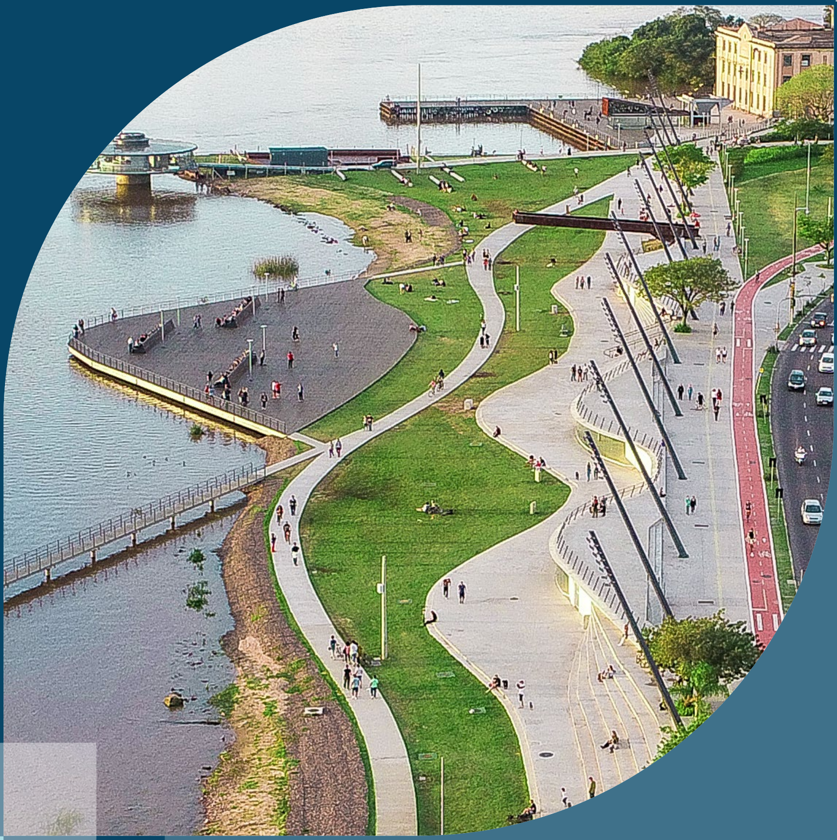
City Climate
Finance Gap Fund

Methodology for quantifying the environmental, economic and social risks and benefits of Nature-based Solutions

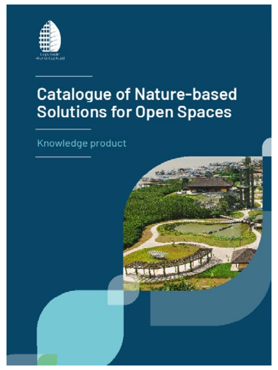
Knowledge product

Adopted for the implementation of linear and river parks, as well as the guide to NbS impact indicators in linear and river parks



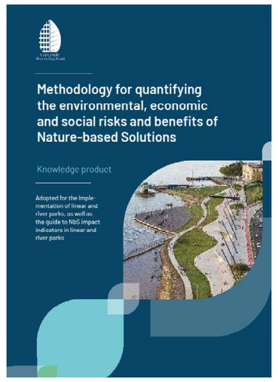
This publication combines a trilogy of resources centred around the implementation of Nature-based Solutions (NbS), with a particular focus on linear and riverine parks. It encompasses a Catalogue of Nature-based Solutions (NbS), a detailed methodology for effective implementation, and an assessment framework for quantifying environmen-tal, economic, and social risks and benefits. Additionally, it provides a practical guide for formulating a business model, with a particular focus on linear and river parks.

Trilogy



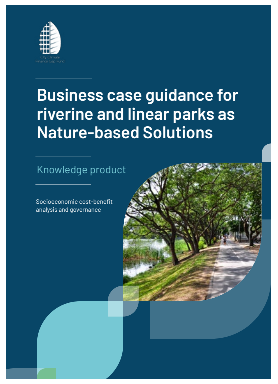
Catalogue of Nature-based Solutions for open spaces

The Catalogue offers a four-step method for selecting the most suitable NbS for different contexts, ranging from water management to the components of these solutions and the selection of plants for phytoremediation of pollutants. The Catalogue aims to guide municipal authorities, urban planners, and environmentalists to incorporate NbS into their planning, with the goal of creating greener cities resilient to climate change. The structure of the Catalogue presents practical Brazilian cases to illustrate the importance of NbS in understanding the multifunctionality of open spaces.



Methodology for quantifying the environmental, economic and social risks and benefits of Nature-based Solutions (NbS) adopted in the implementation of linear and riverine parks and guide to NbS impact indicators in linear and riverine parks

The material provides an assessment of methodologies to quantify the environmental, economic, and social benefits of NbS adopted in linear and riverine parks, and a guide to indicators for quantifying the benefits of NbS in green areas. After a comparative assessment of nine methodologies, this report indicates a robust and relatively simple-to-apply methodology to assess quantitatively and qualitatively how NbS adopted in the implementation of linear and riverine parks can make cities more liveable, healthier, and fairer for their inhabitants.



Business case guidance for riverine and linear parks as Nature-based Solutions: socioeconomic cost-benefit analysis and governance

The guide aims to fill the gap in comprehensive guidance on NbS for urban planners and managers, emphasizing the multifaceted benefits of riverine and linear parks, including flood risk management, biodiversity enhancement, and promotion of human health and well-being. It describes the use of cost-benefit analysis (CBA) in parks and other NbS, discussing financial sustainability and the importance of community involvement and social governance structures. The goal is to equip professionals with the necessary tools to create robust Business Models that transform the concept of riverine and linear parks into tangible, resilient urban spaces.

Acknowledgements

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Bandeirantes Stream in Campinas/SP (photo: Daniel Nogueira Maekawa, 2022).

Presentation

This product is an executive summary of a methodology for quantifying the environmental, economic and social risks and benefits of Nature-based Solutions (NbS) adopted in the implementation of linear and river parks. It is a guide to indicators for quantifying the benefits of NbS in linear parks. These products are part of the scope of the project Support for Project Preparation for Urban Progress (SuPPUrbP) – PN 202091189, which refers to: 1) Development of a methodology for quantifying the environmental, economic and social risks and benefits of Nature-based Solutions (NbS) adopted in the implementation of linear and river parks; 2) Basic design of the Bandeirantes Stream Linear Park, in the municipality of Campinas/SP; and 3) Economic-financial modelling for maintenance of the Jardim Maravilha River Park, in the city of Rio de Janeiro/RJ.

This product aims to provide a robust yet simple application methodology for evaluating the quantitative and qualitative impact of Nature-based Solutions (NbS) on the liveability, health and fairness of cities for their inhabitants when adopted in the implementation of linear and river parks.

The work on the development of this product mainly consisted of:

1. A survey of the main international methodologies for quantifying the impacts of NbS benefits;
2. The evaluation of these methodologies in terms of their applicability to quantifying the environmental, economic and social benefits of Nature-based Solutions associated with linear and river parks with regards to aspects such as ease of application, necessary data, flexibility of use at different stages of an NbS and the possibility of evaluating multiple benefits;
3. The indication of the most appropriate methodology for quantifying benefits according to these criteria;
4. The suggestion of indicators to measure the environmental, social and economic benefits of implementing and managing linear and river parks.

Pajeú Park in Sobral, CE. Source: Sobral Municipality.

Introduction

The European Commission defines urban ecosystems as socio-ecological systems comprising green and built infrastructure.

Urban ecosystems are areas where most of the human population lives, and the flows of matter and energy from cities significantly affect other types of ecosystems, whether natural or rural.

While urban areas represent mainly human habitats, they also generally include significant areas for synanthropic animal species, which are adapted to these modified habitats (EUROPEAN COMMISSION, 2016).

In this context, urban green infrastructure is understood to be the multifunctional network of. Urban green spaces are therefore structural components of urban green infrastructure . These spaces are partially or fully covered by vegetation, including all types of vegetation, ranging from a single tree to an urban forest (EUROPEAN COMMISSION, 2016). Urban green infrastructure is defined by the European Commission (2016) as

> **"a strategically planned network of natural and semi-natural areas, with environmental features designed and managed to provide a wide range of ecosystem services It incorporates green spaces (or blue spaces in the case of aquatic ecosystems) and other physical structures in terrestrial, freshwater, and marine areas".**

The concept of Nature-based Solutions, which are defined as actions for the protection, recovery and sustainable management of natural or modified ecosystems that help to promote human well-being and protect local biodiversity (IUCN, 2020), is related to the concept of "urban green infrastructure", insofar as NbS in urban areas must be planned as integrated elements and components of a network of areas intended for provide ecosystem services (and the benefits derived from them) to the urban population.

NbS can help to increase and the flow of critical ecosystem services for people by providing better access to these services for urban and rural populations. These services include **life-sustaining processes** (e.g. nutrient cycling), the **regulation of ecological processes** (e.g. flood mitigation) and **improvements to human well-being** (e.g. biological control of zoonoses, scenic beauty, recreational opportunities, etc.).
Ecosystem services are classified into three main categories, according to the Common International Classification of Ecosystem Services (CICES), adopted by the European Environment Agency (Table 1):

I. Provision services

II. Regulation and maintenance services

III. Cultural services

Table 1 Categories of ecosystem services and definitions, according to CICES (v.5.1)

Provision services
It covers all nutritional and non-nutritional and energy products of living systems, as well as abiotic products (including water).
Regulation and maintenance services
All the ways in which living organisms, separate from or in conjunction with abiotic factors, can regulate or moderate environmental characteristics that affect human health, safety or comfort.
Cultural services
All the non-material benefits of ecosystems (biotic and abiotic) that affect people's physical and mental states.

Source: HAINES-YOUNG & POTSCHIN (2018).

BROWN et al. (2014) present a different approach to categorise the benefits of Nature-based Solutions (NbS):

1. Optimised ecosystem services delivery;
2. Disaster risk reduction, scarcity risks, risks of disruption of natural processes (e.g. climate);
3. Direct financial value (when the ecosystem service is the provision of a good of commercial value, such as water, food, wood, etc.);
4. Economic diversification (by bringing new economic alternatives to a locality or region, such as leisure and tourism);
5. Cultural or spiritual values (related to principles such as identity, tradition, social cohesion, recreation and spirituality).

Figure 1 Graphical representation of the principles inherent in the concept of Nature-based Solutions

The IUCN Global Standard on Nature-based Solutions

For many years, the IUCN (International Union for Conservation of Nature) has been developing innovative conservation initiatives that simultaneously help to protect, manage and restore the environment while providing tangible and sustainable benefits for people. This type of approach is now widely known as Nature-based Solutions (NbS). The IUCN established the first global definition of NbS in 2016: "actions to protect, sustainably use, manage and restore natural or modified ecosystems, which address societal challenges effectively and adaptively, providing human well-being and benefits for biodiversity" (IUCN, 2020).

The IUCN's Global Standard for Nature-based Solutions (IUCN, 2020) aims to ensure that the reliable application of this approach and monitor and measure its adoption for adaptive management, inspiring other people and organisations. The IUCN standard for identifying NbS comprises 8 criteria and 28 indicators (Figure 2).

According to the IUCN Standard:

Criterion 1 outlines the process of clearly identifying the societal challenge(s) facing stakeholders and rights holders, as well as establishing an understanding of the associated opportunities and challenges. The design of the solution should aim to address a societal challenge, taking into account the wider social, economic and environmental contexts of the challenge and solution are set.

Criterion 2 addresses the need for an NbS to be designed with consideration of relations and connections in not only the biophysical and geographical context, but also the economic, political and cultural spheres. It must also take into account the complexity and uncertainty that occur in living dynamic environments.

Criterion 3 outlines the importance of ensuring that the NbS delivers net gains for biodiversity and ecosystem integrity. Therefore, the design and implementation of NbS must proactively seek to enhance ecosystem functionality and connectivity. This will also ensure the long-term resilience and durability of NbS.

Criterion 4 emphasises the importance of cost-benefit and economic viability analytics in the design phase, taking into account every aspect required for implementation and maintenance, aswell as translating NbS benefits into economic values to attract investment more effectively.

