UN environment programme

FORESIGHT *Brief*

March 2021

023

Early Warning, Emerging Issues and Futures

Nature-Based Solutions for Urban Challenges

Background

The Foresight Briefs are published by the United Nations Environment Programme to highlight a hotspot of environmental change, feature an emerging science topic, or discuss a contemporary environmental issue. The public is provided with the opportunity to find out what is happening to their changing environment and the consequences of everyday choices, and to think about future directions for policy. The 23rd edition of UNEP's Foresight Brief provides an overview of the current state of knowledge on the implementation and effectiveness of nature-based solutions (NbS), and their potential to provide a broad range of important ecosystem services.

Summary

Climate change was recently added to the wide range of agelong social challenges stemming from urbanisation. These challenges are becoming increasingly urgent to address. This is because cities are developing at the fastest pace. Nature-based solutions (NbS) can be used to address certain social challenges in urban areas as they pertain to climate change and thus to improve the cities' resilience to climate change, quality of life of the city's dwellers and to increase biodiversity in the city through the creation of green spaces. In this Brief we focus on the potential and application of NbS towards adaptation to climate change in urban areas.

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Introduction

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Currently, already half of Earth's population lives in urban areas, and projections suggest that it is likely to increase by up to 68% or more by mid-century (United Nations Department of Economic and Social Affairs [UN DESA] 2018). Urban expansion has heavily drawn on natural resources, consumed vast spaces, and led to the degradation and destruction of valuable ecosystems, thereby depriving us of the wealth of benefits they provide. This trend is likely to continue in future and will inevitably intensify if we do not undertake immediate action.

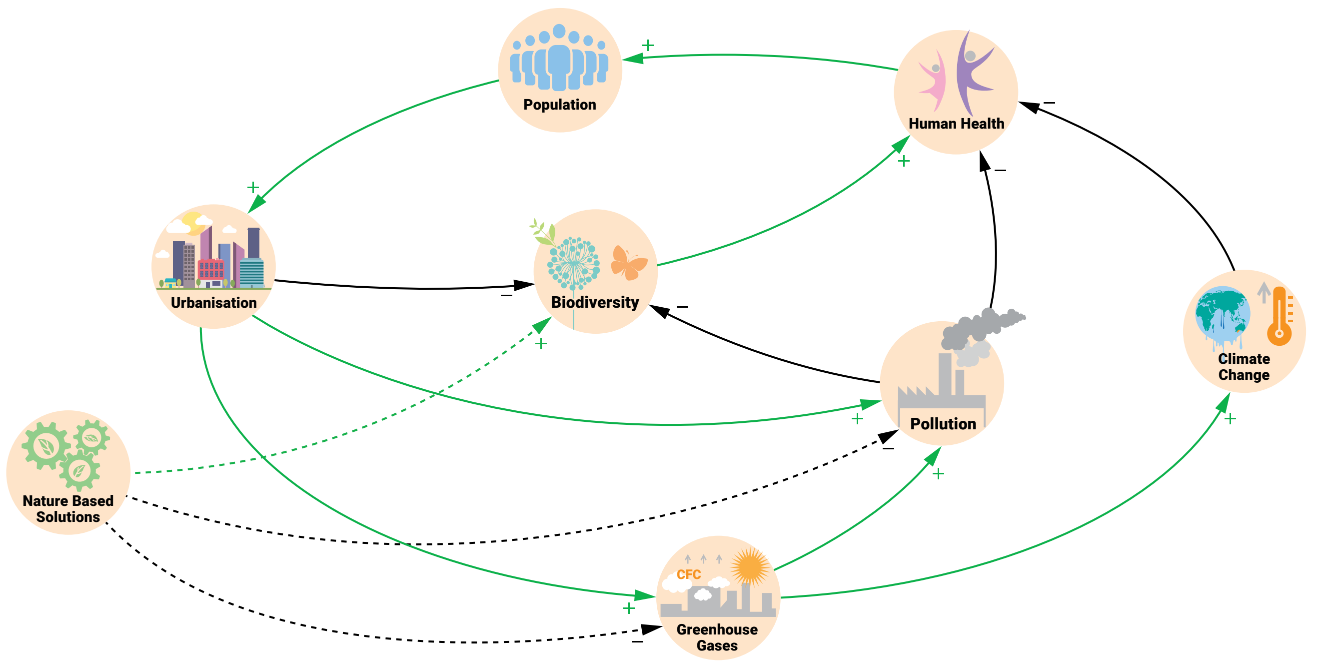
The cities are affected by, and conversely exert their influence on, environmental conditions occurring both within their proper areas and in the surrounding areas. In many instances the range of those mutual influences is truly broad, which is for example the case of many water or airborne environmental processes. Recently, climate changes occurring on the global scale, have added to the list of significant environmental stressors and challenges that are key to address.

