135	292
Compensatory restoration area due to suppression (ha)	186	187
Total restoration (ha)	321	479

Source: Developed by the authors based on DAEE (2020).

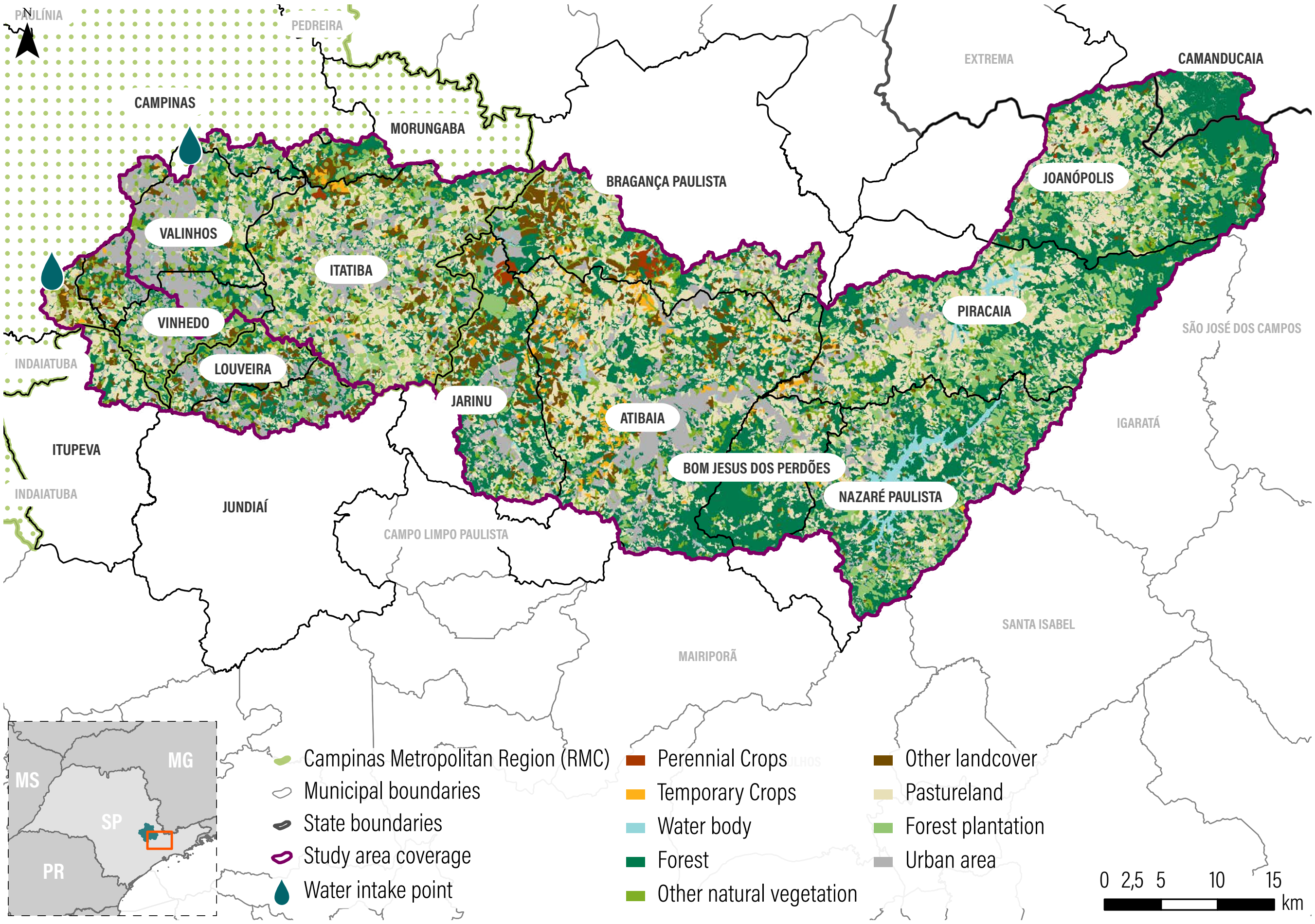
PUBLIC POLICIES AND NATURAL INFRASTRUCTURE STRATEGIES FOR CAMPINAS AND REGION

Planning interventions in Campinas and region requires the mapping of public policies and initiatives already underway. For example, the study area is classified as a very high priority zone for restoration of native vegetation and water recharge in the state of São Paulo (Rodrigues et al., 2008). In addition, the RMC and the upstream area have a highly fragmented landscape, with less than 19% of vegetation cover. The main fragments protected in Conservation Units are in the municipality of Campinas, where several environmental protection areas are located. Such areas are classified as sustainable use, with different levels of occupation and use, such as Mata de Santa Geneva - a Relevant Ecological Interest Area (ARIE, in Portuguese) with 252 hectares and rich biodiversity.

The landscape's high forest fragmentation, especially in the Atibaia and Capivari river basins, together with the diagnosis of high priority for restoration, indicate the need for a large investment in the recovery of native vegetation. The municipality's water sources policy provides for the implementation of Municipal Plans for the Atlantic Forest and Cerrado biomes, which must be integrated with the implementation of natural infrastructure.

The heterogeneous mosaic of land use and land cover in the river basins should be highlighted, with patterns that vary along their length. While in the further upstream region, at the head of the river basin, there is a relative presence of fragments of native forest and reforestation (silviculture), in the portions closer to the SANASA water catchment points a more significant presence of built areas is observed. Figure 3 illustrates the current landscape in the region.

Figure 3 | Current land use and coverage map in the Atibaia and Capivari river basins



Source: PCJ River Basins Agency (2018).

Forest restoration actions carried out in the region show that there is interest and motivation from several actors to engage in natural infrastructure strategies for water. Among them, there are initiatives linked to the Nascentes program, of the São Paulo state government, and to SANASA, both in partnership with the Campinas municipal government. In addition, the river basins committee leads other projects focused on the charging for the use of water resources and intended for application in the PCJ River Basins region.

Under the Nascentes program, there are also projects with commitments in place or available for contracting, included in the program's project portfolio. Such projects are jointly enabled by or executed with different actors, involving private organizations, such as Da Serra Ambiental, Ceiba Consultoria Ambiental, Centro Ambiental Consultoria e Projetos de Meio Ambiente and Tríade Consultoria Ambiental, and non-governmental non-profit organizations, such as Iniciativa Verde and SOS Mata Atlântica. The program also has a bank of areas composed of Conservation Units, settlements and rural properties with PPA liabilities, which are indicated for restoration by third parties.

The Reconecta RMC program, which involves the efforts of municipal governments in the metropolitan region, supported by initiatives such as INTERACT-Bio and Cities4Forests, demonstrates that it is possible to obtain a return from investments in ecosystem services. The Reconecta RMC is part of RMC's Integrated

Urban Development Plan (PDUI, in Portuguese) and is a guiding element for the payments for environmental services program in the municipality of Campinas, for example.

The Payments for Environmental Services program of the municipality of Campinas (Municipal Law No. 15.046/2015) is a monetary incentive instrument for initiatives that favor the maintenance, recovery or improvement of ecosystems, especially for the production of water. Currently, the Campinas Secretariat for the Environment and Sustainable Development (SVDS, in Portuguese) coordinates and implements this program in 17 qualified properties – which have already implemented or are currently implementing the necessary environmental adaptations – through a public grant program. The secretariat also conducts technical analyzes on more than 150 properties that have already received non-monetary incentives, through other programs of the portfolio, such as reforestation in protected areas (PReNAC Rural - recovery of springs and riparian areas program) and donation of sewage treatment systems. (PSRS - sustainable rural sanitation program).

The combination of restoration initiatives already undertaken in the territory can make the resources allocated by existing financial mechanisms more efficient, as they are not sufficient for the current demand. Connecting forest restoration actions to incentives and identifying priorities can more efficiently support fundraising efforts and allocation of investments. Some examples stand out in encouraging and strengthening the forest restoration agenda in Campinas and region: the Campinas's Metropolitan Development Fund (Fundocamp – Complementary State Law No. 870/2000 and Decree No. 50.553/2006), linked to the Campinas Metropolitan Agency (Agemcamp), which applies resources of common interest to the municipalities that make up the RMC, as well as the Environmental Preservation, Maintenance and Recovery Fund (Proamb – Municipal Law No. 9.881/1998), linked to the SVDS, which receives cash flows on an ongoing basis (oil royalties) as well as on a one-off basis (fees and fines).

The collection of data on the main sources of funds invested in programs related to the approach of this study, in the period analyzed from 2011 to 2019, allowed the identification of: (i) projects financed via Fundocamp with a total financial contribution estimated at BRL 1.9 billion, (ii) projects of the PCJ River Basins Committee – out of which, approximately BRL 85 million come from federal collection (Federal PCJ collection) and BRL 137 million from state collection (São Paulo PCJ collection), (iii) contracts with resources from FEHIDRO (State Fund for Water Resources) that totaled the estimated amount of BRL 13.7 million. In short, the information collected combined with the results presented below demonstrate the consonance between the approach of this study and the application of resources in water management of the region covered by the study.

DEMANDS FOR THE EXPANSION OF NATURAL INFRASTRUCTURE IN CAMPINAS AND REGION

Restoring forests and ecosystems is justified by the recognition of their immaterial value. It brings environmental benefits related to the conservation of biodiversity and social benefits such as the promotion of well-being. In addition, there are economic benefits generated from assets ranging from timber and non-timber products to ecosystem services, such as aquifer recharge, pollinator refuge, thermal comfort, etc.

In the current climate crisis and the prospect of growing impacts related to the water crisis on cities, the restoration of forests is an important asset for mitigation, adaptation and recovery of the resilience of natural ecosystems. It can be motivated by legal obligation, either through remediation of damages or environmental regularization, or by public and private voluntary initiatives (Batista et al., 2019).

Considering the different motivations of the different restoration initiatives, specific challenges were identified that still need to be addressed in the natural infrastructure agenda in Campinas and region, of which four stand out.

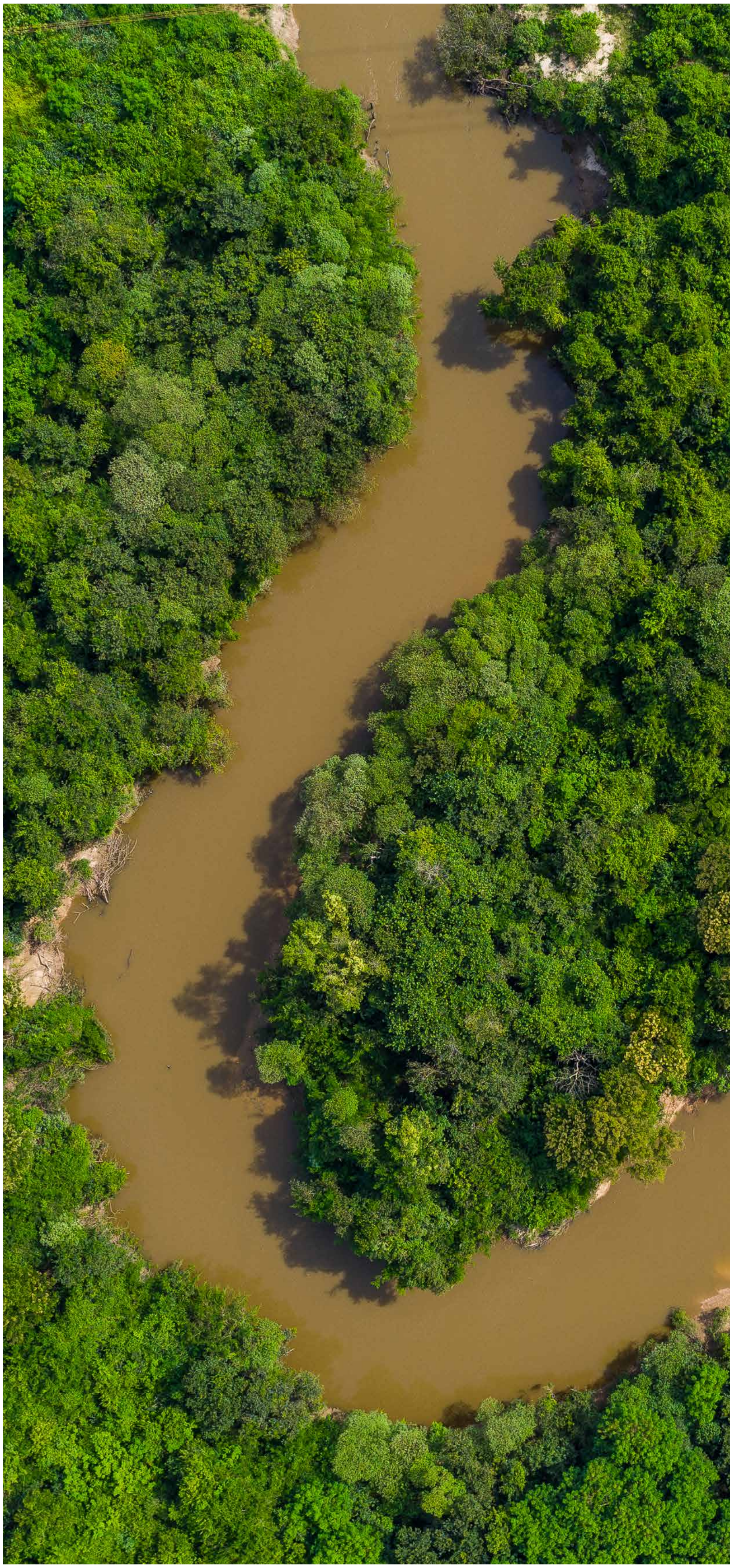
1. **Correctly assess the benefits of restoration for water management:** the economic benefits of restoration are generally ignored, so that the activity is always seen only from the perspective of cost, without a fair consideration of the benefits generated.

2. **Account for natural infrastructure as an investment, not a cost:** currently restoration, even for the purpose of protecting water sources, is not recognized as an investment, which restricts financing and prevents its leverage via tariff review, for example.

