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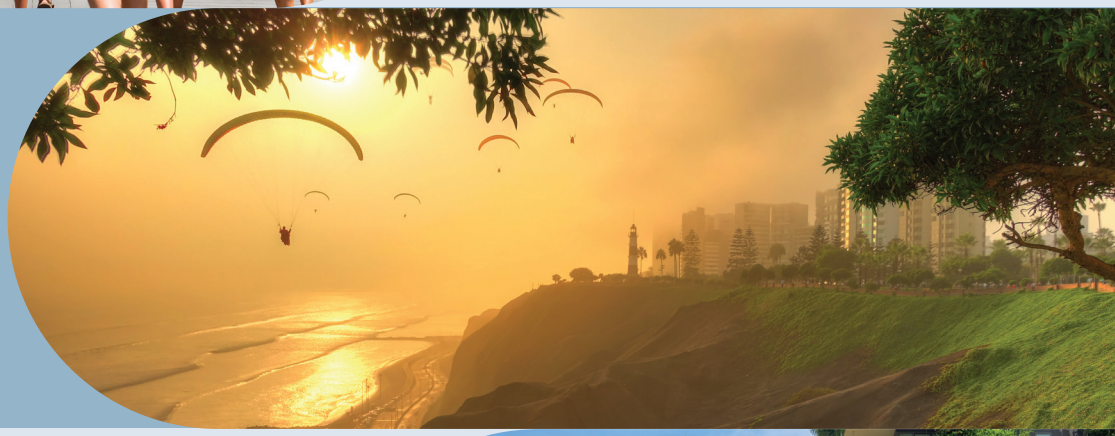
Natural Asset and Biodiversity Valuation in Cities

TECHNICAL PAPER

June 2019



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Abbreviations

ABC Waters	Active, Beautiful, Clean Waters
ACT	Australian Capital Territory
A/SSSI	Area or Site of Special Scientific Interest
BCA	Building and Construction Authority (Singapore)
BWSSB	Bengaluru Water Supply and Sewerage Board
GEF	Global Environment Facility
GIS	geographical information systems
GPSC	Global Platform for Sustainable Cities
GSURR	Global Practice for Social, Urban, Rural, and Resilience
HEAT	Health Economic Assessment Tool
InVEST	Integrated Valuation of Ecosystem Services and Tradeoffs
OCSE	Office of the Commissioner for Sustainability and the Environment
SAR	Special Administrative Region
SEEA	System of Environmental-Economic Accounting
SOE	State of the Environment
WAVES	Wealth Accounting and the Valuation of Ecosystem Services
WFD	Water Framework Directive

Executive Summary

Cities are increasingly recognizing the role of the natural environment in shaping healthy and livable places that enhance human capital. With urban populations expected to grow by 2.4 billion people by 2050, innovative policies that protect and enhance the value of the environment are required to avoid substantial losses in natural habitat and create favorable places to live. Many city governments are now taking the lead in developing innovative policies to pursue green urban development. These policies prioritize the conservation and enhancement of urban natural assets, ranging from trees on city streets to wilderness areas around cities.

Urban natural assets provide a wide range of direct and indirect benefits to people, businesses, and society. These benefits include basic needs like water and clean air, climate regulation, and opportunities for exercise and recreation. However, urban green infrastructure must be protected, enhanced, and managed in order to provide these benefits. Thus it is critical that urban decision makers understand the full range of benefits that these assets provide and their value. Taking both a conceptual and practical approach, this paper develops a framework that cities can use to assess their natural assets and inform efficient investment and policy decisions. The paper also explores the crucial role of biodiversity in underpinning the functions of natural assets and biodiversity's intrinsic value to urban dwellers.

Cities are beginning to use natural capital accounting as a tool to assess and monitor the quality of their environment and to inform effective policy making. Natural capital accounting takes stock of environmental assets and assesses their value based on the amount of goods and services they can provide. Quantifying the services provided by natural assets and assessing the value derived from them allows cities to make explicit the role these assets play in residents' lives. It also provides policy makers with the framework to examine the functioning of natural assets over time and allows them to examine how alternative management policies might change the services natural assets provide. The paper presents an overview of how cities can build a natural capital account and integrate the results to support policy making. It also discusses approaches to and challenges in integrating biodiversity into cities' accounting practices and policy making.

A number of cities are already trying innovative approaches to accounting for natural assets and biodiversity; these highlight best practice and areas for future development. This paper reviews some of these leading approaches and draws out lessons for other cities. In particular, the paper finds that the results of urban natural capital accounting have not been extensively integrated into policy making. It further finds that most of the city-level biodiversity plans reviewed are limited to high-level goals, have limited links to the economic benefits of biodiversity, and do not consider legislative, regulatory, or funding elements in their action plans to conserve biodiversity.

This paper offers policy guidance to help cities bridge these identified gaps. Urban decision makers have a set of policy options to manage the variety of natural assets in and around cities. Cities can use assessments in planning, creating, and maintaining urban natural assets to maximize value to urban residents. The paper also presents a high-level practical action plan for cities to follow, including a step-by-step approach to planning a green urban development strategy.

Section 1. Introduction

1.1 Context of Work

In response to growing awareness of the environment's importance to cities, a global movement has arisen to "green" urban development. Urbanization is often associated with improvements in standards of living, which depend on job opportunities and better public goods provision than in rural areas. However, the process of urbanization also acts as a pressure on cities' limited resources, institutions, and infrastructure. The pressures on vital ecosystems from urban development are often large and threaten the benefits residents derive from the environment. Cities are beginning to recognize the role that the environment plays in economic growth, and as a result are seeking to conserve and enhance these benefits. Throughout this paper we use the term "green urban development" to refer to the process of pursuing improvements in urban living standards while prioritizing the conservation of natural habitats and environmental processes in and around urban areas.

Rapid urbanization can be a threat to natural habitats and global biodiversity, compromising human well-being. The recent report by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services concluded that around 1 million animal and plant species are now at risk of extinction, with one-third of this risk arising in the last 25 years (IPBES 2019). Urbanization is the third largest threat to habitat loss globally, with 3,014 of 8,688 threatened or near-threatened species at risk due to current trends (Maxwell et al. 2016). Projected urban growth between 2000 and 2030 threatens 290,000 km² of natural habitat, in particular habitats typically found in developing countries such as tropical moist forest (The Nature Conservancy 2018). With an extra 2.4 billion people added to cities by 2050 due to economic and population growth, a suite of smart policies that put conservation at the heart of spatial planning is required to avoid substantial losses in natural habitat.

The effect that nature in cities has on human well-being and urban resilience is now well understood, and clear examples of successful management can inform best practice. There is a large evidence base for benefits provided by the environment, referred to as ecosystem services, to build policy from and inform future planning. Provisioning services, such as food and water, differ from regulating and cultural services, such as air quality and aesthetic quality; the former can be directly used or consumed by people, whereas the latter offer benefits that are less tangible but nonetheless vital to people's lives. Maintaining the functions and availability of the environment in and around cities equips cities with nature-based solutions to meet residents' needs now and in the future (Millennium Ecosystem Assessment 2005). External factors, such as climate change, threaten to increase already high urban temperatures in many cities and put more pressure on resources like water, in turn requiring cities to place climate change adaptation at the heart of urban policy (IPCC 2014).

Cities are also increasingly taking the lead in driving innovative policy and designing initiatives tailored to the needs of residents in an urban context. Environmental policies are no longer solely under the purview of national governments. Cities are leading action on climate policies, biodiversity, and urban resilience. C40 Cities, for example, is a network of 94 cities taking ambitious climate mitigation action at the local level. This coalition represents more than 700 million people and 25 percent of the global economy (C40 Cities 2017). Other organizations, including Cities Alliance, are connecting innovating cities so they can share best practices for sustainable development. Box 1 summarizes examples of four different cities that have successfully pursued ambitious green urban development policies.

Box 1: Examples of Four Different City Visions of Green Urban Development

Singapore, which calls itself a garden city, is now being recognized as a "city in a garden." Singapore has focused on bringing nature to the city and has retrofitted its buildings to green standards, resulting in several thousand buildings with a Building and Construction Authority (BCA) Green Mark status since 2005.[a] The city's major target is for 80 percent of buildings to have the Green Mark by 2030.

Curitiba, referred to as the ecological capital of Brazil, has a network of 28 parks and wooded areas that represent over 50 m^2 of green space per person (an increase from 1 m^2 in 1970). This is a result of residents planting 1.5 million trees along the city streets and a greenbelt circling the city to contribute to flood mitigation.

Cape Town, which topped the green space metric in the Africa Green City Index, boasts an estimated 289 m^2 of green space per person. It is identified as the most biodiverse city in the world, and in 2018 was recorded conserving around 65 percent of the Biodiversity Network (Bio Net).[b]

London has become the first-ever National Park City under a project that seeks to make the city greener, healthier, and wilder. Currently 47 percent of the city's area consists of green and blue spaces. The goal is to reach 50 percent by 2050.

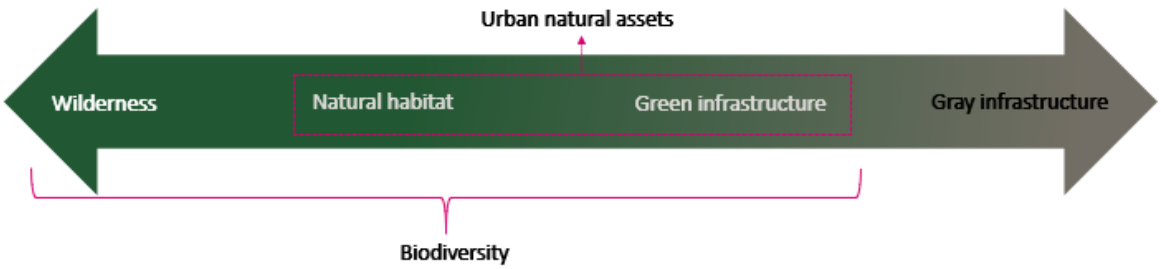
Sources: UN Environment 2018; Singapore Building and Construction Authority 2019 (for Singapore); Mikesh 2019 (for Curitiba); Economist Intelligence Unit 2011 (for Cape Town); National Park City Foundation 2019 (for London).

a. The BCA Green Mark Scheme began in 2005 as a way to drive Singapore's construction industry to build environmentally friendly buildings. The BCA Green Mark provides a meaningful differentiation of buildings and has positive effects on corporate image, leasing, and resale values.
b. Biodiversity Network is the spatial conservation plan for the City of Cape Town.

1.2 The Urban Environment and Natural Assets

Urban environments are made up of a network of built and natural features. Throughout the report we refer to these as assets or infrastructure. As with other classes of assets available in an economy, these provide benefits to urban residents (UK Defra 2017). Figure 1 shows the gradient of the natural and built environment in cities and its relationship to assets and infrastructure. On the extreme left and right are wilderness and gray infrastructure, which represent the areas that are least and most built-up respectively. Table 1 defines and provides examples for each of the elements on the gradient. Natural habitats and green infrastructure contain a combination of natural and built features and can exist within and beyond the city boundary.

Figure 1: The Gradient of Naturalness within and outside Cities



Source: Based on McDonald 2015.

Table 1: Types of Environments within and outside Cities

Type	Description	Examples
Wilderness	Natural area left untouched by human development	Rainforest, desert, deep ocean
Natural habitat	Natural area with ecosystem functions affected by surrounding or nearby urban areas	Rivers, forests
Green infrastructure	The network of natural and built environmental features in urban areas	Urban parks, constructed wetlands, ponds
Gray infrastructure	Non-natural features	Roads, buildings, bridges, dams, pipes

Cities have a significant number of options for investing in green urban development by planning, creating, and maintaining urban natural assets in and around the city. Cities can deploy different types of natural asset features to suit different local environments, habitats, and ambitions (Natural England 2009). Specific types of natural assets in urban areas include a wide range of potential investments available to cities at different spatial scales:

- **Small built features**: Green roofs/walls, green corridors, street trees, small green spaces, water features
- **Medium spaces**: City farms, public squares and commons, sport pitches, public/domestic gardens
- **Urban parks**: Local parks, regional or national parks
- **Natural areas**: Wetlands, rivers, and woodlands.

Work on quantifying the role that urban natural assets play for city residents is burgeoning as natural capital accounting is applied to urban areas. Landmark studies have been conducted at scales relevant to cities. For example, urban natural capital accounts have been undertaken in global cities like London, as well as for smaller urban areas in Northern Ireland and Greater Manchester (Vivid Economics 2017; Urban Pioneer 2019; Coldwell, Rouquette, and Holt 2018). These accounts have successfully demonstrated the value of urban natural assets and are reframing the way cities think about investing in

the environment. Cities are also working to integrate biodiversity considerations into the management of their natural assets by quantifying and monitoring the role that diversity of habitats and species plays both in and around cities.

Through linking management and investments in natural assets to physical and economic metrics, natural capital accounting techniques are being used by cities to prioritize and mainstream green urban development. Urban natural assets provide a range of benefits to urban residents, the environment, and the city economy. These include improved health and well-being for residents, support to wildlife and habitats, and regulation of temperature, air, and water quality (Vivid Economics 2017). Improvements in a city's quality of life generally explain a substantial part of its employment growth due to increases in human capital (Shapiro 2006). Thus attractive and healthy cities are also often the most productive and globally competitive (Economist Intelligence Unit 2018).

1.3 Challenges in Pursuing Green Urban Development

Cities face several challenges in pursuing efficient green urban development, which ensures the benefits of urban natural assets are sustained. Efficient investment decisions balance current and future urban needs. Because of the long-lived nature of many investments, decisions made now will affect the welfare of people long into the future. Consequently, protecting urban natural assets and investing in green infrastructure ensure that environmental benefits are available over the long term.

The challenges facing cities include the following:

- **Limited resources:** Growing urban populations put pressure on the limited land resources in cities, which often results in urban sprawl. Cities, as a result, face significant trade-offs between providing for gray and green infrastructure.
- **Lack of financial capacity:** Budgets for green infrastructure are already constrained because their benefits are not well understood; and as demand for land for housing increases, budgets come under further pressure. Investments in green infrastructure could be subject to cities' capacity to leverage finance and their ability to raise up-front investment capital.
- **Lack of institutional capacity:** Cities, particularly in the early stages of development, may lack the institutions that help support and pursue green urban development. Institutions may be inadequate to manage substantive capital investments or lack effective authority to design and implement policies that support green development.
- **Inconsistent values and norms:** One obstacle to green cities is authorities' and urban residents' limited understanding of the benefits of green infrastructure and development. Moreover, some city authorities are focused on achieving short-term urbanization goals, often at the expense of long-term sustainable planning and outcomes.
- **External pressures:** Many city governments face the challenge of increasing pressure on resources driven by rapidly growing populations. Currently around 1 billion urban dwellers (32 percent) worldwide live in housing classified as slums (UN Habitat 2017). The growth of informal settlements is difficult for city governments to control, and informal settlements often form on marginal land. A lack of adequate infrastructure can leave residents exposed to hazards such as poor-quality drinking water and inadequate protection against floods and landslides.