Cities are the first to experience impacts from climate change. They are in fact at the frontline and battleground of climate change mitigation. Rising temperatures, heat waves, extreme precipitation events, flooding, and droughts, or even dust storms resulting from desertification of surrounding rural areas, are all causing economic losses, social insecurity and affecting human well-being. This is particularly important given the fact that the influx of people into cities most often occurs in low-lying, vulnerable areas with improvised housing, increasing the sheer number of people exposed and overall vulnerability of urban populations.

The COVID-19 pandemic and associated economic crises have further highlighted the vital importance of our relationship with nature, given the links that have been made between the emergence of the virus and the ongoing destruction of ecosystems and exploitation of wild species (IPBES 2020), while also delaying urgent action related to the protection and restoration of nature (UNEP 2021).

Traditionally, urban planners and practitioners in land and resource management have relied on conventional engineering to adapt to climate change, but this may not always be cost-effective, sufficient, or sustainable. To address the societal challenges from climate change and urbanization in a sustainable way, nature-based solutions should be considered as sound alternatives to man-made technology.

A Systems Thinking Perspective



Population growth results in increased urbanisation and growth of cities, causing increased global warming causing greenhouse gases and pollution as well as reduced biodiversity. These in turn adversely impact human health and this reduces population growth. Nature-based solutions can improve biodiversity in cities, as well as reduce pollution and greenhouse gases thereby improving human health. (+) Influence is in the Same direction, (-) influence is in the Opposite direction.

Defining NbS

The concept of Nature-based solutions (NbS) was introduced towards the end of the 2000s by the World Bank (World Bank 2008) and the International Union for Conservation of Nature, (IUCN 2009) to highlight the importance of biodiversity conservation for climate change mitigation and adaptation. Since then, the concept of NbS has been shaped by several actors and its scope of application has broadened beyond the climate-related, and now also covers other goals and applications.

For instance, IUCN and the European Commission have developed their own definitions of NbS. According to the IUCN definition, NbS are actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits (IUCN 2016).

The European Commission defines NbS as solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social, and economic benefits and help build resilience. Such solutions bring more and more diverse, nature and natural features and processes into cities, landscapes, and seascapes, through locally adapted, resource-efficient and systemic interventions (European Commission 2016).

Both definitions, while broadly similar (they share the overall goal of addressing major societal challenges through the effective use of ecosystem and ecosystem services), also have a few significant differences. IUCN's definition emphasises the need for a well-managed or restored ecosystem to be at the heart of any NbS, while the European Commission definition is somewhat broader and places more emphasis on the practical, implementation phase, i. e. applying solutions that not only use nature but are also inspired and supported by nature.

Irrespective of the differences in the approach, both definitions can be combined into one functional concept or approach: to fully utilize and apply the potential of the natural systems for human uses,

According to IUCN guidance (IUCN 2020) for a solution to be considered an NbS, it is imperative for it to provide simultaneous benefits to biodiversity and human well-being. ***Therefore, each solution must either maintain or enhance biodiversity, without which an action cannot be classified as NbS.***

