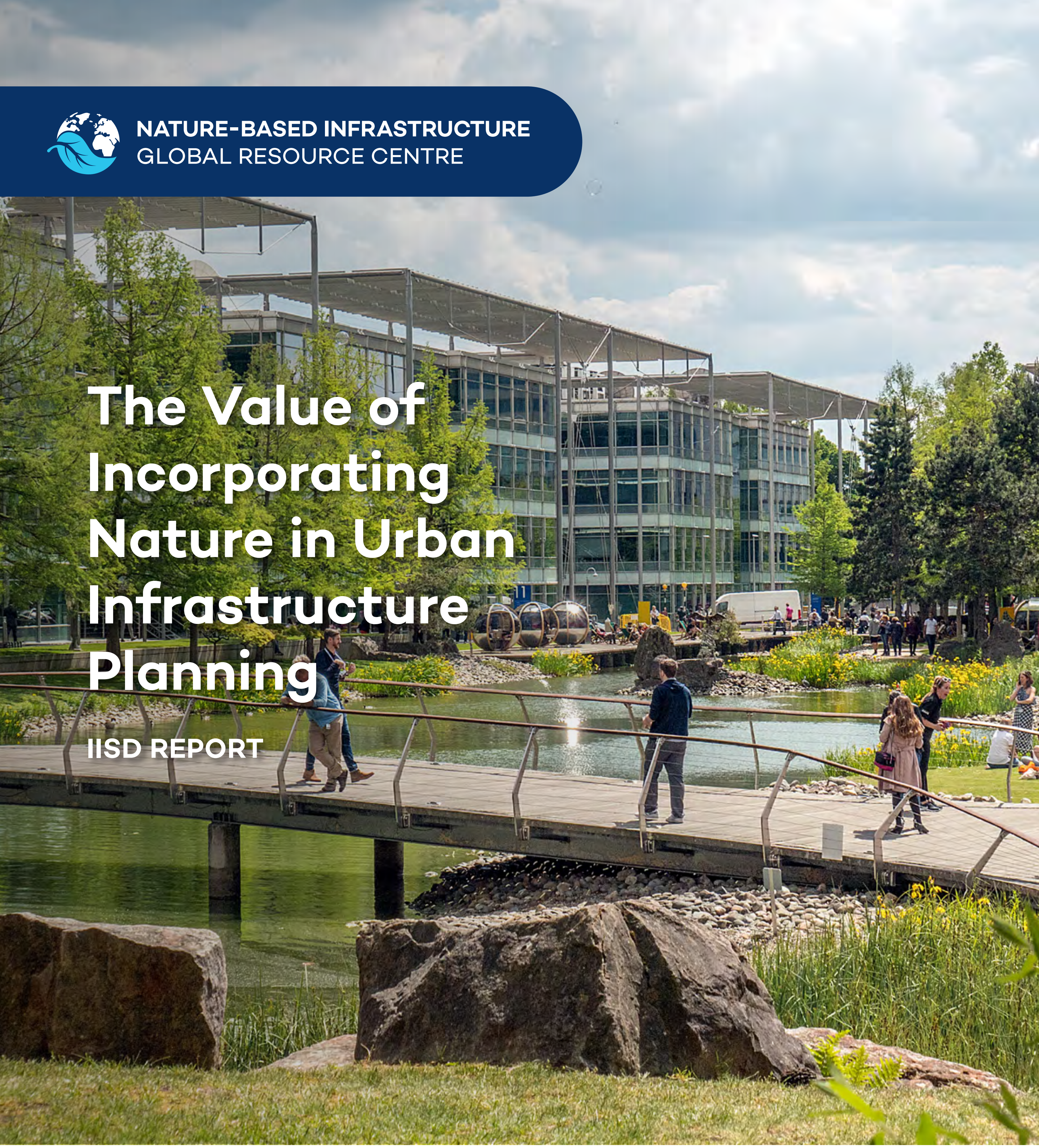

NATURE-BASED INFRASTRUCTURE
GLOBAL RESOURCE CENTRE

The Value of Incorporating Nature in Urban Infrastructure Planning

IISD REPORT

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The Value of Incorporating Nature in Urban Infrastructure Planning

December 2022

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Key Messages

Urban development—if done unsustainably—is one of the main drivers of biodiversity loss. Population growth in cities makes infrastructure needs in urban areas particularly high and places enormous pressure on the environment. Climate change further exacerbates this impact.

Building *with*—rather than against—nature has direct benefits for cities. Nature-based infrastructure (NBI) provides cost-effective and climate-resilient infrastructure solutions and generates a wealth of co-benefits for citizens, such as reduced air pollution and improved well-being.

NBI in cities is, on average, 42% cheaper and creates 36% more value than relying only on grey infrastructure if avoided costs and co-benefits are taken into account. International Institute for Sustainable Development case studies show that for each dollar invested, NBI in cities can generate up to 30 times that amount in returns for society, making investments in urban nature economically viable.

Building with nature also supports investments in other sustainable infrastructure, such as mobility, water, and energy, by increasing their resilience and effectiveness. Additional research is required to better understand and quantify these benefits and fully leverage nature's contribution to sustainable cities.

To make the most of the benefits of NBI, the value of nature must be at the heart of strategic, cross-sectoral urban planning. Planners, policy-makers, and budget holders need to use a systemic perspective to understand how to best maximize the benefits of NBI for sustainable cities.

Table of Contents

List of Figures

List of Boxes

1.0
The Challenge:

Meeting the needs of growing urban populations in the face of climate change and environmental degradation

More than half of the global population lives in cities, and urban areas will be home to an additional 2.5 billion people by 2050 (United Nations, 2018; UN Department of Economic and Social Affairs, 2018; UN-Habitat, 2016). By 2070, 58% of the world's population will live in cities (UN-Habitat, 2022). Constructing and using infrastructure such as buildings and roads, providing energy and water for urban activities, and transporting goods and people across cities takes a toll on the local environment and the global climate: cities are responsible for 70% of global greenhouse gas (GHG) emissions, even though they take up only 2% of the world's land (UN-Habitat, 2016).

Human activities such as urbanization and pollution also threaten more species with extinction than ever before. The global assessment report on biodiversity and ecosystem services warns that about 25% of plant and animal species are threatened, suggesting that around 1 million species already face extinction (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, 2019). A recent study estimates that over 850 different vertebrate species are directly threatened due to habitat loss from urban land expansion (Simkin et al., 2022).

Cities around the world are embracing their responsibility for people's well-being and the environment.

More than 11,000 local authorities have committed to cutting their emissions as part of the Covenant of Mayors (European Commission, n.d.), while more than 1,000 cities have committed to the UN's Race to Zero campaign. To maximize the value of nature and biodiversity in cities, over 200 cities and regions collaborate in the CitiesWithNature (2020) initiative, and around the world, Sustainable Development Goal (SDG) 11 drives efforts to make cities inclusive, safe, resilient, and sustainable.

Yet, cities are facing massive challenges in creating urban environments where people thrive. In short, urban areas struggle with challenges in two broad areas: 1) providing effective access to necessary resources and services and 2) increasing risk exposure. City dwellers and economic activities require a large amount of energy, water, food, and construction materials. At the same time, efforts to provide such services leave people and urban assets increasingly exposed to air and water pollution, extreme heat, fires, storms, floods, and landslides. All of these challenges are exacerbated by climate change and inequality, particularly affecting the urban poor (Intergovernmental Panel on Climate Change, 2022).