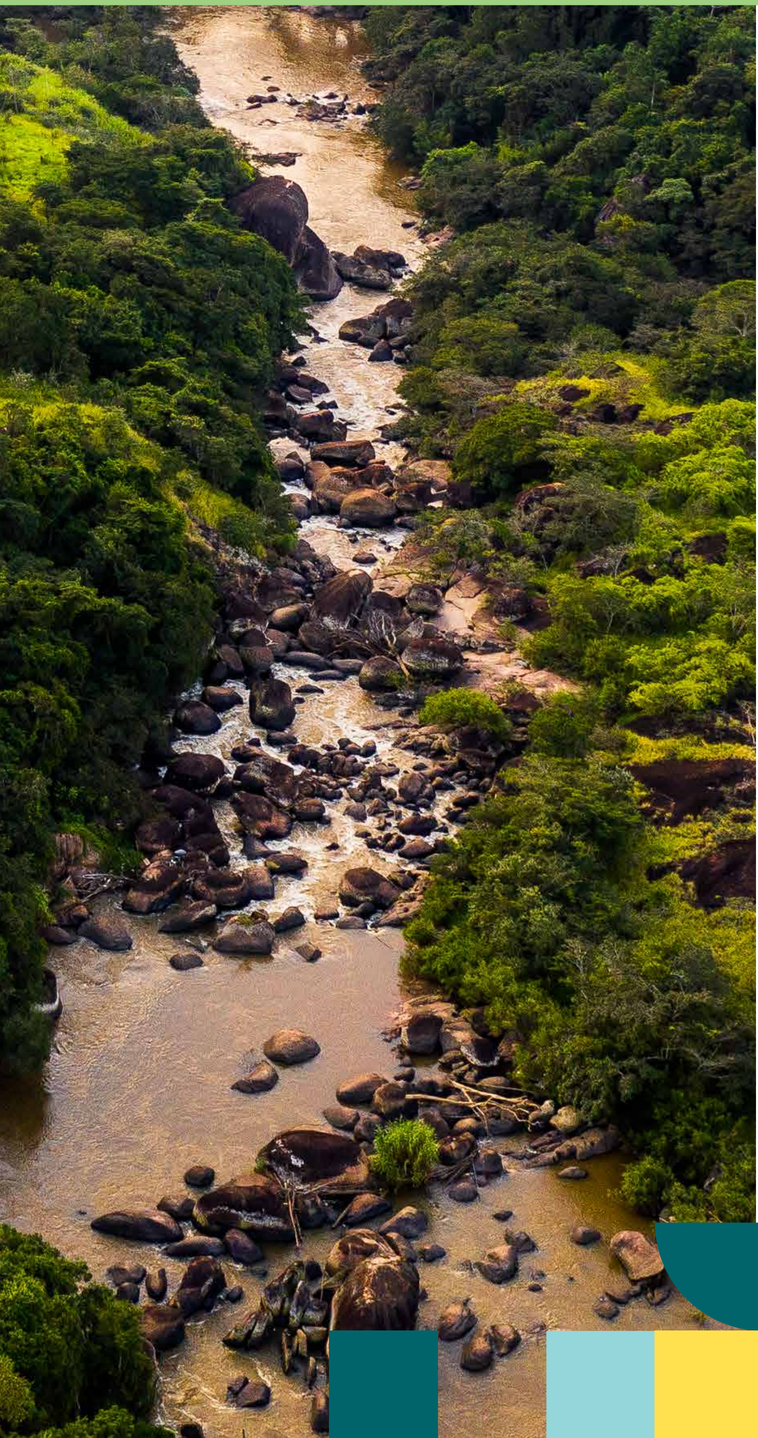
3. **Secure and scale up funding for natural infrastructure:** restoration programs have been ambitious, but, as in most parts of the world, accessing sufficient funds to operationalize natural infrastructure projects is an ongoing challenge. Although there are mechanisms and strategies in place in the region to guarantee funds for restoration, insecurity about funding raises questions about the feasibility of implementing natural infrastructure plans, as well as about their long-term sustainability.

4. **Engage rural landowners to conserve, restore and manage natural infrastructure:** despite the large deficit of PPAs and Legal Reserves (LRs) that should be regularized by law, rural landowners in the region rarely engage in restoration projects for various reasons, among them, lack of investments in rural extension and technical assistance focused on restoration.

Considering these four challenges, this study brings contributions through the analysis of local data, shared by SANASA, literature review, stakeholder consultations and biophysical and financial models, demonstrating the benefits generated by restoration, namely: improved water quality under the turbidity parameter, and the economic aspects related to costs savings in turbidity treatment.



ASSESSMENT OF NATURAL INFRASTRUCTURE FOR SEDIMENT CONTROL



This chapter presents the results of the assessment of investments in natural infrastructure, which accounts for benefits of natural infrastructure for water in Campinas and region, as well as costs and benefits incurred in restoration projects linked to environmental compensation of reservoirs. It also summarizes the methods adopted, biophysical results and benefits of natural infrastructure geared towards improved water quality.

METHODOLOGY

The Green Gray Assessment (GGA) methodology allows the analysis of the overall financial performance of different natural (green) and built (grey) infrastructure investment options by examining each of the common priorities identified by local stakeholders and provides project recommendations to optimize results (Gray et al., 2019). This approach is based on the GGA/WRI methods (Gray et al., 2019; Gartner et al., 2013) and on the Watershed Investment Readiness Assessment (Ozment et al., 2016). Tools from the Restoration Opportunities Assessment Methodology (ROAM) (IUCN and WRI, 2014) were also used to strengthen the analysis, especially in the stages of identification of key actors in the social context, strategic management, and natural infrastructure investment objectives.

The methodology consists of six detailed steps:

The first step involves the definition of the natural infrastructure objectives intended with the conservation or implementation of forest restoration. This stage received contribution from stakeholders through roundtables, workshops, bilateral and multilateral consultations led by WRI Brasil (Appendix A). In addition, the definition of objectives considered sources of information from public documents prepared by institutions operating in the region.

In the second step, evaluation scenarios are specified, outlined in a way that makes it possible to compare and quantify the achievement of objectives, depending on the scale and type of strategy adopted for natural infrastructure. Among the proposed scenarios, there is a reference, considered a baseline, which represents the present condition in which no additional natural infrastructure effort is carried out. All other scenarios are compared to this baseline (Appendix A).

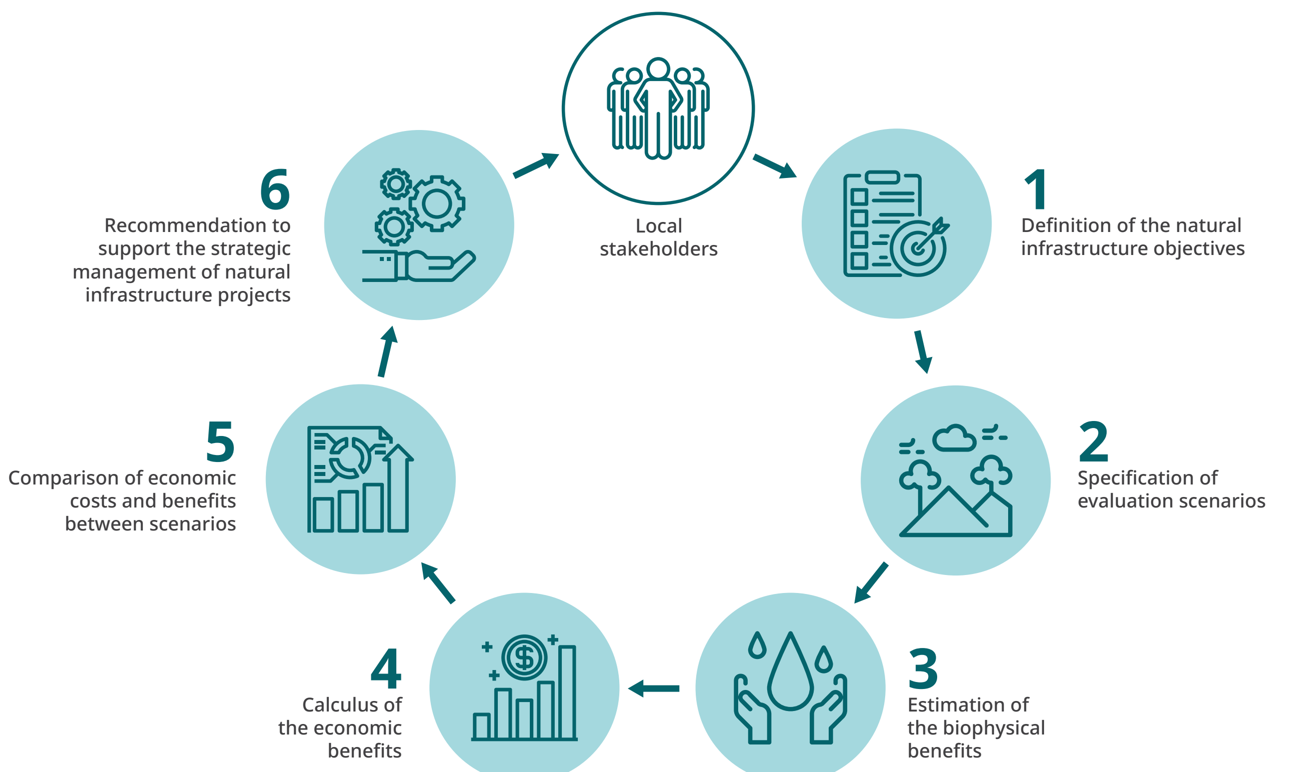
The third step estimates the biophysical benefits (Appendix B). Such benefits are measured in quantitative biophysical units, such as tons of sediment, cubic meters of water, concentration of suspended solids or turbidity levels. These results are compared with the estimated values for the baseline scenario, as if they were typical comparisons of "before" and "after" investments in natural infrastructure. The differences found are assumed as additionalities resulting from the ecosystem services provided by natural infrastructure, such as avoided sediments, reduced turbidity, etc.

The fourth step calculates the economic benefits through the monetization of ecosystem services provided or added by natural infrastructure, computed in the previous step. Here, benefits are priced in terms of avoided costs or depreciation, and are not, therefore, cash-generating. The estimates correspond to savings generated by the volume of chemical products that are no longer consumed due to reductions in turbidity, the avoided costs of dredging or the decrease in equipment depreciation resulting, for example, from the reduction in abrasiveness promoted by lower concentrations of suspended solids in treated water (Appendix C).

The fifth step compares economic costs and benefits between scenarios. The generated benefits are offset against the costs of conservation or implementation of natural infrastructure. Such financial analyzes are based on discounted cash flows, through the calculation of conventional indicators, such as Net Present Value (NPV), Internal Rate of Return (IRR) and Payback. Sensitivity analyzes are also conducted to assess the behavior of financial performance of natural infrastructure in the face of important variations in discount rate, forest efficiency in sediment retention and restoration costs (Appendix C).

Finally, **the sixth step consists of recommendations to support the strategic management of natural infrastructure projects** aimed at decision-makers and local and regional stakeholders. These recommendations aim to inform about possible investment actions by companies, sanitation companies and the state connected to water management (Appendix C).

Figure 4 | GGA/WRI Methodology



Source: Authors. Adapted from Gray et al. (2019).

ASSESSMENT SCENARIOS

In this study, the natural infrastructure investment scenarios were previously defined by the stakeholders in order to clarify specific issues: (1) what is the role currently played by native vegetation in the region in the maintenance of water quality and what is the value of these services provided by natural infrastructure? (2) How much could be added in environmental services to water quality with the expansion of natural infrastructure through forest restoration of degraded areas? And (3) what benefits could be achieved with the forest restoration efforts foreseen in specific projects already planned in the region?

To address these issues, three scenarios were assessed in addition to the baseline scenario. In all scenarios, climatic factors were considered constant and the demands for water followed the functions of population growth and consumption elasticity, resulting in demands close to those forecasted by the PCJ. It was also assumed that there would be no changes in land use and cover in the river basins, unless explicitly indicated in the scenarios.

The proposed scenarios are:

- **Reference (REF) – Baseline scenario that represents the current situation of the river basins in terms of land use and its implication in the production of sediments and water turbidity.** It reflects the status quo and is therefore a reference for all other scenarios. The benefits of conserving or restoring natural infrastructure are always accounted for as gains beyond the baseline, while the removal of vegetation means losses in relation to the baseline.
- **Large-Scale Vegetation Loss (P76000) – All remaining native vegetation currently existing in the river basin is converted to pasture.** This scenario, although unlikely, aims to assess the role of current vegetation in controlling erosion and maintaining turbidity levels. It also reveals the potential impact on water quality arising from the suppression of 76 thousand hectares of forests. The financial analysis related to this scenario considers the benefits generated by the conversion of vegetation, discounted at the social discount rate of 5% per year, over a 40-year horizon. The discount rate represents the estimated social discount rate in Brazil (Lopez, 2008).
- **Large-Scale Restoration (R14000) – Restoration of 14 thousand hectares currently occupied by degraded pastures, in addition to the conservation of all existing native vegetation remnants.** This scenario measures the additional benefits that could be achieved with forest restoration in areas already deforested and with low added value for the rural economy, considering an area of 14 thousand hectares of pastures with the highest levels of degradation in the region. The benefits generated by this increase in forest cover are estimated at a social discount rate of 5% per year, over 40 years.
- **Reservoir Compensation Restoration (R800) – Restoration of 800 hectares to compensate for the suppression of vegetation and PPA formation connected to the ongoing construction of two reservoirs in the region.** This scenario measures the costs and benefits of restoring 800 hectares as compensation and PPA formation for the new reservoirs. Of this area, 427 hectares will be restored around the dams, in strips 100 meters wide, as required by the Brazilian Forest Code. Another 373 hectares related to compensation for suppression of vegetation will be restored in the areas of the Atibaia river basin that present a higher level of sediment production and, therefore, a better cost-effectiveness ratio (see Table 1).

In terms of the restoration costs, the values estimated for the Reconecta RMC program were considered as reference, assuming the values of restoration implementation as investment. The opportunity cost of land is included, equivalent to the lease value of low-productivity pastures, following the values published by the Institute of Agricultural Economics (IEA, 2021), namely BRL 300 per hectare per year. A further 12% was added to the total value of investments as transaction costs. The benefits were estimated in line with the other scenarios, that is, restricted to the avoided costs in water treatment due to the implementation of natural infrastructure (in this case, the restoration of 800 hectares). A time horizon of 40 years was considered, with a discount rate of 5% per year.

Table 2 summarizes the main attributes and objectives of each of the tested scenarios.

Table 2 | Scenarios, objectives and expected results

SCENARIO	CHANGE IN THE COMPOSITION OF NATURAL INFRASTRUCTURE	OBJECTIVE	METHOD OF CHANGE IN THE COMPOSITION OF NATURAL INFRASTRUCTURE	EXPECTED RESULTS
REF	No change	Establish the baseline (reference) for exported sediments and water turbidity levels	None	Exported sediments (t/year), concentration of suspended solids (mg/L) and average turbidity (NTU) under current conditions
P76000	Loss of the 76 thousand ha of forests currently existing in the study region	Estimate the services currently provided by forests in retaining sediment and reducing water turbidity	Hypothetical extraction – The replacement of forests with pastures is simulated	Increases in exported sediments (t/year), concentration of suspended solids (mg/L) and average turbidity (NTU) in relation to the reference scenario values
R14000	Forest restoration of the 14,000 ha currently occupied by pastures, with moderate and high degree of degradation	Estimate the additional services provided by large-scale forest restoration in the landscape	Hypothetical addition - The replacement of pastures with forests is simulated	Decreases in exported sediments (t/year), concentration of suspended solids (mg/L) and average turbidity (NTU) in relation to the reference scenario values
R800	Forest restoration of 427 ha around the reservoirs and 373 ha currently occupied by pastures with the highest degree of degradation in the region	Estimate the additional services provided by the restoration of specifically located forests	Hypothetical addition - The replacement of pastures with forests is simulated	Decreases in exported sediments (t/year), concentration of suspended solids (mg/L) and average turbidity (NTU) in relation to the reference scenario values

Source: Authors.

THE BIOPHYSICAL BENEFITS OF NATURAL INFRASTRUCTURE

The biophysical estimates carried out in step 3 of the GGA/WRI show that the Atibaia river basin receives an annual discharge of 62 thousand tons of sediments due to soil erosion, with an average of 270 kg per hectare per year, while the portion of the Capivari river, upstream from the Campinas catchment, receives an annual discharge of 18 thousand tons of sediment, with an average of 770 kg per hectare per year. Considering the estimated curves for the conversion of sediments to suspended solids and then to turbidity, the results indicate average levels of suspended solids of 190 and 280 mg per liter in the Atibaia and Capivari rivers, respectively, and average levels of turbidity of 38 and 87 NTU. Thus, in the REF baseline scenario, a total of 70 thousand tons of sediment exported annually was estimated, with an average suspended solids concentration of 206 mg per liter and an average turbidity of 44 NTU.

The comparison of the P76000 scenario with the REF baseline scenario elucidates the benefits of vegetation maintenance. The 76 thousand hectares of native vegetation that make up the forest remnants in the river basins are mainly located in areas of difficult access – which is probably the reason they are still preserved– and are naturally more fragile to erosion, as they are located in regions with high slopes, tops of hills and floodplain areas or riparian forests. The preservation of vegetation cover prevents the additional discharge of 34 thousand tons of sediments per year, which is equivalent to affirming that each preserved hectare of forest currently provides an ecosystem service of 436 kg per year in terms of avoided sediment discharge.