This approach of biodiversity protection, namely: restoration and sustainable management of the ecosystems for the benefit of people and nature, lies at the foundation of UN's call and Decade of Ecosystem Restoration (UN 2019) proclaimed in March 2019. This important UN initiative has strong relevance to other major multilateral environmental international agreements and UN outcome documents related to sustainable development, biodiversity conservation and climate change. In particular, it contributes to the implementation of the 2030 Agenda for Sustainable Development, the Paris Agreement adopted under the United Nations Framework Convention on Climate Change (UNFCCC), the UN Convention to Combat Desertification (UNCCD) (UN 1994), and the Sendai Framework for Disaster Risk Reduction (SFDRR) (UNISDR 2015). The key aspects of sustainable city development, climate change and conservation of biodiversity, have also been addressed by the UN in its "Transforming our World – the 2020 Agenda for Sustainable Development" (UN 2015) and are represented in Sustainable Development Goals (SDGs) 11, 13, and 15, respectively, which are directly linked to the achievement of the Aichi Biodiversity Targets and the post-2020 global biodiversity framework (CBD 2020) as formulated within the Convention on Biological Diversity (CBD).

The concept of NbS is embedded in a wider picture of other concepts and approaches to conservation, sustainable use and management of the natural systems

for human well-being, namely, ecosystem services (ES) and green infrastructure (GI) (Kabisch *et al*. 2016). The GI is defined as a strategically planned network of natural and semi-natural areas with other environmental features, designed and managed to deliver a wide range of ecosystem services and protect biodiversity in both rural and urban settings (EC 2012). In fact, the GI should be rather cumulatively referred to as **green and blue infrastructure**, so that the various freshwater and marine aquatic and water-dependent ecosystems (such as rivers, lakes, wetlands, coral reefs, mangroves, seagrass, etc.) are considered and recognized, although obviously they relate only to some cities.

The ES are defined as the various contributions (of provisioning, regulation, cultural nature) that ecosystems make to human well-being (Haines-Young and Potschin 2018).

All these concepts and approaches have been introduced in the past two decades to strengthen the role of nature in its widest meaning in policymaking from the global to the site level.

Table 1. NbS, GI and ES - overview of the concepts

Concept	Nature-based Solutions	Green Infrastructure	Ecosystem Services
Roots/origin	New concept, definition still under debate/development	Concept with a history of about two decades; in Europe more recent; definition quite well established but also divergent	Longest history and definition well established, although still debated
	Rooted in climate change mitigation and adaptation	Rooted in controlling urban sprawl, ecological network creation, but also stormwater management	Rooted in biodiversity conservation
Current focus	Dealing with multiple societal challenges; biodiversity seen as central to solution	Broad socioecological focus, with major role for landscape architecture and landscape ecology	Biodiversity conservation by (economic) valuation of services provided by nature
Governance focus	Integrative and governance-based approaches are embraced	Participatory planning processes are favoured	Focus on governance aspects, participation
Use in urban context	Urban focus from the start	Well established	Urban ES have been in focus only more recently
Application in (planning) practice	Still needs to be developed, but has a strong action focus (problem solving)	Very well established	Partly established, but needs operationalisation through other concepts (such as GI, NbS)

Additionally, the concept of Ecosystem-based Adaptation and mitigation (EbA) which has been used can be practically considered an integral part of NbS, since it particularly pertains to "the adaptation policies and measures that take into account ecosystem services in reducing the vulnerability of society to climate change, in a multi-sectoral and multi-scale approach".

The various concepts and approaches listed above have co-evolved and are widely overlapping in terms of their scope and definition of nature. On the one hand, they are motivated by the concern to better protect nature, and specifically biodiversity, in a human-dominated world. On the other hand, the use of nature is considered as an option to complement, improve, or even replace traditional engineering approaches, for example, for storm water management. Therefore, all these concepts are clearly focusing on human interests, aiming to assert the environmental, social, and economic benefits that people gain from nature. Moreover, they are problem-focused, and they require inter- and transdisciplinary approaches.

Why is the issue important?

Climate change has significantly added to the original range of environmental, economic, and social problems caused by urbanisation – therefore, adaptation to climate change in urban areas is a key priority. NbS can prove extremely helpful in addressing this challenge.

Urban microclimate

Scientific studies show that climate change may have far-reaching impacts and consequences for the microclimate of urban areas. These consequences will differ among cities located in different geographic regions and climate zones. Here we show some examples in urban areas of Europe.

