DESIGNING NATURE-BASED SOLUTIONS FOR GREEN AND BLUE INFRASTRUCTURES FOR REACHING THE SDGS

NAVRHOVÁNÍ PŘÍRODNÍCH ŘEŠENÍ PRO ZELENOU A MODROU INFRASTRUKTURU PRO DOSAŽENÍ SDGS

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Keywords:
Nature-based Solutions; green and blue infrastructure, urban resilience; Sustainable Development Goals, innovations.

Abstract:
Recent data show intensification of climate change phenomena, such as more frequent heavy rains and rising sea levels with consequent impacts on cities. Since the 2018 Intergovernmental Panel on Climate Change (IPCC) report outcomes are not positive, and a significant change is needed to keep the increase of temperature below 2 Celsius Degree, the United Nations are pushing to accomplish the Sustainable Developments Goals (SDGs). This report investigates how Nature-based Solutions (NbS) for green and blue infrastructure can help meet the SDGs, focusing primarily on Goal 11 (Sustainable and Resilient Cities) and how the situation is for the accomplishment of SDG11 among the European countries. European Research and Innovations Agenda promotes the use of NbS in green and blue infrastructure since more natural and easy solutions to maintain. In conclusion, some NbS are shown as potential uses for the urban environment considering the future projection of floods at the European level.

Poslední data ukazují intenzifikaci jevů změny klimatu, jako jsou častější silné deště a stoupající hladiny moří s následnými dopady na města. Vzhledem k tomu, že výsledky zprávy Mezivládního panelu pro změnu klimatu (IPCC) z roku 2018 nejsou pozitivní a je zapotřebí výrazná změna, aby se zvýšení teploty udrželo pod 2 stupně Celsia, usiluje OSN o dosažení cílů udržitelného rozvoje (SDGs). Tato zpráva zkoumá, jak mohou řešení založená na přírodě (NbS) pro zelenou a modrou infrastrukturu pomoci plnit cíle udržitelného rozvoje, přičemž se zaměřuje především na cíl 11 (udržitelná a resilientní města) a to, jaká je situace pro jeho dosažení v evropských zemích. Evropská agenda pro výzkum a inovace podporuje využívání

NbS v zelené a modré infrastruktuře, protože se jedná o přirozenější a snáze udržovatelné řešení. Závěrem lze říci, že některé NbS mají potenciální využití pro městské prostředí s ohledem na budoucí predikci povodní na evropské úrovni.

Introduction

Nowadays, there is a growing consciousness that green and blue infrastructure can offer various ecosystem services to support resilient urban environments. For instance, landscape architects and municipalities explore urban landscape design possibilities to use green elements to control air temperature, air quality, water storage and drainage, and noise reduction.
A broad literature is about new and effective strategies for reducing the rainwater runoff from the cities due to impermeable surfaces; the outcome is the design of a greener, more inviting urban environment, which lowers the risk of flooding and drought damage. This result is a sample of a decisive step towards more resilient cities that are adequately prepared for the next future (Fridell et al., 2020).

From now, there is a need to translate academic knowledge on the functionality of green and blue infrastructure into principles and how to integrate these methodologies into the design of multifunctional infrastructure with the help of Nature-based Solutions (NbS) (Gehrels et al., 2016). NbS are inspired and supported by nature; consequently, they are cost-effective and offer environmental, economic, and social benefits while helping build resilience (Delcroix, 2019; European Commission, 2020c). NbS can guide the stormwater runoff retention, detention, and infiltration, using solutions such as green roofs, blue-green roofs, bio-retention swales, and rain gardens. A few examples of NbS considered for using directly on the brooks or watercourses are dry polders, *noue paysagère* (floodable ditch), and restoration of the stream beds.

These more sustainable and resilient strategies will lead to reaching faster the goals set by the United Nations for 2030 (United Nations, 2015c, 2015b). For incentivising the use and knowledge about NbS, the European Union made some calls and results packs under the umbrella of the Horizon 2020 programme (H2020, 2014-2020). For instance, one package is "Nature-based solutions: Transforming cities, enhancing well-being" (European Commission, 2020a), aimed at developing innovative and user-friendly solutions for building sustainable, resilient and prosperous societies in order to mitigate the climate change impacts, such as floods or more frequent storm and the consequent power outage (Karagiannis et al., 2017). This package collects a series of EU projects, all addressing the Nature-based Solutions thematic.

The objective of the study

The rapid growth of urbanisation stresses the necessity of new sustainable paradigms for transition strategies toward resilient cities. This manuscript showcases different possible Nature-based Solutions (NbS) for blue and green infrastructure that can help at improving the climate responsiveness and resilience in the built environment and at meeting the Sustainable Development Goals (SDGs) (United Nations, 2015c, 2015b), in particular the Goal 11, aimed at sustainable cities and communities. Firstly, the future risk of flooding in Europe caused by rivers and sea-level increases is presented to understand which countries could be more

affected by those threats. Secondly, a brief overview of European programmes, and mostly SDGs, is given to showcase the link with the NbS. Thirdly, to help reach the target and EU goals, some resilience assessment tools, especially focused on meteorological disasters, are presented. Finally, a few examples of NbS for future developments are highlighted.