The loss of this vegetation would imply an increase in average turbidity of almost 70%, jumping from the current 44 to 75 NTU. The loss of this vegetation would have a significant impact on water treatment operations, which would require additional consumption of chemicals and energy, as currently occurs in the rainiest quarter. In the Atibaia river, the average turbidity between December and February, months of the rainy season, when the water flow is high, was calculated at 92 ± 28 NTU compared to 28 ± 17 NTU in the other months of the year, while the Capivari river showed an average turbidity of 152 ± 67 NTU against 85 ± 64 NTU for the same periods of the year.

The conservation of forest remnants is relevant for the maintenance of water quality, but sediment management from the perspective of natural infrastructure must go much further. The 30 municipalities of the RMC and upstream have a joint deficit of 36 thousand hectares of PPA and 8 thousand hectares of LR, which means that 44 thousand hectares should be restored just to meet the requirements of the Forest Code.

Currently, of the 140 thousand hectares of pastures in the region, 10% are in a moderate to high level of degradation – and are therefore economically used in a very inefficient way –, of which 73% are located in areas that should be conserved as PPAs. If these 14 thousand hectares were restored as required by law, and as suggested in the R14000 scenario, a decrease of around 9% in sediments exported to water courses could be expected in relation to the current level (7.5 thousand t/year), reducing average turbidity by 14% in the Atibaia river and 17% in the Capivari river. Operationally, sanitation companies could gain the equivalent of an extra quarter per year with average turbidity levels that are currently only recorded in the dry season, between May and October. On average, the restoration of 14 thousand hectares would reduce sediment discharge by around 6.5 thousand tons per year, reducing turbidity by almost 10% compared to average conditions.

Restoring 14 thousand hectares requires the mobilization of a group of local decision-makers, starting with the rural producers themselves, who are required to do so by law. However, they often lack technical guidance, financial support and even direct and indirect incentives for the recovery of degraded areas and forest restoration. Although there are local initiatives such as those listed in Chapter 1, the efforts needed to achieve restoration at scale to adapt rural properties and still benefit the entire landscape must be much more ambitious.

Considering long-term impacts and ambitious scenarios is essential; however, small-scale actions in the short term would already bring considerable benefits. The restoration of 800 hectares, for the formation of PPAs and compensation referred to in the R800 scenario, would be able to reduce exported sediments by about 3.2 thousand tons per year, lowering average turbidity by 4% in relation to the baseline scenario. Despite its small scale, this decrease in turbidity would bring significant economic benefits in terms of avoided costs in water treatment in the long term, as described in the next subchapter.

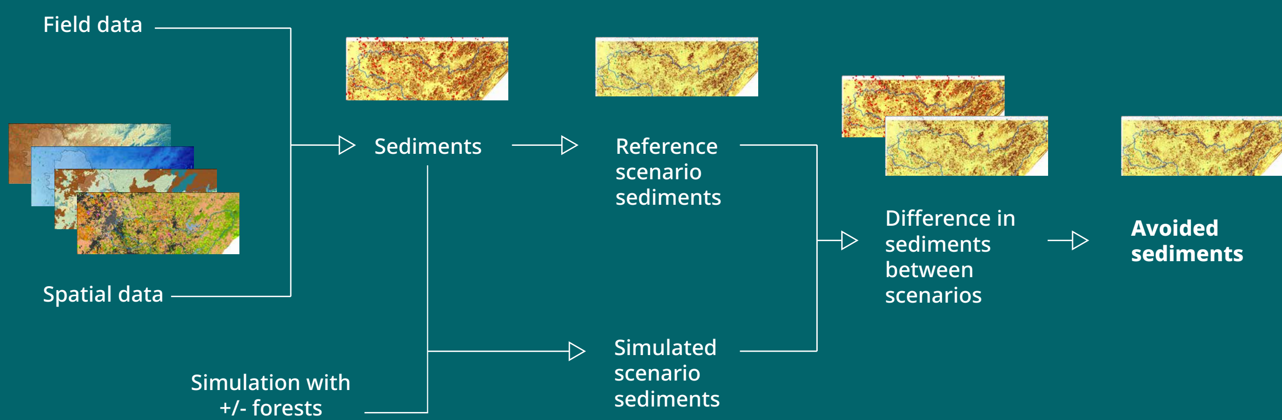
Table 3 | Biophysical results of scenarios

BIOPHYSICAL RESULTS	REF	P76000	R14000	R800
Total sediments exported at catchment points (t/year)	70,000	104,000	63,500	66,800
Total suspended solids in collection (mg/L)	206	317	198	206
Turbidity in collection (NTU)	44	75	40	42

Source: Authors.

BOX 1 | MEASURING THE BIOPHYSICAL BENEFITS OF NATURAL INFRASTRUCTURE

Biophysical changes caused by natural infrastructure are estimated using the InVEST model (Sharp et al., 2020) combined with calibrations of data obtained in the field.



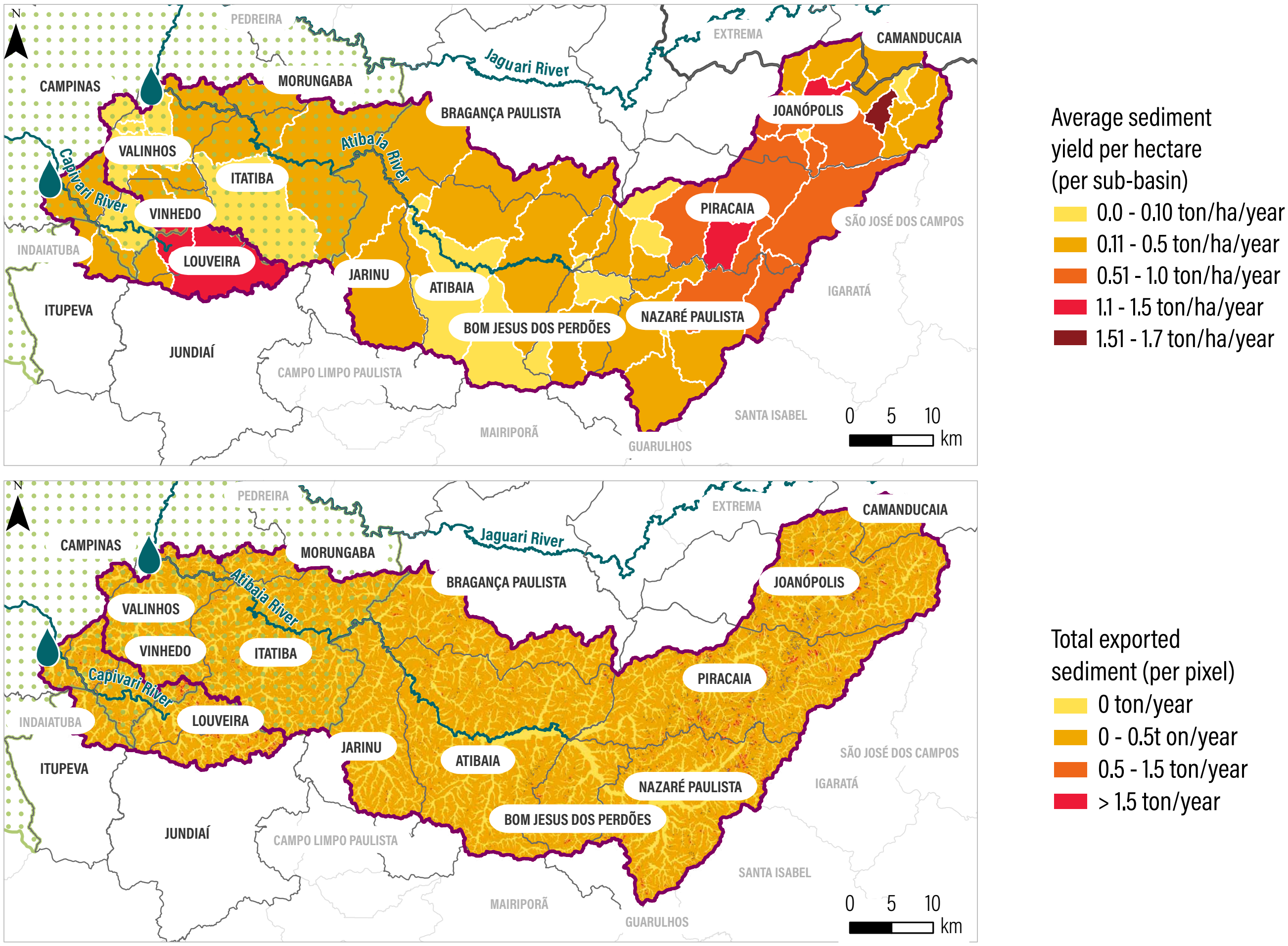
Source: Authors.

The first step consists of estimating the existing attributes in the river basin of interest as they are currently presented, considering attributes of the reference scenario. Spatial data, such as soil erodibility and erosivity, digital terrain model, land use and land cover and others, are interpolated by specific InVEST functions; in this case, the function called SDR (Sediment Delivery Ratio) is used to estimate the export of sediments in the river basin. Field data, which in this study were collected and shared by SANASA (suspended solids and turbidity measured at 10 different points on the Atibaia and Capivari rivers), are input to calibrate the SDR function, in order to approximate the simulation results as much as possible to the results obtained in the field.

Once the calibration is done, the spatial results that are closest to the field data are considered ideal parameters to measure the sediments exported in the reference scenario. A sediment map of the river basin is generated with pixel-by-pixel ranking of the areas with the highest sediment export rates. In the case of this study, this reading is restricted to sediments produced in pixels currently classified as pastures (each pixel corresponds to an approximate area of a square measuring 30x30 meters, that is, approximately 900 m^2). Figure 5 shows a summary of the results of this first step, illustrating the average sediment export estimates by micro basin. Thus, it becomes possible to identify the portions of the basin that tend to show the greatest contribution to the total export of sediments.

In the second step, the InVEST model simulates hypothetical situations with spatial data and modified parameters. In the land use and land cover map, pastures are replaced by forests or vice versa (simulating restoration or deforestation, respectively) in enough areas as to achieve the objectives defined in each scenario, always following the decreasing order of sediment export, pixel by pixel, in order to optimize the replacement effect. The total volume of sediments in this new scenario is then compared to the volume in the baseline scenario (third step), and differences are considered as results from natural infrastructure (details in the Appendices).

Figure 5 | Estimate of sediments exported to the Atibaia and Capivari rivers sub-basins



Source: Authors.

ECONOMIC BENEFITS OF NATURAL INFRASTRUCTURE

In addition to the biophysical benefits generated by reducing soil erosion (sedimentation) and improving water quality, economic benefits can be measured by applying cost curves as a function of turbidity variation, projected from primary data provided by SANASA. The estimated costs for the Atibaia and Capivari rivers sub-basins are shown in Table 4.

Table 4 | Reference operating costs for treatment, cleaning and depreciation of equipment used in the management of sediments and water turbidity (BRL cents/m³)

	ATIBAIA	CAPIVARI	WEIGHTED AVERAGE
Chemical products	12.63	15.01	13.30
Sand replacement	0.03	0.06	0.03
Anthracite replacement	0.07	0.13	0.07
Iodine management	1.33	2.45	1.34
TOTAL	**14.06**	**17.65**	**14.73**
Equipment depreciation and wear and tear	2.38	4.38	2.39

Source: Developed by the authors based on data provided by SANASA in 2020.

Extrapolating to the entire study region and considering that the Capivari river source area represents less than 10% of the total area (micro basin of only 25 thousand hectares) and 6% of the collected volume, the average cost curve as a function of average turbidity (Grey et al., 2019) is presented according to the equation below:

$$C = 0.059 * T^{0.208}$$

Where **C** is the treatment cost in BRL and **T** is the turbidity level in NTU.

Considering the estimated curve, the 76 thousand hectares of native vegetation that make up the forest remnants in the basins, provide sediment retention and avoided turbidity services totaling BRL 6.6 million per year. This cost savings amount is possible due to the avoided costs in the use of chemical products that would be necessary to treat the almost 215 billion liters of water demanded annually by the population of the region, if the turbidity levels were raised from the current 44 to 75 NTU as a consequence of the forests being cleared and occupied by degraded pastures. These services are equivalent to no less than 53% of SANASA's expenditure on chemical products used in the annual treatment of almost 100 million m^3 of water.

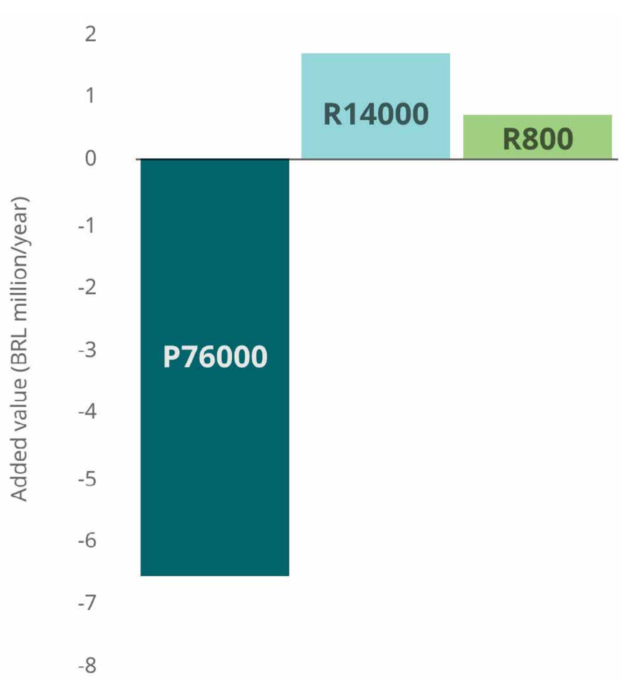
If, in addition to maintaining the installed natural infrastructure, its expansion was promoted through forest restoration of degraded pastures, according to the different proposed scenarios, annual benefits would be added ranging from BRL 693 thousand (R800) to BRL 1.7 million (R14000).

Two important assumptions must be clarified.