The urban temperature is dependent on global development. In the cities, rising global temperatures are supplemented and fortified by additional, city-derived factors. The urban heat island (UHI) is a resulting effect which is seen as a major problem of urbanisation (Gago *et al*. 2013) (**Figure 1**). The main parameters of urbanization that have a direct bearing on UHI are:

- increasing number of dark surfaces such as asphalt and roofing material with low albedo and high admittance,
- decreasing vegetation surfaces and open permeable surfaces such as gravel or soil that contribute to shading and evapotranspiration,
- release of heat generated through human activity (many additional sources of thermal energy such as cars, air-conditioners, etc.) condensed over a relatively limited area.

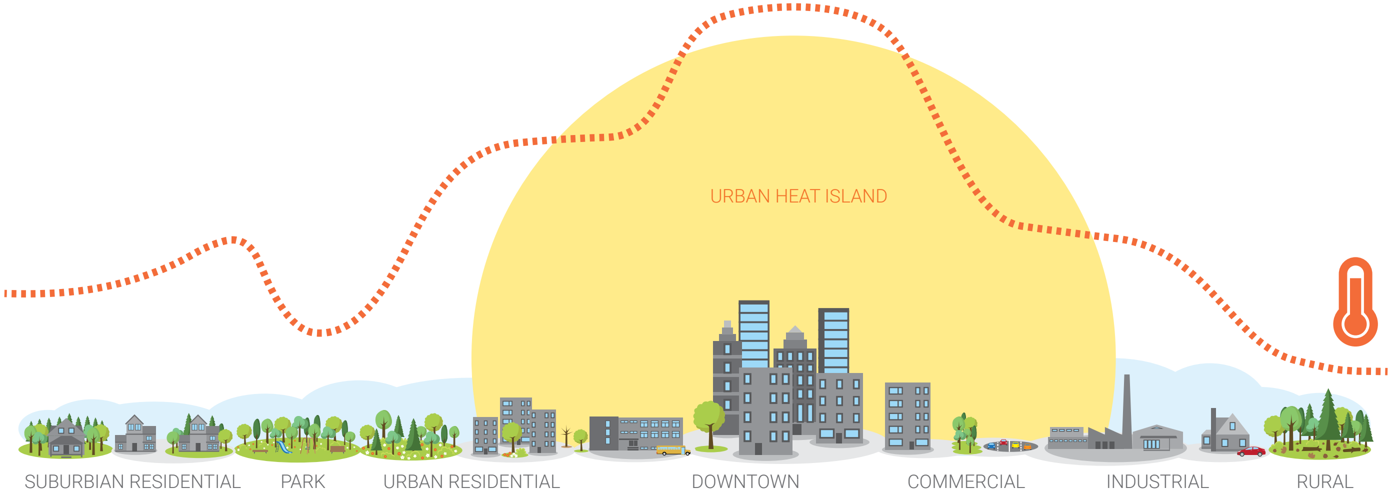


Figure 1: Urban Heat Island reduction
Source: UNEP/GRID-Warsaw Centre

The urban climate itself is suggested to increase the heat stress experienced by people during periods of high temperature (Pascal *et al*. 2005). This is an important issue, as it was evaluated that the occurrence of 83 heatwaves in Europe between 1980 and 2019 resulted in over 140,000 deaths and more than US$12 billion in damages (Harrington *et al*. 2020).

The effect on urban temperatures is not the only negative consequence of climate change for urban areas in Europe, as it also impacts urban hydrology of European cities. Several models have pointed to a direction of decreasing total summer precipitation and increasing intensity of storms interspersed with drought. Increasing high-precipitation events together with a large area of impervious surfaces, typical for urbanized areas in Europe, will lead to a substantial amount of runoff (**Figure 2**). As a result, the current urban drainage systems of European cities will exceed their capacities more frequently, causing economic loss, increased discomfort and even loss of lives (Semadeni *et al*. 2008). Paradoxically, the need to quickly dispose of the excessive amounts of rainwater frequently contributes to another serious problem, namely drought caused by ineffective retention. So, the important objective could be to improve water retention of urban spaces, improving its availability for various purposes (watering of city greenery or private gardens, or simply allowing for slow transpiration cooling the surrounding space), while simultaneously preventing flooding.