Criterion 5 outlines the importance of inclusive, transparent and empowering governance processes during NbS-related decision making to increase the likelihood of positive outcomes for biodiversity, society and the economy.

Criterion 6 shows that it is necessary to identify potential trade-offs resulting from NbS implementation, raising awareness of this issue. Damaged stakeholders must be compensated, and possible compensation must be negotiated in a fair and inclusive manner.

Criterion 7 indicates that the application of adaptive management principles, underpinned by a theory of change and iterative learning processes based on scientific evidence, can also increase the success of NbS.

Criterion 8 focuses on the need for NbS to align with sectoral, national and other policy and regulatory frameworks. This will enable NbS to make significant contributions to national economic, social and conservation targets, thereby increasing recognition of its importance and enhancing its potential for long-term sustainability.

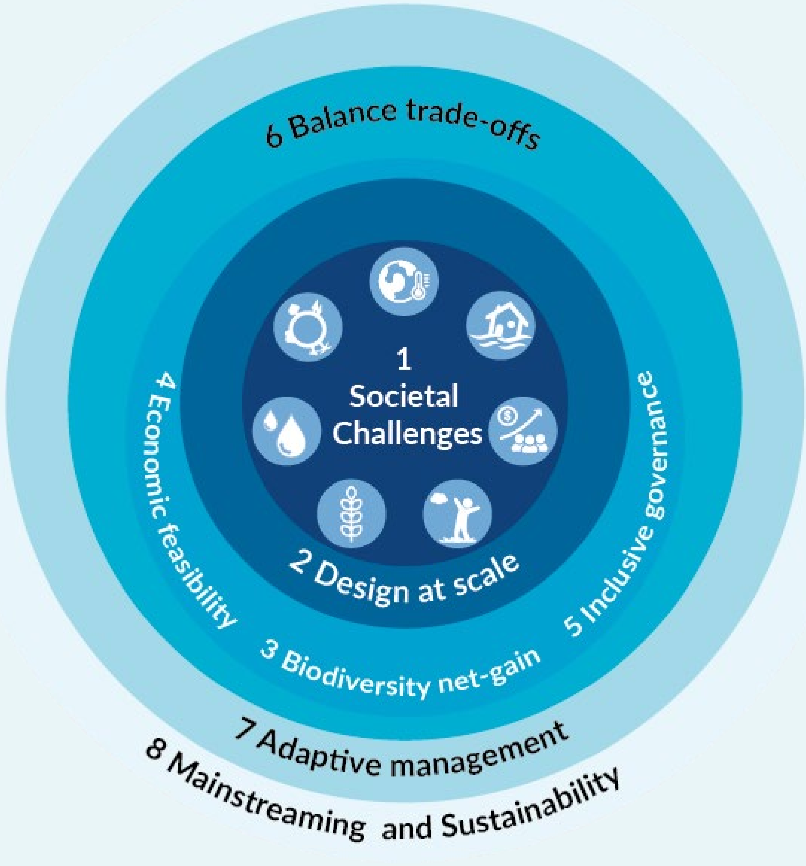

Figure 2 IUCN Global Standard Guidelines on Nature-based Solutions (adapted from IUCN, 2020).

Relationship between the IUCN Global Standard guidelines and the quantification of NbS impacts

According to the IUCN (2020), the outcomes of NbS on human well-being should be periodically identified, evaluated and compared. NbS must deliver tangible benefits that are relevant to human well-being. Specific, measurable, achievable, realistic and time-bound goals (SMART goals[1]) should always be used as a reference for the expected benefits, as these are important for accountability and to support adaptive management. The need for a necessary and robust assessment of the impacts of NbS is associated with guidelines 1 ("NbS effectively addresses societal challenges") and 7 ("NbS is managed adaptively, based on evidence"). The same publication states that a monitoring and evaluation plan is essential to determine whether the planned NbS strategy effectively delivers the intended results and thus effectively addresses the societal challenge. It also allows unexpected risks or impacts to be identified, indicating the need for a change in strategy or action. If NbS have synergies with other interventions or approaches, these should be included in the monitoring and evaluation plan (IUCN, 2020).

1 The SMART methodology was developed in the early 1980s by consultant George T. Doran. SMART – which in English is an adjective that means "intelligent" or "cunning" – is an acronym for Specific, Measurable, Achievable, Realistic and Time-bound. Therefore, a SMART goal incorporates all these criteria to help focus your efforts and increase the chances of achieving your goals.

The importance of indicators to measure the benefits of NbS

According to BROWN et al., 2014, measuring and communicating progress against the goals of a policy, programme or project is primarily carried out through the use of indicators.

Indicators can play a central role in decision-making and adaptive management, as well as providing an important interface between science and policy. In different administrative spheres, indicators of ecosystem services can support processes of ecosystem accounting, and natural capital reporting. This facilitates the integration of an ecosystem approach into policies and development plans.

Uses for such indicators include:

- Decision-making and definition of public policies;
- Planning for environmentally sustainable economic development;
- Assessing, monitoring and reporting changes in ecosystems and their effects on the economy and human well-being; and
- Ecosystem management.

Although the use of indicators is considered the most appropriate way to measure benefits related to the increase or maintenance of ecosystem services (and, consequently, of Nature-based Solutions), BROWN et al. (2014) indicate that developing ecosystem services indicators is challenging due to their limited capacity to convey information about ecosystem services in general, even if it varies widely between services. In addition, according to the authors, the available indicators for most ecosystem services are not comprehensive and are often inadequate to characterise the diversity and complexity of the benefits they provide. Another major problem is that the available data is often insufficient to support the use of these indicators. These limitations are even more evident when it comes to indicators of cultural services.

It is important that the results obtained from indicators representing the flow of ecosystem services can easily be translated into tangible benefits for people. This is because, by definition, ecosystem services are the flows of material, energy or information derived from "stocks of natural capital" that provide human well-being (CONSTANZA et al., 1997).

For instance, a Nature-based Solution can effectively reduce the turbidity of raw water abstracted for public supply. However, this environmental gain will only be recognised by society if it can be easily translated into a benefit for the affected population. In this case, this could be achieved by disclosing the savings in water treatment costs (and the subsequent price reduction in consumer tariffs).

These difficulties are even greater when quantitative indicators are not applicable. Using the same example reduced turbidity can make water bodies more aesthetically attractive to people who come into visual or physical contact with them, but the "aesthetic gain" is very difficult to measure.

A robust NbS impact assessment framework implies careful reflection and planning of monitoring and evaluation processes in the NbS design phase, since, by definition, NbS are multifunctional and a single NbS delivers a set of benefits, so it is important that indicators are defined for each benefit derived from a NbS (DUMITRU & LOURIDO, 2020).

The challenges of quantifying the benefits of NbS

Despite their importance, NbS are still poorly understood and insufficiently monitored. This makes it difficult to assess their positive impacts correctly, particularly in the form of quantifying the increase in the supply of ecosystem services.

According to the European Commission (2021a), **robust methods, evaluation frameworks and indicators are needed to quantify the multiple levels of interaction associated with NbS, from planning to implementation.**

Constructing an evidence framework on the benefits of NbS is a fundamental step towards increasing the acceptance of these solutions as an effective way to address urban environmental issues such as water drainage, physical and mental health problems and the control of zoonoses. Following this approach, it is crucial to develop simple and effective for monitoring and quantification methodologies for the implementation of Nature-based Solutions in urban environments.

According to CONNOP et al. (2020), for NbS to become more widespread and unlock opportunities for expansion and scaling up, **a more holistic evaluation framework is needed to understand its benefits, co-benefits and drawbacks. This will enable decisions to be made based on a cost-benefit approach.**

BRILL et al. (2021) argue that accounting for the benefits of NbS helps to build the business case for "green solutions", thus supporting their acceptance and implementation in a wider scale.

The main challenge in defining methodologies for quantifying the environmental, economic and social benefits of Nature-based Solutions (NbS) is that there are currently no standardised, widely recognised methods for identifying, estimating, and monitoring these benefits, making it difficult to convince decision-makers to invest in these solutions (BRILL et al., 2021).

Another factor to consider is that the choice of a quantitative assessment method largely depends on the type of NbS to be assessed, and how its direct and indirect beneficiaries perceive the benefits (the measurement metrics must make sense to the target audience).

According to BRILL et al. (2021), engaging beneficiaries and other stakeholders in the design and implementation phases of NbS is essential, as is collecting data throughout all phases of the project, for the subsequent quantification of the benefits of these green interventions in the landscape.

The Connecting Nature initiative states that NbS assessment must be able to identify the strengths and weaknesses of specific interventions in relation to cities' strategic planning objectives[2].

2 Available at: https://connectingnature.eu/innovations/impact-assessment

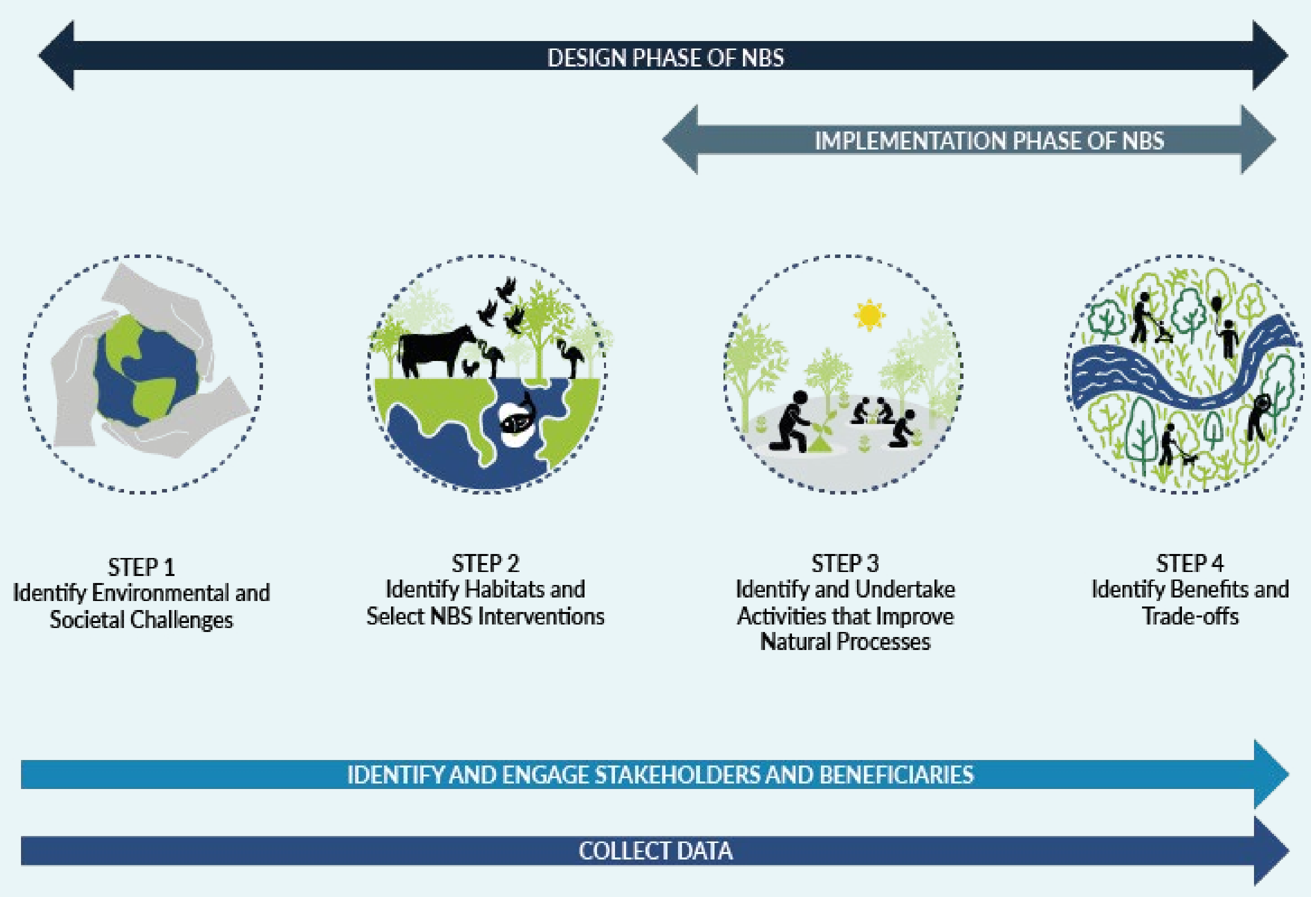

Figure 3 Proposed steps to be followed to identify benefits in the design and implementation phases of NbS (adapted from BRILL et al., 2021).