For example, France faced its worst drought in 2022 since data records started on this topic. In August 2022, more than 100 municipalities in France ran out of drinking water, and people across western Europe experienced one heat wave after the other and record-high temperatures (Breeden, 2022). Around the world, 1.7 billion urban residents experience extreme heat (Tuholske et al., 2021), which represents a major health risk, especially for vulnerable groups like children, elderly people, and those living in precarious conditions.

Providing people and businesses with the infrastructure they need requires massive investments. Sixty percent of buildings that will exist globally by 2050 have not been built yet. This is roughly the equivalent of constructing new floor space the size of Singapore or

New York every month (C40, 2022). The demand for urban mobility is expected to double between 2016 and 2050, with most of this growth concentrated in developing countries (International Transport Forum, 2021). The infrastructure investment required to meet global infrastructure needs by 2040 is USD 94 trillion, and current investment trends leave us with an investment gap of USD 15 trillion (Global Infrastructure Hub, 2022). According to Organisation for Economic Co-operation and Development (2017) estimates, USD 6.9 trillion in infrastructure investment is needed annually to meet the SDGs and climate goals of the Paris Agreement.

This policy brief explores how nature-based infrastructure (NBI) responds to these challenges and supports the creation of sustainable cities. We start by illustrating what makes cities sustainable and the potential role of NBI. Next, we summarize research findings about the value of four NBI types for sustainable urban infrastructure: urban green spaces, green roofs, stormwater infrastructure, and wetlands and lakes. The literature review is complemented by selected NBI case studies that have been assessed with the Sustainable Asset Valuation (SAVi) methodology. Finally, we conclude by arguing that sustainable cities require strategic, cross-sectoral urban infrastructure planning with nature at its core.

2.0
What Makes Cities Sustainable, and How Can NBI Help?

2.1 What Makes Cities Sustainable?

United Nations SDG 11 calls for action to ensure that cities are inclusive, resilient, and sustainable. It contains multiple targets related to urban sustainability: adequate housing, access to sustainable (public) transport systems, participatory and integrated settlement planning, the protection of natural and cultural heritage, reducing the environmental impacts of cities, disaster risk management and protection from disasters, climate action, and access to green and public spaces. The Paris Agreement specifically invites cities to scale up their efforts to reduce emissions and build climate resilience (United Nations Framework Convention on Climate Change, 2016).

Depending on local dynamics, cities around the world are facing diverse futures, and the definition of what makes a city sustainable can differ (UN-Habitat, 2022). While rising inequality and climate impacts are concerns around the world, other priorities vary between developed and developing countries. For example, cities in developed countries are challenged to modernize aging infrastructure, manage cultural diversity, and meet the needs of aging populations. In contrast, cities in developing countries may also have to deal with these issues but also grapple with rising poverty levels, high youth unemployment, and the need for adequate infrastructure and affordable housing.

In its latest *World Cities Report 2022*, UN-Habitat underlines that "building economic, social and environmental resilience, including appropriate governance and institutional structures, must be at the heart of the future of cities" (UN-Habitat, 2022). To this end, cities must reduce poverty and inequality, foster socially inclusive economies, consider public health in urban development, mitigate and adapt to climate change, and protect ecosystems (UN-Habitat, 2022).

Sustainable cities also have an important role to play in meeting the goals of the Convention on Biological Diversity (CBD). The *First Draft of the Post-2020 Global Biodiversity Framework* demands urgent action across society to put biodiversity on a path to recovery by 2030 (CBD, 2021). Specifically, cities can contribute to the targets to increase urban green and blue spaces to support human well-being, reduce pollution, and maintain and enhance nature's benefits for air quality, water management and protection from extreme events. The CBD also refers to cities when it demands that signatories "fully integrate biodiversity values into policies, regulations, planning, development processes, poverty reduction strategies, accounts, and assessments of environmental impacts at all levels of government and across all sectors of the economy" (CBD, 2021, p. 7).

Infrastructure is a critical element in achieving these objectives and creating sustainable cities. Urban areas need a variety of assets, including buildings, roads and other transport infrastructure, power

> "Building economic, social and environmental resilience, including appropriate governance and institutional structures, must be at the heart of the future of cities."
>
> **UN-HABITAT, 2022**

generation and distribution, water distribution, and wastewater management. For cities to be sustainable, the infrastructure itself also has to be sustainable.

Sustainable infrastructure systems are "planned, designed, constructed, operated and decommissioned in a manner that ensures economic and financial, social, environmental (including climate resilience), and institutional sustainability over the entire infrastructure life cycle" (United Nations Environment Programme [UNEP], 2022). The infrastructure can be nature based, built in a conventional way, or combine elements of both as hybrid infrastructure. In its 10 good practice principles for sustainable infrastructure, UNEP underlines that sustainable infrastructure needs to provide value for money and quality services, be inclusive and resilient, and foster health and well-being (UNEP, 2022). To foster sustainable cities, infrastructure for mobility, energy, and water has to provide access to services while avoiding negative effects on air and water pollution and, hence, human health.

A popular concept for sustainable urban development is the 15-minute city where everyone can meet their basic needs within a short walk or bike ride (see Box 1). Strategic and well-planned density and mobility, as well as urban nature-based solutions, can be particularly helpful for driving urban sustainability and a green recovery from the COVID-19 pandemic (Callenberg et al., 2022).

Box 1. The 15-minute city: Daily needs within arm's reach

The 15-minute city is a popular vision for livable, people-oriented cities. Cities such as Paris, Bogota, or Melbourne use the 15-minute city as a guide for creating vibrant, human-scale neighbourhoods that avoid traffic and foster health and well-being (C40 Cities Climate Leadership Group, 2021):

> Among other things, it means strengthening transit connections with the rest of the city to serve the trips that people want or need to make, as well as ensuring that residents of all ages, backgrounds and abilities can meet their daily needs locally, in a short walk or bike ride from home (C40, 2021).

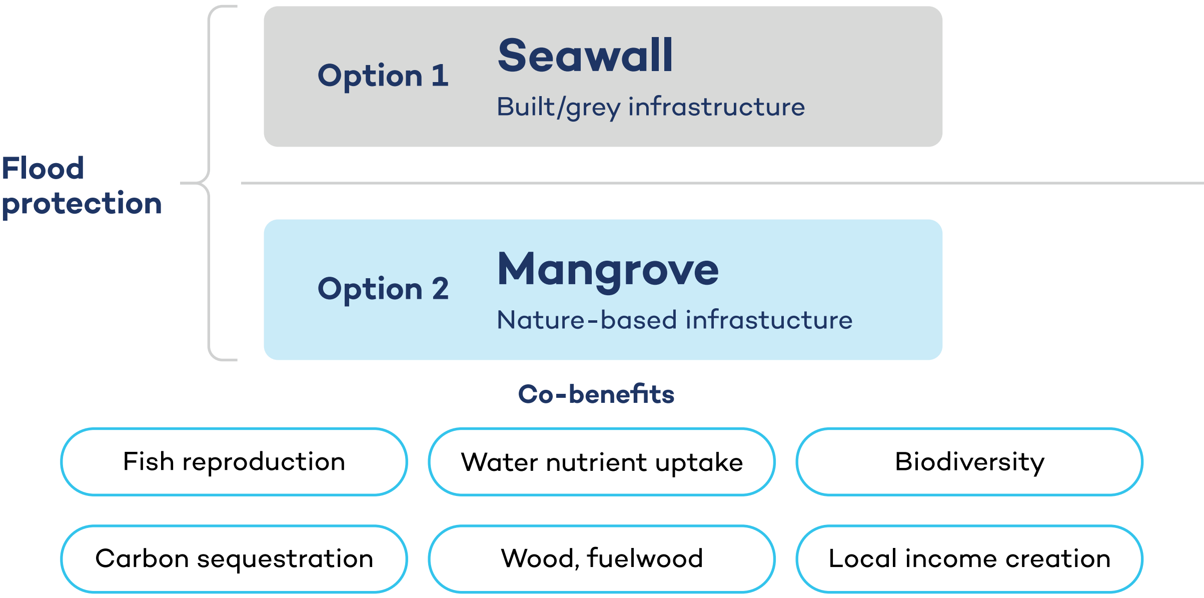
To achieve this goal, urban planning needs to foster "complete" neighbourhoods that provide for their residents' daily needs, such as education, places of work, health care, grocery stores and pharmacies, and green spaces for recreation. Through measures like widened sidewalks, expanded cycling networks, and reclaiming car-dominated spaces, a 15-minute city helps build more sustainable transportation and vibrant neighbourhoods.