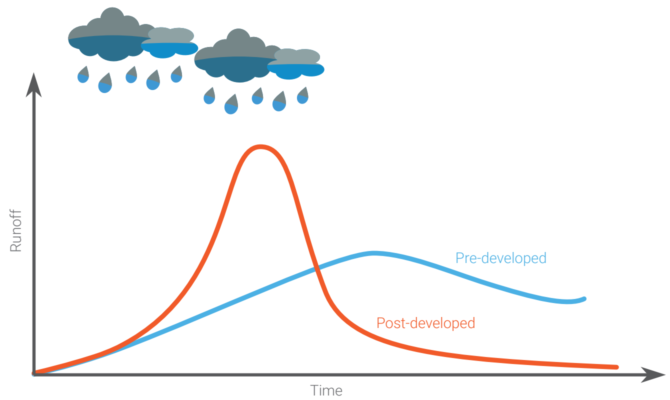


Figure 2: Impact of urbanization on runoff
Source: UNEP/GRID-Warsaw Centre

NbS role

Vegetation can play an important role in "bringing back" the urban climate closer to a pre-development state. This includes the following:

- studies have shown that urban parks have a cooling effect on the whole city by approx. 1°C in daytime mean temperature, with indications that larger parks or other systems with trees have a stronger effect (Bowler *et al*. 2010),
- the surface type will also influence the cooling effect of the blue or green infrastructure. For instance, surface temperatures of water bodies are lower compared to vegetated areas which in turn are markedly cooler than streets and roofs (Leuzinger *et al*. 2010),
- individual urban trees can influence urban temperatures by contributing to reducing UHI. The climactic performance is dependent on the tree characteristics such as tree type (coniferous/ broadleaved) and canopy shape and thickness, where sparse crowns with large leaves have a higher cooling capacity (Leuzinger *et al*. 2010),
- novel types of vegetation systems such as green roofs and green walls can also alter the energy balance of urban areas (Enzi *et al*. 2017). The direct advantage of these systems is, they can be added as a complement to existing blue and green infrastructure and that they make it possible to utilise spaces that normally are not green (Enzi *et al*. 2017),
- green walls have indeed been shown to reduce wall temperatures (Cameron, Taylor and Emmett 2014) and street canyon temperatures by close to 10 °C during the day in hot and dry climates (Alexandri and Jones 2008),
- green roofs and other vegetation have been shown to have large effects on annual storm water runoff and on peak flows (Bengtsson 2005; Stovin *et al*. 2013; Stovin 2010).

The process of reducing the urban heat island by trees is shown on the **Figure 3**.