Cabrinha Spring Revitalization in Londrina/PR (Landscape Architecture Project by Guajava Landscape Architecture and Urbanism Office, Paulo Pellegrino and Silvio Motta, photo: Arthur Cordeiro, 2018).

1 Ecosystem services (and other benefits) promoted by linear/river parks

The European Commission – EC (EUROPEAN COMMISSION, 2016a), the IUCN (Cohen-Shacham et al., 2016) and other scholars relate Nature-based Solutions to the concept of ecosystem services (ES) and natural capital (EGGERMONT et al., 2015; MOTHERS and JACOBS, 2017; NESSHOVER et al., 2017; POTSCHIN et al., 2016, apud ALMENAR et al., 2021).As suggested by the EC and stated more directly by other authors (ALBERT et al., 2019; BUSH and DOYON, 2019, apud ALMENAR et al., 2021), NbS contain stocks of natural capital or are actions to maintain and increase the flow of ES towards human beings. For instance, Eggermont et al. (2015, apud ALMENAR et al., 2021) categorise NbS based on their contributions to ecosystem health, establishing a direct link between ES and NbS:

I. **Better use of ecosystems;**

II. **Sustainable and multifunctional ecosystem management; and**

III. **Design and management of new ecosystems.**

The scope of the main societal challenges addressed by NbS includes:

However, other specific challenges are also being recognised in this context (IUCN, 2020). A key aspect of NbS is that they generally offer multiple benefits, with an NbS intervention typically addressing a range of issues (UNEP, 2022).

This article presents a brief list of the main ecosystem services that can be provided or increased through the implementation of linear/fluvial parks and associated NbS, based on technical literature addressing NbS-derived benefits (DIMITRU, A. & LOURIDO, D., 2020; GFDRR & WORLD BANK, 2021; CGEE, 2022). According to the Common International Classification of Ecosystem Services (CICES[3]), the benefits listed fall under the categories of cultural benefits (such as recreation) and regulatory benefits (such as flood mitigation and reduction of sediment input). Some benefits indirectly derived from the increase in these ecosystem services are also indicated, such as social cohesion and health improvement. However, they are not listed by CICES as ecosystem services, although they are often indicated by CICES as benefits of a given ES. Table 2 presents indicators related to these ecosystem services and benefits, along with a short description of the benefits associated with NbS near water bodies. These indicators are revisited in detail in the "Guide to indicators" section.

3 Available at: https://cices.eu/

Table 2 Ecosystem services and other benefits provided by linear/riverside parks

Ecosystem Services/benefits (Cont.)	Type	Description	Indicators
Flood mitigation	Regulation	NbS can reduce flood impacts by slowing water flows and storing water volumes	• Runoff • Runoff/precipitation ratio • Underground water flow • Maximum flow rate • Flooded area • Population affected by flooding • Economic losses per flood event
Reduction of sediment input	Regulation	NbS can reduce pollution and silting impacts by trapping sediments before they reach water bodies	• Water quality index • Sediment load (solid discharge)
Recreation	Cultural	NbS as urban green spaces offer places for sports, contemplation and recreational activities, which are essential for the physical and mental health of citizens	• Green space/inhabitant ratio • Green space/total area ratio • Average distance to public green spaces • Visitors in public green spaces
Increased mobility	Cultural	NbS as urban green spaces can provide new routes of locomotion to work, school, etc.	• Average distance travelled inside the green space as part of the locomotion route • Reduction of distance between key points of the city or neighbourhood
Social cohesion	Cultural	NbS as urban green spaces can offer places for social inclusion and social interactions, especially for less favoured populations	• Community involvement with planning and management of public green spaces • Crime rate in and around public green spaces • Events held indoors or near public green spaces
Health improvement	Cultural	Exposure to natural environments increase physical and mental health aspects	• Zoonoses in the locality of the green space (borough or other administrative division) • Mental illness in the locality of the green space (borough or other administrative division) • Diseases related to a sedentary lifestyle (borough or other administrative division)
Economic development	Cultural	New economic opportunities motivated by the greater influx of visitors to the NbS locality	• Businesses within and near public green spaces • Taxes on goods and services paid in the area surrounding the green space (borough or other administrative division) • Economic losses per flood event

1.1 Flood mitigation

The ability of natural areas to reduce the incidence and severity of floods associated with heavy rainfall has been studied for several decades (ANDRÉASSIAN, 2004; HAMILTON, 2008). Although the magnitude of flash floods depends mostly on factors external to the landscape in which they occur (such as heavy and concentrated rainfall events in a short time), it can be exacerbated or reduced due to land use patterns, which affect surface runoff, infiltration and water storage.

According to Hamilton (2008), by maintaining or increasing the infiltration and storage capacity of water in the soil, forests and other types of natural vegetation influence the temporality and quantity of surface runoff to rivers and can delay and mitigate flow peaks; this relationship was also observed in experimental basins in Rio Grande do Sul (TUCCI & CLARKE, 1997). The maintenance of natural vegetation in watersheds can reduce flood runoffs and peaks, reducing the impacts of local flooding. Forested basins generally register a lower frequency and peak flow rate for small and medium-sized storms, especially at the watershed scale (CALDER et al., 2007).

Friedrich (2007) argues that the linear park presents itself as an alternative to channelling, which is based on rectification, waterproofing and, sometimes, even the buffering of the bed, by allowing the infiltration and slower flow of water during flood events. Santos & Campos (2006) argue that it is important to give collective uses to the banks and floodplains of urban rivers to avoid their occupation by residential or commercial uses in these areas of recognised risk, since the creation of a leisure area works as an artifice motivating the collective adoption and protection of this space and, in a way, discourages irregular occupations.

1.2 Sediment input reduction

The most common contribution that vegetation provides to the hydrological balance of watersheds is to maintain good water quality (HAMILTON, 2008). The reduction of sediment exports to water bodies can be achieved when riparian forests and floodplains "capture" the sediments transported by surface runoff. These riparian natural areas act as buffer zones that filter sediments, nutrients and contaminants before they reach the water (VAN NOORDWIJK et al., 1998; RANIERI et al., 2004; DOSSKEY et al., 2010, apud CREED & VAN NOORDWIJK, 2018), limiting the transport of sediments that cloud the water and decrease its quality (NEARY et al., 2009, apud CREED & VAN NOORDWIJK, 2018). In addition, riparian forests are particularly important for reducing ravine erosion (VERBIST et al., 2010 apud CREED & VAN NOORDWIJK, 2018).

Forests can have a direct influence on water quality in water bodies, mainly affecting temperature, biological oxygen demand, and sediment and nutrient concentrations (STELZER et al., 2003; MOORE et al., 2005, apud CREED & VAN NOORDWIJK, 2018). This retention of sediments by natural ecosystems increases the quality of drinking water, as suspended solids directly affect the level of water turbidity, which must be decreased to a minimum possible for public supply purposes. In addition, sediments can carry chemicals and pathogens, as well as damage water collection and distribution equipment (GUIMARÃES et al, 2018).

Undoubtedly, the most priority areas for carrying out ecosystem services of sediment retention are the areas of "foot of slope" and fluvial plains, where processes of interaction between the terrestrial and aquatic parts of the basin occur, this region being known as riparian zone (strips of land marginal to water bodies). These riparian zones, when well vegetated, constitute the last barrier to protect water bodies against erosion and pollution.

1.3 Recreation

According to Friedrich (2007), the linear park stimulates social cohesion, mainly through recreational and educational promotion. Urban green spaces, such as linear parks, offer spaces for sports, contemplation and recreational activities that are essential for the physical and mental health of citizens, and which would often not be easily available in other ways (especially in low-income neighbourhoods, where leisure options are often scarce).

1.4 Increased mobility

Linear sidewalks provide benefits of increasing sustainable urban mobility to the local community and can be used to commute to work, school or other activities. Researchers of proGIreg and PHUSICOS projects mention it as the "walkability" factor, or "new links between urban centres and NbS" (EUROPEAN COMMISSION, 2021b). Linear and river parks end up creating new routes of locomotion, by transforming private areas and with restricted access into public open spaces, which can be travelled as parts of the route for different purposes. By encouraging non-motorized locomotion, linear parks also promote healthier lifestyles, both from physical and mental health perspective.

1.5 Social cohesion

The availability of linear parks helps to promote social inclusion of less favoured segments of the population, becoming spaces that mitigate social disparities and provide greater contact between different social strata. Linear parks can also facilitate interactions between people belonging to different neighbourhoods, especially if they cover a wide area of urban territory. These areas can encompass cultural and environmental education actions, providing opportunities for citizenship exercises. They can also constitute a space to strengthen democracy, when the participation of citizens in its conception, planning and management is favoured (MORA, 2013).

1.6 Health improvement

Exposure to natural environments, including NbS in urban settings, has been associated with many health benefits (ULRICH et al., 1991; BERMAN et al., 2008; SPANO et al., 2020, apud SPANO et al., 2021). And the mental health and physical health associated with staying in natural and semi-natural spaces and the practice of physical activities were mainly studied (ALMENAR et al., 2021). But studies on the role of NbS in reducing the risks of diseases of animal origin (zoonoses) have also been gaining ground, especially after the Covid-19 pandemic (an example is the Biota Synthesis project, which recently launched a new line of research dedicated to NbS, one of the themes of study being the reduction in the spread of some zoonoses[4]).

Previous studies on mental health benefits have been mostly experimental, investigating the short-term effects of brief exposure to natural environments on stress reduction and cognitive restoration (KAPLAN and KAPLAN, 1989; BERTO, 2005; NILSSON et al., 2010; CARRUS et al., 2017, apud SPANO et al., 2021). More recently, large-scale epidemiological studies have provided further evidence of the long-term effects of prolonged exposure to green spaces on mental health and well-being across the lifespan (HARTIG et al., 2014; GASCON et al., 2015; MCCORMICK, 2017; DE KEIJZER et al., 2020, apud SPANO et al., 2021).

The control of infectious diseases is a regulatory service whose importance has gained increasing recognition (PARRISH et al., 2008), and 75% of these diseases are related to zoonotic agents (TAYLOR et al., 2001). Vector-borne diseases, especially mosquitoes of the genus Anopheles and Aedes, have a large-scale impact on human health, affecting around one billion people annually and accounting for up to one million deaths per year, including diseases such as malaria, dengue and yellow fever, as well as Chagas (transmitted by triatomines) and schistosomiasis (transmitted by freshwater snails), among others (KARESH et al., 2012).

Evidence indicates that the maintenance of well-conserved ecosystems and their associated biodiversity reduces the transmission of zoonoses to humans (KEESING et al., 2010), either by predators that reduce vector populations or by reducing contact between humans and vectors.

1.7 Economic development

According to Scalise (2002, apud FRIEDRICH, 2007), linear parks in valley bottom regions are feasible and democratic projects, presenting economic possibilities that compensate for the investment in their implementation and maintenance.

They emerge as elements that generate attractiveness to the region around the parks, with greater circulation of potential consumers in the region (increasing visitation to local businesses), valuing the properties in their surroundings (FRIEDRICH, 2007).

It should also be noted that a benefit already mentioned, flood mitigation, has obvious economic connotations, as it generates public and private savings in the allocation of resources to repair socioeconomic damages. This is the benefit of the avoided cost or, as defined by DA MOTTA (1997), the "replacement cost", which represents the expenses incurred by users in substitute goods to ensure the desired level of a given condition (in this case the habitability and healthiness of residential and commercial areas).