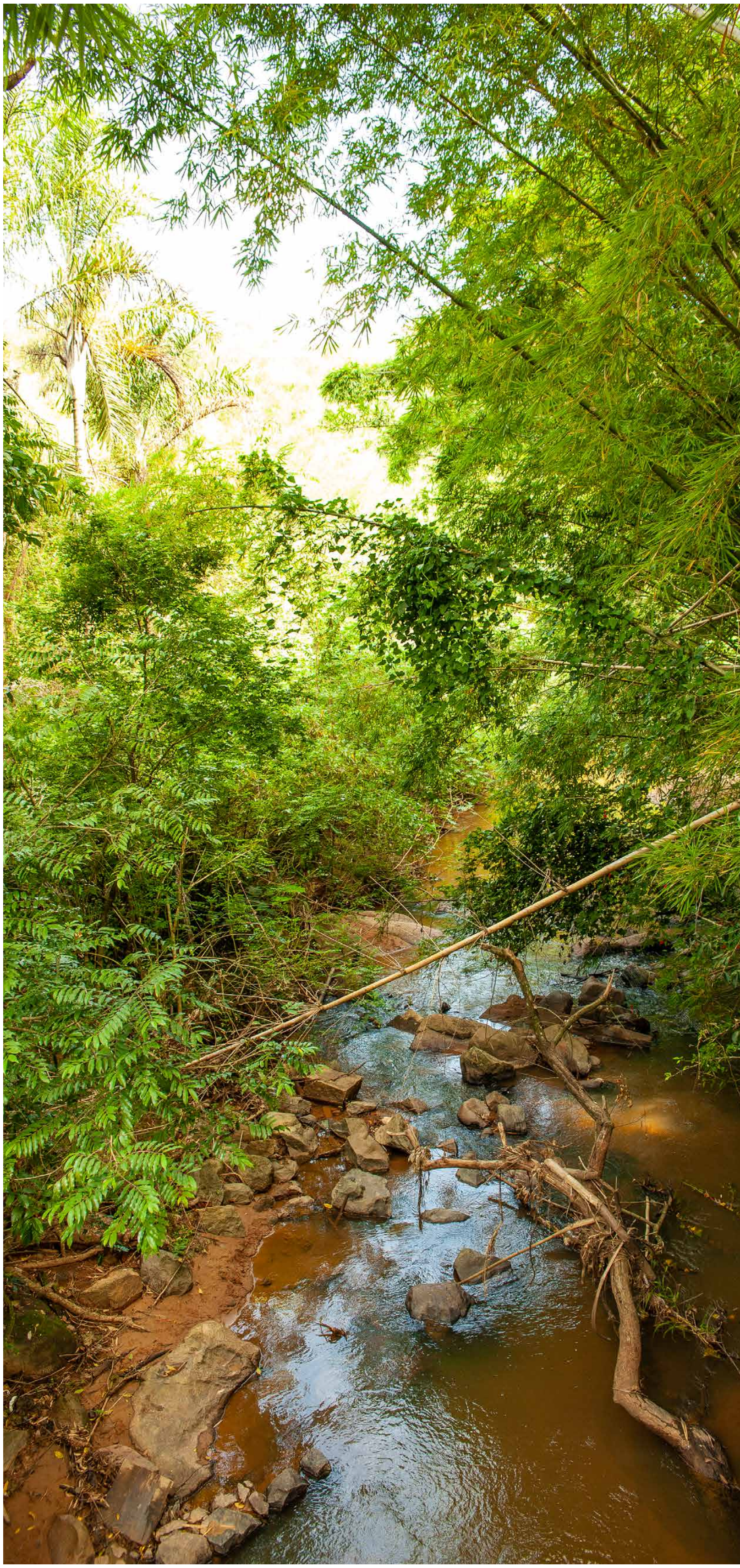
1. The restored forest generates increasing benefits proportional to the growth and development of the forest structure, taking about 50 years to reach its maximum capacity for sediment retention. The benefits considered here reflect the average of the first 40 years, so much higher benefits could be expected with the appreciation of the natural infrastructure and perpetuation of the restored forest (details in Appendix C).

2. The benefits generated by the different scenarios are not proportional to the restored areas because they follow gradients of prioritization of areas with higher levels of sedimentation. Therefore, the marginal efficiency in sediment retention decreases as the areas to be restored grow.

Figure 6 | Added value of natural infrastructure in the different scenarios analyzed



Source: Authors.
Note: the chart indicates the benefits generated by the existing natural infrastructure (current forests) and additional benefits that could be obtained in alternative scenarios of natural infrastructure expansion (restoration).



BOX 2 | MEASURING THE ECONOMIC BENEFITS OF NATURAL INFRASTRUCTURE

The measurement of the economic benefits resulting from natural infrastructure takes place in three steps.

In the first step, the biophysical changes resulting from natural infrastructure are measured in terms of sediments carried into the watercourses and, for that, these sediments (t/year) estimated in the reference and alternative scenarios are converted to suspended solids (mg/L), using the following conversion function for sediments carried into watercourses, suggested by Carvalho (2008).

$$ss = s/10{,}4 * 0{,}087$$

where SS corresponds to suspended solids (mg/L), S is exported sediments (t/day), 10.4 is the average water flow (m^3/s) in the Atibaia river at the catchment point (PCJ River Basins Agency, 2020) and 0.087 is the conversion constant.

In the second step, the concentrations of suspended solids are converted to turbidity, according to a function estimated from paired data of suspended solids and turbidity measured by SANASA, containing 237 pairs at five catchment points, measured between July 2013 and December 2018. The estimated function ($R2=0.67$) was:

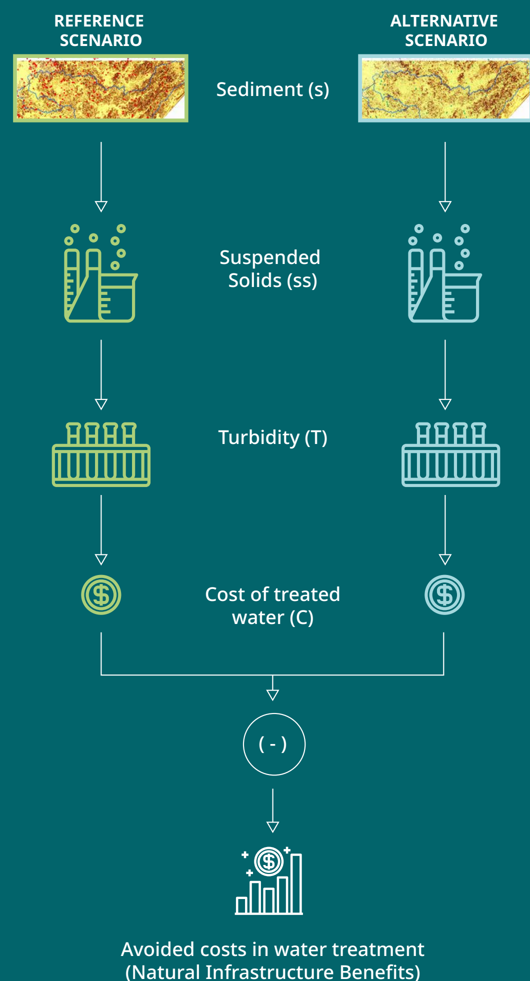
$$T = 0{,}036 * SS^{1{,}326}$$

Where T is the turbidity level (NTU).

The third step is the calculation of the treatment cost according to the turbidity level. The equation was estimated using primary data, provided by SANASA, on average turbidity of treated water, volume of treated water and volume of chemical products used, in monthly values from January 2015 to December 2019, in five water treatment plants (WTP). The prices of chemical products were estimated in electronic trading sessions and the resulting function ($R2=0.79$) was:

$$C = 0{,}059 * T^{0{,}208}$$

Where C is the cost (BRL/m^3) of treated water.



Source: Authors.

The difference in treatment costs between the reference and alternative scenarios is the avoided cost which, multiplied by the volume of treated water, results in the monetary value of the natural infrastructure benefits. Other benefits, such as avoided depreciation and savings in energy consumption, follow the same logic, but, in these cases, the parameters used were the concentrations of suspended solids in linear proportions (see details in Appendices B and C).

COSTS-BENEFIT ANALYSIS OF INVESTMENTS IN NATURAL INFRASTRUCTURE

Large-scale restoration, as described in the R14000 scenario, requires the mobilization of different efforts and initiatives involving river basin committees and consortia, sanitation companies, municipalities, state agencies, rural landowners, companies with environmental compensation liabilities and also public and private investors. This joint and diversified effort is intrinsic to good water resources management practices.

It is important to consider technical constraints when making an investment analysis influenced by the diffuse nature of both costs and benefits of natural infrastructure at the landscape scale. In addition, investors and implementers have different expectations in terms of returns, therefore, it is essential to define the investors' profile and, even if implicit in the discount rate, clearly determine the main beneficiary in order to make the proper distinctions among the expected revenues and any externalities, the project horizon, return expectations, etc.

In other words, it's a matter of business perspective. At the landscape scale, the benefits estimated at BRL 1.7 million per year in the R14000 scenario, due to the decrease in turbidity, can be a positive externality for society and for the sanitation companies, if they are not the ones promoting the restoration. On the other hand, if these companies are the promoters of restoration, rural landowners who assigned or leased land for this purpose would enjoy other benefits, such as increased forest cover to comply with legislation, improved soil protection, expanded pollinator refuge, etc.

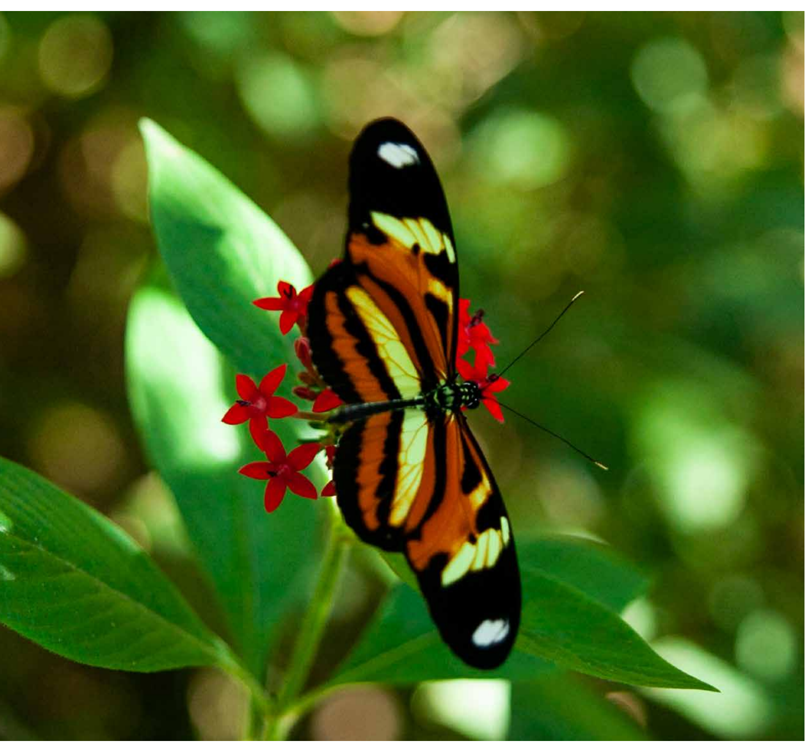
In a typically private compensatory perspective, generally understood as the cost of environmental adaptation, the objective need to restore 800 hectares for the formation of PPA around the reservoirs and compensation for suppression is considered in the R800 scenario. What is not evident in this perspective is that seeking adequacy brings computable benefits. Thus, restoration must be effectively accounted for as an investment, insofar as it can reduce turbidity and water treatment costs, apart from all the co-benefits that natural infrastructure brings in terms of biodiversity conservation and direct protection of water sources. In this context, the implementation of restoration is no longer a cost and is now considered an upfront investment, with the costs corresponding only to the maintenance of natural infrastructure, such as monitoring forest growth (the same amount as the payment for environmental services).

Part of the restoration in the R800 scenario can rely on assisted natural regeneration, understood as the process of isolating the area with potential for spontaneous restoration, provided that it is protected, for example, by fencing. Based on maps of natural regeneration potential (see details in the appendices), it was estimated that one third of the priority areas could be restored by mere fencing, especially among the 373 hectares outside the constitution of PPAs. The expenditures required for each type of restoration were considered according to Table 5.

Table 5 | Expenditures in the implementation and maintenance of natural infrastructure (active and passive forest restoration)

	TOTAL PLANTING (BRL/HA)	ASSISTED NATURAL REGENERATION (BRL/HA)
TOTAL	**16,640**	**9,580**
INVESTMENTS IN FOREST RESTORATION	9,500	3,200
Fencing	3,200	3,200
Soil preparation	1,600	0
Ant and pest control	300	0
Agrochemicals	400	0
Transport of seedlings	50	0
Purchase of seedlings	1,300	0
Labor (including planting)	2,650	0
Transaction costs	1,140	380
LAND USE OPPORTUNITY COSTS	6,000	6,000
Payment for environmental services (PES) – over 20 years	6,000	6,000

Source: Authors.



Considering that forest restoration is implemented over three years, in plots of 300 hectares in the first year, 250 in the second and 250 in the third, and that the opportunity costs of land use and transaction costs are incurred for 20 years after the implementation of each lot, the total costs of implementing natural infrastructure in the R800 scenario would be equivalent to BRL 11.5 million. The gradual growth of the forest and, therefore, the proportional provision of ecosystem services over a 50-year horizon would generate a total avoided cost of around BRL 34.5 million, with an NPV of BRL 335,000 at a discount rate of 5% per year.

NATURAL INFRASTRUCTURE STRATEGIES IN THE STUDY AREA

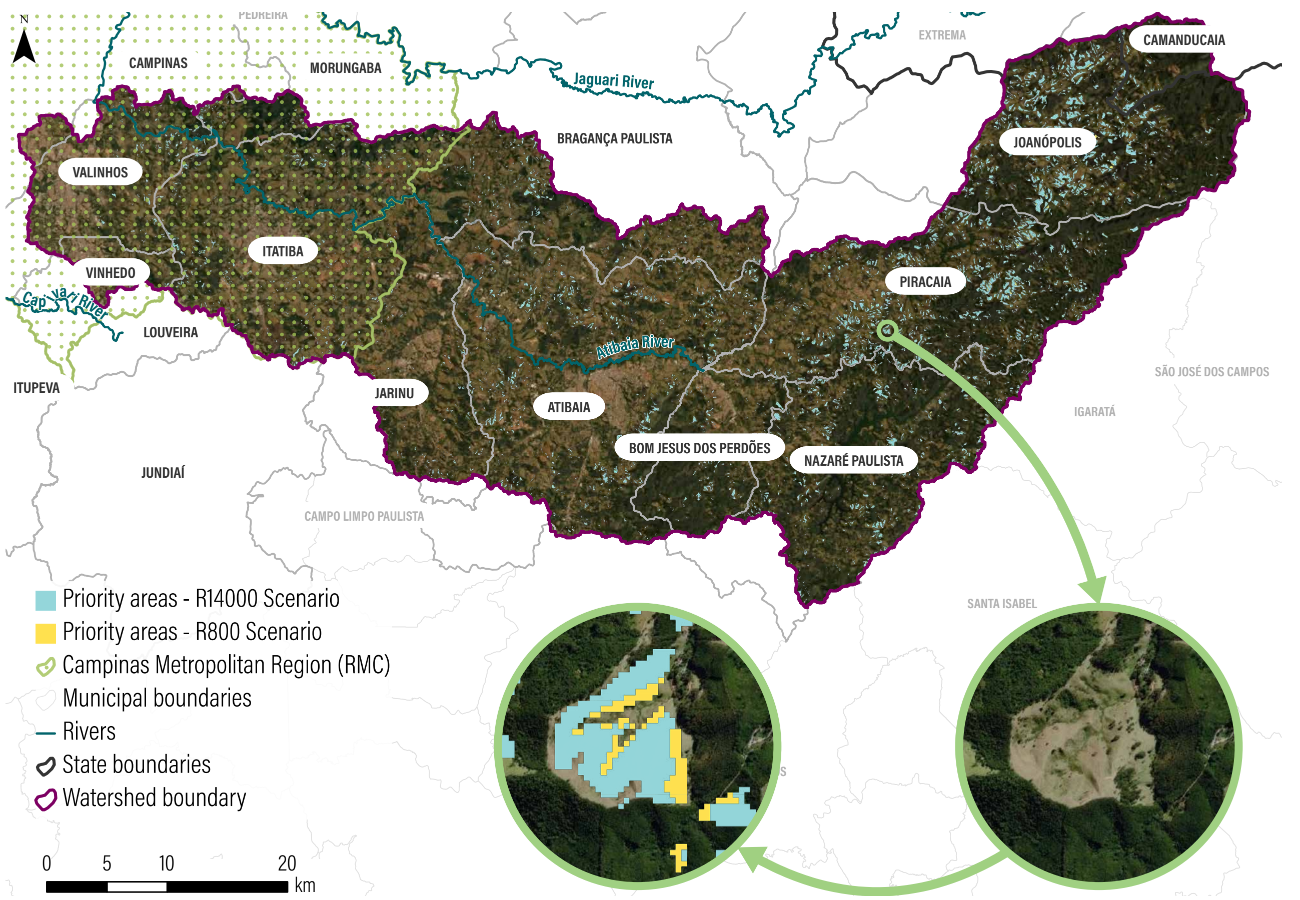
Infrastructure implementation requires investment allied to conventional structure in water management. This chapter presents strategies for implementing the proposed scenarios and the main investment models and sources of funds for their financing

The implementation of the forest restoration scenarios proposed in Chapter 2 are in line with goals assumed by the Brazilian government as part of global commitments aimed at restoring and conserving forests and landscapes, in addition to actions to mitigate climate change. Brazil is a signatory to the Bonn Challenge, a global commitment to bring 350 million hectares of degraded landscapes into restoration by 2030, as well as to the Paris Agreement, which aims to limit the increase in global temperature to 1.5°C by reducing the emission of greenhouse gases. The country is also aligned with regional and local initiatives to restore water sources and springs, structuring biodiversity corridors and protecting sensitive ecosystems.