1. Hydro-Meteorological risk in Europe

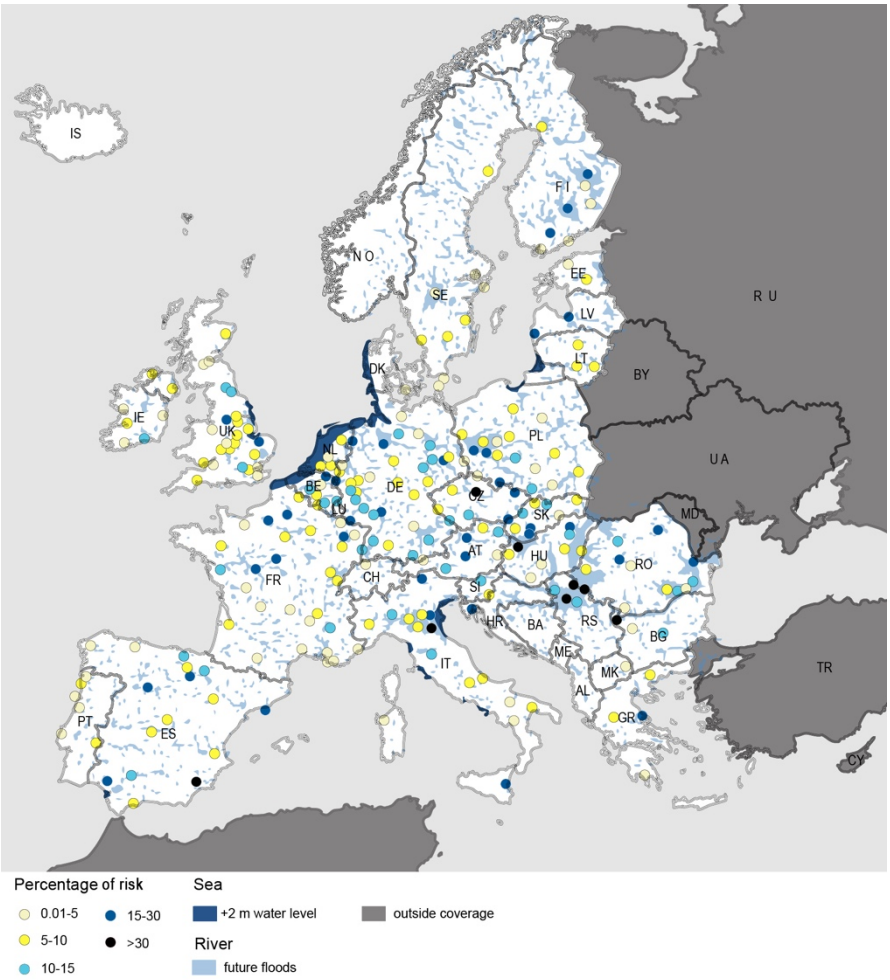
Major disasters have clearly demonstrated the role nature plays in reducing risks to natural hazards in the past decade. Many cities are located in coastal or delta areas where flood risk increases due to climate change, rising sea levels, river discharge, and heavy rains — secondly, land-use changes such as the increase of sealed surfaces and buildings and from subsidence. More and more frequent flooding and consequent damages threaten the urban environment (IPCC, 2018). Furthermore, heat waves become more recurrent because of climate change. This may lead to higher temperatures than the rural surroundings (phenomenon better known as urban heat islands (UHI). These experiences prove that ecosystem services' regulatory role can be cost-effective in reducing risks posed to society by catastrophes.

As a response to this situation, (Pender & Neelz, 2007) noted that the way decision-makers are dealing with the urban flood is varying, changing from a strategy of resistance against flooding to a need for an alteration in flood management strategy, minimising the risks (Faber, 2006; Moura Rezende et al., 2019). In this view, green and blue infrastructure lead to a way to face climate change and promote healthy urban living.

The application for being effective requires design principles able to address the relationship between the infrastructure and impacts of climate change, such as flood risks, flood, heat, water supply and drought, but also guarantee the quality of the ecosystem (water, soil and air quality) (Gehrels et al., 2016).

The European background of natural hazards is mainly characterised by river flooding in terms of economic damage (Siragusa et al., 2020), and it is still frequently considered a direct effect of heavy rainfall (Harrison & Williams, 2016). The river flooding risk is projected to increase in any part of Europe by combining heavy storms or exceptionally high sea levels (Felicioni et al., 2020). In addition to climate exposure, the settlement of new urban areas and the accumulation of assets in low-lying areas close to rivers has amplified the sensitivity to floods (European Environmental Agency, 2017). Figure 1 shows a map with the low-lying urban areas potentially endangered by river/coastal flooding between 2071–2100 and the areas possibly affected by coastal flooding risk under a supposed sea level rise of 2 m and storm surge events. The most exposed coastal cities in Europe are situated in the Netherlands, Germany, Belgium, and areas along the northern Italian coastlines, in specific, Venice.