4 More information on https://biotasintese.iea.usp.br/pt/nature-based-solutions/ and https://www.iai.int/en/post/detail/Nature-Based-Solutions-and-Zoonoses

Orla do Guaíba Park in Porto Alegre/RS (Project by Jaime Lerner Arquitetos Associados, photo: Arthur Cordeiro, 2018).

2 Guide to indicators for quantifying the benefits of NbS in linear/river parks

A survey of indicators was carried out to assess the efficiency of NbS, with emphasis on relevant indicators for assessing the impacts of linear and river park projects. The priority was to suggest environmental, social and economic indicators of relatively easy availability, preferably already collected for other purposes (environmental monitoring, for instance), and that may be useful to verify the contribution of the implementation of these parks in relation to the minimum environmental and social safeguards and their basic requirements.

In this guide, the concept of "green space" is used generally to refer to natural and semi-natural areas in urban territories, with features designed and managed to provide a wide range of ecosystem services to urban populations (linear/river parks included). The term "green space" is frequently cited by several international organisations, including the United Nations Environment Programme (UNEP), the Food and Agriculture Organization (FAO) and the World Health Organization (WHO). These organisations emphasize the importance of green spaces in urban planning to increase sustainability, improve public health and contribute to social well-being.

Based on this survey, a proposal of **35 indicators** to be used to quantify the benefits of linear/river parks is presented (Table 2). The proposed indicators are related to **environmental, social or economic aspects** and were mostly selected among indicators suggested in the most complete and current compendiums on indicators for NbS impact assessment, the publications Nature-based Solution evaluation indicators: Environmental Indicators Review (CONNOP et al., 2020) and Evaluating the Impact of Nature-based Solutions: Appendix of Methods (EUROPEAN COMMISSION, 2021b).

For each indicator, the following items are informed:

The benefit to be evaluated by measuring the indicator;

- The description of the indicator;
- The unit of measurement of this indicator;
- Type of indicator (environmental, social or economic);
- Justifications for using the indicator;
- Possible methods for collecting/estimating this indicator;
- Any observations (particularities, limitations, etc.).

The proposed indicators are suitable either for monitoring the impact of NbS over time (against a pre-implementation baseline) or modeling the benefits of NbS (considering a baseline scenario and alternative scenarios).

The following are the indicators for quantifying the benefits promoted by linear/river parks as a typology of NbS; these indicators are divided into the following categories of benefits: environmental, economic and social (some indicators can be understood as belonging to two or three spheres).

5 It is important to clarify that there may be several methods for measuring each of these indicators and that only one or two methods are suggested here for each indicator.

35 Indicators for NbS

Environmental benefits indicators (18)

1. Carbon removed by vegetation;
2. Carbon stored in vegetation;
3. Runoff/precipitation ratio;
4. Runoff;
5. Underground water flow;
6. Maximum flow rate;
7. Water quality index;
8. Sediment loading (solid discharge);
9. Flooded area;
10. Public green space/total area ratio;
11. Structural ecological connectivity;
12. Native plant biodiversity;
13. Native animal biodiversity;
14. Invasive plant species;
15. Invasive animal species;
16. Air quality index;
17. Days with a lower than recommended air quality index;
18. Monthly average value of the maximum daily temperature.

Economic benefits indicators (5)

19. Economic losses due to flood events;
20. Businesses in and in the vicinity of public green spaces;
21. Taxes on services paid in the locality of the green space (neighbourhood, sub-prefecture, etc.);
22. Average value of residential properties;
23. Average value of commercial properties.

Social benefits indicators (12)

24. Economic losses due to flood events;
25. Businesses in and in the vicinity of public green spaces;
26. Taxes on services paid in the locality of the green space (neighbourhood, sub-prefecture, etc.);
27. Average value of residential properties;
28. Average value of commercial properties;
29. Events held indoors or in immediate proximity to public green spaces;
30. Crime rate in and around public green spaces;
31. Zoonoses in the locality of the green space (neighbourhood, subprefecture, etc.);
32. Mental illness in the green space locality (neighbourhood, subprefecture, etc.);
33. Diseases related to sedentary lifestyle (at the green space's neighbourhood, subprefecture, etc.);
34. Average distance travelled inside the green space as part of a locomotion route;
35. Reduction of distance between key points of the city or neighbourhood.

Table 3 Suggested indicators for quantifying the benefits promoted by linear and river parks

Indicator	Benefit	Unity	Type	Justification for use	Assessment methods	Comments
Monthly average value of the maximum daily temperature	Thermal comfort	Temperature (°C)	Environmental	It is a good indicator to give an idea of the effects of high temperatures on urban comfort and human health.	Collection at a maximum frequency of 1 hour, using precision thermometers or weather stations, to identify the maximum daily temperature; calculation of the average for the period (month, year, etc.).	It is suggested that these measurements be made concomitantly inside green areas and in their surroundings, to calculate the differences (since the expression of the expected benefit is the temperature difference).
Carbon removed by vegetation	Carbon sequestration from the atmosphere/ climate mitigation	Absolute mass (Ton CO_2e) or specific mass (Ton CO_2e/ha)	Environmental	Measures of C storage and sequestration provide a tangible link between the impacts of local land use, planning and management decision-making and climate change mitigation.	Carbon sequestration modelling (variation between pre and post intervention scenarios) based on average carbon stock values for different land uses.	This information can also be obtained from biomass inventories, but this is a much more complex and expensive method.
Carbon stored in vegetation	Carbon storage in the biosphere/ climate mitigation	Absolute mass (Ton CO_2e) or specific mass (Ton CO_2e/ha)	Environmental	Measures of C storage and sequestration provide a tangible link between the impacts of local land use, planning and management decision-making and climate change mitigation.	Carbon stocks modelling based on average carbon stock values for different land uses.	This information can also be obtained from biomass inventories (and allometric equations), but this is a much more complex and expensive method.

Indicator	Benefit	Unity	Type	Justification for use	Assessment methods	Comments
Surface runoff/ precipitation ratio	Reducing the impact of floods	% (Surface runoff/ Precipitation per event or per period)	Environmental	A significant consequence of waterproofing in cities is increased surface runoff in urban areas, which can lead to downpours and flooding.	Direct measurement of surface runoff (using gutters or small reservoirs associated with measuring instruments) or indirect (using hydrological modelling); direct measurement of precipitation (using pluviometers or pluviographs); calculation of the runoff/ precipitation ratio per event or per period.	It is recommended that such edits be made during extreme precipitation events, as these are the times when excess runoff causes damage.
Surface runoff	Reducing the impact of floods	mm/event or mm/period	Environmental	A significant consequence of waterproofing in cities is increased surface runoff in urban areas, which can lead to downpours and flooding.	Direct measurement of surface runoff (using gutters or small reservoirs associated with measuring instruments) or indirect (using hydrological modelling).	Same as above.
Underground runoff	Reducing the impact of floods/ increasing infiltration/ feeding groundwater	mm/event or mm/period	Environmental	As the impermeability of the surface increases, the volume and speed of surface runoff increases and there is a corresponding decrease in water infiltration.	Direct measurement of infiltration (using infiltrometers) or indirect (using hydrological modeling).	Same as above.

Indicator	Benefit	Unity	Type	Justification for use	Assessment methods	Comments
Maximum flow rate	Reducing the impact of floods	m^3/s	Environmental	Maximum flows (also known as peak flows) are closely related to the occurrence of channel overflows and consequent flooding.	Measurement of water level or water discharge.	Same as above.
Water Quality Index	Improving the quality of water for supply and recreation	WQI (dimension-less)	Environmental	The WQI is used on a national scale and is the main way of officially reporting the quality of water for human supply and other uses.	Periodic collection of the parameters that make up the WQI, and calculation of the index (according to http://pnqa.ana.gov.br/indicadores-indice-aguas.aspx).	This method is simpler and more economical when a water quality measuring station is already in place; otherwise, it will be necessary to install and manage a station for this purpose.
Sediment loading (solid discharge)	Improving the quality of water for supply and recreation/ Reducing siltation	Absolute mass (Ton) or specific mass (Ton/ha)	Environmental	A higher concentration of sediment in the water negatively affects its quality and generates greater settling and siltation of river bottoms (increasing the possibility of flooding).	Periodic collection of water quality parameters, such as the concentration of total suspended solids or the use of gutters and the collection and measurement of sediment.	This method is simpler and more economical when a water quality sampling station is already in place; otherwise it will be necessary to install and manage a sediment sensor for this purpose.
Flooded area	Reducing the impact of floods	Square meters, hectares or square kilometers	Environmental/Economical/Social	The area potentially or actually flooded is a direct indicator of the impact of floods on people and economic activities.	Cartographic measurement using remote or local sensing images (e.g. drones), or estimation by hydrodynamic modelling.	Mapping "watermarks" in loco and delineating the boundaries of the floodplain is another possible method. Floodplains vary according to the return time and duration of rainfall.

Indicator	Benefit	Unity	Type	Justification for use	Assessment methods	Comments
Population affected by flooding	Reducing the impact of floods	Number of people (per event or per period)	Social	The population potentially or actually affected by floods is a direct indicator of the impact of floods on people.	Crossing potential or actual flooded areas with demographic geographic data.	The IBGE's statistical grid makes it possible to obtain geographically distributed data from the 2010 Census (https://geoftp.ibge.gov.br/recortes_para_fins_estatisticos/grade_estatistica/censo_2010/https://geoftp.ibge.gov.br/recortes_para_fins_estatisticos/grade_estatistica/censo_2010/).
Economic losses due to flood events	Reducing the impact of floods	Amount (R$) (per event or per period)	Economical	Economic losses due to flooding are a direct indicator of the impact of flooding on people and economic activities.	Estimate based on the area potentially or actually flooded (broken down by type of buildings in this area, residential or commercial) and average value of damage to residential and/or commercial properties.	A recent European Union report offers calculation methods and reference values for the economic damage caused by flooding (https://publications.jrc.ec.europa.eu/repository/bitstream/JRC105688/global_flood_depth-damage_functions__10042017.pdf).

Indicator	Benefit	Unity	Type	Justification for use	Assessment methods	Comments
Green area/ inhabitant ratio	Increased access to green areas	m^2/inhabitant (green area/number of inhabitants in the neighbourhood/city)	Social	This is a well-known indicator of people's access to green areas, proposed by the World Health Organization (WHO).	Calculation based on cartographic (green areas) and demographic (population) data for a given territory: (formula: total extent of green areas/total population).	According to Art. 8, § 1 of CONAMA Resolution 369/2006, a green area in the public domain is "a space in the public domain that performs an ecological, landscape and recreational function, improving the aesthetic, functional and environmental quality of the city, with vegetation and spaces free of waterproofing".
Green area/total area ratio	Increased access to green areas	% (green area/total area of neighbourhood/city)	Environmental	This indicator makes it possible to assess the participation of green areas in the use and land cover matrix of a given territory.	Calculation based on cartographic data (green areas and total area) for a given territory: (formula: sum of green areas/total area).	Same as above.
Average distance to green areas	Increased access to green areas	Metres or kilometres	Social	This is another indicator proposed by the World Health Organization (WHO) to assess people's access to green areas.	Calculation of the distance from each residential square to the nearest green area (using SIG tools), followed by calculation of the average value.	Same as above.

Indicator	Benefit	Unity	Type	Justification for use	Assessment methods	Comments
Visitors in green areas	Use of green areas	Number of people (per period)	Social	This is a direct indicator of the increase in quality of life through contact with green areas. The greater the number of visitors to a given area, the greater the supposed contribution to the local population's quality of life.	Manual (visual count) or automatic (through turnstiles or other visitation control methods) accounting for a certain period.	Detailing and cutouts can be made by gender, income level, education level, etc.
Structural ecological connectivity	Increased biodiversity/ Improved ecological processes	Proximity index (NEAR)	Environmental	A green infrastructure approach, which aims to connect parks and other green spaces, is considered essential for the preservation of biodiversity and to combat the fragmentation of natural and seminatural habitats and increase their connectivity.	Structural connectivity is measured by the proximity of green areas and the natural infrastructure matrix they form in a city. They are usually measured through a geoprocessing analysis that measures distribution and proximity at the municipal level (ZHANG et al. 2019, apud EUROPEAN COMMISSION, 2021b). A well-known methodology for such mapping is the FRAGSTATS tool (SAURA and TORNÉ 2009, apud EUROPEAN COMMISSION, 2021b).	It requires some specialised knowledge of landscape analysis. A conceptual basis can be found in Metzger, 2001 (https://www.scielo.br/j/bn/a/Jbch-d6rjY35PGkY5BHP-z63S/?lang=pt).