Alignment with national and regional initiatives is essential, and it is desirable that implementation alternatives also take into account economic feasibility or better cost-effectiveness ratios. Thus, priority areas for forest restoration were identified in each of the scenarios (except for R800, whose PPAs are non-negotiable) with hierarchical prioritization and focus on the most critical portions in terms of sediment production.

These areas are mainly concentrated in the upstream portions, closer to the headwaters of the Atibaia river basin, but are also present along its entire length, which opens up space for articulation and engagement with various local actors and existing initiatives and public policies, depending on their scale and coverage area in the region.

Figure 7 | Priority area identified for scenarios R14000 and R800 shown in detail



Source: Authors.
Note: The scenarios do not consider the Permanent Preservation Areas, mandatory for the second scenario.

CONVERGING EFFORTS IN CAMPINAS AND REGION

Forest restoration is a topic addressed in several territorial planning and organization official instruments, such as Master Plans, Integrated Urban Development Plans and Municipal and State Plans for the Implementation of Green Areas. Thus, the articulation between actors and the communication between initiatives and projects are of fundamental importance to ensure the continuity of technical collaboration, accelerate and scale the implementation of projects and programs for the conservation of biodiversity and the restoration of ecosystems.

In the specific case of Campinas and region, based on the Large-Scale Restoration (R14000) and Reservoir Compensation Restoration (R800) scenarios, the following actions are specifically recommended:

- Align priorities of the Local Biodiversity Strategy and Action Plan of the Campinas Metropolitan Region and the Reconecta RMC program with the restoration scenarios presented in the study;
- Submit the priority areas for restoration, identified in the study, to the public grant programs for the Payments for Environmental Services Program of the PCJ River Basins Committee;
- Connect the results obtained in this study with the restoration actions led by the São Paulo state government, in line with the global environmental agenda.

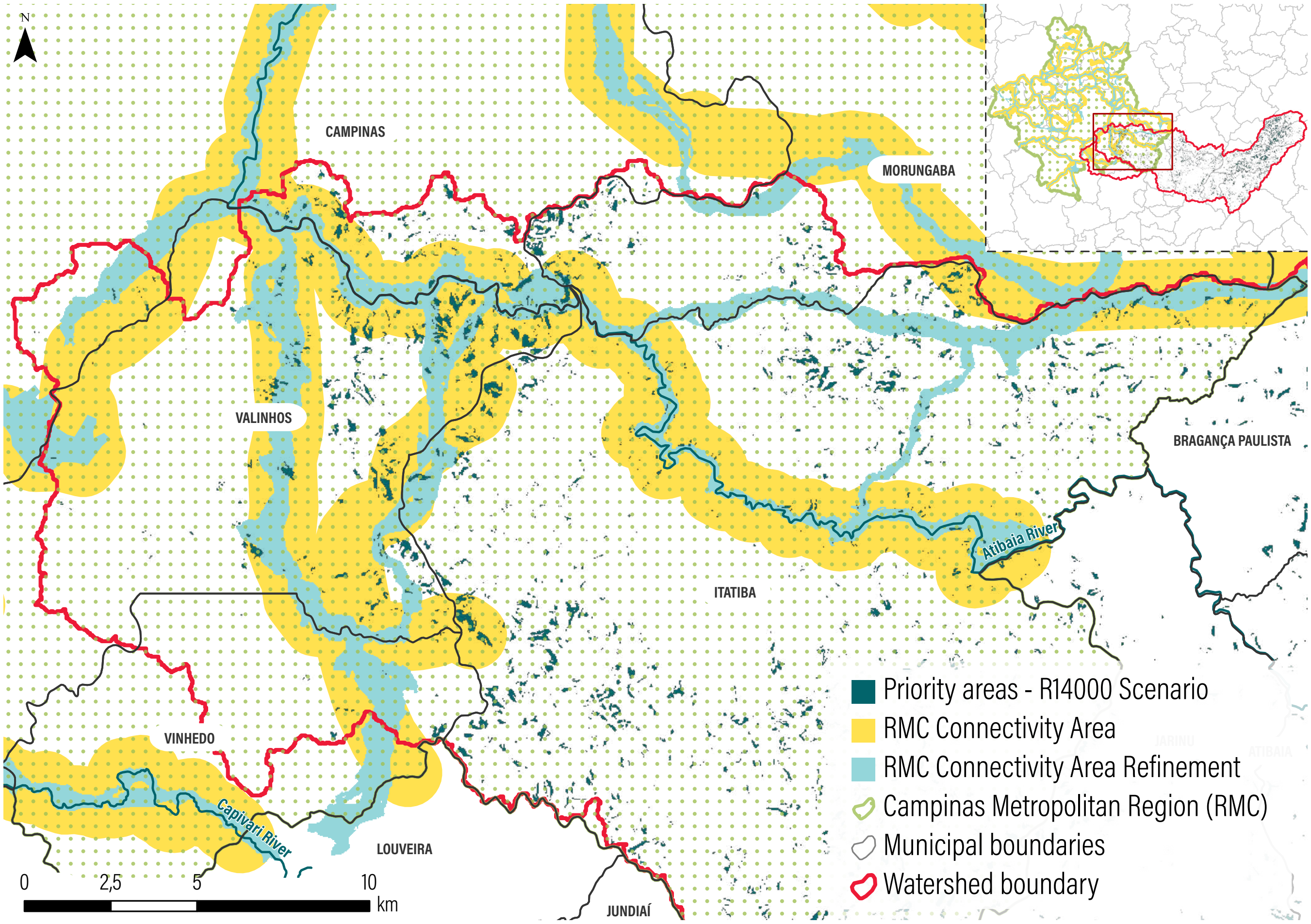
A positive example of intersectoral articulation is the recent effort promoted for the integration of biodiversity actions foreseen in the Reconecta RMC program. SVDS and ICLEI – Local Governments for Sustainability, through the INTERACT-Bio project, spearheaded the development of a map of the connectivity area that guides restoration actions for the reconnection of forest remnants in the region. This effort generated the Local Biodiversity Strategy and Action Plan of the Campinas Metropolitan Region (ICLEI, 2021), which is an important step towards achieving the objectives of these initiatives.

Among the goals of this plan is the incorporation of regional biodiversity guidelines in specific legislation for 100% of the municipalities in the RMC by 2024. And the implementation, by 2030, of 50% (relative number) of the total area (in square kilometers) of the RMC ecological corridors in relation to the baseline of the RMC Connectivity Area mapping carried out by WRI Brasil (WRI Brasil, 2020) –, which includes forest restoration actions. In this sense, it is important to disseminate and share the work developed, communicating contents in a way that is accessible and adapted to the wide range of actors involved, including as a means to support fundraising efforts.

A look at the overlapping of priority areas for restoration, with a focus on water quality, and the design of ecological corridors can generate information that encourages fundraising for implementation, given that the initiatives involve the interest of several organizations. For the case of overlapping areas, the R14000 scenario was considered because of its larger number of overlapping hectares mapped and the environmental benefits of these areas. Assessing the total of 14 thousand hectares for restoration in this scenario, it is possible to see that most of these areas are located in the municipalities upstream of the basin. However, about 1,640 hectares (11% of the total) are in the RMC.

Considering the biodiversity focus foreseen in the action plan and the areas selected in the most ambitious scenario (R14000), there are approximately 130 hectares common to the intended efforts, mostly concentrated in the municipalities of Valinhos (62 hectares), Itatiba (34 hectares) and Campinas (25 hectares). Based on this scenario, interested municipal and regional managers are able to allocate the necessary resources in view of the cost-benefit relationship of the initiatives. Figure 8 illustrates these prioritized areas (in green), as well as the RMC Connectivity Area and its detailing.

Figure 8 | Priority areas for restoration of the R14000 scenario overlapping with the RMC Connectivity Area



Source: Authors.

The joining of efforts by the institutions involved is recommended to integrate actions and projects already in progress, or at least planned or conceived, so that a confluence of projects and actors interested in forest restoration in the region can be achieved.

Further emphasizing the importance of articulation between the main stakeholders, the work of the PCJ River Basins Agency includes instruments for managing water and financial resources through charging for the use of water from rivers under the federal government's domain (Federal PCJ); and rivers governed by the state of São Paulo (State PCJ), in addition to financial compensation resources (royalties) from the hydroelectric sector.

The current PCJ River Basins Plan guides the management of water resources in the period from 2020 to 2035. The plan demonstrates the agency's pioneering spirit from the perspective of preserving its springs and water sources through the technical and managerial robustness contemplated. In the PCJ Committees' Water Sources Policy, Program I address the recovery, conservation and environmental protection of areas of interest and its main highlight is the contribution to the development of the comprehensive rural properties' project (PIP) for application of the Nascentes program in the PCJ river basins. We highlight the pilot project developed in Holambra, responsible for the recovery of 16 hectares of native vegetation around springs and riparian forests in the municipality. The project involved, in addition to the PCJ River Basins Agency and the Nascentes program, Holambra's municipal government, the Secretariat of Agriculture and Supply of the State of São Paulo (SAA), the National Water Agency (ANA) - responsible for the financing of soil management and conservation works – and Fundação Banco do Brasil– which financed ecological restoration interventions.

Program II of the PCJ Committees' Water Sources Policy covers payments for environmental services (PES – PCJ) for projects aimed at the protection and recovery of riparian forests and springs, in addition to the conservation of soils and forest fragments. The program includes actions to carry out ecological restoration and its monitoring based on the allocation of resources arising from the charge for the use of water resources in the PCJ river basins. The program also aims to promote the environmental adequacy of properties through forest restoration of PPA around water springs.

To promote the implementation of the projects, a system of public grant programs has been developed for the municipal governments of the cities where the rural properties are located. The implementation of restoration actions will be followed by the possibility of new public grant programs contemplating environmental services through the maintenance of forested areas. Incorporating the results and data of this study in the definition of the areas to be restored and contemplated by these public grant programs can be one of the ways to implement the scenarios that favor the quality of the water supplied to the municipality of Campinas. An example would be the Florestas do Futuro program, developed by Fundação SOS Mata Atlântica, which selects areas to promote forest restoration in municipalities where the PCJ River Basins Agency operates.

In 2021, the São Paulo state government assumed the commitment to promote the restoration of 1.5 million hectares by 2050, with the Nascentes program included among the efforts mentioned, and performing a prominent role in the territory covered by this study. Through the Project Portfolio, partnerships are established with various entities for the implementation of restoration areas. Therefore, ensuring the continuous involvement of local actors, striving to enhance and coordinate efforts to advance the environmental agenda is essential to address the climate and environmental crises that the world is facing.

Campinas and region are also in the area of operation of initiatives that seek to leverage forest restoration in Brazil. Examples: Atlantic Forest Restoration Pact, which has a commitment to restore 1 million hectares of forests by 2020 and 15 million by 2050, and Conservador da Mantiqueira Program, which supports the creation of local public policies and promotes the necessary conditions for the restoration of the forest landscape in about 1.5 million hectares in the area of influence of Serra da Mantiqueira.

The efforts to implement the scenarios presented in this study are in line with those outlined in the natural infrastructure for water initiative for the Cantareira System (Ozment et al., 2018) and join the actions that aim to improve water quality and assist in water security of large metropolises.

RESOURCE ARRANGEMENTS AND SOURCES

Actual investment in the proposed scenarios involves the development of mechanisms that allow scaled financial flows and the expansion of contributions towards actions aimed at forest restoration for water management in the region. Based on the information gathered within the scope of this study (Appendix A), the following mechanisms were identified as possible enablers of the necessary investments and potential financing sources:

- **Charging of fees for the use of water:** charging for the use of water allows the PCJ River Basin Committees to develop gray infrastructure projects, in addition to forest restoration projects.

Support for projects related to the theme of natural Infrastructure is an expected result of this study. At the same time, SANASA also adds to its social capital proceeds arising from charges for the supply of water to the population of Campinas, funding projects to expand and connect sewage networks and even socio-educational and environmental initiatives aimed at populations in social vulnerability situations.

- **Environmental compensation:** the environmental legislation requires companies that harm the environment to make compensations through the restoration of ecosystems in areas defined by state laws. As presented in the Reservoir Compensation Restoration (R800) scenario, this may be an alternative with the potential to leverage efforts for the implementation of forest restoration with a focus on water management. In addition, the PCJ River Basins Agency receives environmental compensation from the hydroelectric sector, which demonstrates the possibility of relying on this source of funds.
- **Investment in the sanitation sector:** this study presents an additional opportunity for natural infrastructure financing by demonstrating that SANASA can achieve economic benefits by reducing the costs of chemical products used to treat water supplied to Campinas. SANASA's contributions and the sharing of successful experiences in natural infrastructure can leverage and scale investment by companies and sanitation companies in the region's municipalities.
- **Impact investors:** there is a growing concern among investors about quality infrastructures that are more resilient to climate change and, therefore, less vulnerable to idleness or weather events. A poor estimation of the future availability of water resources implies a serious risk of idle operations or an increase in operational costs. Additionally, extreme events greatly affect emergency control and remediation costs, such as those caused by prolonged droughts or torrential rains. Impact investors are interested in infrastructure designed to deal with these contingencies, and which, at the same time, provide positive externalities such as carbon neutrality, biodiversity protection, etc. Such investors conduct evaluations that go beyond conventional rates of return. Natural infrastructure for water is the right investment for this profile of investor and resources managed by Green Bonds.
- **Risk sharing over time:** the combination of different types of investors in natural infrastructure projects is an increasingly common arrangement in the world. Impact investors associated with public investors can assume greater risk attributed to the stages of project implementation, compensating them with higher returns during the consolidation of the provision of ecosystem services, given that natural infrastructures typically appreciate during a project's maturation while conventional infrastructures depreciate. Thus, the risk premium is compensated by the appreciation rates.
- **Payment for Environmental Services:** currently in Brazil, there are two PES initiatives focused on water management that are references in this sector: the Reflorestar program, led by the Espírito Santo state government, and the Conservador das Águas project, in the municipality of Extrema (MG). The knowledge generated by these experiences underpins the incentive to PES actions in the area covered by this study. In Campinas, the PES program is managed by SVDS, while at the regional level, there is a PES plan developed by the PCJ River Basins Agency, through partnerships with municipalities via public grant programs. Both aim at the environmental compliance of properties in spring areas. It is understood that the present study has the potential to expand the performance of the mentioned programs in the territory by demonstrating the benefits that such actions can bring to the region of influence, especially if efforts are distributed among the responsible institutions.
- **São Paulo state's environmental tax (ICMS ambiental paulista):** launched in March 2021, the new environmental tax levied by the state of São Paulo was responsible for promoting

direct changes in the transfer of funds to municipalities, earmarked for the environment. Today, 25% of the total ICMS tax collected is transferred to municipalities, and a change was made to the portion of this transfer earmarked for environmental actions, from 1% to 2%, in a staggered adjustment until 2024. The measure allows smaller municipalities to receive a greater amount of funds for the preservation, conservation and recovery of their natural areas, which could be beneficial for the implementation of the scenarios of this study in smaller municipalities in the Campinas region.