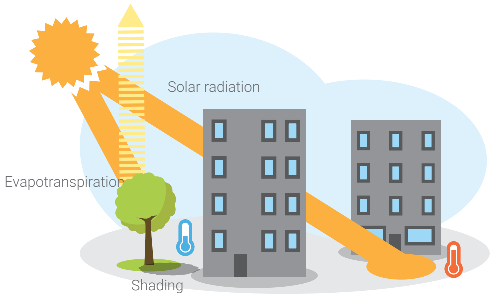


Figure 3: UHI reduction

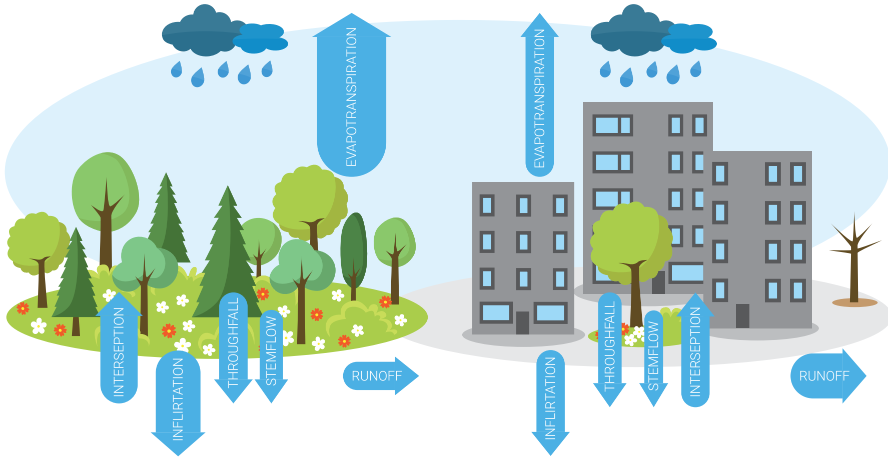


Figure 4: Stormwater runoff reduction

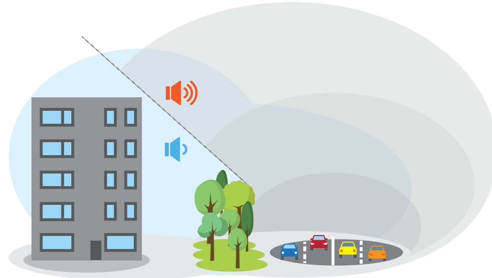


Figure 5: Noise reduction

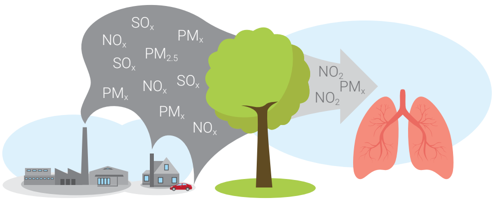


Figure 6: Air purification

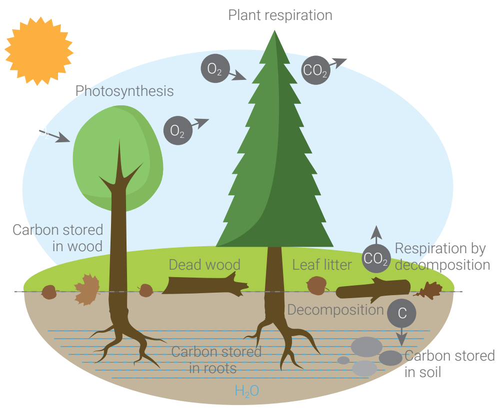


Figure 7: Carbon control

Figure 8: Aesthetics

Figure 9: Recreation

Source: UNEP/GRID-Warsaw Centre

It should be noted that in addition to supporting adaptation to climate change, green infrastructure also provides many other ecosystem services of high importance in urban areas. They include: noise reduction (**Figure 4**), stormwater runoff reduction (**Figure 5**), air purification (**Figure 6**), carbon control (**Figure 7**), aesthetics (**Figure 8**) and recreation (**Figure 9**).

All above mentioned ecosystem services improve the quality of life of city dwellers and, for this reason, when deciding to invest in NbS all of them should be acknowledged.

The COVID-19 pandemic provided a new strong reason and argument for appreciating the value of the natural systems as important providers of numerous health and mental benefits, and generally positively affecting human well-being (UNEP 2021). This is true for both non-urban and urban environments.

Case studies

Nature-based solutions can help to adapt cities to climate change. Both city authorities and the residents become increasingly aware of this fact, and therefore more and more often NbS are considered as part of urban climate adaptation strategies. Below we present three selected case studies of cities where NbS approach to climate change mitigation was applied (a few more examples are mentioned in the footnote[1]). These cities are Rio de Janeiro (Brazil), London (UK) and Lisbon (Portugal). Their locations are presented in the map below (**Figure 10**).

Figure 10: Location of case studies: Rio de Janeiro, London and Lisbon
Source: UNEP/GRID-Warsaw Centre

Rio de Janeiro

In Rio de Janeiro, the climate is tropical, with extremely high temperatures that are particularly harmful in the city's northern zone where there are almost no green areas and where the low-income population live in improvised and often marginalised neighborhoods (favelas). To address this, a pilot project was carried out in a residence located at the dense Arará favela. The existing 36 m² wavy fiber cement tile roof was transformed, in a cost-effective and resource-efficient manner, into a green roof. The monitoring of the

Figure 11: In the heart of a highly built-up and paved area of a Rio de Janeiro favela, with extremely hot temperatures all year round, green roofs can make a big difference.
Source: Freepik

temperatures comparing the vegetated roof and the bare neighbouring control roof showed that the inside of the green-roof house was even 20°C cooler at the peak of the heat during the day! The reduction of storm-water run-off and improved filtering of rainwater was also confirmed. The project showed that green roofs can and should be implemented in poor neighbourhoods as low-cost, lightweight, and low-maintenance solutions to lower indoor temperatures, reduce the urban heat-island effect and storm-water run-off - thus largely improving quality of life in low-income communities (**Figure 11**) (Oppla 2020a).