Indicator	Benefit	Unity	Type	Justification for use	Assessment methods	Comments
Native plant species	Increased biodiversity	Number of species	Environmental	It offers a direct measure of habitat quality for the conservation of plant biodiversity.	Biological field monitoring and calculation of species richness of different taxonomic groups (number of species).	It is interesting to evaluate natural regeneration sites (clearings and understory) to check for the entry of new native species (mainly by zoochory).
Native animal species	Increased biodiversity	Number of species	Environmental	It offers a direct measure of habitat quality for the conservation of plant biodiversity.	Biological field monitoring and calculation of species richness of different taxonomic groups (number of species).	It is important that monitoring is carried out during the rainy and dry seasons to capture seasonal variability.
Invasive plant species	Reducing risks to native biodiversity	Number of species	Environmental	It offers a direct measure of habitat quality for the conservation of plant biodiversity.	Biological field monitoring and calculation of species richness of different taxonomic groups (number of species).	It is interesting to evaluate natural regeneration sites (clearings and understory) to check for the entry of exotic species.
Invasive animal species	Reducing risks to native biodiversity	Number of species	Environmental	It offers a direct measure of habitat quality for the conservation of plant biodiversity.	Biological field monitoring and calculation of species richness of different taxonomic groups (number of species).	It is important that monitoring is carried out during the rainy and dry seasons to capture seasonal variability.

Indicator	Benefit	Unity	Type	Justification for use	Assessment methods	Comments
Air Quality Index	Improved air quality	Air quality index (AQI)	Environmental	It reflects the potential impact of air quality on health, due to the health impacts associated with the concentration of pollutants in the air, mainly on the respiratory system.	Calculation according to "Technical guide for monitoring and evaluating air quality" (MMA, 2020).	Air quality monitoring should preferably be carried out in and around the green area.
Days with an Air Quality Index below the recommended level	Improved air quality	Number of days per period	Environmental	It reflects the frequency of people's exposure to low levels of air quality, with possible impacts on health.	Statistical verification of daily data from the Air Quality Index (AQI).	Same as above.
Businesses in and near green areas	Increased economic activity	Number of registered companies	Economic	The availability of green areas in the vicinity can improve the consumer experience of goods and services, potentially favouring commercial and service activities.	Consultation of municipal permits for commercial activities or services for the location of interest.	It is not always possible to access data broken down by more detailed territorial level than municipality, which makes it difficult to use this indicator.
Service taxes paid in the locality of the green zone (neighbourhood, subprefecture, etc.)	Increased economic activity	Amount (R$) (per period)	Economic	This is a direct economic indicator of greater or lesser economic activity in the regions of influence of green areas.	Consultation of municipal records of service taxes collection by locality (if possible, this level of geographic breakdown).	Same as above.

Indicator	Benefit	Unity	Type	Justification for use	Assessment methods	Comments
Average value of residential properties	Increasing the commercial value of properties	Relative amount (R$/m²)	Economic	The change in the attractiveness of an area due to the presence of public green space or other NbS can be determined by the sale/rental price or estimated value of land or property located near the NbS.	Statistical analysis of advertised values for residential properties located in the area of interest and comparison with other nearby areas without green areas.	Pay attention to other factors that influence real estate prices.
Average value of commercial properties	Increasing the commercial value of properties	Relative amount (R$/m²)	Economic	The change in the attractiveness of an area due to the presence of public green space or other NbS can be determined by the sale/rental price or estimated value of land or property located near the NbS.	Statistical analysis of advertised values for commercial properties located in the region of interest.	Same as above.
Community involvement with planning and management of green areas	Social participation	Number of people involved (per period)	Social	Involving the community in planning and decision-making is very important for achieving well-designed NbS that meet local demands.	Registration of participants in meetings and other events aimed at the planning and managing green areas.	Detailing and cutouts can be made by gender, income level, education level, etc.
Crime rate in and near green areas	Reduction in crime	Number of crimes (per period)	Social	The number of violent incidents, disturbances of order and other crimes is a primary indicator of the perception of personal safety, affecting quality of life significantly.	Statistical analysis of official crime records (broken down by area of interest).	Pay attention to other factors that can lead to an increase or decrease in crime.

Indicator	Benefit	Unity	Type	Justification for use	Assessment methods	Comments
Zoonoses in the locality of the green area (neighborhood, subprefecture, etc.)	Reduction of diseases	Number of cases (per period)	Social	As green areas are habitat for natural enemies (e.g. amphibi-ans) of zoonosis vectors (e.g. mosquitos), a possible reduction in zoonoses can be inferred in the vicinity of well-conserved areas.	Statistical analysis of official epidemiological records of zoonoses (such as dengue and yellow fever).	Pay attention to other factors that can generate variability in the occurrence of zoonoses, such as climatic factors, vector control campaigns, etc.
Mental illness in the locality of the green area (neighborhood, subprefecture, etc.)	Reduction of diseases	Number of cases (per period)	Social	Experimental studies have shown that visiting green spaces stimu-lates physical habits such as walking, running and other outdoor physical activities.	Statistical analysis of official records of mental illness (such as depression and anxiety).	Pay attention to other factors that can generate variability in the occurrence of physical illnesses, such as congenital diseases, etc.
Diseases related to sedentary lifestyle	Reduction of diseases	Number of cases (per period)	Social	Experimental studies have shown that visiting green spaces can bring mental health benefits, such as reducing stress, restoring attention and improving mood.	Statistical analysis of official records of diseases proven to be related to a sedentary lifestyle (such as depression and anxiety).	Pay attention to other factors that can generate variability in the occurrence of mental illness, such as economic, family and social factors, etc.
Average dis-tance travelled within the green area as part of the locomotion route	Increased mobility	Distance travelled (m, km)	Social	Linear sidewalks provide sustainable urban mobility benefits to the local community and can be used for commuting to work, school or other activities.	Research based on interviews with users of green areas about the distances travelled to destinations outside the green area.	Universities and other research institutions can collaborate in investigations of this nature.

Indicator	Benefit	Unity	Type	Justification for use	Assessment methods	Comments
Reduction of distance between key points of the city or neigh-bourhood	Increased leisure options	Distance reduced (m, km)	Social	Linear sidewalks provide sustainable urban mobility benefits to the local community and can reduce walking distances to work, school or other activities.	Research based on interviews with users of green areas about the routes they commonly take to get to work, school or other destinations.	Universities and other research institutions can collaborate in investigations of this nature.
Events held in or near public green areas	Increased mobility	Number of events	Social	Public green areas can serve as centres for cultural, recreational and sporting activities, offering free leisure options, especially for populations with less access to these activities.	Survey of events at the prefecture or subpre-fecture, or local administrative authority. More detailed informa-tion needs to be obtained through research based on interviews.	The information can be increased with data such as: number of participants, average income, educational level of participants, etc.


Ecological Park Major Dr. Clain Ferrari in Indaiatuba, SP. Source: Archdaily, Erich Sacco.

3 Survey of methodologies for quantifying benefits of Nature-based Solutions

A bibliographic survey was conducted to identify the primary methodologies for quantifying the impacts of environmental, economic and social benefits of Nature-based Solutions, as well as the potential associated with their implementation.

A comparative evaluation was conducted based on criteria such as ease of use, practicality of the approach, versatility and scope of measurable benefits. Based on this evaluation process, the methodology that best met the requirements of the present study was identified.

The selected methodology should be able to consider the direct and indirect impacts of NbS implementation, in different phases and timeframes. It should also assess the entire area influenced by and influencing the territory receiving NbS interventions (e.g., the river basin in which a linear park is located, rather than just the immediate NbS coverage area), as well as the various levels of conception (e.g. feasibility studies, basic projects or executive projects). The input data must be compatible with the NbS detailing stage.

The nine methodologies that can be used to quantify environmental, economic and social risks and benefits of Nature-based Solutions (NbS), which are generally adopted in the implementation of linear and river parks, were evaluated and are listed below:

1. EVERARD, M. & WATERS, R. (2013): **Ecosystem services assessment: How to do one in practice**. Institute of Environmental Sciences, London.[6]

2. BROWN, C. et al. (2014): **Measuring ecosystem services: Guidance on developing ecosystem service indicators**. UNEP-WCMC.[7]

3. EUROPEAN COMMISSION (2016): **Mapping and Assessment of Ecosystems and their Services**: Urban ecosystems 4th Report. Publications office of the European Union.[8]
EUROPEAN COMMISSION (2018): **Mapping and Assessment of Ecosystems and their Services**: An analytical framework for ecosystem condition. Publications Office of the European Union.[9]

6 Available at: www.ies-uk.org.uk/resources/ecosystem-servicesassessment
7 Available at: https://resources.unep-wcmc.org/products/measuring-ecosystem-guidance-developing-ecosystem-service-indicators/download/473310
8 Available at: https://op.europa.eu/en/publication-detail/-/publication/c3919882-3904-11e6-a825-01aa75ed71a1/language-en/format-PDF/source-283163281
9 Available at: https://publications.jrc.ec.europa.eu/repository/bitstream/JRC120383/eu_ecosystem_assesse ment_final.pdf

4 NEUGARTEN et al. (2018): **Tools for measuring, modelling, and valuing ecosystem services: Guidance for Key Biodiversity Areas**, natural World Heritage Sites, and protected areas. IUCN.[10]

5 EUROPEAN COMMISSION (2021a): **Evaluating the Impact of Nature-based Solutions: A Handbook for Practitioners** (Independent Expert Report). Dumitru, A. & Wendling, L. (ed.) European Commission -Directorate-General for Research and Innovation.[11]

6 BRILL et al. (2021): **Benefit Accounting of Nature-based Solutions for Watersheds: Guide**. United Nations Global Compact CEO Water Mandate and Pacific Institute. Oakland, California.[12]

7 NATURAL CAPITAL PROJECT (2022): **InVEST 3.12.0. Workbench** User's Guide. Stanford University, University of Minnesota, Chinese Academy of Sciences, The Nature Conservancy, World Wildlife Fund, and Stockholm Resilience Centre.[13]

8 CONNECTING NATURE (DUMITRU & LOURIDO, 2020): **The Connecting Nature Impact Assessment Framework**: developing robust monitoring and evaluation plans for nature-based solutions. Connecting Nature.[14]

9 CONNECTING NATURE & GLASGOW CITY COUNCIL (2020): **Glasgow's Nature-based Solutions dashboard**. Glasgow City Council.[15]

10 Available at: https://portals.iucn.org/library/sites/library/files/documents/PAG-028-En.pdf
11 Available at: https://op.europa.eu/en/publication-detail/-/publication/d7d496b5-ad4e-11eb-9767-01aa75ed71a1
12 Available at: www.ceowatermandate.org/nbs/guide
13 Available at: https://storage.googleapis.com/releases.naturalcapitalproject.org/invest-userguide/latest/en/index.html
14 Available at: https://connectingnature.eu/sites/default/files/images/inline/Impact%20Assessment.pdf
15 Available at: https://glasgowgis.maps.arcgis.com/apps/dashboards/d11c42a0a9d2416ba231392e6798e0ba

4 Approach to evaluating methodologies

The methodologies were evaluated based on the application of the following criteria, each of which was assessed by answering the associated questions :

I. **Ease of application of the methodology:** is the methodology easy to understand and apply, not requiring specialised technical knowledge?

II. **Methodology approach:** is the methodology directed towards practical application, i.e., does it contain practical guidelines for its use in a real case?

III. **Data requirements necessary for applying the methodology:** is the data needed to apply the methodology easily accessible (e.g. free availability in online data repositories) and is the list of data relatively short?

IV. **Degree of international recognition of the methodology:** is the methodology internationally recognised as efficient for assessing the impacts of NbS?