To overcome these challenges, cities need a clearer understanding of the benefits that urban natural assets provide; and to effectively manage their assets, they need a systematic way of prioritizing investments.

1.4 Structure of Report

This Technical Paper is designed to provide city governments, mayors, and administrators with clear guidance to inform the development of their natural capital accounts and action plans. Sections 2–5 provide a theoretical and practical guide to natural capital accounting in cities, as follows:

- **Section 2** analyzes the benefits of natural assets and biodiversity to urban residents and urban economies.
- **Section 3** provides an overview of natural capital accounting and step-by-step guidance for applying natural capital accounting to cities.
- **Section 4** reviews current policy efforts to enhance urban natural assets and biodiversity.
- **Section 5** provides high-level policy guidance to cities for green urban development.

Section 2. The Value of Urban Natural Assets and Biodiversity

There is increasing recognition that economic outcomes valued by cities can be cost-effectively delivered by high-quality natural assets. These outcomes include the health of residents, the resilience of the urban environment, and income opportunities. Additionally, cities have ambitions to protect biodiversity because it can support the functioning of natural assets and is valued by urban residents. This section describes the theoretical relationship between urban natural assets, biodiversity, and economic outcomes in cities.

2.1 Natural Assets and Ecosystem Services in Cities

Natural assets are the elements of the environment that provide benefits to people. These assets include water, soil, land, and other naturally occurring features of the environment. Urban natural assets are the network of natural and seminatural features in cities, including both green infrastructure and natural habitats. Figure 2 shows that parks, water bodies, and other green features, such as street trees, are key urban assets that provide benefits to cities.

Natural assets provide a wide range of direct and indirect benefits to people, businesses, and society. These benefits are referred to as ecosystem goods and services, and are categorized in figure 2 as provisioning, regulating, cultural, and habitat services. Provisioning services, such as food and water, can be directly used or consumed by people. Regulating services like air pollution removal lead to benefits that are less tangible but have large impacts on urban residents' health (Millennium Ecosystem Assessment 2005). Cultural services represent the opportunities for recreation and tourism; by giving city residents and visitors a sense of place, they provide crucial benefits and promote well-being and livability.

Box 2 further clarifies the meaning of "asset," "capital," and infrastructure."

Box 2: Assets, Capital, and Infrastructure

Throughout this paper, the terms natural "assets" and "capital" are used interchangeably. "Assets" refers to the physical stock of nature that can generate value, such as a park or water body. "Capital" then refers to the economic value of services that stem from an asset over a defined lifespan.

"Green and blue infrastructure" is a concept closely related to natural assets and capital and refers to the network of natural assets that provide services in and around the city. Whereas separate pieces of green and blue infrastructure provide benefits that can be expressed in terms of their capital value, the term "infrastructure" emphasizes the strategic nature of these assets, which are most effectively managed by acknowledging interlinkages between different assets. Green and blue infrastructure is also deployed to emphasize its similarity to other types of infrastructure in cities, including roads, water pipes, and street lighting.

Source: OECD 2009.

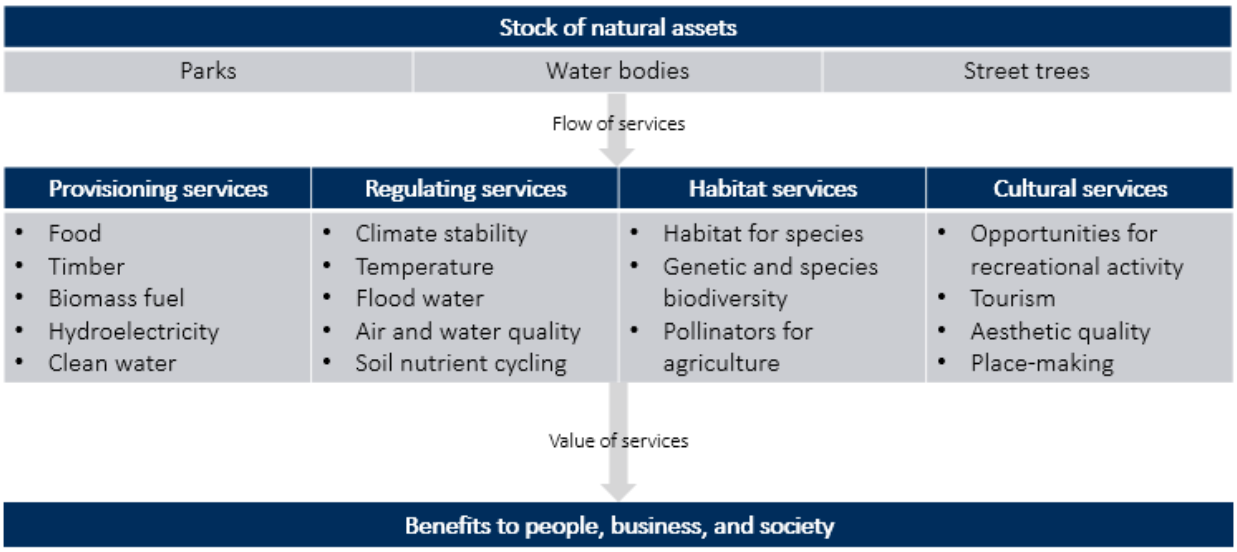
Ecosystem services have a crucial influence on the health of urban residents and the function of city life, supporting productivity and economic growth. They can support basic needs—for example, by providing clean water through well-functioning water purification services (Millennium Ecosystem Assessment 2005). Ecosystems also regulate air quality and local temperatures to support the health of urban residents (Centre for Ecology and Hydrology 2017). Urban natural assets, including parks and sports

pitches, provide cultural services such as space for leisure and physical activity, which also support physical and mental health (White et al. 2016).

Ecosystem services support urban economies through their impact on human health and well-being (figure 2). A primary pathway whereby ecosystems services affect the economy is through impacts on human health (related to exposure to pollution, for example), opportunities for physical exercise, and improved mental well-being (Millennium Ecosystem Assessment 2005). Health outcomes are particularly important as they impact individual productivity and human capital generation, which partly determine the ability to participate in the labor force and generate income. The health of residents and workers also affects businesses, which benefit from a productive workforce. The cumulative effects on individuals and businesses feed back into the public sector, which benefits from higher tax revenues generated from more productive businesses and from the avoided costs of treating ill health. Maintaining the quality of urban natural assets in and around cities can ensure continuing access to these benefits.

Ecosystems beyond traditionally defined urban boundaries also provide critical services to residents and are subsequently affected by urban expansion and policies. Ecosystem services such as water provision often stem from habitats located outside of cities. Thus, cities need to understand the value of and urban impacts on surrounding habitats. They must accurately assess the range of services that non-urban habitats provide in order to integrate these into effective decision making. At the same time, cities must understand and manage the pressure that urban life puts on surrounding areas. New York City's well-known policy of paying for upstream watershed services in the Catskill Mountains to ensure the quality of downstream water supplies represents a successful example of integrating urban policy with regional habitat management (Appleton 2002). Box 3 shows how Bengaluru has integrated ecosystem considerations into policy making to protect and make the most efficient and cost-effective use of water from an asset outside of the city.

Figure 2: Four Categories of Ecosystem Goods and Services Provided by Natural Assets



Source: Based on Millennium Ecosystem Assessment 2005.

Box 3: Case Study: Bengaluru's Efforts to Protect Water Ecosystems Outside of Cities

Bengaluru plans to increase access to clean water and sanitation in order to support a healthy population and a productive labor force.

Bengaluru experienced a 79 percent reduction in local water sources from 1973 to 2017, forcing the city to outsource its supplies to meet increasing demand (Ramachandra, Vinay, and Aithal 2017)**.** The city is not adjacent to a major surface water body and therefore relies heavily on urban lakes and reservoirs. But land conversion, construction, waste disposal, and increased demand for water have degraded and depleted many local sources (Sudhira and Nagendra 2013; Sekhar et al. 2017). As a result, the city has become increasingly dependent on piping in water from the Kaveri River, which is more than 100 km south of Bengaluru (Ramachandra, Vinay, and Aithal 2017). This imposes significant costs on the Bengaluru Water Supply and Sewerage Board (BWSSB), which spends 75 percent of its revenue on electricity to transport water (Lakshmi 2007).

BWSSB has expanded access to water and sanitation by improving the efficiency of distribution systems. The Comptroller and Auditor General of India reported that between 2009 and 2013, half of the water piped in from the Kaveri was lost from leakage or theft due to inadequate plumbing (Saldanha 2016). BWSSB has developed infrastructure to more efficiently and consistently supply water. The Bengaluru Water Supply and Sewerage Project invested in new supply systems to increase access and reduce lost water, built new treatment plants for wastewater, and upgraded pipelines to reduce pressure on local groundwater resources. Efficient infrastructure allows BWSSB to manage demand and prevent losses, recouping the initial investment and costs of transporting water (Venkataraju n.d.).

Bengaluru's long-term efforts demonstrate the importance of proactive management of water ecosystem services in the context of population growth and land conversion. BWSSB has been addressing service supply issues for more than a decade due to insufficient infrastructure. The Bengaluru Development Authority has shown that future degradation can be prevented not only by investing in restoring degraded sources, but also by integrating ecosystem considerations into zoning policies. Managing proactively is typically less costly than restoring degraded ecosystems retroactively (Richards, Passy, and Oh 2017).

Source: Research compiled by Vivid Economics for Cities Alliance, 2019.

2.2 Combinations of Urban Natural Assets and Delivery of Ecosystem Services

Urban natural assets comprise features that provide multiple ecosystem services. Table 2 shows that many natural assets provide regulating services that maintain the quality of the local environment, while some features, such as street greens and gardens, also improve urban aesthetic quality. Large green spaces provide opportunities for physical activities and recreation and thus support the physical and mental health of urban residents. The number, quality, and features of natural assets influence the supply of ecosystem services. Parks and larger natural features also have intrinsic value to urban residents, who may appreciate their existence for ethical, cultural, or other reasons.

Cities can leverage different types of natural assets to target the provision of particular ecosystem services. For example, cities may be interested in promoting opportunities for physical activity. Some cities, however, may be space constrained and unable to create large green spaces like urban parks or sports pitches. Table 2 shows that smaller green spaces and green corridors can also provide these cultural services. Populous cities in China like Chengdu have made efficient use of limited land space by developing pedestrian-focused green spaces that are narrower than traditional parks. These "greenways" are corridors of green spaces that border highways and bodies of water. Greenways can be more accessible, functional, and efficient than large swathes of park space because they can connect the pedestrian areas of the city (Shenggao 2018).

Green and blue infrastructure can also be combined strategically to take advantage of multifunctional benefits. Box 4 shows an example of this approach in Singapore, where simultaneous investments in the stock of green and blue assets expanded opportunities for recreation and improved the city's resilience to severe rainfall events. The multifunctionality of green and blue infrastructure can also have clear implications for the management and funding of investments, since the services provided by these infrastructures can cut across the purview of different government departments. This potentially creates an opportunity for agencies to pool resources, but it also requires cooperation across government and civil stakeholders to manage resources strategically so as to achieve a range of mutually advantageous policy objectives. Box 5 shows an example of an approach developed by Edmonton, Canada, to strategically assess its multifunctional natural assets.

Box 4: Case Study: Singapore's Active, Beautiful, Clean (ABC) Waters Program

Singapore's ABC program was launched in 2006 with the aim of creating a new set of natural assets around its 17 reservoirs and 8,000 km river and canal system. By combining the existing network of blue assets with complementary investments in green assets such as parks and walkways, the program seeks both to provide residents with multifunctional spaces that offer recreational opportunities around water bodies and promote sustainable surface water management in the city.

ABC Waters was developed to create resilient natural assets that provide local environmental benefits. It was an initiative from Singapore's National Water Agency, which devised a set of natural solutions and developed implementation guidance to mitigate the risk of stormwater flooding. By integrating green infrastructure into planning decisions, the aim has been to develop a system in which stormwater is released more slowly into public drainage systems, reducing the chance of flash flooding and damage to the city. The program also includes design principles to harness the potential of green infrastructure investments, such as rain gardens and vegetated swale channels, to improve the quality of water bodies by filtering water returned into rivers and reservoirs following storms.

Initial evaluations indicate that projects incorporating the program's design features have been successful. One study found that a set of interventions had reduced solid pollution in water bodies, although not the release of nutrients. Another study found that design features of one ABC development reduced peak flow by detaining runoff in local precincts.

Sources: Lim and Lu 2016; Goh et al. 2017; PUB Singapore 2018.

Box 5: Case Study: BREATHE—Edmonton's Green Network Strategy

The City of Edmonton in Alberta, Canada, developed a strategy titled BREATHE to manage and program the use of its publicly accessible open spaces in an efficient and sustainable way. The aim was to integrate all open spaces, including various classes of parks, natural areas, utility corridors, and constructed wetland stormwater facilities, within a single strategic plan.

Central to the strategy is the production of a geospatial inventory of all open spaces, along with detailed information on their function and connectivity. Rather than adopting a monetary approach to natural capital valuation or simply quantifying the extent of green areas, the strategy pursues a "multifunctional network planning approach" to assess the distribution of open spaces throughout the city and provide options for government departments and communities to manage spaces in pursuit of neighborhood as well as citywide goals. Open spaces are assessed and scored according to three themes of multifunctionality:

- **Ecology,** to support healthy and resilient ecosystems
- **Celebration,** to provide places for communities to gather and thrive
- **Wellness,** to promote healthy living through recreation, mobility, and environmental benefits

BREATHE serves as a decision-making tool and provides high-level guidance and priorities for managing the Edmonton green network. The strategy aims to support well-programmed and targeted interventions in communities where they are most needed and to avoid ad hoc decision making by network managers. The strategy was unanimously passed by the Edmonton City Council and has also won awards from the Canadian Institute of Planners and the Canadian Association of Landscape Architects.