London

In 1968 the River Quaggy in Lewisham, south London, flooded the centre of Lewisham to a depth of more than 1 metre. There has also been more flooding recently. The aim of the project was to employ flood control and flood risk mitigation measures, while ensuring no loss of urban green areas. Previous flood alleviation measures had consisted of concrete channels and walls, and the plan was to raise these further. This would have led to the loss of many well-established trees. Strong local resistance to the channels and walls resulted in the implementation of an NbS alternative – namely, setback flood defences designed into the gardens of the properties, supplemented by increasing the floodplain in nearby Sutcliffe Park and the storage capacity of the detention basin (**Figure 12**) (Oppla 2020b).

Figure 12: Sutcliffe Park in London - engineered landscape forming water impoundments. River Quaggy flood alleviation scheme.
Source: www.alamy.com

Lisbon

Connecting green spaces by creating green corridors has been one of the city's main priorities. The best example is the Main Green Corridor, connecting Monsanto Forest Park to the city centre through Eduardo VII Park (**Figure 13**). Furthermore, the Eixo Central revamping project, currently being developed, shows how planting street trees and making green areas can create synergies and improve existing grey infrastructure. This helps reduce traffic, giving pedestrians and cyclists more space. Greening these spaces makes better ecological connections possible and contributes to air pollution control. Street trees make the city more attractive, better connect green areas and, provide shade for pedestrians

1 For example:
1) https://cityadapt.com/en/
2) www.unep.org/explore-topics/climate-change/what-we-do/climate-adaptation/ecosystem-based-adaptation/ecosystem-13

Figure 13: Green areas in Lisbon's historic centre
Source: Freepik

and cyclists. As part of its Green Plan, Lisbon also set up a working group to promote and enhance urban agriculture, emphasised in the EU's Biodiversity 2020 Strategy (Oppla 2020c).

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Policy implications and finance options

Nature-based solutions improve human well-being. Again, there are cost-effective solutions, whose benefits outweigh the costs. Many examples of successful application of NbS in lieu of hard infrastructure are known (Jones *et al*. 2012; Chausson *et al*. 2020).

The public finance perspective differs from the cost-benefit perspective. The salient question is what will be the impact of the project on the public budget. Actual cash flows are an issue, rather than cost and benefits. From this perspective, public actors are interested in leveraging their adaptation investments due to their limited budgets.

This is important for ensuring that the integrity and stability of the natural system is not undermined by practices that favour short-term gains but compromise the ability of the system to provide for future generations (IUCN 2020). The following three points are worth considering when exploring options and approaches for leveraging investments in urban NbS.

Collaborative planning

First, NbS are multifunctional and require **cross-sectoral and cross-departmental planning procedures** where different vested interests may be balanced. Considering the multiple and varied applications of NbS, different funds have to be acquired and directed towards respective investments. A hypothetical example could be to create an attractive green space with recreational amenity services. Public health studies have shown that these urban green spaces also contribute to positive health impacts (Naturkapital Deutschland – TEEB DE 2016). Another example may be the protection against flood risks by urban wetlands (ibid). These NbS could be financed not just by the environmental but also by the health or the municipal water department. Thus, the clearer the "return of investment" for each of the affected sectors, the more likely are respective decision-makers to invest in such "novel" and innovative alternatives to well-known city plans. The required information may either be supplied by science or be included in administrative assessment methodologies, such as cost-benefit analyses that are extended to cover the environmental dimension (Hanley and Barbier 2009; Hansjürgens 2004) or multi-criteria analyses (Janssen 2001; Tsianou *et al*. 2013).