While mixed-use, self-sustained neighbourhoods can form the building blocks for sustainable cities, connectivity over longer distances in the city and its surroundings is another important aspect. To reduce traffic from private vehicles, avoid GHG emissions, and reduce air pollution, cities around the world are prioritizing sustainable mobility solutions and so-called transit-oriented development. This approach creates compact, well-connected, mixed-use developments near transit stops to maximize the potential of public transportation and walking. For example, the cities of Tianjin, Ningbo, and Shenzhen in China apply transit-oriented development to address environmental degradation and improve residents' quality of life.

2.2 How Can NBI Contribute to Sustainable Cities?

The term NBI describes areas or systems that harness nature to provide infrastructure services for people, the economy, and the environment. Examples of NBI include naturally occurring ecosystems, such as forests, mangroves, wetlands, and grasslands. But NBI can also be a combination of engineered or "grey" structures with nature-based solutions, such as rain gardens and green roofs. NBI delivers key infrastructure services, such as flood protection, water filtration, and temperature regulation. In addition, it offers valuable co-benefits for communities and the environment. For example, NBI can sequester carbon, function as a habitat for threatened species, support people's livelihoods, and offer space for recreation. Figure 1 illustrates how mangroves protect communities from floods, similar to the conventional solution of building a seawall, while also providing co-benefits for biodiversity and local livelihoods.

Figure 1. The benefits of mangroves for flood protection



NBI does not just function as sustainable urban infrastructure itself, but it enables and supports wider infrastructure systems, making conventional grey infrastructure more efficient and reducing the need for new infrastructure investments (see Section 3). For example, urban green spaces help to keep urban temperatures at bay, which in turn reduces heat-related efficiency losses of power systems and supports a stable energy supply from renewable sources. By strategically integrating NBI into cities, stakeholders can unlock great benefits for other infrastructure sectors and create thriving urban communities.

Research indicates that NBI can provide the same services as conventional infrastructure but is up to 50% cheaper than grey infrastructure that provides the same infrastructure services (Bassi, Bechauf, Casier, & Cutler, 2021). This makes NBI an important solution for closing the infrastructure investment gap. In addition, NBI provides 28% better value for money by delivering valuable co-benefits (Bassi, Bechauf, Casier, & Cutler, 2021). Results from case study valuations in cities indicate that the NBI is, on average, 42% cheaper and creates 36% more value than relying only on grey infrastructure if avoided costs and co-benefits are taken into account.[1] These cost savings are primarily due to lower upfront investments for NBI, especially when nature is already in place. In addition, NBI is often more climate resilient than built infrastructure and cheaper over time because it actively avoids costs in relation to extreme weather events.

Cities around the world are beginning to leverage the potential of nature to build climate resilience and improve the quality of life of vulnerable urban communities. For example, urban planning in Kigali (Rwanda) aims to maximize ecosystem services in the city by restoring wetlands, which reduces flood risks, contributes to upgrading living conditions in unplanned settlements around the wetlands and provides Kigali's residents with attractive green spaces for recreation, such as Nyandungu Wetland Park (Rwanda Environment Management Authority, 2021). For such interventions Kigali receives support from UrbanShift, a Global Environment Facility-funded cities program. To make use of nature's benefits for sustainability, UrbanShift specifically supports integrated approaches to city planning that embrace urban NBI (World Resources Institute, 2022).

In another example, Argentina's third-largest city, Rosario, launched a program for urban food production in 2001, which has since evolved into a tool for job creation and climate adaptation (Maassen & Galvin, 2021). Underutilized areas such as flood-prone lowlands, strips along highways, and designated greenbelts are converted into agricultural spaces, which provide employment opportunities for the urban poor, shorten the food supply chains, and provide Rosario's residents with fresh fruit and vegetables. At the same time, the urban agriculture project reduces flood risks by absorbing water and decreases GHG emissions by reducing food imports.

Box 2. The International Institute for Sustainable Development's Sustainable Asset Valuations of infrastructure projects

SAVi is a methodology, based on systems thinking, that supports the identification, quantification, and analysis of the costs, benefits, and risks of infrastructure projects over their entire life cycles. It combines system dynamics modelling, financial models, and spatial models to provide a customized assessment of the environmental, social, and economic risks and externalities of infrastructure. Each SAVi assessment is co-created using a transparent, multi-disciplinary, and multistakeholder approach.

The International Institute for Sustainable Development (IISD) has applied the SAVi methodology[2] to more than 40 infrastructure projects around the world, covering a variety of different assets like roads, wastewater treatment plants, buildings, and NBI; an additional 50 projects will be supported over the coming few years. All SAVi assessments of NBI projects are available on the NBI Global Resource Centre.[3]

[1] The Annex of the flagship report, *How Can Investment in Nature Close the Infrastructure Gap?*, provides the details of the calculation of cost-savings and added value of NBI vs traditional grey infrastructure (Bassi, Bechauf, Casier, & Cutler, 2021).

[2] Visit the SAVi website here: https://www.iisd.org/savi/

[3] The NBI Global Resource Centre is an initiative—led by IISD with the support of the Global Environment Facility, UN Industrial Development Organization, and the MAVA Foundation—that brings together partners to assess, value, finance, and deliver NBI. Visit the website here: https://nbi.iisd.org/

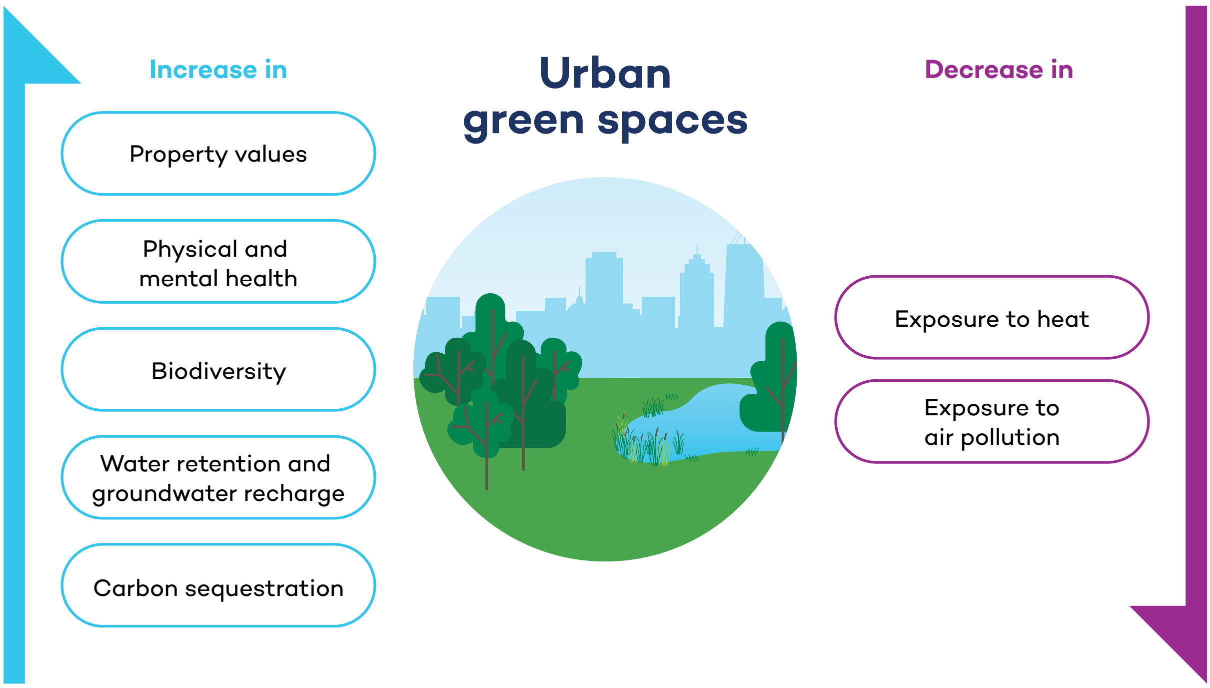
3.0
The Value of NBI for Sustainable Urban Infrastructure