Source: City of Edmonton 2016.

Table 2: Typology of Urban Green Infrastructure and Associated Ecosystem Services

	Green infrastructure	Cultural			Regulating		Provisioning		Option value
		Recreation	Physical activity	Aesthetic, place-making	Water quality	Air quality	Food	Water	Bequest, intrinsic
Small built features	Green roof/wall			●	●				
	Green corridor		●	●					
	Street trees			●		●			●
	Small green space	●		●		●			
	Water features	●		●				●	
Medium-size spaces	City farms	●					●		
	Public squares, commons	●	●	●					
	Sports pitches	●	●						
	Public/domestic gardens	●		●		●	●		
Parks	Local parks	●	●	●		●			●
	Regional/national parks	●	●	●		●			●
Natural features	Wetlands, rivers	●			●			●	●
	Woodland					●			●

Sources: Friends of the Greenbelt Foundation 2017; Natural England 2009.

2.3 Biodiversity in Cities

While cities and other stakeholders are often interested in protecting biodiversity, the impact of biodiversity on the supply of ecosystem services is not well articulated. Biodiversity plays a role in supporting the provision of ecosystem services in cities and is also intrinsically valuable to people**.** The following section outlines the conceptual approaches to assessing the benefits of biodiversity to inform policies focused on natural asset provision.

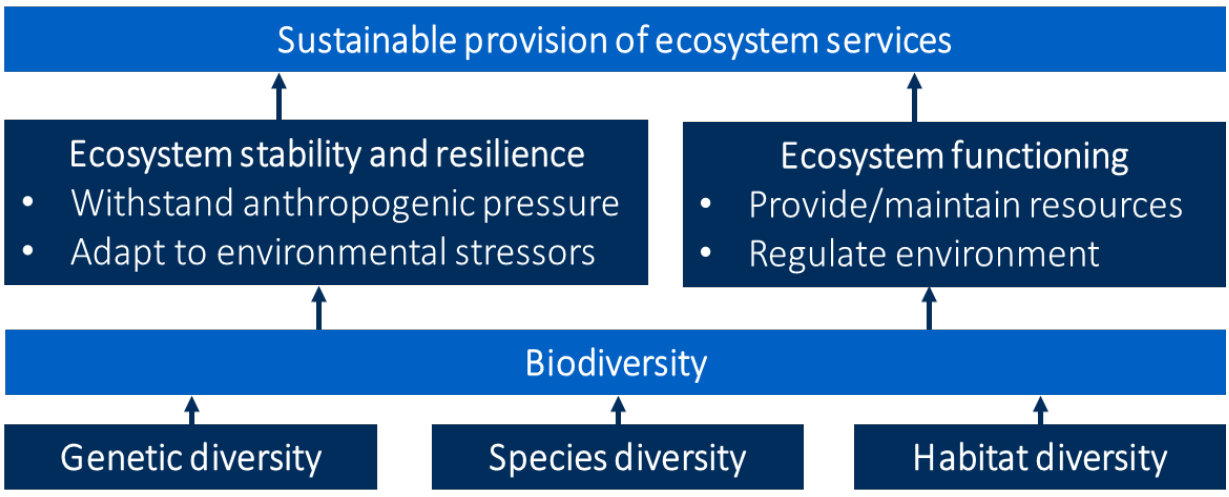
2.4 Defining Biodiversity

Biodiversity definitions have in common an emphasis on diversity—that is, differences between organisms—at a variety of scales, rather than the abundance of any one species or trait. Biological variability of an ecosystem refers primarily to three types of diversity (CBD 1992):

1. **Diversity within species**, or the genetic differences between organisms of the same species
2. **Diversity between species,** or the diversity of functional traits of species within an ecosystem
3. **Diversity of habitats,** or the variation of habitats within and across ecosystems

All three types of biological variation are important for long-term ecosystem functioning and stability (figure 3). Ecosystems rely on a variety of organisms, performing a range of functions, to operate efficiently and to be resilient to external pressures. In turn, the quality and quantity of services delivered in both the short and the long term can be affected by changes in biodiversity (Science for Environment Policy 2015). For example, many plants and trees depend on a set of insects and animals to perform pollination functions. Ecosystems that rely on a smaller number of pollinators to perform these functions are more vulnerable to environmental stressors that threaten those species. Since climate change threatens the survival of many species, biodiverse ecosystems are more likely to remain functional in the long term, since they may have a greater number of species able to perform essential functions (Brander and Eppink 2012; Cambridge Conservation Initiative 2016).

Figure 3: Influence of Biodiversity Ecosystem Functions and Response to External Changes

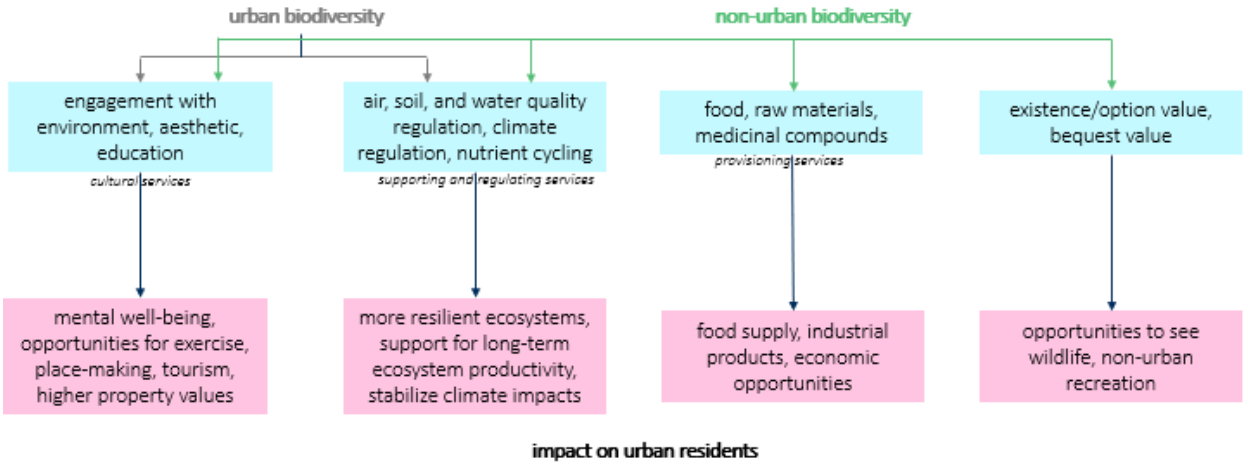


Source: Based on Cambridge Conservation Initiative 2016.

Where biodiversity supports the delivery of ecosystem services, it can be considered a factor that underlies the quality of urban natural assets. Figure 4 shows how urban biodiversity can improve the experience of city life and regulate the quality of urban environments through the delivery of ecosystem services. For example, an important ecosystem service provided by some natural assets is regulation of local air quality. Trees and vegetation cover help remove pollutants harmful to human health from the atmosphere (Centre for Ecology and Hydrology 2017). Research has shown that more biodiverse vegetation is more efficient at removing air pollution because different species have the ability to remove different pollutants (WHO and SCBD 2015). Although the role of biodiversity in underpinning ecosystem services is not necessary, research shows that biodiversity loss could reduce the efficiency of ecosystem functioning (Science for Environment Policy 2015).

Urban residents benefit from biodiversity through access to green spaces. Natural assets can supply important cultural services, and biodiversity in those spaces can increase the value of those services. Biodiverse green spaces, as opposed to homogenous lawns or mown grassland, include a greater variety of vegetation types and a greater number of natural features, and they are better able to support diversity in insects, animals, and soil macrofauna (Southon et al. 2017). Even though biodiverse green spaces could be costlier to maintain than spaces such as lawns or paved areas, they are more aesthetically pleasing, encourage more recreational visits to green spaces, and provide more opportunities for urban residents to engage with the natural environment (WHO and SCBD 2015). In turn, they support the physical and mental health benefits of residents and improve the overall quality of urban life (Kothencz et al. 2017). There is also evidence that exposure to a diverse set of animals, insects, plants, and bacteria in urban green spaces can have a positive impact on human health by increasing immune function (Flies et al. 2017).

Figure 4: How Urban Residents Benefit from Biodiversity Locally and Outside Cities



In addition to supporting the supply of ecosystem services, conserving urban biodiversity can be intrinsically valuable to urban residents. The intrinsic or option value of biodiversity is the value that people or governments place on conserving biodiversity outside of its instrumental value. People may value biodiversity purely for its existence, for the option of viewing or using it in the future, for moral or ethical reasons, or for cultural reasons (Cambridge Conservation Initiative 2016). Biodiversity conservation for intrinsic reasons is often pursued in policy making but is less often considered in biodiversity valuation assessments. For example, the U.S. Endangered Species Act prioritizes protecting any and all species at risk of extinction, regardless of the role the species plays in ecosystems or the value it provides to people (Wetzler 1993).

Urban residents may also benefit from biodiversity outside of cities, which can underpin critical ecosystem services. Urbanization and development are naturally in conflict with habitat for biodiversity, although city residents benefit from biodiverse ecosystems around cities. Cities have an impact on non-urban biodiversity through land conversion, habitat fragmentation, pollution, and resource depletion. Moreover, cities have tended to locate in high-biodiversity areas such as transport corridors and near water bodies, and therefore urban expansion can have a disproportionate impact on global biodiversity (McDonald 2015). However, cities can play a role in safeguarding biodiversity by carefully planning urban expansion around key surrounding habitats. In addition, cities and regions that integrate wider peri-urban land use policies to control agricultural expansion can further reduce any damaging effect of more urbanization. For example, Malawi's deforestation reduction strategy is headlined by urban policy efforts to reduce Lilongwe's impact on Malawi's most biodiverse forests (see box 6).

Box 6: Case Study: Malawi's National Charcoal Strategy

Malawi's National Charcoal Strategy demonstrates that city governments can play an important role in managing pressures on rural and peri-urban ecosystems like forests. Urban demand for charcoal drives deforestation, meaning that cities have a critical role in managing demand, regulating sustainable trade, and developing alternative fuel sources. Malawi's National Charcoal Strategy 2017–2027 seeks to reduce deforestation and its impacts on biodiversity by making charcoal supplies more sustainable and shifting urban energy sources away from biomass.

Malawi's most biodiverse woodlands have been deforested at a rate of 1–3 percent annually since the 1970s, due to a growing urban population and demand for biomass fuel. Lilongwe is Malawi's capital and houses the country's largest urban population. The city has urbanized rapidly over the past decade, with a population of nearly 1 million in 2018 (Malawi National Statistical Office 2018). A quarter of the population is below the poverty line, and 9 percent are living at less than half the poverty line (Lindstrom 2014).

The Dzalanyama Forest Reserve provides both biomass energy and essential regulating services to the Lilongwe River Basin and its residents. The majority of residents in Lilongwe currently rely on biomass for fuel, which has led to unsustainable rates of deforestation around the city (World Resources Institute 2014). Surrounding forests provide important regulating services for air quality, climate, and soil quality.

The National Charcoal Strategy 2017–2027 is a comprehensive plan to combat the drivers of deforestation in both rural and urban areas. The strategy is a nationally driven policy to reduce urban demand for charcoal and strengthen rural regulations on logging. The policy is an ambitious and well-considered plan that addresses the trade-off between reducing deforestation and improving rural livelihoods, as well as the trade-off between reducing charcoal consumption and ensuring urban energy access.

Urban governance complements rural efforts to strengthen law enforcement against unsustainable charcoal production. Lilongwe seeks to reduce unsustainable deforestation by regulating the charcoal supply chain, for example by improving the enforcement of regulations; stopping illegal charcoal production and transportation; establishing a regulated, sustainable charcoal supply chain; and encouraging the private sector to invest in sustainable charcoal production (MNREM 2017).

Source: Research compiled by Vivid Economics for Cities Alliance, 2019.

Biodiversity can be conceptualized as underpinning ecosystem services, but also as providing intrinsic value to people. Understanding that biodiversity has both instrumental and intrinsic value is important because it determines how cities measure urban biodiversity and account for it in investment and policy making. In the next section, we outline how cities can use natural capital accounting to inform decision making, and how both values of biodiversity can be included in natural capital accounts.

Section 3. City Natural Capital Accounting Overview and Guidance

3.1 Introduction to Natural Capital Accounting

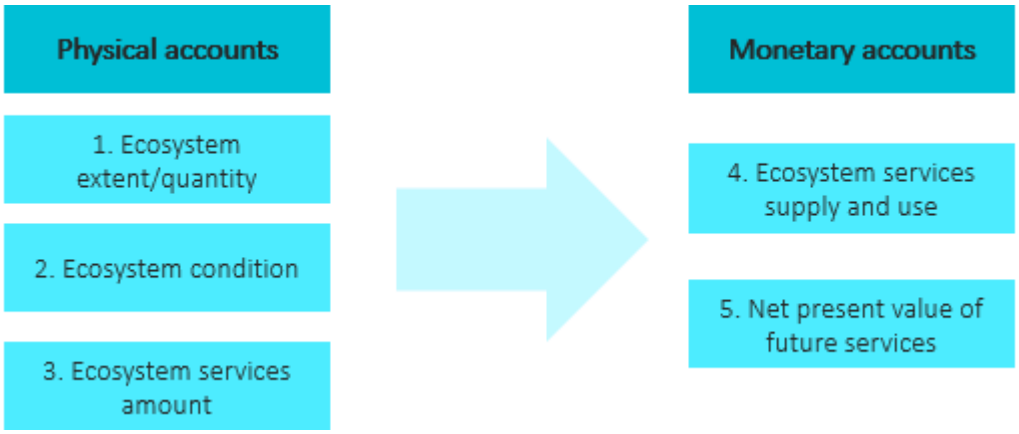
Accounting is a system for assessing and managing assets. In financial accounting, an asset is typically a tangible resource that produces economic value, like property or machinery. Despite the role that natural assets like forests, water, and green spaces play in an economy, they are often not included in traditional economic accounts, which primarily measure the value of goods and services bought and sold. This omission is problematic because assets that are either not valued or undervalued may be ignored in policy making, potentially leading to inefficient allocation of city budgets.

Natural capital accounting expands the set of assets considered to underpin the economy. Natural assets are classes of asset provided by the environment and include natural resources such as water bodies, land, and ecosystems (Hein et al. 2016; UK Defra 2017). Natural capital accounting is a systematic way of accounting for and monitoring losses and gains in these assets and making explicit the role of these assets in the economy (UK Defra 2017).