As mentioned in the previous section, the overlapping of priority areas for forest restoration, aiming at the management of water resources, has immense potential to leverage fundraising for implementation of natural infrastructure, as it involves the interest of several organizations and generates benefits for all the parties involved.

BOX 3 | CO-BENEFITS OF WATER INFRASTRUCTURE

This study is focused on assessing the benefits of sediment management obtained from forest restoration for water management, as the lack of land management, especially of degraded pastures, is the main source of sediment pollution. Other types of management, such as forest conservation, agroforestry systems, silvopastoral systems or the management of natural areas can also contribute to this and other objectives. Regarding the water management aspect, the main focus of this study, the implementation of forest restoration actions has a direct impact on the protection of available water resources, especially springs and catchment areas for water supply, promoting better quality of available water, in addition to providing protection for soils that are vulnerable to erosion.

Although not detailed or measured in this study, there are potential co-benefits of forest restoration for water management that can contribute to the adaptation to climate change and mitigation of its effects, such as food production, income generation, recreation and leisure, carbon sequestration and disaster risk reduction.

One of the main impacts is the preservation of fauna and flora in the landscape, protecting local biodiversity. Linked to this and adding to the environmental benefits, soil conservation and increased vegetation cover can promote socioeconomic impacts, such as job creation related to the provision of forest products, which fosters a local and circular economy. Planted forests can generate income for rural producers, recover the soil, in addition to providing products such as wood from native species, fruits, oils and seeds, and reduce the deforestation and extraction pressure suffered by native forests intended for conservation and preservation.

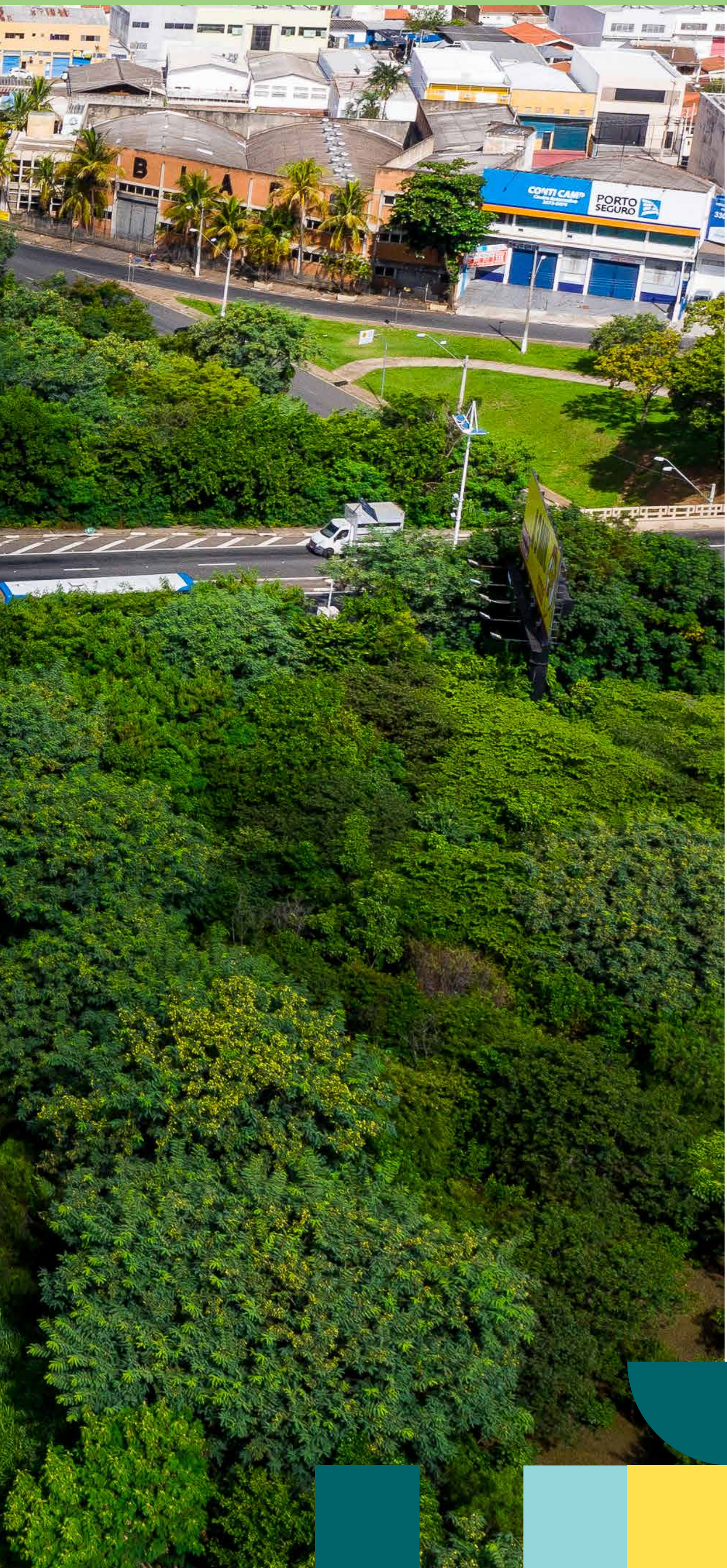
The promotion of sustainable agricultural production, such as the dissemination of agroforestry systems (AFS), brings improvements to water quality and availability, reducing the addition of pesticides and chemical fertilizers to the soil and, consequently, to the water.

The restoration of the ecological function of degraded areas, in addition to increasing land productivity, can contribute to fire prevention and the removal of carbon from the atmosphere, which leads to improved air quality and mitigation of high temperatures.

The possible types of management, as well as their location, are determined in accordance with the intended benefits and, when measured, have the potential to improve the cost-benefit ratio of the allocated investments.

It is also worth noting that the positive economic impacts promoted by the investment in natural infrastructure for water management carried out by SANASA, as described in the scenarios in Chapter 2, arising from the lower use of chemical products, generate savings that can be converted into investments on additional natural infrastructure or other sanitation structures. Moreover, natural infrastructure leads to the distribution of water with lower concentrations of chemicals, which directly benefits the population’s health.

CONCLUSIONS



The data and assessments described in this study demonstrate how natural infrastructure is an important approach in the recovery of springs and improvement of water quality for the municipality of Campinas and region, which requires a joint action strategy for its implementation.

This study presents the financial assessment for investments in nature, which protect and complement the water supply system of Campinas and region, inserted in the Atibaia and Capivari river basins. The study is concentrated on the analysis of the benefits arising from natural infrastructure (increase in forest areas) for water management.

These contributions add to the growing and increasingly compelling evidence that natural infrastructure can be a powerful tool for water management. The value proposition of natural infrastructure for water is currently focused on the assessment of two potential benefits of forest restoration: reduced water treatment costs and improved water turbidity. In the future, sediment control and water treatment costs, as well as regulating water rhythm and flows in relation to climate change, are expected to play an even more prominent role in water management.

Some of the elements highlighted in this report help to achieve these goals:

- Promote technical support for decision makers regarding the management of water resources, demonstrating the importance of the role of natural infrastructure in the achievement of goals related to sediment pollution and water availability;
- Guide the refinement of natural infrastructure strategies to deliver results with efficiency, prioritization and scale;
- Emphasize the permanent need for research and local data collection;
- Provide a new framework to promote dialogue and partnerships that lead to win-win opportunities for the water sector and natural infrastructure programs; and
- Support the mobilization of financial resources and investors for the implementation of the proposed natural infrastructure scenarios.

The application of the proposed methodology and the analysis of results relied on primary data provided by SANASA on the volume of treated water and the volume of chemical products used in water treatment in the city of Campinas and region, strengthening the economic analyses. The results bring new perspectives to mobilize environmental restoration projects by recognizing the benefits of natural infrastructure, especially in terms of avoided costs.

Although the region requires large-scale restoration efforts, due to the level of landscape degradation and the intense demand for increasingly scarce water resources, this study shows that initiatives focused on sediment retention and water improvement bring important benefits, and are also economically viable.

The broader scenarios, which foresee the restoration of 800 and 14 thousand hectares, demand the confluence of different stakeholders as a strategic condition for their implementation. Throughout the study, it becomes clear that the expansion of technical-scientific knowledge about natural infrastructure and the joining of efforts among actors and stakeholders are essential to increase the scale of investments. The overlapping of areas presented in this study shows the possibility of joining efforts between the initiatives underway in the territory, which also scales up investments.

Many restoration projects have goals that are not related to any economic valuation, such as those intended for wildlife shelter, ecological corridors, leisure or thermal comfort. These are generally considered non-refundable projects because they do not generate monetized benefits. This study strengthens the logic of restoration projects such as those mentioned and takes an important step forward by demonstrating that it is possible to identify and recognize avoided cost services provided by restoration, an important argument to be added to the ecological and social justifications for increasing natural infrastructure. In addition, other restoration scenarios, such as compliance with the Forest Code, must be considered to assess the economic and environmental gains in the management of water resources.

The incorporation of the scenarios presented in this report is not limited to economic gains related to avoided costs with water treatment. Further studies may examine additional green and gray infrastructure scenarios and benefits to further strengthen the business model.

Thus, the main approaches to achieving benefits from natural infrastructure are listed below.

- **Expanded natural infrastructure practices.** Natural infrastructure can take many forms, such as AFS, forestry or even good agricultural practices (GAP) – improved pasture or sustainable pasture management, terracing in contour lines, rainwater infiltration basins, adequacy of rural roads with water destination, among others. These expanded practices should be selected based on their relevance in the production of natural infrastructure benefits, as well as their feasibility and compliance with guidelines for land use and occupation.
- **Natural infrastructure to increase water availability in periods of drought or water crises.** Although scientific reports are not yet sufficient to determine whether restoration in the Atlantic Forest can increase water availability in the short term, the benefits of natural infrastructure over the long-term can already be captured (Gartner et al., 2013) and used to assess the water security of landscapes. This fact is essentially important in view of the concern with scenarios similar to that of a new water crisis in the state (Agritempo, 2021), as previously pointed out. The study on natural infrastructure developed for the Cantareira System, in 2018, pointed out, for example, that an 8% increase in forest cover would lead to a 36% reduction in sediment export and bring a 28% return on investment to water infrastructure management over 30 years (Ozment et al., 2018).
- **Increase in agricultural productivity and income generation.** Income generation opportunities and profitability of forest restoration could be further studied, tested,

reported and incorporated into the program's outlining and evaluation. Investments in natural infrastructure may be designed to increase pasture productivity and farmers' net income through crop-livestock-forest integration, also including agroforestry or silvopastoral systems.

- **Promotion of public policies that integrate natural infrastructure agendas and instruments of the National Water Resources Policy.** Natural infrastructure is an efficient instrument that meets, through planting and forest conservation actions alone, several demands of landscape planning and management, such as adequacy and compliance with the Forest Code, Economic-Ecological Zoning and watersheds planning.
- **Engagement of different funding sources interested in the benefits of the topic addressed by the study.** The development of a transversal narrative focused on the management of water resources, basic sanitation, conservation of springs and recovery of degraded areas can provide an important tool for prospecting partnerships, creating the possibility of engaging different investors and, consequently, scaling the implementation of actions related to the natural infrastructure, climate change, mitigation and adaptation agendas, in addition to the provision of ecosystem services.

In addition to supporting the local decisions of water resource managers, the assessments presented provide the best data and methods available to facilitate the natural infrastructure investment analysis (GGA/WRI) in Brazil and worldwide. This study serves as the basis for an in-depth analysis of the financial performance of the use of natural infrastructure for water. The information and approaches presented can be applied to the RMC as new data become available or can be used to assess the role of natural infrastructure in the achievement of other water management goals, and could become a successful investment case on the theme, inspiring other municipalities and Brazilian metropolitan regions to replicate the practices.

NOTES

1. INTERACT-Bio – The INTERACT-Bio project aims to integrate biodiversity and ecosystem services into urban planning, territorial management and urban infrastructure projects. Implemented by ICLEI – Local Governments for Sustainability, the project was carried out in Brazil, India and Tanzania. INTERACT-Bio is funded by the German Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) through the International Climate Initiative (IKI). In Brazil, the project is implemented in the metropolitan regions of Campinas, Belo Horizonte and Londrina. For more information: https://cbc.iclei.org/INTERACT-Bio-portuguese/
2. Cities4Forests – Cities4Forests is a global network of cities that seeks to integrate inner, nearby and faraway forests into municipal master plans and development programs. For more information: https://wribrasil.org.br/pt/o-que-fazemos/projetos/cities4forests
3. Local Biodiversity Strategy and Action Plan of the Campinas Metropolitan Region presents a guide for articulated actions between the municipalities that make up the RMC, aiming at the promotion of initiatives focused on biodiversity conservation, maintenance of ecological processes, provision of ecosystems services and landscape recovery. Available in full at the link: https://americadosul.iclei.org/documentos/plano-de-acao-para-implementacao-da-area-de-conectividade-da-rmc/
4. Reconecta RMC – The Reconecta RMC program aims to establish mutual cooperation between the municipalities that make up the RMC for actions focused on the recovery and conservation of fauna and flora, especially with regard to the exchange of technical knowledge and the conduction of actions related to this goal. Available in full at the link: https://novo.campinas.sp.gov.br/secretaria/verde-meio-ambiente-e-desenvolvimento-sustentavel/pagina/reconecta-rmc
5. NTU – The water turbidity monitoring unit is expressed in nephelometric turbidity units (NTU). For more details, please see Appendix B
6. Reservation – Technical term used by water supply companies to refer to water available in reservoirs.

APPENDICES

APPENDIX A. METHODOLOGY FOR STAKEHOLDER CONSULTATION AND DEVELOPMENT OF INVESTMENT ASSUMPTIONS AND PORTFOLIOS (GGA/WRI STEPS 1 AND 2)

This appendix explains the method and data sources of the first stage of the GGA/WRI methodology, presented in Chapter 2. Since 2017, ICLEI – Local Governments for Sustainability has been responsible for the development of the INTERACT-Bio project, designed to improve the use and management of natural resources in the RMC. The interest in developing this study arose from SANASA's contact with WRI Brasil, in January 2019, initially focusing on the analysis of natural infrastructure for water as a complementary strategy to guarantee quality and volume in water supply. From this point onward, a series of convergent actions, such as the adhesion of the municipality of Campinas to the Cities4Forests initiative, allowed the advancement of discussions, with events and online meetings about natural infrastructure for water taking place, with participation of various actors in the territory (municipalities, universities, the prosecutor's office of the state of São Paulo, etc.).

The mapping of actors and stakeholders was assessed throughout 2020 to identify the institutional relationships within the coverage area and the main investments announced and implemented in the municipalities belonging to this area.

The first step was the listing of the main institutions, from the public and private sectors and civil society, as well as associations and interest groups for the coverage area defined for the study. The main actors identified for the development of a natural infrastructure strategy for the region were: Agemcamp (Campinas's metropolitan agency), Fundocamp (Campinas's metropolitan region development fund), PCJ Committees; SANASA, Iniciativa Verde, Nascentes program and the Conservador da Mantiqueira program.

The second stage involved an analysis of announced, ongoing and committed projects, available for contracting or even canceled investments. The mapping comprised the main areas of operation, with investments in the following themes: forest restoration, water collection, distribution and supply, in addition to basic sanitation.

The actions and projects identified were organized into a matrix of municipalities and projects, which consider the area defined for restoration, including information on laws and/or deliberations related to the actions and the estimated investment amount, in order to understand the nature of investments and what has been applied in Campinas and region. From this diagnosis, inputs were provided for territory contextualization.