This section demonstrates why NBI should be at the core of urban infrastructure planning. We focus on the benefits of urban green spaces, green roofs, stormwater infrastructure, and wetlands and lakes. These types of NBI can reduce flood damage, mitigate urban heat islands, reduce energy use and increase efficiency, improve air and water quality, sequester carbon, enhance biodiversity, increase property values, provide opportunities for recreation, and improve physical and mental health (Bassi et al., 2019; Demuzere et al., 2014; Global Future Council on Cities of Tomorrow, 2022; House et al., 2016).

3.1 Urban Green Spaces

Urban green space is defined as any urban area covered completely or partially by vegetation, such as grass, trees, or shrubs (De Haas et al., 2021; World Health Organization [WHO], 2017). This includes parks, gardens, forests, meadows, and other vegetated areas (De Haas et al., 2021; WHO, 2017). Urban green spaces support physical and mental health, particularly among children and the elderly (European Environment Agency, 2022). They can also increase surface water storage and groundwater recharge, improve air quality, sequester carbon, raise property values, and reduce extreme heat (Bockarjova & Botzen, 2017; Brill et al., 2021; Demuzere et al., 2014).

Figure 2. The outcomes of investing in urban green spaces



One important climate adaptation benefit of urban green spaces is that they reduce water runoff and flood risks (see Box 3). Urban trees intercept rain, store water in leaves, and release it through evapotranspiration. Compared to built-up areas, green spaces also increase permeable surfaces, which allows more water to infiltrate the soil ("Trees and Stormwater Runoff," 2017). In addition, green spaces reduce air pollution from small particulate matter by intercepting and absorbing airborne particles (Nowak et al., 2006). In the case of trees, particles are deposited on the leaves and then fall to the ground or are washed off by rain (Nowak & Heisler, 2010).

Green spaces also bring considerable benefits to biodiversity, especially by offering valuable habitats for species under pressure from environmental change. This contrasts with conventional urban development, which typically degrades ecosystems and destroys natural habitats (Global Future Council on Cities of Tomorrow, 2022). In turn, biodiversity can play an important role in ensuring healthy cities by, for example, filtering water through soils and controlling pests.

Moreover, urban green spaces also foster the well-being of city dwellers by providing opportunities for recreation, community activities, and aesthetic value, which all contribute to mental and physical health (House et al., 2016). For example, a recent study in Berlin showed that a walk in the city's urban forest considerably reduced stress among participants compared to a walk in the streets (Sudimac et al., 2022).

Box 3. Tree planting in Ethiopia

SAVi assessments of urban green spaces on water retention, flood damage, air pollution, extreme heat, and biodiversity demonstrate the extent to which NBI reduces the costs of flood damage to buildings and infrastructure and helps make cities more resilient to climate impacts.

For example, SAVi was used to assess the systemic outcomes of planting trees in Addis Ababa, Ethiopia, considering different scenarios for the number of trees planted (11 million or 25 million) and tree maintenance (30% or 84% long-term survival) (Cutler et al., 2022).

As a growing city, Addis Ababa is becoming more exposed to flood risks as vegetation is replaced by impervious surfaces, such as roads. Moreover, up to 80% of the population lives in informal settlements that are often located in flood-prone areas, which contributes to high death tolls (Birhanu et al., 2016; UN-Habitat, 2007). Depending on the tree-planting scenario In our SAVi assessment, the trees retain between 431,000 m^3 and 1,647,000 m^3 more water than in the business-as-usual scenario (Cutler et al., 2022). This means a 2.4%–9.3% increase in water retention. To retain so much rainwater, the city would otherwise be required to invest in the construction of rainwater tanks. The runoff retention from the trees can eventually help avoid flood damage to property of between USD 410,150 and USD 1,491,456. Planting and maintaining 25 million trees could avoid an estimated 48 people dying from floods, saving more than USD 4.2 million in health costs (Cutler et al., 2022).[4]

Air pollution is also a serious challenge in Addis Ababa. The concentration of particulate matter far exceeds WHO guidelines and leads to increasing numbers of premature deaths (WHO, 2006). We found that planting 25 million trees across the city (and maintaining them well) could avoid USD 4 million in costs from mortality caused by air pollution (Cutler et al., 2022). Planting the trees in Addis Ababa could also cool the average city temperature by 0.61°C–1.41°C and mitigate climate change by storing 0.969 million to 4.401 million tonnes of carbon dioxide (tCO_2) (Cutler et al., 2022).

[4] In all case studies examined, assessments were conducted in the local currency and results converted to USD for this publication.