Natural capital accounting is achieved by taking stock of natural assets and assessing their value based on the amount of goods and services they can provide. Figure 5 shows the structure of a typical natural capital account, which includes a physical account of the stock of natural assets and a monetary account of the value provided by the assets. The physical account reflects the quantity and quality of natural assets, both of which help determine the flow of ecosystem services that natural assets provide to people, businesses, and the economy. The monetary account translates these services into economic terms by estimating the net present value of current ecosystem service supply and use, and the value of services into the future.

Economic valuation provides a common framework to compare the value provided by different natural assets and the services they provide. Other types of assets and infrastructure, such as roads or schools, often take precedence over natural assets and green infrastructure in economic decision making, because the economic benefits of the former are routinely made explicit in planning decisions. By quantifying the role natural assets play in the economy in monetary terms, policy makers and planners can directly compare the contribution of natural assets with other physical assets in the economy. This step affords a more complete picture of various investment decisions, such as valuing the creation of green infrastructure and evaluating the effects of gray infrastructure investments on services provided by nature.

Figure 5: Components of a Natural Capital Account



Source: Based on UK Defra 2017.

3.2 Approaches to Ecosystem Services Valuation

Valuing the contribution of natural assets to the economy can be challenging because many of the services that stem from natural assets are not priced in traditional markets. For example, street trees may be undervalued because the benefits they provide in improving local air quality and mitigating respiratory illness are not considered (Donovan et al. 2013). Because many natural assets lack a market, they are assumed to have little to no economic value, and their contribution to the economy is frequently overlooked in policy. But this oversight could potentially lead to adverse economic outcomes and missed investment opportunities. For example, given that outdoor pollution exposure in cities leads to more than 3 million early deaths each year (WHO 2016), air quality regulating services are particularly important in developing cities, where populations are often exposed to high levels of air pollution (Satterthwaite 2003). Valuing the impact of key services like pollution removal allows policy makers to compare the costs of natural asset investments with alternative health interventions.

To overcome the lack of markets for many natural assets and the services they provide, natural capital accounts utilize a variety of methods to estimate the value of different ecosystem services. Box 7shows that some methods may be more suited to particular types of ecosystem services. Estimating the value to production, for example, may be useful for critical regulating services, such as soil quality regulation, but not appropriate for cultural services like opportunities for physical activities (Mader et al. 2011).

Box 7: Guide to Monetary Valuation Methods for Non-marketed Natural Assets

Ask people to state their preferences for paying for a natural asset: Directly ask people how much they value the natural environment or are willing to accept changes to it.

- Example: Conduct a survey that asks respondents to indicate how much they would be willing to pay in annual taxes for conserving a number of acres of natural habitat.

Observe behavior and preferences via existing markets: Use market prices and costs to observe how much people value different components of natural assets.

- Example: Infer the premium urban residents are willing to pay to live near green spaces by comparing similar houses located in different neighborhoods.

Estimate natural assets' contribution to production: Value the flow of goods and services or avoided costs provided by natural assets that support economic activity.

- Example: Estimate how much it would cost to build a replacement for a natural process, such as water quality purification or pollination.

Source: Mader et al. 2011.

3.3 Natural Capital Accounting in Cities

Natural capital accounting was first developed at national scales, and a significant amount of global work has been done on methodologies for incorporating natural assets in national accounts. For instance, international frameworks for developing national natural capital accounts include the System of Environmental-Economic Accounting (SEEA) and Wealth Accounting and the Valuation of Ecosystem Services (WAVES). These frameworks have developed standardized processes for natural capital accounting that incorporate natural assets, such as forests and water, alongside traditionally measured assets in the national economy. However, these frameworks are better suited for use at country scale, and natural capital accounting in cities tends not to follow these approaches strictly.

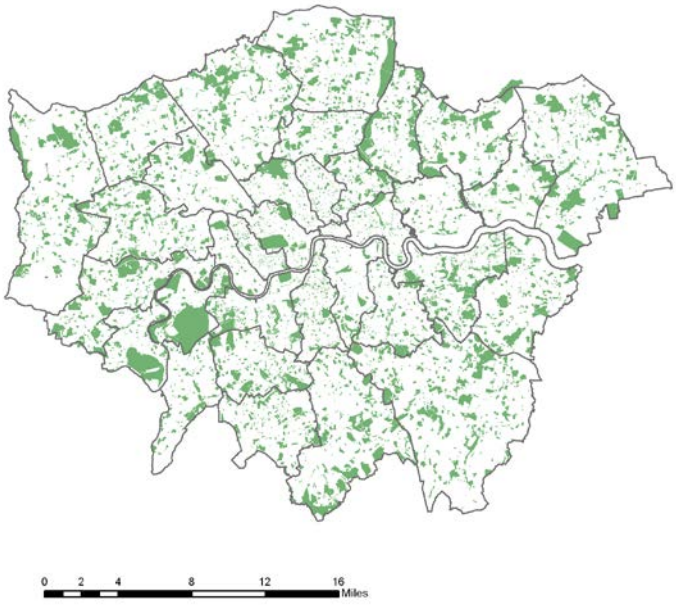
Cities are increasingly using natural capital accounting as a tool to assess and monitor the quality of their environment and inform effective policy making. Natural capital accounting methodologies are evolving to account for the role that natural assets play in cities; methodologies include assessing the value of public parks and urban waterbodies (Vivid Economics 2017). These accounts are also evolving to assess the value of localized green infrastructure investments, such as street trees, and to quantify the ecosystem services that support livable cities, by (for example) assessing the value of recreation (Iamtrakul, Teknomo, and Hokao 2005), impacts on human health (White et al. 2013), and flood risk reduction (Kim, Lee, and Sung 2016).

Assessing the value of natural assets allows cities to evaluate trade-offs, which is important because urbanization puts pressure on limited resources. Natural capital accounting can help highlight the benefits of natural assets that face competing demands. For example, as urban populations grow, ensuring that land is available for housing may conflict with protecting urban greenspaces. In many

settings, protecting green spaces is given lower priority than providing additional housing units, despite the services supplied to residents from these spaces. Natural capital accounting can demonstrate the value of green spaces in the form of recreational opportunities and improved health outcomes, allowing policy makers to make better-informed land use decisions that balance residents' needs. National natural capital accounts in Botswana and Colombia have been used to inform land use decisions surrounding competing demands for water. In Botswana, the water accounts have guided regional development and spatial planning of industries to improve the efficiency of water use (Vardon et al. 2017).

Natural capital accounting can help cities make better investments by providing a framework for including natural assets in decision making. Since many natural assets and ecosystem services are not valued in traditional markets, there is little financial incentive to invest in natural assets. Natural capital accounting demonstrates the monetary value of investing in natural assets and the financial losses that can result from lack of conservation. An assessment of the United Kingdom, for example, found that between 2003 and 2013, all forms of natural capital declined in value by more than £700 per capita (Martinez-Oviedo and Medda 2018). Box 8 describes how natural capital accounting in London has helped transform the perception of green space—from something costly to provide and manage to a value-creating asset (Vivid Economics 2017).

Box 8: Case Study: London's Natural Capital Accounting as a Spur to Debate about Benefits and Costs of Urban Parks



Londoners have access to an extensive network of 32,000 acres of public parks and green spaces (see map above). However, the economic value this network provides has not been well understood.

***Natural Capital Accounts for Public Green Spaces in London*, a report published by the Greater London Authority, National Trust, and Heritage Lottery Fund, estimated that London's public parks provide more than £5 billion in ecosystem service values per year.** The report explained the methods of accounting for a range of economic benefits provided by London green spaces; for example, it estimated the avoided mental and physical health costs due to these spaces, worth £42 and £67 respectively per year to the average Londoner.

The natural capital accounting work reframes London's public parks as value-creating natural assets rather than costly liabilities. Investment analysis found that for each £1 spent on maintaining parks, Londoners enjoy £27 of benefits. This analysis has helped managers of these assets make the case for sustained or greater spending on parks. Although it is difficult to link specific policy decisions to the creation of the accounts, policy makers have commented that the accounts have reframed discussions around management of green spaces, in particular focusing attention on management that maximizes value rather than minimizes costs.

Source: Vivid Economics 2017.

3.4 Building a Natural Capital Account

This section provides step-by-step guidance on building a natural capital account for cities, and indicates the data required to perform each step. Building a natural capital account is one of many actions cities can undertake in their pursuit of green urban development. For an explanation of the larger process of integrating the findings of natural capital accounting into urban policy and planning, see appendix A, which details a high-level action plan for cities to help pursue green urban development. See appendix C for the methodology used to produce the natural capital account for London.

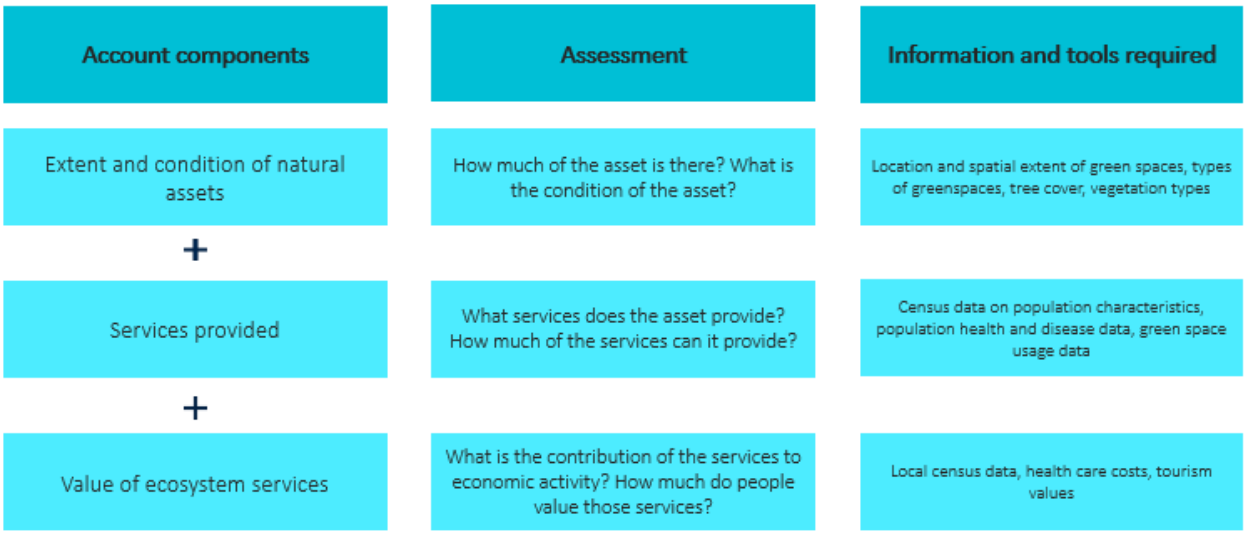
Prior to beginning work on the construction of a natural capital account, cities can begin planning so that the necessary pieces are in place to succeed. The preliminary work should address the following areas:

- **Ambition:** There should be agreement at the start about the general and specific goals of the accounting exercise and the analysis underpinning it. To ensure that the account supports the needs and ambitions of a variety of city decision makers and users, a set of stakeholders should be identified and asked to provide input into the goals of the project. Decision makers should also define the scope of assets under consideration by aligning these with strategic objectives. For instance, is the natural capital account focused on a particular type of asset, such as green spaces, or will it encompass a wider set of green and blue assets located beyond city boundaries?
- **Skills:** Constructing a natural capital account requires robust modeling of the ecosystem services stemming from the city's natural assets and their associated economic benefits. To carry out this modeling, a team of expert environmental scientists and economists is typically required. The team should also include specialists with geographical information systems (GIS) skills to process and display spatial data.

  Data: Successful completion of the account depends on the availability of a range of city-level data. The levels of data required are detailed in the following section, but a preliminary overview of data availability is required to confirm that project ambitions can be met. At this stage, it is also possible to consult with stakeholders with access to additional data and identify data gaps so that alternative data options can be considered. Essential data needed to begin construction of a natural capital account are (i) maps and spatial data of natural assets; (ii) spatial census data (population, demographics, housing units) to link assets to beneficiaries; and (iii) data or assumptions on use of natural assets—e.g., survey data on park use.

Figure 6 shows an overview of the components of the natural capital account, the questions each component aims to answer, and details of the specific information required to complete the assessment.

Figure 6: Steps in Building a Natural Capital Account



STEP 1: Assess the extent and condition of urban natural assets. Natural capital accounting should include those urban natural assets that cities are most interested in assessing, protecting, or enhancing. These can include not only assets within urban areas, but also natural habitats outside city boundaries that benefit urban residents, such as watersheds or forests. This step evaluates natural assets' quantity, quality, and spatial configuration and is based on land cover data and relevant condition indicators, as shown in table 3.

- **Quantity** is assessed according to the amount of each asset. For example, vegetation cover quantity will be based on number of hectares, while tree cover quantity could be total canopy cover, hectares of woodland, or number of street trees.
- **Quality** can be assessed on relevant condition indicators, depending on the features and types of natural assets. For example, the quality of a green space can depend on the combination of physical and built features, which can influence how willing people are to use these spaces. Other measures of quality relate more directly to the ability of an ecosystem to function effectively, such as a wetland's purification of the water supply.
- **Spatial configuration** assesses how fragmented the assets are within a given landscape. This can inform how accessible spaces are to both people and wildlife.

Table 3: Methods for Assessing the Extent and Condition of Urban Natural Assets

Condition indicators	Assessment method	Outputs
Land cover types	Use mapping data to determine amount of green space available and land cover types.	Quantity of green space and types of vegetation within each space
Tree cover	Use mapping data, mostly derived from satellites, to determine how much of green space is canopy cover.	Quantity of tree canopy cover
Features	Determine features available in green spaces (e.g., water features, play spaces, sports pitches, etc.).	Number and types of green space features
Access	Use housing and/or census mapping data to determine the proximity of population to green spaces.	Size of local populations, accessibility points including transport options
Spatial configuration	Use mapping data to assess how fragmented green spaces are.	Neighborhood greenness, habitat connectivity

STEP 2: Develop a register of ecosystem services provided by each natural asset. The ecosystem services provided by urban green spaces, for example, are shown in table 4. Green spaces primarily provide cultural and regulating services that benefit urban residents but can also provide other regulating services such as air quality regulation and carbon sequestration. The extent of ecosystem services provided by green spaces depends on the extent and condition assessed in step 1 and the size of the beneficiary populations.