V. **Possibility of application in different phases of the implementation of an NbS:** can the methodology be applied both in the planning phase of the NbS and in the implementation or maintenance phases?

VI. **Possibility of application at different levels of NbS design:** can the methodology be applied in the feasibility studies phase, as well as in basic projects or executive projects?

VII. **Possibility of assessing the economic viability of NbS:** does the methodology incorporate or allow the association with economic feasibility assessments (e.g. cost-benefit analysis)?

VIII. **Possibility of evaluating the multiple benefits of an NbS in the environmental, social and economic spheres:** is the methodology capable of evaluating different types of benefits, both environmental, social and economic?

The following table summarises the aspects evaluated for each methodology, in relation to its suitability as a methodology for quantifying the benefits of Nature-based Solutions associated with linear and river parks.

		Methodologies for Quantifying the Impact of Environmental, Economic and Social Benefits of Nature-based Solutions								
	Criteria	Ecosystem services assessment: how to do one in practice (EVERARD & WATERS, 2013).	Measuring ecosystem services: guidance on developing ecosystem service indicators (BROWN, C. et al., 2014).	Mapping and assessment of ecosystems and their services (COMISSÃO EUROPEIA, 2016 e 2018).	Tools for measuring, modelling, and valuing ecosystem services: guidance for key biodiversity areas, natural world heritage sites, and protected areas (NEUGARTEN et al., 2018).	Evaluating the impact of Nature-based Solutions: a handbook for practitioners (Independent Expert Report) (COMISSÃO EUROPEIA, 2021a).	Benefit accounting of Nature-based Solutions for watersheds: guide (BRILL et al., 2021).	InVEST 3.12.0. Workbench (NATURAL CAPITAL PROJECT, 2022).	The Connecting Nature Impact Assessment Framework (DUMITRO & LOURIDO, 2020).	Glasgow's Nature-based Solutions dashboard (CONNECTING NATURE & GLASGOW CITY COUNCIL, 2020).
I	Ease of application of the methodology	**Yes**	**Yes**	**Partly**	**Partly**	**Yes**	**Partly**	**Partly**	**Yes**	**Partly**
I	Justification	The methodology is generic and flexible in nature, recognising that there are many types of economic development or territorial management systems that require the evaluation of ecosystem services, but for different purposes.	As it is a generic and flexible methodology, it can be easily applied by following its basic principles.	The methodology is clear in pointing out the initial steps for evaluating ecosystem services - (1) defining the typologies of "urban green spaces"; (2) mapping this space; (3) defining the indicators - but it does not describe how to measure these indicators.	This is a comparative assessment of various methodologies, rather than a methodology for quantifying NbS impacts per se. Therefore, it is necessary to choose one of the suggested methodologies and access technical guidelines specific to this methodology.	This manual aims to be a facilitator of knowledge about NbSs, providing a friendly way of planning, monitoring and evaluating them. To this extent, the manual works as a tool for the main stakeholders in the NbSs value chain, aiming to facilitate a better understanding of their impacts, helping to inform about the implementation of a NbS and its results (occurred or potential).	This publication indicates the recommended methods for quantifying the benefits related to hydric regulation ecosystem services. The guide provides a starting point for identifying and measuring the benefits resulting from investments in NbS but is not a methodology in itself.	The tool's models have an online manual which indicates, for each model: its conceptual approach; its basic form of working; a description of the input data and the possible sources for obtaining the data; the model's calibration procedures; and a description of the results. Even so, they require some knowledge of geoprocessing to prepare the geographic that will serve as input for the models, and to interpret the results.	The methodology is presented in a step-by-step approach, which allows a logical connection of the different processes linked to the survey on the benefits of NbS.	The development of an online platform with impact indicators of NbS, such as the one developed by Glasgow City Council, requires specialised knowledge for building web-based platforms (such as data programming, website creation, etc.), as well as the need for technicians dedicated to feeding, updating and maintaining the platform.

		Methodologies for Quantifying the Impact of Environmental, Economic and Social Benefits of Nature-based Solutions								
	Criteria	Ecosystem services assessment: how to do one in practice (EVERARD & WATERS, 2013).	Measuring ecosystem services: guidance on developing ecosystem service indicators (BROWN, C. et al., 2014).	Mapping and assessment of ecosystems and their services (COMISSÃO EUROPEIA, 2016 e 2018).	Tools for measuring, modelling, and valuing ecosystem services: guidance for key biodiversity areas, natural world heritage sites, and protected areas (NEUGARTEN et al., 2018).	Evaluating the impact of Nature-based Solutions: a handbook for practitioners (Independent Expert Report) (COMISSÃO EUROPEIA, 2021a).	Benefit accounting of Nature-based Solutions for watersheds: guide (BRILL et al., 2021).	InVEST 3.12.0. Workbench (NATURAL CAPITAL PROJECT, 2022).	The Connecting Nature Impact Assessment Framework (DUMITRO & LOURIDO, 2020).	Glasgow's Nature-based Solutions dashboard (CONNECTING NATURE & GLASGOW CITY COUNCIL, 2020).
II	Practical approach to the methodology	**No**	**No**	**Partly**	**Partly**	**Yes**	**Partly**	**Yes**	**Partly**	**Yes**
	Justification	The methodology provides basic principles for evaluating ecosystem services but does not go into the practical details of how to carry out this evaluation.	As described in the applications topic of this methodology, it serves as a starting point and indicates a simplified process and should be supplemented with other sources to obtain details.	The methodology has a practical approach in terms of suggesting indicators, but it does not provide technical guidance on how to evaluate the benefits of SbN based on these indicators.	As a compendium of different methodologies, the publication can be understood as a stage prior to the practical application of a methodology.	This manual provides a protocol for selecting key impact indicators of NbS and methods for their assessment, which can be applied to monitor reference values. It provides detailed information to guide the development and implementation of a monitoring and evaluation plan for NbS.	This guide presents a step-by-step process for identifying the potential benefits of NbS in the design and implementation phases of a project but only indicates other practical approach methodologies for carrying out this assessment.	InVEST's models are completely geared towards application in real cases. The tool provides clear guidelines on how each model should be fed and calibrated and how the results should be interpreted.	Although the methodology aims to provide a pragmatic, step-by-step overview of the development of impact assessment process of NbS, it does not cover more practical aspects, such as the indication of specific methods for measuring the benefits of NbS.	Glasgow's impact dashboard of NbS takes a practical approach, presenting indicators used for other purposes (health, education, environment, etc.), most of the data being produced by the city itself, but which can reflect the influence of NbS on the quality of life of its residents.

		Methodologies for Quantifying the Impact of Environmental, Economic and Social Benefits of Nature-based Solutions								
	Criteria	Ecosystem services assessment: how to do one in practice (EVERARD & WATERS, 2013).	Measuring ecosystem services: guidance on developing ecosystem service indicators (BROWN, C. et al., 2014).	Mapping and assessment of ecosystems and their services (COMISSÃO EUROPEIA, 2016 e 2018).	Tools for measuring, modelling, and valuing ecosystem services: guidance for key biodiversity areas, natural world heritage sites, and protected areas (NEUGARTEN et al., 2018).	Evaluating the impact of Nature-based Solutions: a handbook for practitioners (Independent Expert Report) (COMISSÃO EUROPEIA, 2021a).	Benefit accounting of Nature-based Solutions for watersheds: guide (BRILL et al., 2021).	InVEST 3.12.0. Workbench (NATURAL CAPITAL PROJECT, 2022).	The Connecting Nature Impact Assessment Framework (DUMITRO & LOURIDO, 2020).	Glasgow's Nature-based Solutions dashboard (CONNECTING NATURE & GLASGOW CITY COUNCIL, 2020).
III	Data requirements for applying the methodology (availability)	**No**	**Yes**	**Yes**	**Partly**	**Yes**	**Partly**	**Yes**	**Yes**	**Yes**
	Justification	The methodology is quite generic in terms of the data that can be used for an ecosystem services assessment, limiting itself to saying that information can be obtained from "official reports and documentation; scientific literature; technical journals and reports; interviews; websites and forums".	Although the methodology is theoretical and aimed at providing generic recommendations, it indicates which types of data can be used as indicators for evaluating the benefits resulting from the increase in ecosystem services through actions such as NbS. There is a chapter of the publication dedicated to this topic (Step 6: Gather and review data).	One of the results of this report is to offer an assessment of suitable data and indicators sets for mapping and evaluating urban ecosystems and their services.	The publication provides a general description of the data requirements needed to apply each methodology evaluated but does not specify the data needed to use each platform.	The methodology has a chapter entirely dedicated to the acquisition of data for quantifying the impact of NbS, as well as the process of obtaining, processing, integrating and others.	As the authors themselves point out, in a section indicating the limitations of the publication, "detailed descriptions of the applications of the method and the data needed to conduct the analysis are beyond the scope of this phase of the work".	The models in the InVEST tool require data that is relatively well known to environmental technicians and easy to obtain, and the manual for each model indicates possible sources of data or procedures for producing them.	The methodology indicates as one of its steps the development of a "data plan" and cites types of data that can be used as impact indicators of NbS.	As the data is collected by the municipality and other entities for other purposes (health, environment, urban planning, security, etc.), it is easy to obtain (if there are agreements with different departments/ agencies/ secretariats to make the data available on an ongoing basis).

		Methodologies for Quantifying the Impact of Environmental, Economic and Social Benefits of Nature-based Solutions								
	Criteria	Ecosystem services assessment: how to do one in practice (EVERARD & WATERS, 2013).	Measuring ecosystem services: guidance on developing ecosystem service indica-tors (BROWN, C. et al., 2014).	Mapping and assessment of ecosystems and their services (COMISSÃO EUROPEIA, 2016 e 2018).	Tools for measuring, modelling, and valuing ecosystem services: guidance for key biodiversity areas, natural world heritage sites, and protected areas (NEUGARTEN et al., 2018).	Evaluating the impact of Nature-based Solutions: a handbook for practitioners (Independent Expert Report) (COMISSÃO EUROPEIA, 2021a).	Benefit accoun-ting of Nature-based Solutions for watersheds: guide (BRILL et al., 2021).	InVEST 3.12.0. Workbench (NATURAL CAPITAL PROJECT, 2022).	The Connecting Nature Impact Assessment Framework (DUMITRO & LOURIDO, 2020).	Glasgow's Nature-based Solutions dashboard (CONNECTING NATURE & GLASGOW CITY COUNCIL, 2020).
IV	National and international recognition of the methodology	**No**	**Yes**	**Yes**	**Yes**	**Yes**	**Partly**	**Yes**	**Partly**	**Yes**
	Justification	Although at the time of its release (2013) there was not much technical material on ecosystem service valuation, which led to some recognition at least at national level (England), this publication has a relatively low level of citations, according to Google Scholar (28 citations).	The methodology is cited by 50 other publica-tions, according to Google Scholar.	It is a document produced by the European Commission to serve as a standard guide for evaluating ecosystem services in European cities. It has been cited by 195 publications, according to Google Scholar.	As it is published by an organisation recognised as one of the most important at a global level for nature conserva-tion, it can be assumed that the publication itself has wide recognition. The publication has 70 citations, according to Google Scholar.	The methodology does not yet have many citations (48), but this is possibly because it is quite recent (2021). Further-more, the fact that it is an official document of the European Commission proves the high level of interna-tional recognition that the methodology enjoys.	Despite being the result of a joint initiative by worldwide organisations (UN Global Compact, The Nature Conservancy, Danone and others), this publication apparently still doesn't have much repercus-sion in the academic and technical community (it only has 3 citations on Google Scholar).	Yes, several publications that have produced compendiums on methodologies for evaluating ecosystem services, methodologies for evaluating the impacts of environmental projects and other approaches indicate the InVEST tool as one of the most complete and flexible methodolo-gies for these purposes. These include publications evaluated here, such as Brown et al. (2014), Neugarten et al. (2018), European Commission (2021) and Brill et al. (2021). The article that makes the academic presentation of the InVEST tool (Nelson et al., 2009) has 2628 citations, according to Google Scholar.	The methodology is still little cited (4 citations in Google Scholar) but can be understood as a product strongly related to another methodology evaluated here (European Commission, 2021), since one of the main authors was editor of the aforementioned publication and the approach to assessing NbS impacts is very similar.	This experience is widely publicized by the Connecting Nature initiative as a successful case of involving municipal governments in monitoring the impact of NbS on improving the environmental conditions of cities and the quality of life of their citizens.