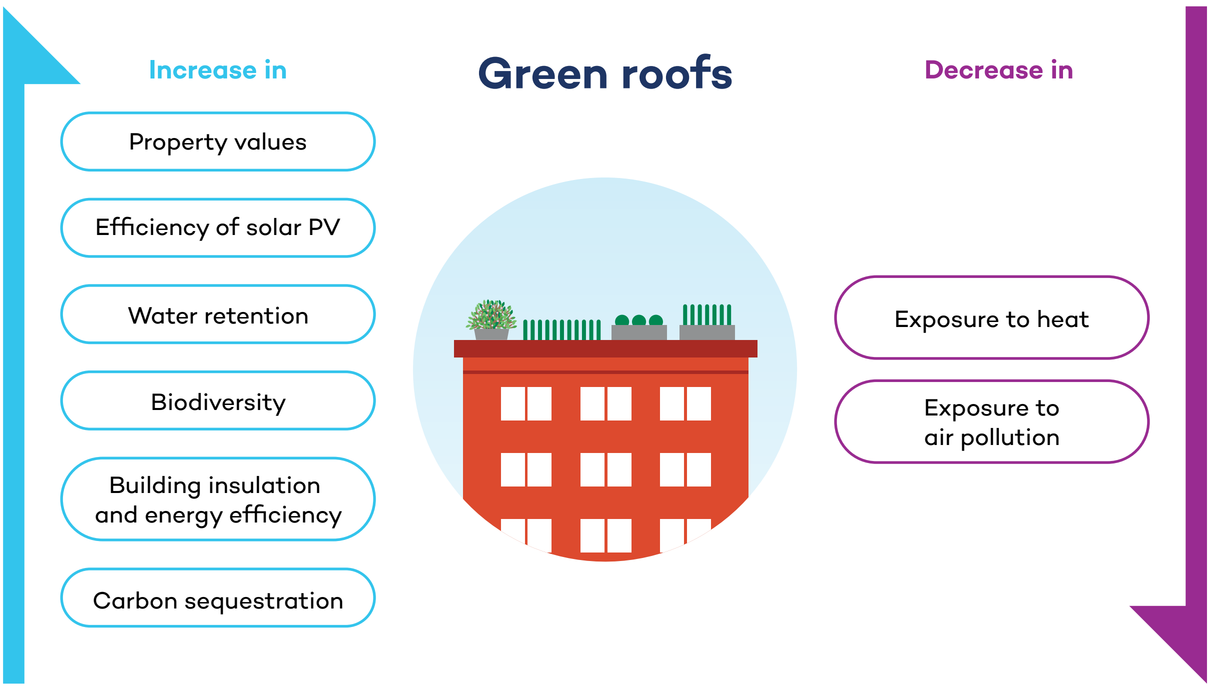
3.2 Green Roofs

A green roof is any roof covered with a substrate that is used to grow vegetation (Van der Meulen, 2019). Green roofs can be classified as either "intensive" or "extensive." Intensive roofs have a thick substrate layer (20–200 cm) that can support a wide variety of vegetation, including small trees and shrubs, and can function as rooftop gardens or parks. Extensive green roofs have a substrate layer that is only 6–20 cm, typically used to grow grasses, mosses, and sedum species (Manso et al., 2021; Van der Meulen, 2019; Vijayaraghavan, 2016).

Green roofs can provide several benefits. They can reduce stormwater runoff, improve air quality, reduce energy use, increase the efficiency of rooftop solar photovoltaic (PV) panels, mitigate urban heat islands, increase property values, and store carbon (Banting et al., 2005; Clark et al., 2008; Getter et al., 2009; Manso et al., 2021). Green roofs and facades provide shade and cooling for buildings, which helps mitigate the urban heat island effect and reduces the need for other forms of cooling, like air conditioning (Bassi et al., 2019). It has been estimated that installing green roofs can reduce energy consumption by 15%–45% (Bassi et al., 2019). A study in Sydney (Australia) compared a green roof with a conventional roof of identical office buildings and found that the green roof was up to 20°C cooler while also insulating the building in colder periods (Irga et al., 2021).

Interestingly, property owners in dense urban areas do not have to choose between a green roof and producing renewable energy with solar panels, as these can be combined in so-called bio-solar roofs. Combining the two can even make solar panels more effective because the efficiency of solar PV panels decreases as they heat up beyond their optimal temperature. In an Australian study, combining solar PV panels with green roofs produced 3.63% more energy, which corresponded to an additional retail value of more than AUD 2,500 over 8 months (Irga et al., 2021).

Figure 3. The outcomes of investing in green roofs



In dense urban areas, green roofs also create valuable habitats for biodiversity. Extensive green roofs, which are minimally disturbed by humans, can support insects, sensitive plants, and birds (Peck et al., 1999). Roof gardens can also improve air quality by removing pollutants and can result in increased property values through their aesthetic and recreational benefits (Banting et al., 2005; Manso et al., 2021).

Box 4. Green roofs in South Africa

In the City of Tshwane (South Africa), IISD applied the SAVi methodology to assess NBI investments in Rainbow Junction, a 140-ha mixed-use development (Cutler & Scholtz, 2021). More specifically, Cutler and Scholtz (2021) analyzed the outcomes of creating green roofs on the new buildings and planting additional trees. The assessment indicated that installing 67,000 m^2 of extensive green roofs (10% of the planned roof area) could retain 91,455 m^3 of rainwater, reducing the need to manage and treat stormwater.

Green roofs can also reduce health risks from extreme heat and reduce the need for conventional forms of cooling like air conditioning. The assessment identified that covering 10% of the buildings with green roofs could save 688,425 kWh for cooling, corresponding to USD 16,859,077 in energy costs (Cutler & Scholtz, 2021). Similarly, planting 1,000 additional trees would cool down temperatures and cut energy needs for air conditioning by 156,000 kWh or USD 3,820,338 per year.

According to the SAVi assessment, a single 500 m^2 green roof in Rainbow Junction would also store 187.5 kg of carbon (0.69 tCO_2), and installing extensive green roofs on 10% of the planned roof area would store 25,125 kg of carbon (91.1 tCO_2) (Cutler & Scholtz, 2021).

3.3 Stormwater Infrastructure

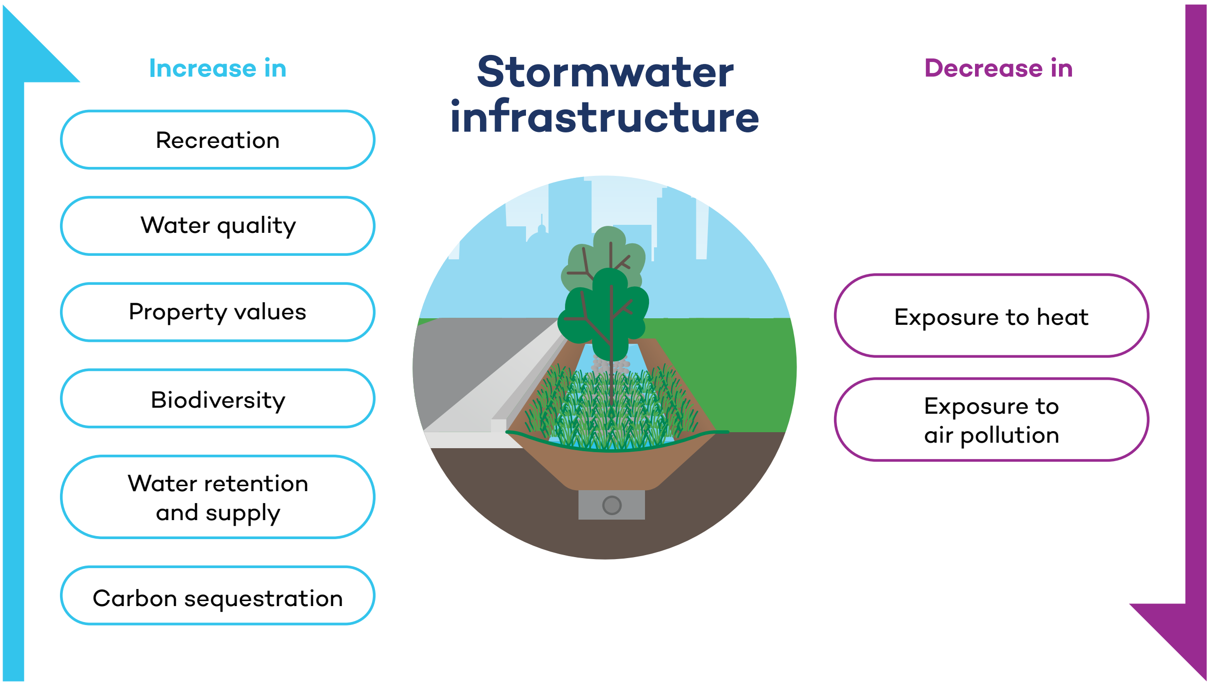
Nature-based stormwater infrastructure includes bioswales, rain gardens, green roofs, wetlands, floodplains, and street trees. Unlike grey stormwater infrastructure, which is designed to remove water, NBI manages water where it lands and treats it as a resource.

Nature-based stormwater infrastructure absorbs water and increases water infiltration, which decreases stormwater runoff volume and speed while also removing pollutants (House et al., 2016; Lilauwala & Gubert, 2019). A global comparative study found that bioswales, vegetated buffers along water bodies, and constructed wetlands, on average, retain more than 50% of the water, though the performance differs depending on climatic conditions (Koiv-Vainik, 2022).