Engaging the Private Sector in Public-Private Partnerships

Second, **public-private partnerships** may enable urban decision-makers to form alliances that create a favourable climate for NbS investments. Citizens, local businesses, and potentially even larger enterprises may have an interest in parks, protected areas, urban forests, clean watersheds, and a generally resident-friendly, liveable city. Especially large enterprises with several locations prefer those with a good living condition because that helps them attract high-quality personnel. It opens new opportunities to engage and even support such developments financially. The more stakeholders organize themselves in networks and associations to defend and propagate their interest in, for example, the conservation of farmlands and forests (Bryant 2006), the more likely it becomes a success to balance these land-use pursuits with other land-use interests such as housing development. Dedicated programmes such as Payments for Ecosystem Services (PES) may protect important areas for public services (Szkop, Sylla and Wiśniewski 2018). For instance, a law introduced in Peru has enabled municipal authorities to financially reward local stakeholders from upstream communities for proper management of watersheds - thus securing a sustained provision of hydrological ecosystem services for the city dwellers. This mechanism is seen as an opportunity to improve water quality and water security for both upstream communities and urban water users in downstream cities (Jenkins, Gammie and Cassin 2016). Similar mechanisms may be used. For example, urban businesses requiring adequate supply of clean water for their operations.

Integration with the state fiscal systems

Third, **the proper integration of ecological public functions within a country's fiscal system** may help and enhance the implementation of NbS in urban areas. Creating incentives not just for private land users through fiscal mechanisms such as taxes or cap-and-trade-based mechanisms for development rights, but essentially incentivizing nature. Affine investment behaviour of public authorities may constitute a well-functioning but not yet well-known addition in the policy mix. For example, conservation easements can be offered, in which the government provides a tax reduction to private landowners in exchange of converting their land into a private reserve. This could be aimed at watershed management - but also in other contexts, such as tourism - to improve supply of ecosystem services. This approach has been tested in South Africa (Stevens 2018) and Costa Rica (Szkop, Sylla and Wiśniewski 2018). It has been shown that the integration of ecological indicators in municipal fiscal transfers, incentivizes the respective governments to create additional protected areas (Sauquet, Marchand and Féres 2014; Droste *et al.* 2015; Ring 2008). Depending on the indicator, urban green spaces and their ecological public functions could be supported through ecological fiscal transfer mechanisms. The incentive would for example function in the following way: if a city would receive a portion of fiscal transfers only if it supplied a certain amount of green spaces per capita, it might be profitable for the city to invest a certain amount, to assure such additional income.

Finally, the COVID-19 pandemic has demonstrated the links between degradation of biological diversity and human well-being. The pandemic has brought about dire consequences and impacted on whole economies, as well as created enormous burdens on health and public utility systems. It is believed that environmentally sound fiscal reforms that include NbS can be explored as a key component of post-pandemic recovery (UNEP 2021). It should also not escape our attention that such concepts as ecological safety, environmental standards, green infrastructure and ecosystem services are listed among main principles for various "Build Back Better" strategies aimed at safeguarding our future in the wake of future imminent global hazards.

Conclusions

The preceding points highlight the potential routes of how investments into NbS may be supported. There are different leverage points and a coherent policy has to be well thought out in the form of a policy mix (Ring and Barton 2015). In addition, there are different sources of funds available from which such investments may be financed: municipal budgets, public-private funds, or fiscal transfer funds. Thus, there is no one-size-fits-all panacea but rather a toolbox of potentially suitable instruments which may be employed to greater or lesser success in different circumstances. In future, further and more extended case studies across different world regions, would also provide better evidence on the policy recommendations as proposed.

Acknowledgements

This Brief has been prepared mainly based on the following monograph1/strategy2/guidline3:

1) Kabisch N., Korn H., Stadler J., Bonn A. 2017. Nature-Based Solutions to Climate Change Adaptation in Urban Areas – Linkages Between Science, Policy and Practice
2) UNEP. 2019. UN decade on ecosystem restoration 2021–2030
3) Cohen-Shacham E., Walters G., Janzen C., Maginnis S. 2016. Nature-based Solutions to address global societal challenges.

Specific, source references cited in the above-mentioned major publications – as well as directly in the text of this Brief – are listed in the Reference List.

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** Updated on 30 April 2021*