STEP 3: Model ecosystem services. Given the set of ecosystem services identified, the next step is to model the flow of services stemming from the natural asset. Accurately modeling ecosystem services requires the expertise of environmental specialists who understand and can quantify the physical quantity of services. For instance, quantifying the amount of water provided by a water body requires input from hydrologists. Where experts are not available to assess the flow of an ecosystem service, analysts often rely on parameters derived from studies conducted in similar settings.

The aim of modeling ecosystem service flows is to determine in physical units the quantity of the service provided, or to select a qualitative indicator that sufficiently captures the state of an ecosystem. Modeling conducted in this step is both a critical input into the monetary valuation of ecosystem services and an important measurement of ecosystem functioning in its own right. Since accurate quantification of ecosystem service flows can be time-consuming and costly, a mixture of methods is often deployed to derive a level of accuracy suitable for a natural capital assessment. These methods can include

- Quantification by expert using locally derived data and bespoke modeling
- Quantification using peer-reviewed or industry standard models applied to local setting
- Expert-based metrics
- Qualitative assessments

Estimating an ecosystem service flow can require data on both ecosystem functioning and the beneficiary population. The quantity of ecosystem services supplied depends not only on the extent, condition, and functioning of an asset, but also the population that is affected. Spatial mapping is often a key component in this regard, since linking the service flow to the population requires accurately mapping both location of natural assets and the population these assets affect. For example, the opportunity for physical activity is an important service provided by green spaces. Table 4 shows that estimating the amount of physical activity undertaken in parks depends on the size and quality of the parks, the size of the population with access to the parks, and the preferences of the local population for visiting parks and undertaking physical activity. Cities can utilize a range of methods to collect survey data and can utilize emerging technologies, like cell phone data, to better understand population engagement with green space features.

Table 4: Sample Register of Ecosystem Services Provided by Urban Green Spaces and Associated Data Needs

Asset	Ecosystem service	Type of service	Data needs
Green space	Physical activity and health	Cultural	Amount of green space Survey/observed data on park visit frequency and activities Census data on population characteristics and health outcomes Disease costs
	Mental well-being	Cultural	
	Amenity value	Cultural	Amount of green space Hedonic pricing model relevant to city context Property values
	Air quality	Regulating	Amount of green space Vegetation types Air quality data Health costs of air pollution
	Carbon sequestration	Regulating	Amount of green space Vegetation types Tree cover Carbon price

STEP 4: Translate the physical flow of services into economic benefits to urban residents and economies. The economic value of ecosystem services depends on the ecosystem services register from step 2 and an economic model of the impact of those services on the urban economy. Box 9 describes a sample of key resources that cities have at their disposal to model the economic benefits of urban natural assets.

The economic values depend on the beneficiary population with access to the ecosystem services and their preferences and behaviors. For example, an ecosystem service provided by urban vegetation is air pollution removal, which has positive impacts on human health. The value of pollution removal depends on both the extent and condition of the vegetation and on initial pollution levels, which affect how much pollution can be removed. Critically, it also depends on the local population, and the avoided health care

costs and productivity benefits from cleaner air. Thus air pollution removal is more valuable in highly polluted and densely populated urban areas (Office for National Statistics 2018). A natural capital account for Greater Manchester, for example, found that the health benefits from ecosystem services are the highest in Central Manchester, where concentrations of people and air pollution are higher than elsewhere in the area (Urban Pioneer 2019). Economic values for other ecosystem services, such as parkland for recreation, are also higher where there are many actual users, since the physical and mental health benefits depend on people visiting these spaces.

STEP 5: Estimate the net benefits of natural assets and conduct policy appraisal. The costs of managing natural assets can be deducted from the monetary value of ecosystem services to understand net benefits. Many natural assets inside or around cities require monetary spending to maintain, enhance, or create the ecosystem services they provide. For instance, the upkeep of city parks requires budget to pay staff to perform maintenance. The net benefit of a city's natural capital is calculated by deducting the amount spent annually on natural assets from monetary benefits provided.

Benefits and costs are often compared over a long time horizon to fully understand how spending decisions compare to monetary benefits. Annual costs and benefits can change from year to year, and using a long time horizon allows decision makers to assess changes in investment policy along with projected changes in the value of natural assets. For example, if a city is planning an investment program aimed at improving its stock of natural assets, spending will change over time along with the value of ecosystem services provided as the condition of the asset changes. Modeling future costs and benefits requires amending future natural capital values to account for anticipated changes in ecosystem services, beneficiary populations, or monetary values. Finally, the future monetary values of services are discounted to account for time preference or the cost of borrowing.

Alternative policies or projects that affect the value of ecosystem services can be evaluated by comparing the costs and benefits of projects under a range of possible scenarios. Since investment may change the flow of services, projects can be appraised by evaluating how different decisions alter the size or distribution of benefits compared with costs. This approach has been applied in Stirling, Scotland, and is described in box 10.

Box 9: Resources for Estimating the Economic Values of Ecosystem Services

There are multiple tools and policy documents that can provide guidance on the appropriate modeling techniques and data needs to estimate the economic values of ecosystem services. Several examples are listed below:

- **Health Economic Assessment Tool (HEAT):** The HEAT tool is designed to enable users without expertise in impact assessment to conduct economic assessments of the health impacts of walking or cycling. The tool is based on the best available evidence and transparent assumptions about physical activity in urban environments. It is intended to be simple to use and appropriate for a wide variety of professionals at both national and local levels.
- **Greenkeeper**: Greenkeeper is an online tool developed to support investors and managers of urban green infrastructure in the United Kingdom. Greenkeeper uses big data from a range of sources to understand how people use and value urban green infrastructure. The tool allows users to model the environmental and economic benefits of green spaces, as well as assess the impact of investments in green infrastructure. Greenkeeper is expected to launch in September 2019.
- **GLOBIO:** GLOBIO is a modeling framework for calculating the impact of environmental drivers on biodiversity in the past, present, and future. GLOBIO is based on cause-effect relationships, derived from the literature. To use GLOBIO no detailed species data are needed. Instead, the model uses spatial information on environmental drivers—mainly derived from the Integrated Model to Assess the Global Environment (IMAGE)—as input.
- **InVEST:** InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) is a suite of free, open source software models used to map and value the goods and services from nature. InVEST enables decision makers to assess trade-offs associated with alternative management choices and to identify areas where investment in natural capital can enhance human development and conservation. The tool set includes 18 ecosystem service models designed for terrestrial, freshwater, urban, marine, and coastal ecosystems, as well as a number of "helper tools" to assist with understanding and visualizing outputs. New urban modules (e.g., urban cooling, stormwater management, urban recreation) are currently being developed to complement the software suite.

Sources: WHO 2017 (for HEAT); PBL Netherlands Environmental Assessment Agency 2002 (for GLOBIO); Vivid Economics, Barton Wilmore, and University of Exeter 2019 (for Greenkeeper); Natural Capital Project 2019 (for InVEST).

Box 10: Case Study: Stirling's Natural Capital Development Plan

Stirling, a small city in Scotland of around 40,000 people, commissioned a report to examine the impact of new green investments on natural capital and the benefits it provides.

Current natural capital assets across the city were mapped to establish a baseline. Different ecosystem services—including recreation, physical health, air quality regulation, and tourism—were then modeled and mapped to describe the flow of services and their distribution across the city. The monetary value of these services was also estimated and mapped.

A key purpose of the report was to estimate how natural capital values would change under a set of proposed investment scenarios. The annual benefits were assessed in combination with capital investment and annual operating costs, in accordance with implementation schedules set out in the proposed investment plan. The economic performance of the investments was assessed over a 50-year period to estimate the lifetime value of the projects.

Two projects were assessed as part of the appraisal. The net value of services provided by an investment in a city park area was estimated to increase from £73 million to £161 million, equal to 220 percent. A river project was also estimated to increase natural capital value from £74 million to £204 million, a 275 percent increase.

Source: Natural Capital Solutions 2018.

3.5 Biodiversity in Natural Capital Accounting

Biodiversity is often not included in natural capital accounts, which can lead to its benefits being overlooked. This section provides practical ideas for supplementing natural capital accounting and biodiversity policies to make them more targeted and effective. Biodiversity provides three categories of values to cities that are often hidden or missing in natural capital accounting (Cambridge Conservation Initiative 2016):

1. Support for the productivity of ecosystems and the supply of ecosystem services
2. Support for the functioning and resilience of ecosystems, and therefore the sustainability of ecosystem services
3. Intrinsic value to individuals

Few urban natural capital accounts assess the value of biodiversity because current biodiversity metrics do not proxy for the specific economic benefits of urban biodiversity. Table 5 shows how most biodiversity metrics focus on measuring observable features of habitats, such as the abundance of particular species or the diversity of vegetation cover. Newer biodiversity metrics use the structure of the landscape as a proxy for how much life it has the capacity to support, based on its features and connectivity (Calabrese and Fagan 2004). Other biodiversity metrics measure the amount of investment in conservation or policy integration of biodiversity considerations as another proxy for biodiversity (Chan et al. 2014).

Table 5: Overview of Biodiversity Metrics

Metric	Definition/examples
Total species richness	A mathematical index of species diversity in a given community, such as a Shannon or Simpson Index.
Key species diversity proxies	A mathematical index of species diversity based on an observable species that is a target or proxy for ecosystem health. For example, avian ecological diversity is often used as a proxy for total landscape biodiversity because landscape attributes, spatial connectivity, and vegetation diversity are all correlated with bird biodiversity.
Vegetation richness	A mathematical index of habitat or vegetation diversity in a given landscape, such as a Shannon or Simpson Index.
Landscape connectivity	A measure of the size and distribution of patches of habitat, and the ease through which a typical species can move through a landscape. Connectivity reflects a habitat's capacity to support life.
Financial/policy metrics	Investment in conservation, number of policies, population awareness of the importance of biodiversity.
Compound metrics	Indexes that weight multiple biodiversity metrics such as the Singapore Cities Index or the Aichi Biodiversity Targets.

Sources: Morris et al. 2014 (for total species richness and vegetation richness); Savard, Clergeau, and Mennechez 2000 (for key species diversity proxies); Calabrese and Fagan 2004 (for landscape connectivity); Chan et al. 2014 (for compound metrics).

Biodiversity can be considered a feature of natural assets or a natural asset itself in natural capital accounting. Biodiversity can be considered a quality of natural assets because it directly supports the ecological function of ecosystems, and therefore increases the value of natural assets through the supply of ecosystem services. Biodiversity can alternatively be considered an asset itself when cities have an objective for a specific species or varieties of species outside of their contribution to ecosystem services**.** Cities may have ambitions to protect particular species or biodiverse regions by conserving natural habitats for a variety of reasons. These could include legal requirements, obligations to international conventions like the Aichi Biodiversity Targets, or biodiversity's intrinsic value. Therefore, cities have two options for including biodiversity in natural capital accounts:

- **Option 1: Biodiversity as a supporting function can be implicitly integrated into natural capital accounting as a condition of natural assets**. For example, biodiversity is a quality of urban green spaces that affects the frequency of visits and the enjoyment of visitors. Biodiversity is also a quality of watersheds and soils that affects their ability to provide essential regulating services (Cambridge Conservation Initiative 2016).
- **Option 2: Biodiversity can be explicitly included in natural capital accounts as an urban natural asset.** The extent of the biodiversity asset can be evaluated based on the size of population or target species or the area of protected habitat. The condition of the biodiversity asset can be assessed based on the health of the population and risk of extinction. For example, the IUCN (International Union for Conservation of Nature) Red List of Threatened Species assesses the global status of nearly 100,000 animal, plant, and fungus species (IUCN 2019). The stock of the target population can then be included as a physical asset in the natural capital account and assessed based on changes to the population over time.

The selection of one of these options depends partly on the objectives of the account and partly on the availability of evidence and data on the role of biodiversity underpinning the functioning of natural assets. On the one hand, cities may wish to use a natural capital account as a tool to quantify and monitor the stock of biodiversity, by including indicators that measure key components of biodiversity over time. In this case, including biodiversity using option 2 is most appropriate. On the other hand, option 1 is more appropriate if the objective of the accounting exercise is to quantify the role of biodiversity in delivering services. In this case, evidence of the link between local biodiversity and functioning of ecosystem services is required.

Section 4. Current Practices in Maintaining and Enhancing Urban Natural Assets and Biodiversity

Natural capital accounting and urban biodiversity policy making are limited and have primarily been tested in developed cities. Findings from urban natural capital accounts indicate that in many cities, data needed to evaluate the role of natural assets are available, but that there has been limited attempts to account for natural assets and biodiversity in a systematic way. Cities with limited institutional capacity and resources may find the detailed data requirements of natural capital accounting an obstacle in assessing the benefits of urban natural assets.

4.1 Lessons Learned from Urban Natural Capital Accounting

Natural capital accounting has provided an increased evidence base for benefits of natural assets. Urban natural capital accounts in the United Kingdom and in Philadelphia in the United States have demonstrated that urban green spaces provide significant value to both urban residents and urban economies. The Philadelphia natural capital account also highlights that the tax revenues from housing prices and tourism, along with cost savings from regulating services that accrue to local governments, are nearly US$40 million per year. In addition, the accounts also shed light on the distributional consequences of natural assets in cities, and on the possible unequal distribution of benefits. Box 11 gives an example of how benefits are distributed in the context of natural assets' impact on real estate prices.

A common finding among natural capital studies is that green infrastructure provides significant value to residents, particularly via impacts on physical health; see for example studies of London (Vivid Economics 2017), Northern Ireland (Coldwell, Rouquette, and Holt 2018), Greater Manchester (Urban Pioneer 2019), and Philadelphia (Philadelphia Parks Alliance 2008). Particularly in London and Manchester, where the benefits of green infrastructure on mental health are measured (in addition to the benefits on physical health), the natural capital accounts find that green spaces support large health care cost savings for both residents and local governments. Manchester estimates that access to green spaces leads to more than £260 million in reduced health care costs per year from improvements in mental well-being alone.

Despite these findings, there is limited policy integration of urban natural capital accounts. The four urban natural capital accounts outlined in table 6 all provide recommendations for incorporating the findings of natural capital accounting into urban policies; but they also indicate that there is no consistent framework across cities for incorporating these findings into mainstream policy decisions. For instance, there is consensus that natural capital accounting shows promise for informing investment decisions as practiced on a country scale by several WAVES-affiliated countries, but little evidence of its application in urban settings. There is also agreement among the findings that natural capital accounting can be used to inform decisions on where to deploy natural assets to maximize benefits to local populations as well as to identify deprived or underserved areas. However, clear examples of policy that have stemmed from the production of accounts in urban settings are lacking.