By filtering stormwater and letting it infiltrate the soil, nature-based stormwater infrastructure also contributes to groundwater recharge and clean water supply (Bassi et al., 2019). It can also support biodiversity, provide opportunities for recreation, increase property values, and regulate temperatures (Bassi et al., 2019; Demuzere et al., 2014; Lilauwala & Gubert, 2019).

For example, in an analysis of stormwater management options in Philadelphia (United States), a study found that, unlike conventional grey infrastructure, a hybrid solution incorporating NBI would increase recreational opportunities, reduce heat-related fatalities, improve air quality, and decrease energy demand for cooling. Considering a 40-year time horizon, the hybrid option was projected to create cumulative benefits worth USD 2,846.4 million, compared to only USD 122 million created by the grey infrastructure option (Stratus Consulting Inc., 2009).

Figure 4. The outcomes of investing in nature-based stormwater infrastructure



Box 5. Stormwater management in South Africa

In a South African SAVi assessment, IISD analyzed several infrastructure options for managing stormwater in a flood-prone area, the Paterson Park Precinct in Johannesburg. These options included the construction of a concrete culvert as the grey infrastructure option, a renaturalized stream as a fully nature-based alternative, and a hybrid solution combining both solutions (Wuennenberg et al., 2021).

The assessment found that, over the entire life cycle of the infrastructure, the hybrid and fully nature-based options were the most cost-effective. Crucially, the NBI options provided social, environmental, and economic benefits that the grey infrastructure, by design, cannot deliver. For example, the NBI reduces flood risks, creates landscaping jobs, increases property values and tax revenues, sequesters carbon, and improves water supply.

In the SAVi assessment, avoided costs of flood damages represented the largest benefit from the NBI options. Over 40 years, the fully renaturalized stream avoids USD 10.6 million in flood damages, while the hybrid alternatives could avoid USD 9.7 million. By increasing soil permeability compared to grey infrastructure, the NBI option also contributes to an additional water supply worth about USD 3 million over 40 years. This case highlights how investing in NBI can support climate adaptation in South Africa.

3.4 Wetlands and Lakes

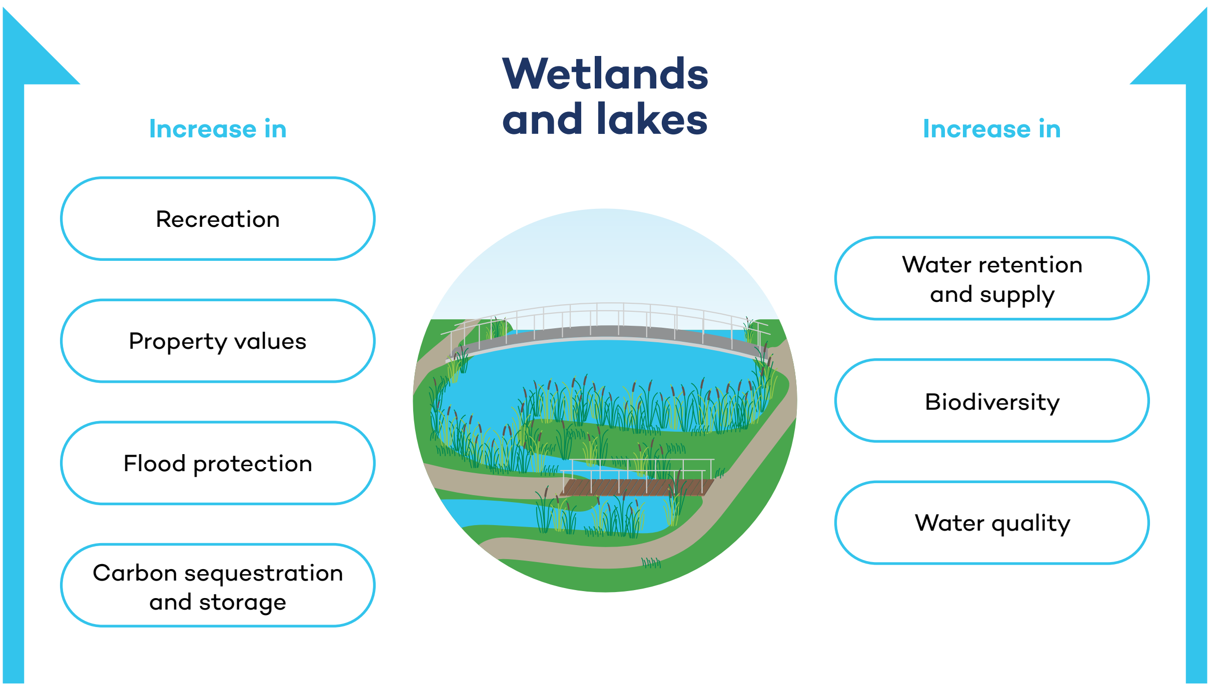
Lakes and wetlands, including marshes, swamps, peatlands, and mangroves, provide many infrastructure services. For example, wetlands can remove heavy metals and nutrients from water (Aziz & Van Capellen, 2021; Castro et al., 2022; Millennium Ecosystem Assessment, 2005). Specifically, studies have shown that wetlands can reduce nitrogen and organic matter concentrations by more than 70% and may be more efficient than grey wastewater treatment infrastructure (Liquete et al., 2016; Millennium Ecosystem Assessment, 2005).

Wetlands can also protect against coastal and inland flooding. For example, salt marshes and mangroves reduce both wave energy and height (Dicks et al., 2020; Parvathy & Bhaskaran, 2017). Similarly, inland wetlands regulate water flows, which can mitigate downstream flooding (Millennium Ecosystem Assessment, 2005).

Globally, wetlands store 20%–30% of total soil carbon (Nahlik & Fennessy, 2016) and play an important role in climate change mitigation. Peatlands alone contain 25%–30% of the carbon in terrestrial plants and soils yet cover only 3%–4% of the world's land area (Millennium Ecosystem Assessment, 2005). Storing an estimated 540 gigatonnes of carbon, they are the largest terrestrial carbon sink (Dicks et al., 2020; Millennium Ecosystem Assessment, 2005). Likewise, mangroves are some of the most carbon-rich wetland ecosystems in the world, storing over 900 megagrams of carbon per ha (Alongi, 2014; Donato et al., 2011).

Wetlands also provide multiple provisioning services. For example, they are home to many plant and animal species, which support fisheries, including high-value commercial species, and produce other market goods (Dicks et al., 2020; Hutchison et al., 2014; Millennium Ecosystem Assessment, 2005). Wetlands and lakes are also a source of fresh water and can enhance groundwater recharge (Millennium Ecosystem Assessment, 2005).

Figure 5. The outcomes of investing in wetlands and lakes



In urban settings, wetlands have been shown to increase property values. For example, a study in Putrajaya (Malaysia) found that residential property values decrease by 5.9% per km as the distance from the Putrajaya Wetlands Park increases (Syafiqah et al., 2017). Finally, wetlands create tourism opportunities, which can be a large contributor to local economies (Dicks et al., 2020; Millennium Ecosystem Assessment, 2005).

Box 6. Lake conservation in India

IISD conducted a SAVi assessment of the long-term conservation of Lake Dal in Srinagar, India (Bassi et al., 2018). Lake Dal is a major natural asset in the State of Jammu Kashmir that suffers from human pressures such as untreated sewage and fertilizer runoff. These pressures are decreasing water quality in the lake, resulting in negative effects on fish stocks and recreational activities. In the SAVi assessment, Bassi et al. (2018) analyzed how improved wastewater treatment with a conventional water treatment plant can help conserve the lake and how such grey infrastructure could be complemented with an artificial wetland (hybrid solution).