		Methodologies for Quantifying the Impact of Environmental, Economic and Social Benefits of Nature-based Solutions								
	Criteria	Ecosystem services assessment: how to do one in practice (EVERARD & WATERS, 2013).	Measuring ecosystem services: guidance on developing ecosystem service indicators (BROWN, C. et al., 2014).	Mapping and assessment of ecosystems and their services (COMISSÃO EUROPEIA, 2016 e 2018).	Tools for measuring, modelling, and valuing ecosystem services: guidance for key biodiversity areas, natural world heritage sites, and protected areas (NEUGARTEN et al., 2018).	Evaluating the impact of Nature-based Solutions: a handbook for practitioners (Independent Expert Report) (COMISSÃO EUROPEIA, 2021a).	Benefit accounting of Nature-based Solutions for watersheds: guide (BRILL et al., 2021).	InVEST 3.12.0. Workbench (NATURAL CAPITAL PROJECT, 2022).	The Connecting Nature Impact Assessment Framework (DUMITRO & LOURIDO, 2020).	Glasgow's Nature-based Solutions dashboard (CONNECTING NATURE & GLASGOW CITY COUNCIL, 2020).
V	Possibility of applying the methodology at different stages in the implementation of an NbS project	**Yes**	**Yes**	**Yes**	**Partly**	**Yes**	**Yes**	**Yes**	**Yes**	**Partly**
	Justification	The methodology can be used both in the design phase of a NbS, when identifying the most relevant ES and the expected benefits, and in the implementation and monitoring phases. The guide even indicates that some steps of the methodology can be skipped if the aim is to carry out a retrospective evaluation.	As the primary objective of this publication is merely to provide basic guidelines on how to define and measure indicators, the methodology presented can be applied at any stage related to the implementation of a NbS, whether in the planning stage, its actual implementation or even its maintenance.	Although the methodology was developed primarily to serve the planning of green infrastructure in cities, it has a framework that allows it to be used in the implementation and maintenance phases of NbS as well.	The publication presents different methodologies that can be applied in the planning, implementation and maintenance phases of a NbS.	The methodology was developed to be applied in a "project cycle" approach, from the stakeholder engagement phase, through planning, implementation and monitoring.	The methodology is explicitly aimed at applying benefit assessment of NbS to water issues in the different phases of a project, mainly in the design and implementation phases.	As the InVEST models employ use and land cover maps and associated parameters that are supplied by the user, it is possible to simulate the impacts of implementing an NbS project at any of its stages.	Although the methodology emphasizes the need to develop an impact assessment plan already in the planning phase of a NbS, the methodology can be perfectly used at other points in the process, and its potential application in the implementation phase is mentioned a few times.	As this is a tool for disseminating impact indicators of NbS, it is mainly aimed at the implementation and maintenance phases. Eventually, however, a similar tool could be developed during the planning phase, incorporating data that could represent a "baseline" (pre-implementation situation of NbS).

		Methodologies for Quantifying the Impact of Environmental, Economic and Social Benefits of Nature-based Solutions								
	Criteria	Ecosystem services assessment: how to do one in practice (EVERARD & WATERS, 2013).	Measuring ecosystem services: guidance on developing ecosystem service indica-tors (BROWN, C. et al., 2014).	Mapping and assessment of ecosystems and their services (COMISSÃO EUROPEIA, 2016 e 2018).	Tools for measuring, modelling, and valuing ecosystem services: guidance for key biodiversity areas, natural world heritage sites, and protected areas (NEUGARTEN et al., 2018).	Evaluating the impact of Nature-based Solutions: a handbook for practitioners (Independent Expert Report) (COMISSÃO EUROPEIA, 2021a).	Benefit accoun-ting of Nature-based Solutions for watersheds: guide (BRILL et al., 2021).	InVEST 3.12.0. Workbench (NATURAL CAPITAL PROJECT, 2022).	The Connecting Nature Impact Assessment Framework (DUMITRO & LOURIDO, 2020).	Glasgow's Nature-based Solutions dashboard (CONNECTING NATURE & GLASGOW CITY COUNCIL, 2020).
VI	Capacity to apply the methodology at different levels of a NbS design	**Yes**	**Yes**	**Yes**	**Partly**	**Yes**	**Partly**	**Yes**	**Yes**	**No**
	Justification	The methodology can be adapted to different information availability and purposes, so it can be used in different contexts and phases of NbS planning.	As the methodol-ogy is primarily aimed at providing basic recommen-dations on the definition, collection and interpretation of indicators, which should be defined according to the context and phase of each SbN project, it can be applied at any conception stage of a NbS.	The methodology can be applied to different moments in the planning and design of a NbS and is adaptable to different availability of information and data.	The publication presents different methodologies that can be applied in the different phases of the conception and planning of a NbS, such as feasibility studies, basic design or executive design.	The methodology is easily adaptable to the level of detail involved in planning a NbS.	As this is a publication that points out different methodologies for different purposes of assessing the benefits of SbN for water resources, the potential and application at different stages of the conception of a NbS will depend on the methodolo-gy chosen.	InVEST models are flexible in terms of the level of detail of the information they are fed with. It is very easy to run the same model in the different conception and planning phases, obtaining more accurate answers as the information becomes more detailed. All you must do is replace the use and land cover base that feeds the model or adjust the parameters to reflect different environmental behaviours in the same use/land cover class.	The methodology has the flexibility to be used based on different levels of detail, associated with different planning phases and products of a NbS.	Given its wider spatial scope (covering the entire municipali-ty and all the NbS there), the tool is not suitable for simulating impacts on specific projects of NbS.

		Methodologies for Quantifying the Impact of Environmental, Economic and Social Benefits of Nature-based Solutions								
	Criteria	Ecosystem services assessment: how to do one in practice (EVERARD & WATERS, 2013).	Measuring ecosystem services: guidance on developing ecosystem service indicators (BROWN, C. et al., 2014).	Mapping and assessment of ecosystems and their services (COMISSÃO EUROPEIA, 2016 e 2018).	Tools for measuring, modelling, and valuing ecosystem services: guidance for key biodiversity areas, natural world heritage sites, and protected areas (NEUGARTEN et al., 2018).	Evaluating the impact of Nature-based Solutions: a handbook for practitioners (Independent Expert Report) (COMISSÃO EUROPEIA, 2021a).	Benefit accounting of Nature-based Solutions for watersheds: guide (BRILL et al., 2021).	InVEST 3.12.0. Workbench (NATURAL CAPITAL PROJECT, 2022).	The Connecting Nature Impact Assessment Framework (DUMITRO & LOURIDO, 2020).	Glasgow's Nature-based Solutions dashboard (CONNECTING NATURE & GLASGOW CITY COUNCIL, 2020).
VII	Possibility of assessing the economic viability of the NbS	**Partly**	**Partly**	**No**	**Partly**	**Partly**	**Partly**	**Yes**	**Partly**	**Partly**
	Justification	The authors briefly discuss the relevance of making economic valuations of the changes investigated in ecosystem services and make recommendations on the level of complexity of these analyses according to the purpose of the impact assessment of the NbS. However, they do not go into the merits of indicating economic valuation methods.	The methodology itself does not propose any form of economic valuation, but it does mention other tools that can be used for this (InVEST, Co$ting Nature, ARIES).	Despite recognising the socioeconomic benefits provided by NbS, the methodology does not present techniques or point to other methodologies for the economic valuation of NbS.	The publication presents different methodologies for assessing the economic viability of a NbS.	Despite emphasizing the need to evaluate economic benefits and proposing indicators related to cost-benefit analyses, the methodology does not provide specific guidelines on how to carry out economic feasibility analyses of NbS.	As this is a publication that points out different methodologies for different purposes of assessing the benefits of NbS aimed at water resources, the potential for use in assessing the economic feasibility of a NbS will depend on the methodology chosen.	Most InVEST models have an associated economic valuation module, which makes it possible to obtain financial values associated with ecosystem service flows. And the outputs of InVEST models can easily be used for economic and/ or social analysis.	Despite indicating opportunities for the economic valuation of benefits and pointing out some economic indicators, the methodology does not directly address economic feasibility analysis methods.	The online platform only shows one economic indicator (number of companies, by region and sector of activity).

		Methodologies for Quantifying the Impact of Environmental, Economic and Social Benefits of Nature-based Solutions								
	Criteria	Ecosystem services assessment: how to do one in practice (EVERARD & WATERS, 2013).	Measuring ecosystem services: guidance on developing ecosystem service indicators (BROWN, C. et al., 2014).	Mapping and assessment of ecosystems and their services (COMISSÃO EUROPEIA, 2016 e 2018).	Tools for measuring, modelling, and valuing ecosystem services: guidance for key biodiversity areas, natural world heritage sites, and protected areas (NEUGARTEN et al., 2018).	Evaluating the impact of Nature-based Solutions: a handbook for practitioners (Independent Expert Report) (COMISSÃO EUROPEIA, 2021a).	Benefit accounting of Nature-based Solutions for watersheds: guide (BRILL et al., 2021).	InVEST 3.12.0. Workbench (NATURAL CAPITAL PROJECT, 2022).	The Connecting Nature Impact Assessment Framework (DUMITRO & LOURIDO, 2020).	Glasgow's Nature-based Solutions dashboard (CONNECTING NATURE & GLASGOW CITY COUNCIL, 2020).
VIII	Possibility of evaluating the multiple benefits of a NbS, in the environmental, social and economic spheres	**Yes**	**Yes**	**No**	**Partly**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
	Justification	The methodology recognises that the ecosystem services of green infrastructure provide multiple and interconnected environmental, social and economic benefits, and addresses different types of benefits, which can be evaluated based on the principles of the methodology.	Since the methodology suggests indicators for different categories of ecosystem services (support, supply, regulation and cultural), it allows for the assessment of different benefit spheres of NbS.	Despite recognising the different types of benefits generated by SbN in the environmental, social and economic spheres, the methodology does not offer specific guidelines on how to measure these benefits.	The publication presents different methodologies for evaluating benefits of different kinds (environmental, social and economic).	The impact indicators of NbS, detailed in this manual and the accompanying Methods Appendix, cover the environmental, social and economic domains in the assessment of NbS.	Although it focuses on water resources, the guide presents different categories of benefits that are likely to occur after the actions are implemented. These benefits cover five main themes: 1) water quantity; 2) water quality; 3) carbon; 4) biodiversity; and 5) socioeconomic.	InVEST is a package of different models (more than 20), capable of analysing different ecosystem services. It is possible to use a set of models to evaluate different benefits of NbS and obtain not only environmental results (linked to ecological processes or ecosystem services) but also economic or social results (from optional modules or using the model outputs for other analyses).	The need for a comprehensive, integrated and cumulative assessment of the impacts that SbN can have on society is emphasised in this methodology, and indicators related to these different spheres are suggested.	The online platform incorporates environmental indicators (such as habitats, connectivity, etc.), social indicators (crime rates, life expectancy, diseases) and economic indicators (number of companies).

Bandeirantes Stream in Campinas/SP (Source: Daniel Nogueira Maekawa, 2022).

5 Methodology selected to quantify benefits derived from linear/river parks

The methodology indicated for this purpose, among those evaluated, was the modelling of Ecosystem Services through the **InVEST tool (Integrated Valuation of Ecosystem Services and Tradeoffs)**, developed by the Natural Capital Project initiative, coordinated by Stanford University/USA. This initiative has developed a package of models that quantify and map ecosystem services, which is constantly being improved and releases new models periodically.

The InVEST tool is a set of models developed to quantify, map and value the ecosystem services that sustain human life and activities. Its operation is based on production functions that define how changes in the structure and/or function of an ecosystem affect the flows and availability of ecosystem services, including services such as the regulation of water infiltration into soils and the recharge of aquifer systems (NATURAL CAPITAL, 2022). **It is a free and stand-alone software (download available at:** https://naturalcapitalproject.stanford.edu/software/invest).