Table 6: Findings from Urban Natural Capital Accounts in the United Kingdom and the United States

City/region	Annual value of services	Highest-value service	Key findings from study
London	£5 billion	Physical health	• Park benefits mainly accrue to households but are costly for local authorities. • Natural capital accounting can inform public health investment in green infrastructure. • Natural capital accounting can inform investment in green infrastructure in deprived areas.
Northern Ireland (two nature reserves)	£840,000 and £2.8 million	Recreation and physical health	• Green infrastructure offers high value for money; net benefits of parks were 50–80 times higher than net costs of maintenance. • Location and type of green infrastructure should be deployed related to demand and deprivation, • Natural capital accounting business cases for investment should be developed. • New policy frameworks for the wider use of natural capital accounting should be developed.
Greater Manchester	£866 million	Recreation	• A natural capital investment plan should be developed. • Consideration should be given to how natural capital accounting can be integrated into plans/strategies. • Natural capital accounting can be used to maximize the value of the environment. • Natural capital evidence can be used to bid for funding.
Philadelphia	US$1.9 billion (£1.5 billion)	Recreation	• Natural capital accounting provides a piece of missing information about how cities work and how parks contribute. • Natural capital accounting may allow park advocates and housing advocates to work toward mutual objectives.

Sources: Vivid Economics 2017 (for London); Coldwell, Rouquette, and Holt 2018 (for Northern Ireland); Urban Pioneer 2019 (for Greater Manchester); Philadelphia Parks Alliance 2008 (for Philadelphia).

Previous urban natural capital accounts highlight the limits cities face in undertaking assessments. Urban natural capital assessments have mainly been conducted by cities in Europe and North America, which face fewer capacity constraints than those in developing countries, and which have more resources and more data readily available. Natural capital accounting relies on a number of spatial data sources and population characteristics, which can constrain a city's ability to produce a set of accounts. Additionally, an important part of accounting is maintaining and monitoring assets over time. This step requires repeated data collection, which may also limit a resource-constrained city. Lastly, the studies in the United States and the United Kingdom show that the integration of biodiversity in natural capital accounting is in its infancy. The London and Manchester accounts note that urban biodiversity is valuable, but they do not assess it because of data limitations.

Box 11: Effect of Natural Assets' Location on Property Prices and on Distribution of Ecosystem Services

The availability of land is often the most pressing constraint in urban areas. Competition for space means that the cost of urban living can be high. Demand for urban amenities such as access to green and blue assets further increases the cost of housing in certain parts of the city. Studies in multiple cities show that property prices tend to be higher in close proximity to these assets. Higher prices are driven by location preferences of households who are willing or able to pay for access to the benefits of natural assets. For instance, recent work from the United Kingdom shows that the presence of a small green space within 200 m of a property increases its value by 0.5 percent. Large green and blue spaces increase value by 1.4 percent and 3.6 percent respectively. A number of studies in rapidly growing Chinese cities, such as Jinan and Guangzhou, have also found that property prices increase with proximity to or views of urban green spaces.

These findings have important implications for the management of urban green space and the distributional consequences of land use in cities. While the increase in property prices near green spaces can help make the business case for investing in natural assets, higher costs of living may reduce access to these spaces for residents lower down the income distribution. These issues are summarized below:

- **Incentives and revenue from providing natural assets:** Real estate developers and city authorities are aware that creating natural assets can increase the value of newly built properties and the value of existing housing. This knowledge may lead to the creation of new natural assets located near those willing to pay for them by living in new real estate developments. The ability of developers to command higher rents from land can be a significant source of revenue for local authorities, especially where authorities auction off land and development rights for urban expansion to the highest bidder.
- **Access to natural assets and distribution of benefits:** The ability of higher-income households to pay higher prices for access to urban public goods can cause property prices to rise in areas with natural assets. Employers may also prefer to locate in areas with high-quality natural assets to create desirable workspaces and attract skilled workers, further increasing demand for property in these areas and increasing prices. This pressure on prices could result in unequal access to green and blue spaces across the income distribution. The potential consequences are that lower-income residents obtain fewer benefits (e.g., health benefits) from green infrastructure, further promoting economic inequalities.

Sources: Brander and Koetse 2011; Kong, Yin, and Nakagoshi 2007; Jim and Chen 2006; Kahn and Walsh 2015.

4.2 Review of City Biodiversity Action Plans

We conducted a rapid evidence review of seven city-level biodiversity action plans and strategies, drawn from North America, Europe, Africa, and Asia (Nilon et al. 2017; Urban Biodiversity Hub 2019). The city government plans were evaluated against the following criteria:

- **Baseline data:** Does the plan collect and use baseline data?
- **Biodiversity goals:** Does the plan have general (or specific) biodiversity goals (e.g., protect a certain species or group of species)?
- **Biodiversity targets:** Does the plan have quantitative targets to support biodiversity goals?
- **Biodiversity benefits as policy basis:** Does the plan link actions or policies to defined benefits of biodiversity in urban areas?
- **Biodiversity-ecosystem services integration:** Does the plan integrate biodiversity and ecosystem services in policies or actions?
- **Commitment to implementation:** Does the plan describe funding arrangements?
- **Regulatory elements:** Does the plan include elements that are mandated?
- **Monitoring elements:** Does the plan have actions or policies on monitoring progress?

Table 7 summarizes the findings of the rapid evidence review of the city-level biodiversity action plans. Box 12 briefly reviews the Singapore Index on Cities' Biodiversity.

Most urban biodiversity plans tend to be limited to high-level goals, with only a few that include measurable targets to track progress. Among the city plans reviewed, almost all utilized baseline data on species and habitats to put forward their biodiversity vision and strategic goals. However, very few plans set explicit quantitative targets. For example, biodiversity plans for Johannesburg, Chicago, Cape Town, and Hong Kong SAR, China, set detailed visions and strategic goals to protect and enhance biodiversity and its associated habitats, but they did not include any measurable targets (City of Johannesburg 2009; Chicago Department of Planning and Development 2006; City of Cape Town 2009; Hong Kong Environment Bureau 2016). On the other hand, Vancouver's main objective in its action plan included a quantitative target: to restore or enhance 25 ha of natural areas by 2020 (Vancouver Board of Parks and Recreation 2016). Similarly, London's plan includes targets on achieving 30 percent shrub cover at all Sites of Importance for Nature Conservation (SINC) and achieving a 10 percent annual increase in wildlife records (City of London Corporation 2016).

Biodiversity plans tend to review and target specific components of biodiversity but do not link biodiversity goals to ecosystem benefits. Among the cities reviewed, the City of Johannesburg was the only city to recognize the importance of biodiversity in providing ecosystem services, as captured in its overall vision: "to conserve and manage biodiversity . . . to ensure delivery of sustainable and equitable ecological goods and services to the citizens of Johannesburg, now and in the future" (City of Johannesburg 2009). Hong Kong SAR, China, briefly acknowledged the value of biodiversity in supporting ecosystem services. However, none of the plans, including Johannesburg's and Hong Kong's, formed their biodiversity goals on the basis of their links to ecosystem benefits.

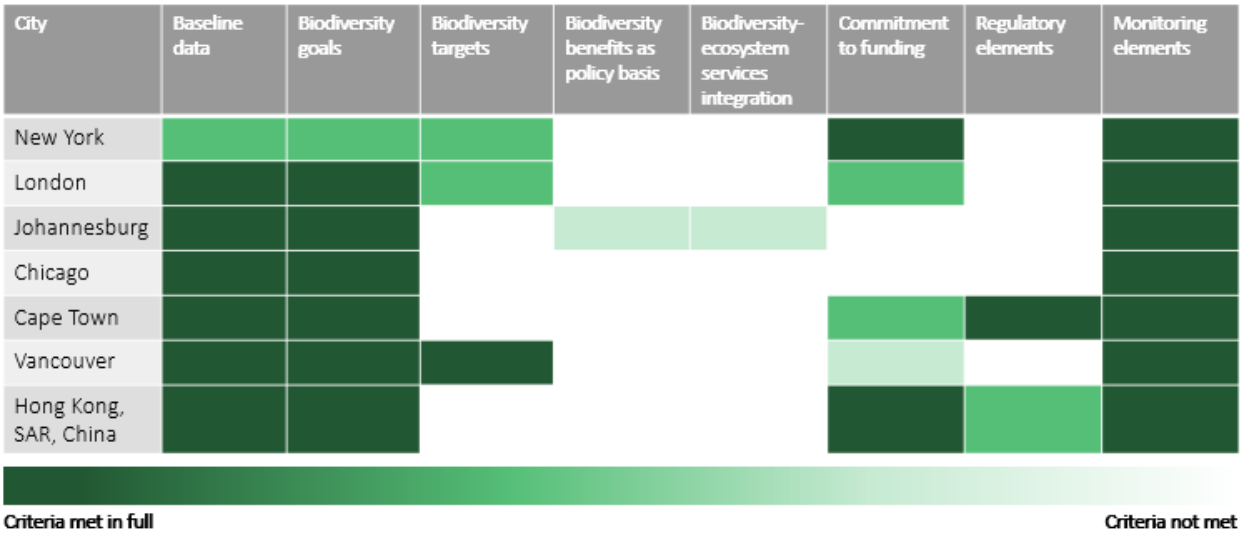
Very few cities consider legislative or regulatory elements in their actions plans to conserve biodiversity. Cape Town and Hong Kong SAR, China, were the only two cities to consider these elements. Cape Town's strategic plan included regulatory actions—for example, actions to develop and implement biodiversity

offset policy, green tax (households' policy), or developers contribution policy. The plan also included legislative actions—for example, actions to develop a policy to give effect to biodiversity bylaw. Hong Kong's strategic plan recognized the various legislative elements for biodiversity and habitat protection already in place.

Most biodiversity plans vaguely include commitment to implementation in terms of funding support. Among the city plans reviewed, funding options are often identified as action plans. Hong Kong SAR, China, is the only city that shows a clear commitment to funding: the government has put aside an additional resource of US$150 million to support the initiatives proposed in its Biodiversity Action Plan for three initial years.

Currently, urban natural capital accounting and city biodiversity action plans lack sufficient integration into the policy process. In the next section, we discuss how the findings from natural capital accounts and biodiversity assessments could be integrated into the urban planning and decision process to inform and improve policy decisions on green urban development. Appendix B also provides a list of biodiversity indicators that are relevant to cities.

Table 7: Summary Findings from Rapid Evidence Review of City-Level Biodiversity Action Plans



Sources: Based on City of New York 2007; City of London Corporation 2016; City of Johannesburg 2009; Chicago Department of Planning and Development 2006; City of Cape Town 2009; Vancouver Board of Parks and Recreation 2016; Hong Kong Environment Bureau 2016.

Box 12: Case Study: Singapore Index on Cities' Biodiversity—An Assessment Tool for Measuring Urban Biodiversity and Conservation Efforts

The Singapore Index weights a variety of species, habitat, ecosystem, and governance indicators of biodiversity conservation. The main components are abundance of particular species, quantities of selected ecosystem services, and governance initiatives to protect and manage biodiversity. Based on 23 indicators, a city can score a maximum of 92 points on the Singapore Index. The index is not intended for comparison across cities, but rather for internal use to guide policy priorities.

In a study of 14 cities that implemented the Singapore Index, it was found that the process has significant limitations; still, the index can be a useful tool for bringing together stakeholders across multiple disciplines. The study found that there are four key gaps in the Singapore Index that limit implementation and policy integration:

1. The indicators require a significant amount of data.
2. It is challenging to analyze the results of the index, since city contexts vary substantially.
3. The ecosystems and ecosystem services captured within the tool are limited.
4. The social-ecological integration components need further development.

The weighted index captures several important components of urban biodiversity and provides measurable targets for progress. However, the indicators are skewed toward those that are most easily measured and not necessarily those providing the greatest economic value.

Sources: Kohsaka et al. 2013; Chan et al. 2014.

Section 5. Policy Guidance for Green Urban Development

5.1 Integration of Natural Capital Accounting and Urban Biodiversity into the Urban Planning and Decision Process

The aim of this section is to inform the integration of natural capital and biodiversity accounting techniques into the policy process cities use to pursue green urban development. This integration is one of the many actions cities should undertake in their pursuit of green urban development. To get an overview of all the steps in the process, please refer to appendix A, which details a high-level action plan for cities pursuing green urban development.

Although many cities with constructed natural capital accounts are learning from the accounts, the use of accounts to inform policy decisions is still in its infancy. Further development requires the following:

- The integration of accounts to effectively support policy decisions
- The integration of data collection with data analysis for policy relevance
- Repeated data collection and production of accounts

Both the physical and the monetary accounts provide useful information on the status, value, and risk profiles of urban natural assets and biodiversity. Physical accounts inform the current status and the change from the historical status of urban natural assets and biodiversity (status profile); monetary accounts inform assets' and biodiversity's links to the city economy and other sectors (value profile); and scenario modeling helps cities understand changes to accounts and the economy based on future trends in urbanization, demographics, and environmental course (risk profile).

When deciding on the appropriate policy response concerning urban natural assets and biodiversity, city decision makers could find the natural capital accounting framework useful for the following purposes:

- Identifying policy priorities and issues
- Designing policy responses and implementation
- Assisting monitoring, evaluation, and adaptation

Table 8 details how natural capital accounting could be used within the policy process. The extent of natural capital accounting and scenario modeling that a city can undertake is constrained by its financial, institutional, and skills capacity; thus the options shown in table 8 for integrating natural capital accounting into the policy process should be adopted to fit specific purposes and budgets. Cities should identify and undertake the short-term actions they are able to carry out with their existing capacity, and should also identify and plan for the long-term actions that would require further investment.

Box 13 includes a case study of how the Australian city of Canberra has used natural capital accounts for policy decision making.