The assessment found that a grey infrastructure upgrade provides benefits of USD 2,867 million, which clearly outweighs the associated investment of about USD 19 million. Moreover, complementing the treatment plant with a 500-ha wetland further improves water quality and avoids harmful sewage overflows, resulting in even higher net benefits of USD 4,354 million. While the hybrid solution only costs about 9% more than the purely grey option, its net benefits are more than 60% higher (Bassi et al., 2018).

Improving Lake Dal's water quality through better wastewater treatment particularly benefits the local tourism and fishing sectors. We estimate that a hybrid infrastructure upgrade could boost tourism revenues by USD 4,640 million by 2060 and increase revenues from fisheries by USD 38 million.

3.5 How NBI Creates Synergies With Other Urban Infrastructure

NBI can be a valuable lever for fostering sustainable urban mobility. Current transportation systems provide mobility services but generate significant negative health, environmental, and economic impacts, such as congestion, safety concerns, and high CO_2 emissions. Current transportation systems, which are predominantly based on private vehicles powered by internal combustion engines, lead to air pollution, a primary health risk in cities. Globally 2.5 billion people, or 86% of the urban population, breathe air that exceeds the WHO pollution guidelines by seven times (Southerland et al., 2022). In 2019 alone, air pollution is estimated to have contributed to 1.8 million deaths, mainly linked to high concentrations of tiny particulate matter (Southerland et al., 2022).

Other than negative health impacts, air pollution also influences the potential for public and non-motorized transport in cities. Cyclists and public transportation users are more exposed to air pollution than private vehicle users. This increased risk discourages people from using public and non-motorized transportation (NMT), especially in highly polluted cities. By reducing air pollution, green spaces and green roofs improve the conditions for NMT and contribute to sustainable urban mobility.

NBI can also create supportive conditions for sustainable mobility by regulating temperatures and providing attractive green corridors for NMT. Public transportation and NMT are both vulnerable to extreme heat. Under intense heat, many people avoid walking, cycling, and waiting at transit stops (Fraser & Chester, 2017). By providing shade and reducing outdoor air temperature, NBI reduces exposure to heat and supports these modes of transport. In turn, transport corridors offer a key space for a network of NBI in cities, such as green paths, trees along roads, and green roofs on bus stops. Sustainable mobility options such as mass transit and cycling also require less space than transport systems built around private vehicles, which can free up space for NBI, even in dense urban areas.

In addition to air pollution and heat, transport infrastructure is vulnerable to floods from extreme precipitation events. Floods put people in danger, disrupt transportation systems, and cause costly damage. By regulating water flows and avoiding flood damages and service disruptions, NBI, such as nature-based stormwater infrastructure and green roofs, can further improve the conditions for sustainable mobility.

Box 7. Non-motorized transportation in India

In a recent SAVi assessment, IISD estimated the impacts of NMT in the city of Coimbatore, India (Kapetanakis et al., forthcoming). The project consists of a comprehensive network of walking and cycling routes across the city, implemented over a 15-year period. It will have a wide range of benefits, including reduced air pollution and CO_2 emissions, health benefits from increased physical activity, a reduction in the number of road accidents, and increases in retail and property prices.

IISD's economic valuation found that investing approximately USD 121 million in the project will yield net benefits of USD 486 million to USD 510 million over a 23-year period. For example, the NMT network will lead to health benefits worth USD 84 million and USD 91 million, respectively, by increasing physical activity and reducing air pollution. In addition, the shift from motorized transport to the NMT network will reduce CO_2 emissions worth USD 2 million over the project period (Kapetanakis et al., forthcoming).

Yet, the assessment also considers that cycling in a polluted urban environment tends to have worse health effects than using motorized forms of transport. This increased exposure to air pollution reduces the overall health benefits for NMT users. Implementing NBI in Coimbatore would be a way to improve air quality and thus create healthier conditions for walking and cycling.

NBI can also complement and support existing water management infrastructure and systems. As a result of climate change and rapid urbanization, cities struggle to provide their citizens and businesses with sufficient and clean water, maintain a healthy and biodiverse environment, and protect people and assets from floods. For example, only 62% of people living in cities have access to safely managed sanitation (WHO & United Nations Children's Fund

[UNICEF], 2021), and 45 urban areas with more than 3 million inhabitants are expected to face high water stress within the coming years (UNICEF, 2021). NBI can complement conventional wastewater treatment plants by increasing water quality and retaining stormwater to avoid sewage overflows. In addition, NBI supports clean water supply by allowing water to infiltrate the ground and restore groundwater resources. NBI, such as floodplains, also reduces the risk of river floods and extremely low water levels by retaining and slowly releasing water.

Box 8. Forest restoration in Indonesia

IISD applied the SAVi methodology to assess how forest restoration improves water availability and addresses land degradation in Indonesia (Bassi, Bechauf, Cutler, Gouett, & Guzzetti, 2021). In the upper Brantas River Basin in East Java, deforestation for agriculture has degraded the land and triggered environmental concerns such as soil erosion, biodiversity loss, decreased water retention, and increasing flood risks. In downstream areas, water scarcity is becoming an increasing problem for residents and water-intensive industries. To address these challenges, local and international stakeholders plan to implement agroforestry and riparian bamboo plantations as well as absorption wells and so-called biopori holes that enhance water retention.

The SAVi assessment showed that these land restoration measures are more cost effective than building a reservoir for water storage and also provide large societal benefits. Specifically, over 20 years, these interventions generate net benefits of between USD 104.34 million and USD 131.59 million in avoided flood and erosion damage along with improved water quality, carbon storage, job creation, agroforestry, and bamboo production. The assessment estimated that improved land management on a large scale could increase groundwater recharge by up to 6.1% a year, thus contributing to a reliable water supply for industrial activities in the watershed (Bassi, Bechauf, Cutler, Gouett, & Guzzetti, 2021).

Finally, NBI also represents an opportunity to foster universal energy access, increase the share of renewable energy and improve energy efficiency while also protecting people from dangerously intense heat. Energy generation and electricity transmission are vulnerable to extreme events that disrupt power generation and distribution infrastructure. Heat also reduces the efficiency of power generation from thermal generation and solar PV and increases transmission losses. For example, a study in the United States estimates that from 2040 to 2060, rising temperatures from climate change will reduce average summertime transmission capacity by 1.9%–5.8% while simultaneously increasing peak loads by 4.2%–15% (Bartos et al., 2016). NBI that reduces outdoor air temperatures can help reduce the loss in power generation efficiency and transmission losses. It avoids costly investments in power generation and grid infrastructure upgrades that would be needed to offset future efficiency declines.

While the body of evidence about the systemic benefits of nature is growing by the day, more research is needed to understand and quantify the synergies between NBI and other sustainable infrastructure. It will need systemic assessments that look beyond single assets and sectors, as well as careful consideration of local knowledge.

4.0
Incorporating Nature in Urban Planning

Realizing the potential of NBI in city planning requires integrated approaches that leverage the synergies between NBI and urban sustainability. As discussed above, NBI can be a tool for urban investments that not only deliver direct infrastructure services but also support existing and new grey infrastructure. NBI in cities helps to simultaneously work toward many aspects of sustainable urban infrastructure and increased well-being, such as transport, housing, health, climate adaptation and mitigation, economic opportunities for all, culture and recreation, and biodiversity.