Among the data collected on forest restoration, the projects developed within the scope of the Nascentes program, spearheaded by the São Paulo state government with the aim of promoting ecological restoration in priority areas, aiming at the protection and conservation of water resources and biodiversity, stand out. The program has a large number of projects, already committed and available for contracting, and supported by partners who work on the elaboration and development of these projects.

SANASA is responsible for actions that range from infrastructure works – such as the installation of sewage networks and connections in socio-economically vulnerable territories, with projects linked to the financing of works – to awareness programs aimed at ensuring access to drinking water, such as the Sustainable Action Program (PAS).

However, in this work, the main source of funds and initiatives related to the addressed themes is linked to the PCJ Committees, responsible for financing projects and establishing indicators for contracting, ranging from royalties and compensation to the participation of funds, such as FEHIDRO (State Fund for Water Resources), linked to the Secretariat of Infrastructure and the Environment of the State of São Paulo, in addition to funds from the collection of the State PCJ and Federal PCJ. Within the scope of this study, deliberations of the PCJ Committees between 2011 and 2019 were analyzed.

In its entirety, the map of initiatives identified 281 projects in all PCJ Basins, covering the municipalities present in the area of the five sub-basins that supply the RMC: Jaguari, Atibaia, Ribeirão Quilombo, Capivari and Capivari-Mirim. Of the 72 municipalities, only 17 did not have any ongoing projects or activities during the survey, within the defined period of 10 years (from 2011 to 2019).

Based on the mapping of initiatives, sources of funds and mechanisms present in Campinas and region, consultations were carried out to ensure the involvement of interested parties in the definition of this study's parameters, and also in the outlining of strategies for the implementation of opportunities for restoration linked to the natural infrastructure for water agenda. Such consultations took place between January 2020 and April 2021, at online events and meetings due to the Covid-19 pandemic.

APPENDIX B. METHODS AND ASSUMPTIONS FOR BIOPHYSICAL MODELS AND MAPPING COMPONENTS (GGA/WRI STEP 3)

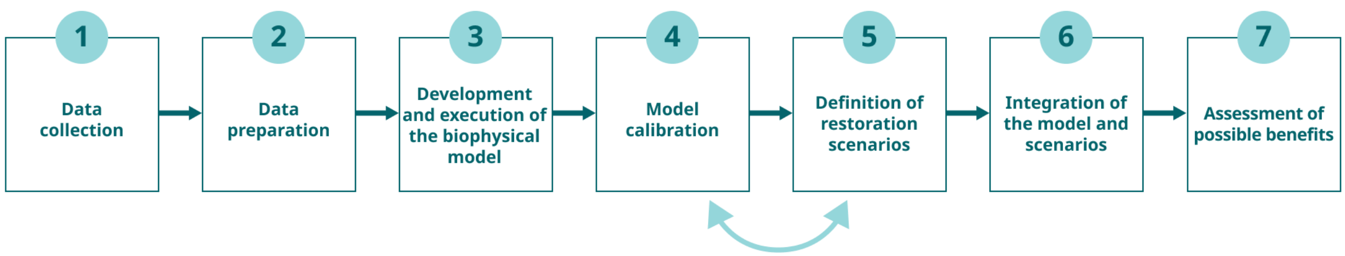
General flowchart for the execution of biophysical models

The GGA/WRI methodology encompasses several steps to estimate the potential impact on water quality. The overall flowchart in Figure B1 shows the steps required for this analysis.

Step 1 – Data collection
Collection of input data necessary to run the biophysical model, namely: Land Use/Land Cover (LULC), precipitation, soil and elevation map (Shuttle Radar Topographic Mission - SRTM).

Step 2 – Data preparation
When preparing the input data, it is necessary to adjust it to the same image size and project it to the same coordinate system. Vector layer attributes and biophysical table parameters must be standardized.

Figure B1 | General flowchart of the analysis of restoration scenarios for the Atibaia-Capivari Green and Gray Infrastructure Assessment



Source: Authors.

Step 3 – Development and execution of the biophysical model
Execution of the Sediment Delivery Ratio (SDR) using the data prepared and organized in the previous step, with default parameters.

Step 4 – Model calibration
Calibration is a necessary step to adjust the result generated by the biophysical model to the actual observed data.

Step 5 – Definition of restoration scenarios
The restoration goal is based on the chart of exported sediments versus available area to be restored.

Step 6 – Integration of the model and scenarios
The current LULC layer is replaced by the LULC restoration scenario in order to estimate the possible sediment reduction if the region is restored.

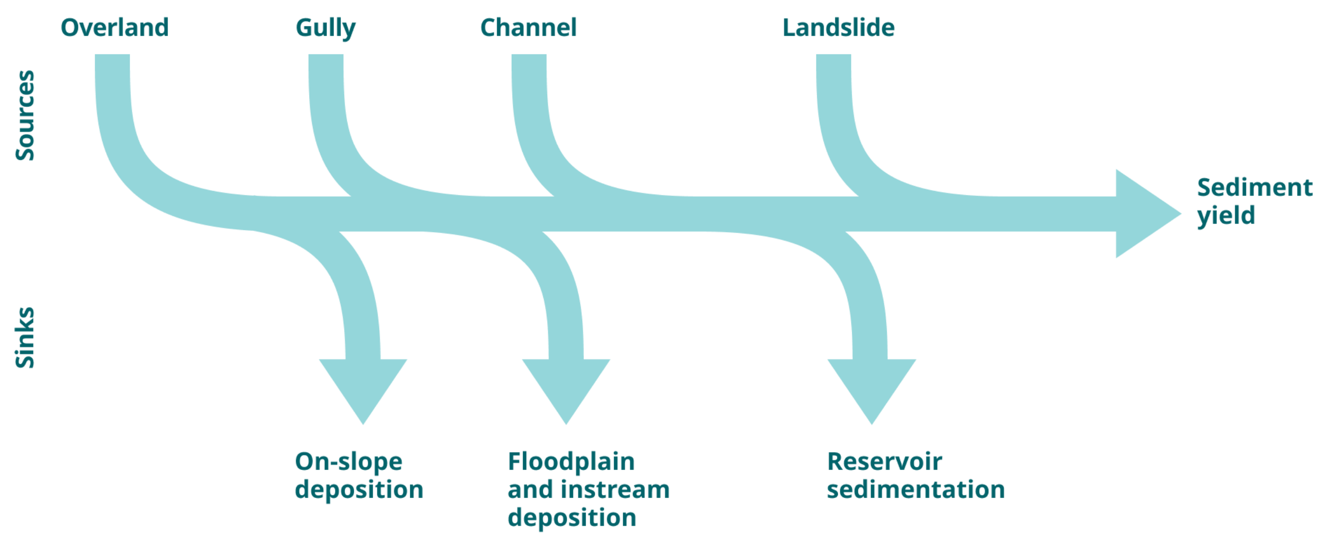
Step 7 – Assessment of possible benefits
The restoration scenario is compared to the current LULC in order to estimate the possible reduction in sediment export.

Sediment modeling

To identify the hectares to be restored with the greatest potential for sediment reduction and to estimate the general impacts of this reduction with natural infrastructure, the SDR was used, considering the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) 3.9.0 model developed by the Natural Capital Project (Sharp et al., 2020). This model generates a spatially explicit result that quantifies the sediment export potential in the region. Thus, several spatial scenarios of baseline and future land cover were created and the impacts on yield and sediment retention of these scenarios were also modeled.

The SDR function estimates the amount of terrestrial sediments transferred to water courses (Figure B2). There are several potential sources of sediment generation, but the SDR tool only estimates the terrestrial source.

Figure B2 | Layout of the SDR function



Source: Sharp et al. (2020).

The SDR is based on the Universal Soil Loss Equation (USLE), initially proposed by Wischemeier and Mannering (1969). The model estimates soil loss according to biophysical attributes of the assessed region, including: rainfall pattern, soil type, topography, cultivation system and land management practices. The equation is given by the following formulas (Stone and Hilborn, 2012):

$$A = R \times K \times LS \times C \times P$$

Where:

- **A** is the total estimate of soil loss per hectare per year.
- **R** is the rainfall erosivity index, based on monthly rainfall and runoff factor; erosion potential increases with greater intensity and duration of storms.
- **K** represents the soil erodibility index, that is, the potential for soil particles to detach and be transported by rain and runoff. This factor is directly associated with the texture of the soil, although the structure, matter and permeability of the soil can also influence it.
- **LS** is the length and slope factor of the area; steep and long terrain tend to increase the risk of erosion.

- **C** is the crop/vegetation coverage factor; it shows the relative effectiveness of soil/crop management systems in preventing erosion.
- **P** represents the factor of practices favorable to soil management, if there is any type of practice that reduces the amount and rate of water runoff and, consequently, erosion.

Most biophysical factors cannot be controlled, including rainfall pattern, soil type and relief. The land use and land cover classes are the factors that can be changed with the substitution of the land cover type (**C** factor) or the land management practice (**P** factor). Thus, scenarios of land cover change from pasture to forest are evaluated in terms of estimated soil loss based on the difference between the current LULC and its potential restoration scenario. Table B1 presents details on land cover in the area covered by the Atibaia river basin and in the rest of the RMC. Table B2 presents, more specifically, the estimates of pasture area, according to the degree of degradation.

Table B1 | Land cover pattern in the Atibaia river basin area and in the rest of the RMC

CLASSES OF LAND USE AND LAND COVER	AREA IN THE ATIBAIA RIVER BASIN (HA)	AREA IN THE RMC (HA)	TOTAL AREA (HA)
Rocky outcrop	163.98	503.64	667.62
Water mass	3,626.10	4,149.81	7,775.91
Wet area	80.82	523.17	603.99
Built area	29,965.23	73,115.82	103,081.05
Agricultural cultivation - Coffee	453.96	212.76	666.72
Natural field	12,461.67	20,493.63	32,955.30
Agricultural cultivation - Sugarcane	395.91	47,980.44	48,376.35
Agricultural cultivation - Banana	441.72	11,954.52	12,396.24
Agricultural cultivation - Other temporary crops	2,490.84	4,548.33	7,039.17
Native forest	76,047.21	35,748.81	111,796.02
Mineral extraction	43.47	401.58	445.05
Others	7,155.90	6,846.03	14,001.93
Pasture	69,135.93	73,467.90	142,603.83
Reforestation	19,284.39	6,650.82	25,935.21
Exposed soil	5,520.24	28,842.12	34,362.36
TOTAL	**227,267.37**	**315,439.38**	**542,706.75**

Source: PCJ River Basins Agency (2018).

Table B2 | Degree of pasture degradation in the soil cover pattern in each region of the Atibaia-Capivari basin

DEGREE OF DEGRADATION OF PASTURES	AREA (HA)
Not degraded	44,518
Slight	16,234
Moderate	9,100
High	4,936
TOTAL	**74,788**

Source: LAPIG (2021).

Model inputs (data and assumptions)

The sources of data used in the sediment model are described in Table B3, while Table B4 presents the USLE crop/vegetation management factor for each of the land use/land cover classes mapped in the region. Factor **C** values were assigned according to Wischmeier and Mannering (1969). Thus, the process of assigning different land use/land cover classes combined the following criteria:

1. Predominant vegetation type (herbs, shrubs or trees);

2. Estimated percentage of land cover (25%, 50% and 75%);

3. Type of dominant plant in the understory (grass or weed); and

4. Amount of exposed soil (no understory cover) (20%, 40%, 60%, 80%, 90% or more).

These parameters were evaluated for each LULC class considering their characteristics. The **C** factor was assigned from a combination of the parameters.

Table B3 | Summary of data input, description required to run the sediment model, and research source

INPUT	DESCRIPTION	FONTE
Rainfall erosivity index (R)	GIS raster dataset, with an erosivity index value for each cell with a spatial resolution of 1 km. This variable de-pends on the intensity and duration of rainfall in the study area.	Fick and Hijmans (2017)
Soil erodibility index (K)	Soil erodibility value according to different soil types. This measure corresponds to the susceptibility of soil particles to detachment and subsequent transport by rain and runoff. The original data is in vector format and has been converted to raster format, adjusted to a spatial resolution of 30 m.	Oliveira et al. (1999)
Digital Elevation Model (DEM)	GIS raster dataset, with an elevation value for each cell with a spatial resolution of 30 m. The final raster layer was generated using the contour line interpolation pro-cess mapped to the coverage region.	PCJ River Basins Agency (2018)
Land Use/Land Cover (LULC)	GIS raster dataset, with an integer LULC code for each cell. The original data is in vector format and has been converted and resampled to a spatial resolution of 30 m.	Based on photointer-pretation of orthopho-tos from 2012 (PCJ River Basins Agency, 2018)
Biophysical table	Table (.csv) containing model information corresponding to each of the land use classes. It includes a land cover management factor (C) and a favorable-practices factor (P).	Adapted from Wischmeier and Mannering (1969); see Table B4 on the next page

Source: Authors.

Table B4 | Input biophysical data for C and P factors required by USLE

LAND USE / LAND COVER	CODE	C FACTOR	P FACTOR
Native forest	10	0.009	1
Wet area	3	0.003	1
Natural field	6	0.082	1
Agricultural cultivation - Coffee	5	0.21	1
Others	12	0.1384	1
Rocky outcrop	1	0.0001	1
Pasture	13	0.042	1
Water mass	2	0.0001	1
Agricultural cultivation - Other temporary crops	9	0.2	1
Mineral extraction	11	0.45	1
Agricultural cultivation - Other permanent crops	140	0.21	1
Agricultural cultivation - Sugarcane	7	0.1	1
Built area	4	0.0001	1
Reforestation	14	0.17	1
Agricultural cultivation - Banana	8	0.17	1
Exposed soil	15	0.45	1

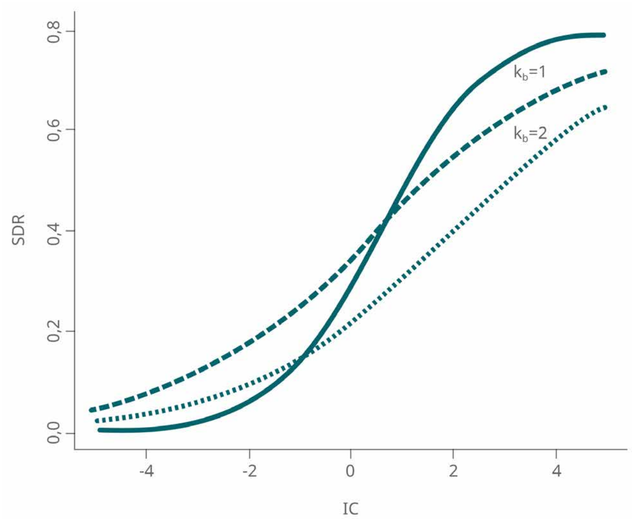
Source: Developed by the authors, adapted from Wischmeier and Mannering (1969).
Note: The *C* factor corresponds to the type of land use/land cover and the *P* factor to the type of soil management to avoid the generation of sediments.

Model calibration

As the USLE is a general equation applied globally, some local factors can be adjusted based on new observations. Thus, the result will be closer to the actual observed data. In many cases, the monitored parameter is the turbidity of water expressed in NTU (nephelometric turbidity units). NTU is basically the optical property of water regarding the absorption and reflection of light; a higher value for turbidity represents greater light dispersion due to the presence of sediments or other elements. As the result of the biophysical model is expressed in sediment tons per year, it is necessary to convert the NTU into suspended sediment values (for more details on this conversion, see the item *Water treatment costs due to the turbidity level*, in the section *Avoided costs in water treatment*, in Appendix C.