Table 8: Natural Capital Accounting Use for Policy Process

Policy decision	Natural capital accounting use	Policy questions answered using natural capital accounting	Natural capital accounting analysis
Policy priorities and issues	Through present accounts data and forward-looking scenarios, natural capital accounting helps identify policy priorities and potential issues.	What is the status of urban natural assets and biodiversity in the city?	Interpretation of physical accounts data from the past and present
		What is the contribution of urban natural assets and biodiversity to the city economy?	Valuation of services provided by assets, alongside analysis of who benefits from them
		Are future trends in development causing degradation in assets and reduction in their contribution to the economy? Could that limit future prosperity?	Assessment of changes in physical and monetary accounts from different scenarios of urban development
Policy responses and implementation	Natural capital accounting supports the design and assessment of different policy options by ensuring a well-informed business case as well as helping select cost-effective options.	What are the economic, social, and environmental costs and benefits of the policy options? Who bears the costs, and who benefits?	Ex ante assessment of policy's costs and impacts on the urban natural assets and the economy, alongside analysis of stakeholders
		What are the trade-offs of different policy options?	Detailed assessment of the pros and cons of each policy option
		Which policy option attains maximum gains with minimum costs?	Cost-benefit assessment of policy options
Policy monitoring, evaluation, and adaptation	Systematic and routine use of natural capital accounting could support regular monitoring of policy goals, evaluation of policy effectiveness and efficiency, and adaptation to form better-suited policy instruments.	Are the policies making progress toward the set goals and target outcomes?	Assessment of policy progress over time against indicators derived from the accounts
		How can existing policy be made more effective and efficient in achieving the target outcomes?	Evaluation of the drivers of progress to adjust policy measures
		What are the post–policy implementation impacts? Are there any unintended consequences?	Ex post assessment of policy outcomes

Source: Elaborated from WAVES 2017.

Box 13: Case Study: Canberra's Use of Natural Capital Accounts for Policy Decision Making

Approximately 56 percent of the Canberra region (Australian Capital Territory, ACT) is land area protected under Australia's National Reserve System. However, greenfield developments, population growth, and other development pressures have resulted in ongoing sustainability issues.

The Office of the Commissioner for Sustainability and the Environment (OCSE), located in the Canberra region, has begun an initiative to apply the natural capital accounting framework in policy decision making. The OCSE has collaborated with the Australian National University for this initiative. Specifically, the initiative is developing and applying natural capital accounting to inform policy recommendations of a forthcoming statutory State of the Environment (SoE) report (2019). The accounts will also be used to regularly monitor and evaluate the adequacy and effectiveness of environmental management policies.

The project process has included establishing a steering committee, developing a draft project plan, holding workshops to review plans, and establishing a working group. The OSCE also intends to develop a manual to assist the ongoing production of accounts and their application to SoE reporting.

The project is continuing to integrate natural capital accounts into the policy process in the following ways:

- Establishing links between the accounts and the ACT's key policy documents, which guide decisions in sectors such as water, transport, air quality, climate change, land, and biodiversity
- Identifying areas that can be decoupled,[a] areas where difficult trade-off decisions need to be made (for example in choosing greenfield sites over urban in-fill opportunities), and addressing questions of hot spots
- Mapping SoE indicators against relevant accounts
- Furthering active engagement with data providers in government to generate accounts for policy relevance

The OSCE also recognizes the importance of a communications strategy to promote better understanding of the policy use of accounts. It is therefore developing a strategy to share with stakeholders the rigorous analysis carried out for the project, along with insights into the benefits of using accounts for the decision-making process (and the disadvantages of not using them).

a. Decoupling occurs when the economy is able to grow without corresponding growth of pressure on the environment.

Source: WAVES 2017.

5.2 Key Policy Tools to Pursue Green Urban Development

Cities can use a variety of policy tools to protect and enhance urban natural assets and their benefits. Available policy options can broadly be classified into laws or regulation, economic measures, ownership, and information. Table 9 summarizes the various policy tools under each of these categories, along with policy examples. Box 14 includes a case study of Singapore's use of economic measures to promote green urban development.

Deploying a mix of policy instruments enables cities not only to target conservation efforts where required, but also to integrate environmental considerations into long-term urban planning. A targeted approach focuses on the direct protection, conservation, and enhancement of critical urban natural assets and biodiversity—for example, through direct conservation measures, assignment of property rights, or public investment in green spaces. An integrated approach, on the other hand, incorporates environmental considerations into development and urban planning policies to ensure critical assets and biodiversity are not lost. Examples of these policies include green infrastructure standards for new developments, mandated cost-benefit analysis for land conversion, or biodiversity offsetting requirements for land use.

Table 9: Key Policy Tools to Pursue Green Urban Development

Policy type	Policy tools	Policy description	Policy examples
Laws/regulation	Regulatory standards	Sets requirements on natural assets or biodiversity levels, or activities that impact these	• Green infrastructure standards • Natural asset level standards • Biodiversity level standards • Cost-benefit analysis for land conversion
	Property rights	Assigns rights to natural assets, biodiversity, or ecosystem services	• Assignment of land or forest property rights • Distribution of water use rights
	Conservation	Protects threatened urban natural assets such as land, water, forest space, or biodiversity from human activity	• Protected green spaces, biodiversity hot spots, water bodies • Establishment of development buffer zones • Purchase of land prior to development
Financial options	Market-based instruments	Uses markets or prices to provide incentives for sustainable ecosystem uses	• Payments for ecosystem services • Subsidies for species protection • Biodiversity offsetting requirement for land use
	Public investment	Uses government expenditure to develop and enhance urban	• Planting of trees

Policy type	Policy tools	Policy description	Policy examples
Financial options (continued)		natural asssets and biodiversity	• Construction of green corridors • Construction of public parks • Maintaining of habitats
Ownership	Ownership or stewardship	Assigns ownership of or responsibility for natural assets and green infrastructure to public authorities or trusts	• Ownership and operation of urban parks by city governments • Assignment of stewardship rights to local stakeholders
Information	Awareness campaigns	Raises awareness of benefits derived from urban natural assets along with critical assets and species; guides their sustainable use	• Information campaigns • Accessible public resources
	Coordination	Fosters coordination in efforts between different government departments and government and the private sector	• Public-private partnership • Cooperation with city stakeholders
	Monitoring	Monitors land use and species to ensure natural assets and critical populations are sustained	• Monitoring of land use changes • Monitoring of development activities' impact on assets • Tracking of specific species' population

Box 14: Case Study: Singapore's Approach to Green Urban Development

In 1965, Singapore was a city filled with slums and choked with congestion; its rivers had become open sewers, and its residents were struggling to find decent jobs. It had limited land and no natural resources.

Given its land constraints, Singapore adopted a high-density development approach coupled with a strong focus on building a sustainable and livable city. For years, the city government focused its efforts on cleaning up polluted areas, supported by the creation of agencies such as the National Parks Board.

The city launched two measures to encourage green infrastructure in new and existing buildings:

- In 2005, the Building and Construction Authority (BCA) of Singapore launched a BCA Green Mark Scheme to drive Singapore's construction industry toward environment-friendly buildings. The BCA Green Mark provides a meaningful differentiation of buildings and has positive effects on corporate image, leasing, and resale values.
- In 2009, Singapore's National Parks Authority launched a Skyrise Greenery Incentive Scheme to encourage installation of greenery in existing very tall ("skyrise") buildings, with the authority funding up to 50 percent of installation costs. Through this initiative, Singapore replaces greenery lost on the ground to development with greenery in the sky.

In addition, the city's Gardens by the Bay park consists of self-sustaining Supertree Groves that also support local biodiversity. The Beach Road project is a city block structure spanning two skyscrapers that provides shelter from heat and rain.

Singapore's pragmatic policy making, long-term planning, effective implementation, and strong determination to become a sustainable city have earned it the status of Asia's most livable city.

Source: UN Environment 2018.

Appendix A. High-Level Action Plan

This appendix presents a high-level action plan to help cities formulate their "green vision" and use natural capital accounting methodologies as the basis for decision making around their natural assets. The plan is split into four sections. First, cities establish the broad set of objectives they wish to pursue in relation to green urban development. Second, cities determine and execute the steps they should follow to gather the data and expertise and carry out a natural capital accounting exercise. Third, they identify and apply ways in which natural capital accounting feeds into the design and assessment of different policy options. Finally, they establish a set of ongoing monitoring and assessment steps to begin the systematic process of integrating natural capital into future decision making.

The action plan is designed as a practical how-to guide for cities in the early stages of considering their green vision. Thus it does not focus on identifying appropriate methodologies for quantifying services or recommending policies to achieve the vision.

This exercise provides cities with a number of benefits:

- It allows them to set out and narrow down the set of objectives that matter most, which aids communication about and discussion of green urban development objectives.
- It helps them identify and prioritize the natural assets and ecosystem services that are most vital.
- It begins the process of building broad internal and external stakeholder support for the development of new natural assets and maintenance of existing natural assets.
- It helps identify data gaps and needs crucial for monitoring the stock of natural assets and services they provide.
- It establishes the relevant set of stakeholders who have a role in managing natural assets.
- It links development objectives to a set of identifiable assets to produce a more credible and actionable plan.

A1 Defining objectives of green urban development

STEP 1: Define broad objectives of green urban development

The city should determine the high-level objectives it aims to pursue. These objectives may already have been articulated, in which case they can be repeated and set out again. Although high-level vision statements can be used to signal the direction of development, a more refined set of objectives sets out green developments thematically, is associated with measurable goals, and has an identified timeline.

The initial broad objectives identified in the high-level vision could include the following:

- Increase resilience of the city to climatic hazards, such as flooding.
- Maintain and enhance public green spaces to provide residents with clean and safe areas for recreation.

Consultation with other city stakeholders can be used to further refine these visions into clearly defined goals, while building both consensus and awareness. Examples of these more refined goals may include the following:

- By 2020, design all newly created infrastructure to be resilient to flood hazards by utilizing green and blue infrastructure that effectively drains excess surface water.
- Increase the number of daily users of parks by 50,000 by investing in a network of connected and well-maintained parks that people can utilize for active travel and recreation.

A2 Developing urban natural capital and biodiversity accounts

Understanding how the city's stock of natural assets can be used to support its stated development objectives is the next step in the action plan.

STEP 2: Assess the type, extent, and condition of natural assets

Type: Cities should first list the categories of natural assets that are located in the city or outside of the city. Here a decision needs to be made about the geographical scope of assets that are assessed. Examples of natural assets relevant to cities include the following:

- **Small built features**: Green roof/wall, green corridors, street trees, small green space, water features
- **Medium-size spaces**: City farms, public squares and commons, sport pitches, public/domestic gardens
- **Urban parks**: Local parks, regional or national parks
- **Natural areas**: Wetlands, rivers, and woodlands.

Extent: Following the classification of types of natural assets, the extent of each asset must be assessed through measurement. The availability of spatial data is critical for accurate measurement in this step. Several types of spatial data are available:

- Land use maps produced by city planning departments
- Land use maps derived from large-scale satellite imaging projects
- Stakeholder and participatory efforts that utilize local knowledge to classify where natural assets are located

The total quantity of each asset can be quantified in physical units, such as area of habitat or number of sites/features.

Condition: Assessing the baseline physical condition of each asset is the next step. This can be conducted through a number of methods, as shown in the table:

Natural asset feature	Condition indicator	Method
Tree cover in green space	Canopy cover or tree count data	Satellite-derived GIS data Observational surveys
Built features in green spaces	Water features, play spaces, sports pitches	Satellite-derived GIS data Observational surveys
Water quality	Nutrient content	Measured water quality at sample sites Expert judgement of quality
Species counts	Number of different bird species	Observational surveys

STEP 3: Identify the services provided in physical units

Cities begin this step by developing a register of ecosystem services provided by each asset.

Using the set of natural assets identified previously, the set of city natural assets should then be linked narratively to the services each provides. An example of this approach is shown below:

		Recreation	Physical activity	Aesthetic, place-making	Air quality	Food
Small built features	Green roof/wall			●		
	Street trees			●	●	
	Small green space	●		●	●	
	Water features	●		●		
Medium-size spaces	City farms	●				●
	Public squares, commons	●	●	●		
Parks	Local parks	●	●	●	●	
	Regional/national parks	●	●	●	●	
Natural features	Wetlands, rivers	●				
	Woodland				●	

As part of this step, cities also need to assess current data sources to quantify the flow of ecosystem services provided. For each ecosystem service, the general modeling approach should be set out alongside the data required to conduct an assessment. The example below is for modeling the ecosystem services and data requirements for a city's green space:

Asset	Ecosystem Service	Type of service	Data needs
Green space	Physical activity and health	Cultural	Amount of green space Survey/observed data on park visit frequency and activities
	Mental well-being	Cultural	Census data on population characteristics and health outcomes Disease costs
	Amenity value	Cultural	Amount of green space Hedonic pricing model relevant to city context Property values
	Air quality	Regulating	Amount of green space Vegetation types Air quality data Health costs of air pollution
	Carbon sequestration	Regulating	Amount of green space Vegetation types Tree cover Carbon price

Finally, gaps in the data needed to carry out a full ecosystem service flow assessment for a natural asset should be detailed. This is done by indicating how the gap might be filled and the associated cost and time spent. This allows cities and stakeholders to discuss the most appropriate way to move forward toward an ecosystem service assessment.

STEP 4: Value of ecosystem services

For each ecosystem service, the city should determine the appropriate model to estimate economic values. Although the city will not be carrying out economic valuation at this stage, it is crucial to scope out the data and expertise needed to conduct a full valuation. In particular, the city should do the following:

- Identify priority ecosystem services to convert into monetary terms
- Identify cities that have conducted similar studies and set out data requirements
- Assess feasibility of collecting economic data to populate models

A3 Integrating urban natural capital and biodiversity accounts into the policy process

The development and production of a natural capital account can feed into the design and assessment of different policy options. Where natural capital accounting supports appropriate policies, a city can begin to build a well-informed business case and select cost-effective options for green urban development.

STEP 5. Identify policy priorities and issues

The accounts could immediately feed into answering the following policy questions in relation to natural assets:

- What is the status of urban natural assets and biodiversity in the city?
- What is the contribution of urban natural assets and biodiversity to the city economy?
- Are future trends in development causing degradation in assets and reduction in their contribution to the economy? Could that limit future prosperity?

Answers to these questions will help cities identify policy priorities, set goals and define target outcomes, and map target outcomes to urban natural assets, green infrastructure, and biodiversity.

STEP 6. Recognize challenges to green urban development

A comprehensive assessment of a city's urban green development helps cities understand the value of their assets. But it also requires them to address the challenges in incorporating natural capital into decision making. These challenges could include the following:

- Limited resources (data, expertise)
- Limited institutional capacity (lack of experience in integrating environmental and urban policy)
- Inconsistent values and norms (reluctance of decision makers to adopt strategic and evidence-based approach)
- External pressures (climate change, population growth)

STEP 7. Identify and assess policy responses, evaluate cost-effectiveness of each, and implement chosen policy actions

Cities can identify and assess potential policy responses by using natural capital accounting to answer the following:

- What are the economic, social, and environmental costs and benefits of the policy options; who bears the costs and who benefits?
- What are the trade-offs of different policy options?