Leveraging the benefits of NBI requires strategic, cross-sectoral urban planning with NBI at its heart (see Figure 6). Urban development strategies and infrastructure plans should span multiple interconnected sectors, such as transportation, health, housing, water, and NBI, and explicitly aim to maximize synergies between these areas (Global Future Council on Cities of Tomorrow, 2022). This requires governance structures and procedures that bring together experts from different disciplines (horizontal collaboration across sectors) and different levels of governance (vertical collaboration).

To maximize the benefits of NBI, planners, policy-makers, and investors can benefit from integrated assessments. Importantly, such integrated cost-benefit analyses and financial assessments that take into account the wider costs and benefits of NBI provide stakeholders with a more holistic perspective on infrastructure investments because they also include environmental and socio-economic outcomes that are overlooked in traditional analyses. This allows project proponents to not only assess the cost of implementing infrastructure but also to identify potential negative side effects and valuable synergies.

Box 9. How the benefit-to-cost ratio highlights the value of NBI

The SAVi assessments of urban NBI highlight infrastructure services and their social, environmental, and economic co-benefits. One indicator that reflects their value is the benefit-to-cost ratio (BCR). Our research finds that for all urban NBI projects presented in this policy brief, the BCR is greater than 1, indicating that they deliver more value to society than the investment required.

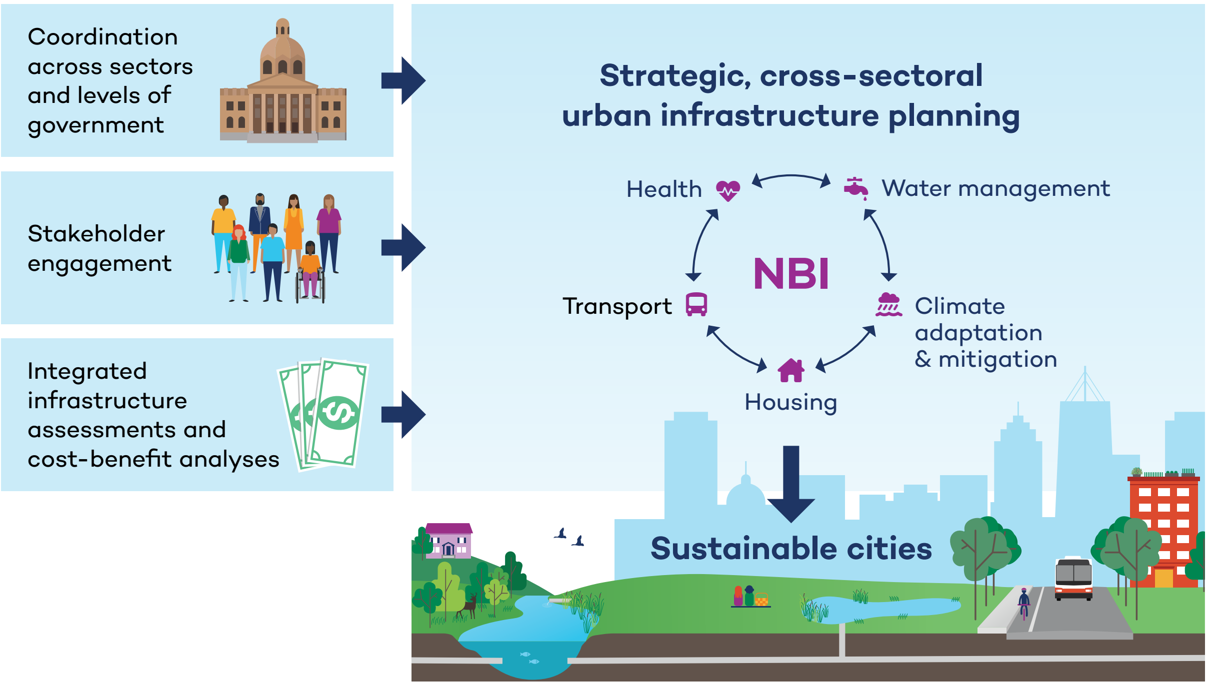
The BCR is 1.17 to 1.42 for planting trees in Addis Ababa (Cutler et al., 2022), 1.21 for creating green roofs in Tshwane (Cutler & Scholtz, 2021), between 4.75 and 4.93 for NMT in Coimbatore (IISD, forthcoming), and 4.93 for stream renaturalization in Johannesburg (Wuennenberg et al., 2021). Remarkably, improved hybrid wastewater treatment in Lake Dal shows a BCR of 22.2 (Bassi et al., 2018), and the assessment of planting trees in Tshwane indicates a BCR of 31.17 (Cutler & Scholtz, 2021). In other words, each dollar invested in tree planting in Tshwane could generate more than 30 dollars in societal benefits.

The challenges and needs of urban areas are diverse and complex, while the performance of NBI and its local outcomes depend strongly on local conditions. Assessments of NBI therefore need to be spatially explicit and customized to the local context, including careful consideration of local knowledge and climate change trends. Instead of relying on sectoral, technical analyses, infrastructure decisions should be informed by integrated assessments that combine insights from different fields, for example, using methodologies like SAVi.

As highlighted in UNEP's 10 good practice principles for sustainable infrastructure, a systems approach for sustainable cities requires comprehensive engagement with multiple stakeholders (UNEP, 2022). Participatory urban infrastructure planning offers valuable opportunities for bringing together diverse stakeholders to discuss challenges, offer potential solutions, and create community-buy in for NBI. Taking community-based approaches to NBI can be a key success factor for realizing the full social benefits of NBI and ensuring it is maintained in the long term.

As part of strategic, cross-sectoral urban planning, climate adaptation and NBI should be mainstreamed in planning processes—for example, by making green roofs and sustainable urban drainage systems and green corridors the default option in new developments. National governments can play an important role in creating an enabling environment for such NBI in cities through planning regulations and financial incentives.

Figure 6. Leveraging the benefits of nature for sustainable cities requires strategic urban planning with NBI at its heart



5.0 Conclusion

Infrastructure is a key enabler of sustainable development. It provides people with the services they need to thrive while also protecting the environment from human impacts such as pollution. At the same time, infrastructure development—if done unsustainably—is one of the main drivers of biodiversity loss and climate change. In cities, infrastructure needs are particularly high because urban areas are challenged by massive population growth and increasing climate impacts.

Building with nature provides valuable benefits for cities. NBI, such as urban green spaces and wetlands, provides cost-effective and climate-resilient infrastructure solutions. In addition to these direct infrastructure benefits, NBI generates a wealth of co-benefits, such as increased biodiversity, reduced air pollution, and improved well-being.

IISD case studies and analyses have shown that when these co-benefits are taken into account, NBI delivers more value to society than the investment required. The urban NBI projects are also, on average, 42% cheaper and provide 36% more value than relying only on grey infrastructure to provide the same infrastructure services.

IISD case studies have also shown that NBI can play an important role in supporting the resilience and effectiveness of existing and new grey infrastructure, such as in the case of non-motorized transportation. Additional research is required to better understand and quantify these benefits and fully leverage nature's contributions to sustainable cities.

To leverage nature's enabling function, NBI needs to become a central part of city planning, project assessments, and financing strategies. Planners, policy-makers, and budget holders need to take a systemic perspective that considers a portfolio of infrastructure investments and maximizes their mutual benefits. This means developing cross-sectoral, strategic plans for sustainable urban development and using systemic assessments to evaluate which NBI investments best support the city's infrastructure and sustainability objectives.

Cities around the world are working hard to create inclusive, healthy, and climate-resilient environments for their residents. Many are committed to ambitious climate goals and to protecting urban biodiversity.

In the face of constrained public budgets and mounting global crises, embracing the benefits of NBI and its synergies with urban infrastructure offers the opportunity to support a transition to sustainable cities.

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