The models are particularly suited for analysing environmental and socio-economic impacts of Nature-based Solutions (NbS), especially in urban green spaces like linear and river parks. InVEST is favoured for requiring relatively less and more accessible input data than other tools (e.g. SWAT, HEC-HMS), while also offering the capacity to identify locations where NbS investments yield the greatest benefits for human well-being and ecosystem conservation.

InVEST is designed to inform decisions on managing natural resources. It essentially provides information on how changes in ecosystems are likely to affects the benefits people receive, as well as the potential harm to ecological flows, biodiversity and human well-being that this could cause.

Decision-makers, ranging from governments to nonprofits and corporations, often manage land and water for multiple uses and must inevitably evaluate the trade-offs between these uses. InVEST's multi-service modular design provides an effective tool for exploring the likely outcomes of NbS development scenarios, as well as for assessing trade-offs between sectors and services.

For instance, government agencies can use InVEST to help determine how to manage green spaces to provide desirable benefits for people, or to develop NbS that sustain the benefits of nature for society, while conserving biodiversity that ultimately sustain this flow of benefits.

Conservation organisations can use InVEST to better align their biodiversity protection missions with activities that improve human livelihoods.

Corporations, such as consumer goods companies, renewable energy and water utility companies, can also use InVEST to decide where and how to invest in natural capital, thereby ensuring that their supply chains are sustainable and secure.

16 Available at: https://naturalcapitalproject.stanford.edu

Based on the results obtained on the flows of ecosystem services and the potential changes to these flows resulting from changes in land use and management, it is possible to conduct socio-economic evaluations to calculate monetary or social welfare benefits.

InVEST can help answer questions such as:

- Where do ecosystem services originate and where are they consumed?
- How might a proposed park impact biodiversity, water quality and recreational activities?
- Which parts of a watershed provide the highest values for sediment retention, carbon sequestration, habitat quality and recreation?
- Where would ecological restoration achieve the greatest benefits in downstream water quality, while optimising natural water flows?
- How will climate change and population growth affect local ecosystem services and biodiversity?

InVEST uses a production function approach to quantify and evaluate ecosystem services. A production function defines how changes in the structure and function of an ecosystem affect the supply of services it generates, given its new environmental conditions and altered ecological processes. Once a production function has been specified, it is possible to quantify the impact that changes in land or water have on changes in the level of production of ecosystem services. In short, the InVEST tool uses a simple framework outlining aspects such as "offer, service, and value" to link production functions to the benefits for people.

One of the main limitations of the InVEST platform models is that they require basic to intermediate skills in geoprocessing software (Geographic Information Systems/GIS, such as ArcGis and QGis software). Therefore, engaging a professional with knowledge in this area is important for correctly applying the models, as well as calibrating them and interpreting the results.

On the other hand, the possibility of representing the quantification of benefits using a spatial approach, that illustrates the distribution of the different ecosystem services or ecological process intensities along the landscape of interest, allows for a deeper understanding of the spatial variability of these benefits, which is often not captured by other methods.

Another advantage is the ability to evaluate several ecosystem services in the same area, enabling analysis of trade-offs (losses and gains) between different ES from the same simulated intervention and identification of potential synergies or reductions in the supply of one ES due to an increase in another.

The following pages detail the answers that this methodology provides to the established evaluation criteria, to illustrate the level of compliance with these criteria.

I – Ease of application of the methodology: is the methodology easy to understand and apply without requiring specialised technical knowledge?

The tool's models have an online manual which is constantly updated according to improvements to each model. This manual clearly summarises aspects such as the conceptual approach of the model in question, its basic form of operation (including illustrating the equations that are applied in computational analysis), the description of the input data and possible sources for obtaining these data, the calibration procedures of the model and the description of the results (also indicating how they should be interpreted). However, basic knowledge of geoprocessing is required to prepare the geographic data for the models, interpret the results and create presentation maps. This involves mastery of tools such as ArcGIS or QGIS.

II – Methodology approach: is the methodology geared towards practical application? Does it contain practical guidelines for its use in real cases?

Yes, the InVEST tool models are fully geared towards real-world application, presenting clear guidelines on how to feed and calibrate each model and how to interpret the results.

III – Data requirements for applying the methodology: is the necessary data easily accessible (e.g. freely available in online data repositories) and is the list of required data relatively short?

Yes, the InVEST models require relatively well-known and widely available biophysical data, such as land use, topography, soil and climate maps. Some models also use socioeconomic data that is just as easy to obtain and apply. In addition, the manual for each model indicates possible sources of data or procedures for their production.

IV – Degree of international recognition of the methodology: is the methodology internationally recognised as efficient for assessing the impacts of NbS?

Yes, several publications that have produced compendiums on methodologies for measuring ecosystem services and assessing the impact of environmental projects indicate the InVEST tool as one of the most complete and flexible methodologies for these purposes. These include publications evaluated in the present report, such as those by Brown et al. (2014), Neugarten et al. (2018), the European Commission (2021a), Brill et al. (2021) and Connecting Nature (2020). The academic article presenting the InVEST tool (NELSON et al., 2009) has received 2,628 citations on Google Scholar.

V – Application in different phases of NbS implementation: can the methodology be applied in the NbS planning phase and in the implementation or maintenance phases?

Yes, since InVEST models employ land use and land cover maps and associated parameters that are provided by the user, it is possible to simulate the impact of an NbS project from the conceptual phase onwards.

VI – Possibility of application at different levels of NbS design: can the methodology be applied in the feasibility study phase, as well as in basic projects or executive projects?

Yes, InVEST models are flexible in terms of the level of detail of the information they are provided with. It is also possible to run the same model preliminarily in the conception and planning phases and then in the executive project phase. This provides more accurate answers according to the level of detail. To achieve this, simply change the land use map in the model (e.g. replace a conceptual model of a linear park with a detailed executive project) or adjust the parameters to reflect different NbS approaches in the target area.

VII – Possibility of assessing the economic viability of NbS: does the methodology incorporate or allow the association with economic feasibility assessments (e.g. cost-benefit analysis)?

Yes, many InVEST models have an associated economic valuation module, which provides financial values associated with the flows of ecosystem services. The outputs of the InVEST models can also be easily used as input for economic and/or social benefit assessments.

VIII – Possibility of evaluating the multiple benefits of an NbS in the environmental, social and economic spheres: is the methodology capable of evaluating multiple benefits of an NbS in the environmental, social and economic spheres?

Yes, as InVEST is a package comprising more than 20 models capable of analysing different ecosystem services, it is possible to use a set of models to evaluate the various benefits of NbS. This allows us to obtain environmental results linked to ecological processes or ecosystem services as well as economic or social results from optional use modules or by using the models' outputs for other analyses.

5.1 InvEST tool models suitable for quantifying the benefits of linear/river parks

The most appropriate ecosystem service models for quantifying the benefits arising from the implementation of linear/river parks are those related to water ecosystem services or those that deal with the human well-being generated by green spaces. Here, we list some of these models that can quantify such benefits. The concept behind each model, the necessary data and the rationale can be found in the online manuals for the tool.

InVEST Seasonal Water Yield: regulation of water flows (surface and groundwater).

- Related NbS: rain garden; rain bed; bioswale; detention pond; retention pond; infiltration pond; rain terrace; vegetated ladder; amphibious reservoir; vegetated polder; step pool; infiltration wall.
- Online manual: https://storage.googleapis.com/releases.naturalcapitalproject.org/invest-userguide/latest/en/seasonal_water_yield.html

InVEST Urban Flood Risk Mitigation: flood mitigation.

- NbS related to microdrainage: rain gardens; rain beds; rain terraces; infiltration walls.
- NbS related to macrodrainage: detention pond; retention pond; infiltration pond; amphibious reservoir; vegetated polder; step pool.
- Online manual: https://storage.googleapis.com/releases.naturalcapitalproject.org/invest-userguide/latest/en/urban_flood_mitigation.html

InVEST Urban Stormwater Retention: urban drainage.

- Related NbS: rain garden; rain bed; bioswale; detention basin; retention basin; infiltration basin; rain terrace; vegetated ladder; hybrid wetland; built filtering island; amphibious reservoir; vegetated polder; step pool; infiltration wall; wooden living support cribwall; riverbanks's living support wall; living grid; retention stone wall, with vegetation; prefab cribwall support with vegetation; gabion walls with vegetation; flat gabions; green nailed soil.
- Online manual: https://storage.googleapis.com/releases.naturalcapitalproject.org/invest-userguide/latest/en/stormwater.html

InVEST Sediment Delivery Ratio: regulation of sediment input to water bodies.

- Related NbS: rain garden; rain bed; bioswale; detention basin (inline); retention pond (inline); infiltration pond; rain terrace; vegetated ladder; hybrid wetland; built filtering island; amphibious reservoir; vegetated polder; step pool; recovery and conservation of natural floodplains; recovery and conservation of riparian forests; recovery and conservation of slopes.
- Online manual: https://storage.googleapis.com/releases.naturalcapitalproject.org/invest-userguide/latest/en/sdr.html

InVEST Nutrient Delivery Ratio: retention of nutrients, such as phosphorus and nitrogen.

- Related NbS: rain garden; rain bed; bioswale; detention pond; retention pond; infiltration pond; rain terrace; vegetated ladder; hybrid wetland; built filtering island; amphibious reservoir; vegetated polder; step pool; recovery and conservation of natural floodplains; recovery and conservation of riparian forests; recovery and conservation of slopes.
- Online manual: https://storage.googleapis.com/releases.naturalcapitalproject.org/invest-userguide/latest/en/ndr.html

InVEST Urban Nature Access: recreation opportunities in green spaces.

- Related NbS: urban parks; squares; amphibious reservoir.
- Online manual: https://storage.googleapis.com/releases.naturalcapitalproject.org/invest-userguide/latest/en/urban_nature_access.html

InVEST Urban Cooling Model: temperature reduction in urban areas.

- Related NbS: green roofs; rain garden; rain terrace; vegetated ladder; support wall; wooden cribwall; living wall; living support wall on riverbanks; living grid; stone wall with vegetation; prefab cribwall support with vegetation; gabion walls with vegetation; green stapled soil.
- Online manual: https://storage.googleapis.com/releases.naturalcapitalproject.org/invest-userguide/latest/en/urban_cooling_model.html

Park Orla Piratininga in Niterói, RJ. Source: Prosustentável.

6 Concluding remarks

This is not an exhaustive list of methodologies and indicators that can be used to quantify the benefits of implementing and managing Nature-based Solutions, particularly in linear/river parks. It is merely an initial suggestion of tools that have previously been used for similar purposes.

The planners, implementers and managers of these parks, along with other relevant stakeholders (particularly those who benefit from NbS) are best placed to define which methods and indicators are most appropriate for measuring and communicating the performance of these green spaces in terms of their environmental, social and economic benefits. This should always be done in a participatory and inclusive way.

Other methodologies and indicators not listed in this publication may prove to be very useful for this function. Similarly, the procedures suggested here may be considered inadequate for the purpose of quantifying the benefits of NbS in specific cases due to unavailable data, complex calculation methods or the specifics of the evaluated areas.

In any case, we believe that the recommended methodology and the guide to NbS impact indicators can serve as an important starting point for each municipality or other territorial jurisdiction to define its own methodological framework. This will enable them to evaluate, verify and publicise the undeniable benefits provided by Nature-based Solutions in urban environments, such as linear and river parks.

The best environment for defining the most appropriate methods for quantifying the benefits of NbS will be provided by the combined knowledge of each NbS developer and the involved stakeholders.

It is also recommended that methods and indicators are used that are easily recognisable and understandable by both technicians and decision-makers, and that have already been used in other evaluations and surveys. The suggested methodology has already been extensively tested and disseminated, as have the majority of the indicators suggested here, which are referred to in the European Commission (2021a). This generally provides a higher level of credibility and consequently a greater acceptance of the conclusions reached. This favours the potential use of these conclusions in managerial decision-making regarding the creation of new Nature-based Solutions and the management of existing NbS.

Igapó Lake in Londrina, SP. Source: Vivian Honorato.

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