Cities can evaluate the cost-effectiveness of potential policy responses using natural capital accounting to determine which policy option attains maximum gains with minimum costs.

Cities can then implement chosen policy actions.

A4 Monitoring green urban development outcomes

Systematic and routine use of natural capital accounting could support regular monitoring of policy goals, evaluation of policy effectiveness and efficiency, and adaptation to form better-suited policy instruments.

STEP 8: Monitor, evaluate, and adapt green urban development strategies

By monitoring and evaluating goals and outcomes against indicators derived from the natural capital accounts, cities can answer the following:

- Are the policies making progress toward the set goals and target outcomes?
- How can existing policies be made more effective and efficient in achieving the target outcomes?

By adapting lessons from monitoring and evaluating for management and future green development planning, cities can better understand post–policy implementation impacts and identify any unintended consequences of the policy.

Appendix B. City Biodiversity Indicators

Indicator	Type of Indicator	Indicator Description and Rationale	Sample Indicator Measurement(s)
Awareness of, understanding of, and support for conservation	Response	This indicator assesses public awareness of and engagement with biodiversity as a critical issue by evaluating how concerned the public is with biodiversity loss and how much understanding there is of the value of biodiversity.	Percentage of people highly engaged with the issue of biodiversity loss
Value of biodiversity integrated into decision making	Response	This indicator assesses how well biodiversity considerations are integrated into economic, social and policy decision-making. This is a difficult concept to measure and no indicator measurement has been developed yet.	Indicator under development
Global biodiversity impacts of urban economic activity	Response	This indicator evaluates the impact of domestic activities, including both production and consumption decisions, on global biodiversity. This is a difficult concept to measure and no indicator has been developed yet.	Indicator under development
Area of land in environmental management schemes	Extent/response	Targeted agricultural and environmental management can preserve wildlife and maintain the environment and natural resources. This indicator assesses the extent of land under the purview of such schemes.	Total area of land (ha) under schemes
Area of forest land certified as sustainably managed	Extent/response	Woodland certification schemes can incentivize sustainable forestry and reduce deforestation pressures on biodiversity. This indicator assesses the proportion of woodland under the purview of such certification schemes.	Percentage of woodland certified
Pressure from air pollution	Pressure	Air pollution from human activities can put pressure on sensitive habitats. This indicator assesses the extent of habitats affected by key pollutants at thresholds above which harmful effects may occur.	Area affectivity by acidity, area affected by nitrogen
Pressure from water pollution	Pressure	Water pollution from human activities can put pressure on sensitive habitats. This indicator assesses the levels of five heavy metals and one organic compound which are particularly hazardous to the marine environment.	Levels of five heavy metals (cadmium, mercury, copper, lead, and zinc) and one organic compound (lindane)
Pressure from invasive species	Pressure	Non-native species which are inadvertently introduced to foreign populations may spread diseases, compete for resources or breed	The number of invasive non-native species

Indicator	Type of Indicator	Indicator Description and Rationale	Sample Indicator Measurement(s)
Pressure from invasive species (continued)		with native populations, threatening the viability of native species. This indicator assesses the extent of invasive species spread across land areas and coastlines.	established across 10 percent or more of the land area, or along 10 percent or more of the coastline
Status of surface water	State	This indicator assesses how well surface water is managed, as classified by the Water Framework Directive (WFD) of the European Union.	The percentage of surface water bodies in each status class and the change in the percentage of water bodies awarded a “good” or “high” surface water status class under the WFD (European Union only)
Extent of protected areas	Extent/response	Protected areas can support critical habitats and threatened species from human impacts. This indicator assesses the extent of land and water under the purview of such measures.	Area of protected areas (ha)
Condition of Areas/ Sites of Special Scientific Interest	State	Areas or Sites of Special Scientific Interest (A/SSSIs) contain habitats or species which are significant to the scientific community. This indicator assesses the condition of these habitats or species.	Percentage of features of A/SSSIs in favorable or unfavorable-recovering condition
Habitat connectivity	State	Connectivity is a measure of the distribution of the ease with which species can move between habitats, based on the extent and distribution of habitat patches. There are a number of connectivity indices under development and in use for biodiversity decision-making.	Indicator under development
Relative abundance of priority species	State	. This indicator assesses the abundance of priority species, reflecting the health of their populations.	Percentage of population size relative to baseline
Distribution of priority species	State	This indicator reflects how widespread priority species are.	Number of 1 km grid squares in which priority species are recorded in any given year

Indicator	Type of Indicator	Indicator Description and Rationale	Sample Indicator Measurement(s)
Bird abundance	State	Bird populations often reflect the state of wildlife in an area because of their responsiveness to environmental pressures. This indicator uses bird population abundance as a proxy for local biodiversity health.	Abundance of common native birds of farmland, woodland, freshwater, and marine (where relevant)
Butterfly abundance	State	This indicator uses butterfly abundance to reflect the availability of resources within a habitat.	Abundance of butterfly populations
Plant abundance	State	This indicator assesses the diversity and abundance of plant life within a particular habitat.	Abundance indicator for a range of widely occurring habitats
Bat abundance	State	Bats can play a key regulating role within ecosystems. This indicator assesses the abundance of bat populations within a habitat.	Changes in the population size of eight widespread bat species, based on summer field surveys and roost counts and winter hibernation counts
Removal of greenhouse gases by woodland	Benefit	Trees provide a number of regulating services which are key for human, animal and plant life. This indicator evaluates the magnitude of carbon sequestration from woodland.	Net removal of greenhouse gases from the atmosphere between two types of woodland, coniferous and broadleaf
Status of pollinating insects	State/benefit	Pollinators provide essential regulating and supporting services to ecosystems. This indicator describes the health of an ecosystem based on the abundance and distribution of key pollinating insects.	Number of 1 km grid squares in which pollinating insects (137 species of bee and 214 species of hoverfly) were recorded in any given year; referred to as the “occupancy index” (based on UK species, can be adapted)

Indicator	Type of Indicator	Indicator Description and Rationale	Sample Indicator Measurement(s)
Expenditure on biodiversity	Response	Public expenditure on biodiversity can reflect how much biodiversity is prioritized and how well it is integrated into decision-making. This indicator assesses the magnitude of expenditure on biodiversity conservation.	Public sector spending on biodiversity alongside spending by non-governmental organizations with a focus on biodiversity and/or nature conservation

Source: UK Defra 2018.

Appendix C. London's Natural Capital Accounts

The following appendix gives a more detailed overview of the methodological approach used to populate the natural capital account for London. The methodology is adapted to the step-by-step approach outlined in the main document.

STEP 1: Assess the extent and condition of natural assets in London

The natural capital account for London focused on the services provided by the city's publicly accessible green spaces. This meant working with London's green space mapping organization, which had mapped the extent and type of green spaces and had designated those that were publicly accessible.

As shown in table 10, parks are the largest areas of public green space in London. These include the Royal Parks and a multitude of smaller parks, gardens, and squares that can be freely accessed. Natural and seminatural urban parks represent the second largest category. These naturally diverse spaces include country parks, commons, woodlands, and nature reserves. Amenity spaces are areas of green space such as village greens and grassy areas used for a variety of informal and formal recreation. Smaller categories of green space in London are allotments and community gardens, as well as play areas primarily used by children.

Table 10: Types of Green Space in London

Type of green space	Area (ha)	Proportion
Parks and gardens	9,207	29%
Natural and seminatural urban green space	8,467	27%
Amenities	6,578	21%
Outdoor sports facilities	6,225	20%
Allotments, community gardens, and city farms	979	3%
Play areas	71	<1%
Total	31,527	100%

Sources: Vivid Economics and Greenspace Information for Greater London 2017.

STEP 2: Model the services provided in physical units

The next step in producing London's natural capital account was to model the services provided by green spaces. This step involved reviewing the relevant literature to identify the appropriate models that could be used to quantify how parks benefit city residents. For all services modeled in London, it was possible to use parameters and assumptions taken from studies of ecosystem services in the United Kingdom. This reduced the risks associated with benefits transfer, which can lead to models of ecosystem service benefits being mis-specified when used in estimations outside the context of the original study.

Table 11 shows the individual calculations underlying each benefit. For calculating the impact of green space on health outcomes, the methodology involves combining epidemiological evidence on the relationship between visits to green space and health outcomes. These assumptions are then combined with data on residential access to green space in London derived from spatial census data. A number of calculations are also supported by use of tools to value specific services. To populate the London account, the number of recreational visits to green spaces was estimated using the ORVal tool. In addition, work derived from the iTree tool allowed for the calculation of the amount of carbon stored in trees and soil. In most cases, each benefit can simply be communicated in physical units. For instance, the amount of carbon stored is reported in tonnes of CO_2 stored in London's green spaces.

Table 11. Calculation of Ecosystem Services' Physical Benefits for London Accounts

Benefit	Calculation	Source
Mental health	Density of green space in ward (%) * population of ward (persons) * improvement in mental health outcomes due to green space density (%)	White et. al. (2013)
Physical health	Area of green space catchment (ha)* contribution of green space to provision of physical activity in catchment (%) *population density (persons/ha)	Bird (2004) for dose response relationship Chief Medical Officers (2011)
Property valuation	Area of green space within 1 km of postcode (ha) * housing density (dwellings/ha)	Smith/GLA (2010)
Air temperature	Reduction in number of deaths	Saraev (2012)
Carbon	**Carbon in soil**: area of green spaces (ha) * carbon sequestered per hectare (tCO_2/ha) **Carbon in trees**: from iTree tool	Saraev (2012) Rodgers et al. (2015)
Recreation	Estimated number of visitors	Outdoor Recreation Valuation Tool (ORVal) Day and Smith (2016)

Source: Research compiled by Vivid Economics.

STEP 3: Undertake economic valuation.

The final step in the accounting methodology is to convert physical benefits from ecosystem services into monetary terms. The valuation methodology for each service is shown in table 12. There are a variety of approaches to valuing the benefits of green space, including avoided costs of illness (mental and physical health) and revealed preferences to locate near or visit green spaces (property valuation and recreation).

Table 12. Converting London's Ecosystem Physical Benefits into Monetary Terms

Benefit	Calculation	Source
Mental health	Expenditure on mental health in London (£/person)	Centre for Mental Health (2010)
Physical health	Proportion of at-risk population going to parks for physical activity (%)* risk reduction for disease due to physical activity (%)*cost of diseases due to physical inactivity for London (£)	Chief Medical Officers (2011)
Property valuation	Property price uplift per ha (%)* house price (£/dwelling)	Smith/GLA (2010)
Air temperature	Reduction in number of deaths * economic value of avoided premature death (£)	Saraev (2012) Department of Health
Carbon	Cost of carbon (£/tCO_2)	UK Department for Business, Energy and Industrial Strategy (2017)
Recreation	Estimated travel cost of each visit (£)	Outdoor Recreation Valuation Tool (ORVal). Day and Smith (2016)

Source: Research compiled by Vivid Economics.

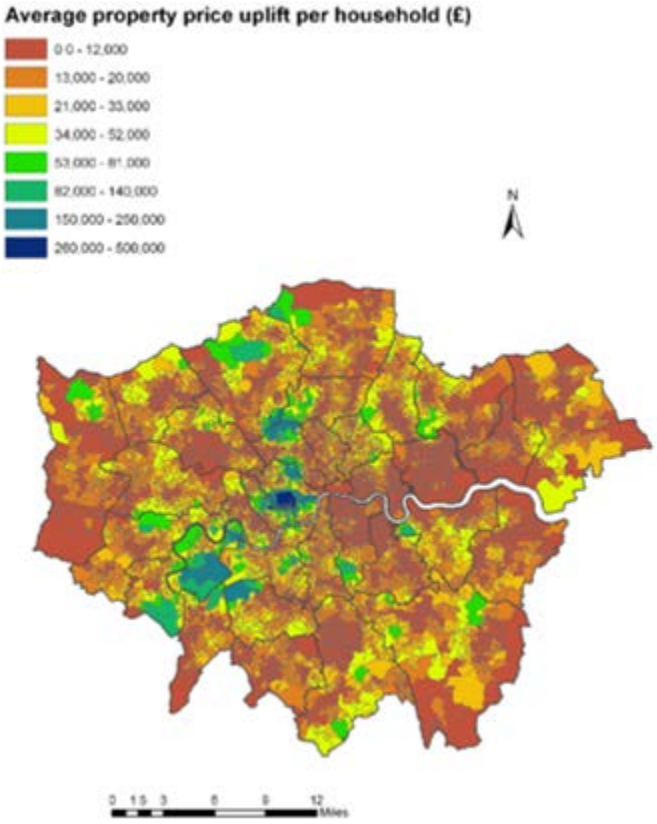
Monetary values can be disaggregated to understand how the average resident benefits and how benefits are distributed across the city. As an example, table 13 shows what average house prices tell us about a typical Londoner's preference to locate near green space. The existence of green spaces creates £64 billion in property value compared to the absence of any green space; and disaggregation reveals that the average household is willing to pay £930 per year for the benefits of living near green spaces. The availability of spatial data also allows calculations to be disaggregated to reveal distributions of benefits in different areas. Figure 7 shows the locations where the willingness to pay to be near green spaces is highest (blue) and lowest (red).

Table 13: Summary of Willingness to Pay to Locate near Green Space in London

Item	Value
Total property uplift	£64 billion
Uplift as a proportion of total property value	3.4%
Number of dwellings	3,300,000
Per dwelling uplift	£17,000
Per dwelling uplift (annualized)	£930
Per person uplift	£410/year

Source: Vivid Economics 2017.

Figure 7: Spatial Disaggregation of Londoners' Willingness to Pay for Green Space



Source: Vivid Economics 2017.

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Cities are increasingly recognizing the role of the natural environment in shaping healthy and livable places that enhance human capital and urban resilience. This paper shares how cities are using innovative approaches for policy making and planning to account for natural assets and to protect and enhance biodiversity. A range of policy options is provided together with a practical action plan for conducting assessments of natural assets in and around cities. With this information cities can holistically assess, plan, create, and maintain natural assets to leverage their value for residents' wellbeing.

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