The SDR function allows the user to calibrate four variables (Figure B3) (Sharp et al., 2020).

Figure B3 | Adjustable variables in the SDR model



Source: Sharp et al. (2020).
Note: The SDR is the sediment delivery ratio, while the IC is the connectivity index. The curves represent the relationship between the SDR and the IC when different values are applied.

Thus, the following variables are available for calibration in the SDR model (Sharp et al., 2020):

- Maximum SDR: Maximum SDR ratio that a pixel can achieve; fraction of topsoil particles finer than coarse sand (< 1 mm);
- IC_0 and k_b parameters: define the relationship between the connectivity index and the sediment delivery ratio (SDR) (Figure B3); and
- Threshold flow accumulation (TFA): creates the potential flow network in the study region. The configuration value varies by region; the result needs to be compared to the actual flow network. Larger values tend to map a flow network with fewer tributaries, while small values correspond to a network with more tributaries.

The calibration processes compare the NTU value converted into exported sediments and the output data from the biophysical model, generating the following outputs (Sharp et al., 2020):

- USLE: potential soil loss in the region (tons/pixel);
- Sediment export: total sediments exported from each pixel that reaches the watercourse (tons/pixel); and
- Sediment retention index: benchmark that verifies if all types of LULC are converted into exposed soil. The amount of sediment should be interpreted as a relative value (tons/pixel).

After initial tests using the input data, the estimated sediment export continued to be higher than expected. The following additional steps were taken in this study:

- Regrouping the original land use/land cover map into a small group of classes based on similar land use/land cover conditions;
- Assigning values to *C* factor (land use/land cover) of the USLE model according to the entries in Table B2; and
- Execution of the SDR model testing different parameters.

The scarcity of field data is a frequent issue in assessing the amount of sediment transported to water courses in certain regions. This was not the case in this study. The availability of data collected in the field by SANASA at its catchment points, especially at the Atibaia river, allowed InVEST's calibration parameters to be properly adjusted, taking the data actually observed as a reference. The parameters used were TFA = 50; k_0 = 0.51; IC_0 = 1.17 and SDR_{max} = 0.8 for the Atibaia river catchment point, based on the reference values determined with the NTU value.

Spatial land cover scenarios used to define investment portfolios

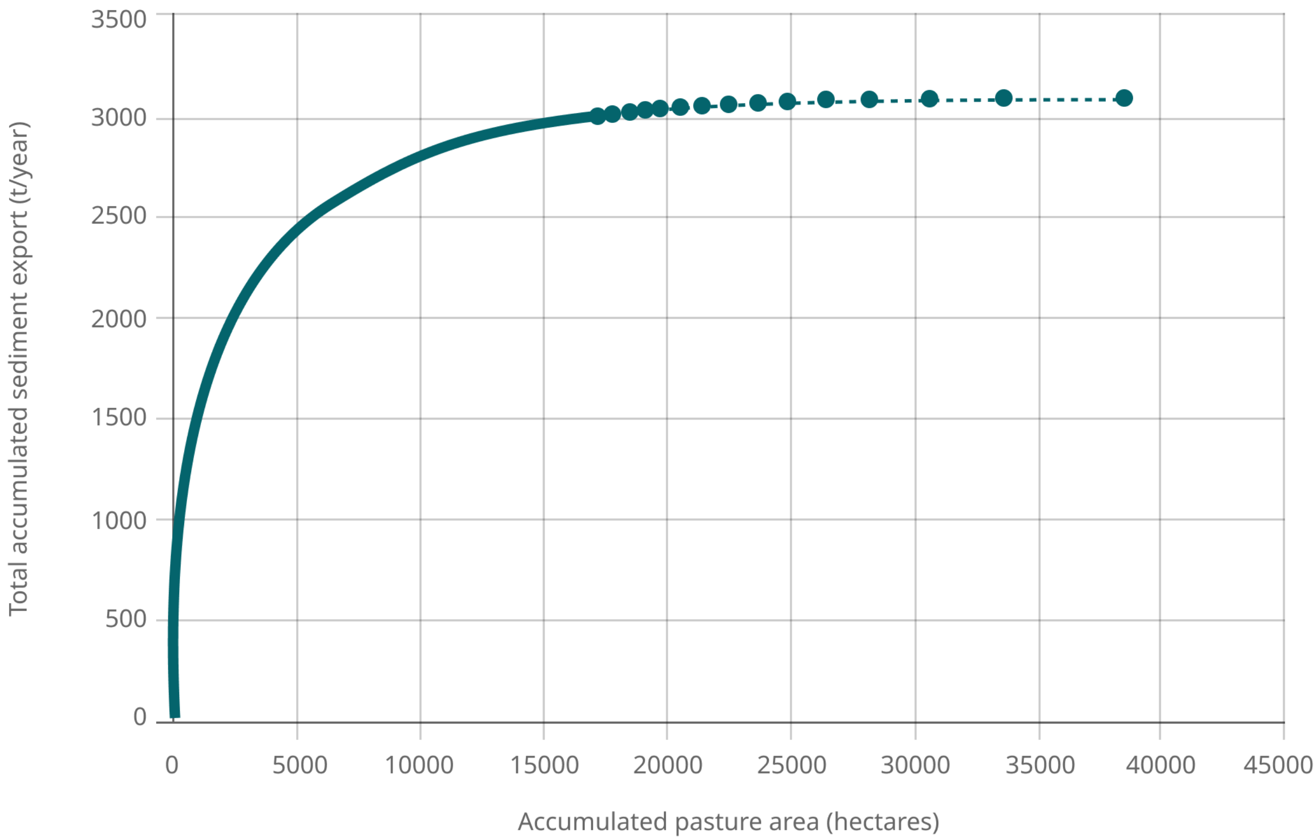
It is assumed that forest restoration would be implemented predominantly in pastures. Thus, the current sediment export surface layer was filtered to the pasture class. The attribute table of this layer contains, for each row, the estimated amount of sediment exported and the number of pixels for that value.

Then, this table was organized containing high values of sediment export. Two fields are added to the table, which will calculate the accumulated values of exported sediments and their respective area. The result of this step is the chart shown in

Figure B4; the y-axis is the accumulated amount of exported sediment, while the x-axis is the accumulated pasture area. The chart allows, for example, the identification of the optimal point based on the sediment yield chart in the region. This point maximizes sediment reduction in the smallest possible number of hectares.

The restoration objectives were established taking these results as a reference, but also considering existing opportunities, such as compensation for reservoir constructions, and the total area covered by severely degraded pastures in the region.

Figure B4 | Cumulative sediment export in the Atibaia river basin



Source: Authors.
Note: the chart shows a potential accumulated sediment export per accumulated pasture area in the analyzed basin, with each point representing the total accumulated pasture (x-axis) and the estimated total sediment exported (y-axis). Each hectare was ranked based on its potential to contribute to a reduction in sediment production. The first point represented (in the lower left corner of the chart) has the highest sediment retention (about 2.5 t/year), while the last point represented in the chart has the lowest sediment retention potential.

Spatial modeling for the application of GGA/WRI

The optimization curve allows the identification of the minimum area to be restored to maximize sediment retention (Figure B4). This curve combines the sediment export estimate with the areas eligible for restoration (in this case, only pastures).

The LegalGeo tool (Oakleaf et al., 2017) was used to select the possible restoration areas in each scenario. The tool selects the eligible areas (pixels) with the highest sediment export value until the area that meets the restoration objective is reached in each scenario.

The InVEST results were translated into annual avoided sediment values, using the method and assumptions detailed by Ozment et al. (2018). Given that the restoration schedule takes place over three years and provides costs and benefits over a 20-year period, total erosion control is a function of the area restored, the age of restoration and the percentage of erosion control observed each year.

Uncertainty

Uncertainty sources can be associated with various factors such as input data, lack of actual data and model calibration and limitations. In the studied region, monitoring of sediment yield is scarce, which may affect calibration. Ozment et al. (2018) performed a similar analysis in an area close to the city of São Paulo, presenting sources of uncertainty that could affect our main results and the relative difference between the scenarios.

Literature review is an important primary source of information. Although some useful references were found, the scarcity of data is still a limitation to obtain more consistent and robust results. Data scale is another source of uncertainty. Most of the data was developed on a regional scale (soil, climate), which can result in an inaccurate representation of local conditions. Thus, the analysis was performed using available data, although in some cases more detailed data could produce better results, with a higher level of confidence.

APPENDIX C. METHODS AND ASSUMPTIONS FOR FINANCIAL ANALYSIS (GGA/WRI STEPS 4, 5 AND 6)

This appendix is based on the study presented by Ozment et al. (2018) and aims to highlight specific methods applied locally to estimate costs and benefits in the return on investment analysis in the Atibaia river basin, as well as underlying assumptions and data sources, based on local consultations.

General assumptions of the models:

Water supply and demand

According to SANASA, the water production rate of the four WTPs with collection in the Atibaia river is 2.9 m^3/s. This demand is expected to grow by about 0.52% per year. This trend was extrapolated over the 40-year horizon.

Table C1 | Estimated water demand based on PCJ and SNIS

YEAR	CAMPINAS (m^3/S)	CAMPINAS AND REGION (m^3/S)
0	2.91	6.80
10	3.08	7.16
20	3.23	7.54
30	3.49	7.94
40	3.75	8.37
50	4.03	8.81

Source: Developed by the authors.

Time horizon

The 50-year time horizon for financial projects in the water sector reflects the weighted average useful life of the most important structures and equipment for water treatment, according to SANASA's depreciation level.

Discount rate

Based on the estimate of the weighted average cost of capital (WACC) of BTG Pactual (8.6%) for the water and sewage sector in Brazil (Junqueira, Pimentel and Castro, 2017), a reference discount rate of 5% was assumed. In the sensitivity analysis (described below), the discount rate ranged from 5% to 12%. These values were determined based on the Brazilian risk premium in financial projects (Assaf Neto, 2010). The Inter-American Development Bank (IDB) recommends a 12% discount rate for public water infrastructure projects in Latin America (Fontanele and Vasconcelos, 2012).

Cost estimates

Investment costs: all the investments needed to implement the restoration.

Operation and maintenance costs: all expenses necessary to promote restoration over time and minimize seedling mortality or ecological failures.

Transaction costs: expenses incurred to involve landowners in restoration projects, design and monitor the program, and manage contracts and payments. These costs were assumed to correspond to 2% of the combined investment costs.

Opportunity costs: in this study, an opportunity cost equivalent to the average Payment for Ecosystem Services project for the Atlantic Forest was assumed.

Benefit estimation

This analysis focuses solely on assessing the avoided costs of sediment management. As described in the study, three water management costs were analyzed: (a) water treatment costs, (b) filter material replacement costs, and (c) depreciation and wear and tear of equipment related to turbidity treatment and sediment filtering.

Costs avoided in water treatment

Using regression models based on the primary data of treated volume and volume of chemical products used (PAC, calcium hydroxide, hydrated lime and quicklime), the costs of the chemical products used were estimated and, subsequently, the following curves: conversion of sediments to suspended solids, conversion of suspended solids to turbidity and, finally, treatment costs per cubic meter as a function of turbidity.

Conversion of sediments to suspended solids: equations developed by Carvalho (2008).

$$ss = s / 10{,}4 * 0{,}0864$$

Where *SS* corresponds to suspended solids (mg/L), *S* is exported sediments (t/day), 10.4 is the average water flow (m^3/s) in the Atibaia river at the catchment point (PCJ River Basins Agency, 2020) and 0.0864 is the conversion constant (Carvalho, 2008).

Conversion of suspended sediments to turbidity: equation based on primary data provided by SANASA.

$$T = 0{,}036178 * ss^{1{,}325856}$$

Where *T* is the turbidity level (NTU) and *SS*, suspended solids.

Water treatment costs due to the turbidity level: equation elaborated according to primary data provided by SANASA and monetized by consulting market prices and public bids for the purchase of PAC, calcium hydroxide, hydrated lime and quicklime, in the proportions used by SANASA.

$$C = 0{,}059325 * t^{0{,}207735}$$

Where *C* is the cost (R$/$m^3$) and *t* the turbidity level (NTU).

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ACKNOWLEDGEMENTS

This report is a product of INTERACT-Bio project and was developed in a partnership between ICLEI – Local Governments for Sustainability and WRI Brasil. The work was made possible thanks to the financial support of donors from both institutions and knowledge sharing from the partners of the INTERACT-Bio and Cities4Forests initiatives.

The work received essential support from the reviewers of this study, who provided inputs and were essential to making the analysis more robust. We express our sincere gratitude to the people who contributed with their time and knowledge: Adriana Isenburg (SANASA), Bruno Incau (WRI Brasil), Daniel Soares, Daniela Facchini (WRI), Henrique Evers (WRI Brasil), João José Demarchi (PCJ), Juliana Ortega (Programa Nascentes), Maíra Fares Leite (COPASA), Paulo Camuri (WRI Brasil), Rodrigo Sanches Garcia (GAEMA) and Thiago Guimarães Rodrigues (WRI Brasil). We would like to specially thank to the team from the Campinas Secretariat for the Environment and Sustainable Development that actively contributed with the research and publication process: Ângela Cruz Guirao, Gabriel Neves, Carla Camarneiro and Mario Jorge Bonfante Lançone.

We are also grateful to the Sociedade de Abastecimento de Água e Saneamento (SANASA) for providing primary data on water turbidity rates at the company's catchment points that supply the municipality of Campinas. This is a study of Green Infrastructure for Water that relies on primary data provided by the company responsible for water supply, which brings greater technical robustness to the proposed assessments.

We also received contribution from experts and technical professionals who participated in virtual meetings and events between 2019 and 2021, especially those from Campinas's municipal government, PCJ River Basins Agency and SANASA. We greatly appreciate our contributors' willingness to share knowledge and experiences on the territory covered by this work.

Finally, we thank Bruno Calixto, Fernanda Boscaini, Joana Oliveira, Suzanna Lund, Fabíola Zerbini and Henrique Corsi, from WRI Brasil, as well as Ana Paula Becker and Marília Israel, from ICLEI – Local Governments for Sustainability, and the reviewers André Caramori and Anaelena Lima.

Supported by:

Federal Ministry
for the Environment, Nature Conservation
and Nuclear Safety

based on a decision of the German Bundestag

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ABOUT ICLEI – LOCAL GOVERNMENTS FOR SUSTAINABILITY

ICLEI – Local Governments for Sustainability is a global network of more than 2,500 local and regional governments committed to sustainable urban development. Active in more than 130 countries, it influences sustainability policies and drives local action for low-carbon, nature-based development in an equitable, resilient and circular manner.

Iclei South America connects more than 100 associated governments present in eight countries with this global movement. In 2018, to continue building strong supportive relationships with its members, the regional secretariat opened two National Coordination offices, in Colombia and Argentina. The office in Colombia is headquartered in the Valle de Aburrá Metropolitan Area (AMVA) and in Argentina it is headquartered in the city of Rosario. Over the years, Iclei South America has distinguished itself in the development and execution of projects on the themes: Climate and Low Carbon Development, Resilience, Solid Waste, Sustainable Public Procurement, Urban Biodiversity, among others.

ABOUT WRI BRASIL

WRI Brasil is a research institute that transforms big ideas into actions to protect the environment and foster Brazil's prosperity in an inclusive and sustainable fashion. It is focused on research and applications of sustainable solutions oriented towards climate, forests, and cities. WRI Brasil combines technical excellence with political articulation and works in close collaboration with governments, private companies, universities and civil society.

WRI Brasil is part of World Resources Institute (WRI), a global research organization whose work extends to over 50 countries. WRI encompasses the work of almost 1700 professionals in offices in Brazil, China, the United States, Mexico, India, Indonesia, Europe, Turkey and Africa.

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