Figure 1: *Percentage of the future risk of flooding in Europe caused by rivers and sea-level increases by 2 m (2071-2100).*



Source of data: European Environment Agency (EEA) and (Felicioni et al., 2020). *Visualisation made by the author.*

2. Nature-based Solutions (NbS)

In the past years, the solution to reduce flood risk was automatically directed to the grey infrastructure, such as dykes, channelising natural streams, providing culverts under roads and bridges, and constructing stormwater detention basins (Kumar et al., 2020). These previous experiences have clearly shown that grey infrastructures alone cannot provide complete protection from this hazard (European Environmental Agency, 2017). Hence, the focus is now shifting towards NbS as a flood control strategy.

The European Commission describes Nature-Based Solutions 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 diverse, natural features and processes into cities, landscapes, and seascapes through locally adapted, resource-efficient and systemic interventions*' (European Commission, 2016).

NbS are, at present, gradually adopted to permit climate change mitigation and adaptation to reduce flood risks and enhance urban ecosystems and potentially offering added benefits (biodiversity, enhancing water and air quality, improving community sociocultural conditions) (Denjean et al., 2017).

Moreover, NbS can be applied by controlling the water-related services of 'natural infrastructure', such as forests, wetlands and floodplains. These solutions can face the risk of

a water crisis and providing flood management benefits while also conserving ecosystem values and functions.
The main difference between natural and green infrastructure is that the first is applicable in the landscape context and the second most at the urban level, but both can deal with flood risk management (International Union for Conservation of Nature, 2016).

3 EU R&I agenda for NbS

European research and innovations (R&I) are vital for fighting climate change, implementing green industrial policies, and reaching sustainable growth (European Commission, 2020c).
This manuscript focuses on design nature-based solutions for blue and green infrastructure that support urban resilience and cities to meet the UN's Sustainable Development Goals (SDGs) (United Nations, 2015c, 2015b). In 2015, the United Nations presented 17 SDGs with 169 related sub-goals, intending to enhance resilience by 2030. The global targets were successively translated into a regionally oriented management system, thereby reducing systems susceptibility to disasters and promoting resilience and adaptability at the national level (Liang & Li, 2020).

Flooding phenomena are more frequent in Europe as presented in the section related to European floods background; indeed, the intensification of climate and land-use change and social growth in flood prone-areas has raised policy-makers' awareness of the necessity to implement the cities with innovative flood risk management solutions (Keesstra et al., 2017). The flood impact challenges nearly all of the SDGs; definitely, floods can damage livelihoods, limiting communities' ability to access the resources they need to rebuild and return to business as usual (SDG 1) (United Nations, 2015b; Vaughan & Norton, 2019). Moreover, the high cost of recovery may weaken infrastructure and other activities such as the communities' ability to continue business as usual and further develop (SDG 9). In the end, the consequences of a flood can influence the social, economic, and infrastructural aspects and the city future by slowing economic growth and limiting their capacity to contribute to sustainable development (SDG 8 and 11).

Studying the effects of climate change and the consequent cascade effects is vital for building urban resilience and understand how countries can address hazards and make communities more resilient to meet the SDGs (United Nations, 2015b; Vaughan & Norton, 2019).
Reaching the goals allows to improve different aspects: increasing access to green spaces through NbS and green infrastructure (GI) would address both SDG 3 (which aims to improve health and well-being) and SDG 10 (aimed to reduce inequalities within societies); SDG 11 focused on *'Making Cities and Human Settlements Inclusive, Safe, Resilient and Sustainable*' is aimed at EU's R&I Nature-Based Solutions agenda (Faivre et al., 2017).

Chyba! Nenalezen zdroj odkazů. shows which potential NbS could help to meet Goal 11. For instance, to pursue Target 11.A, the need to enhance interactions in rural and peri-urban areas is earned by connecting open spaces with different degrees of naturalness (Magaudda et al., 2020).

Table 1: *Overview of the UN's SDG 11 and related Nature-based Solutions.*

GOAL	TARGET	NATURE-BASED SOLUTIONS
SDG 11 Sustainable Cities and Communities	11.A Links between Urban, Peri-Urban and Rural Areas	Green Corridors
	11.B Urban Planning and Policies for Disaster Resilience	Natural Coastal Protection
		Afforestation
		Floodplain Restoration
	11.5 Reduction of Economic Losses due to Water-Related Disasters	Natural Water Retention
		Sustainable Urban Drainage
	11.6 Reduction of Adverse Impacts on Air Quality and Waste Management	Community Gardens
		Green Roofs
	11.7 Safe, Inclusive, and Accessible Green and Public Spaces	Pocket Parks
		Street Trees

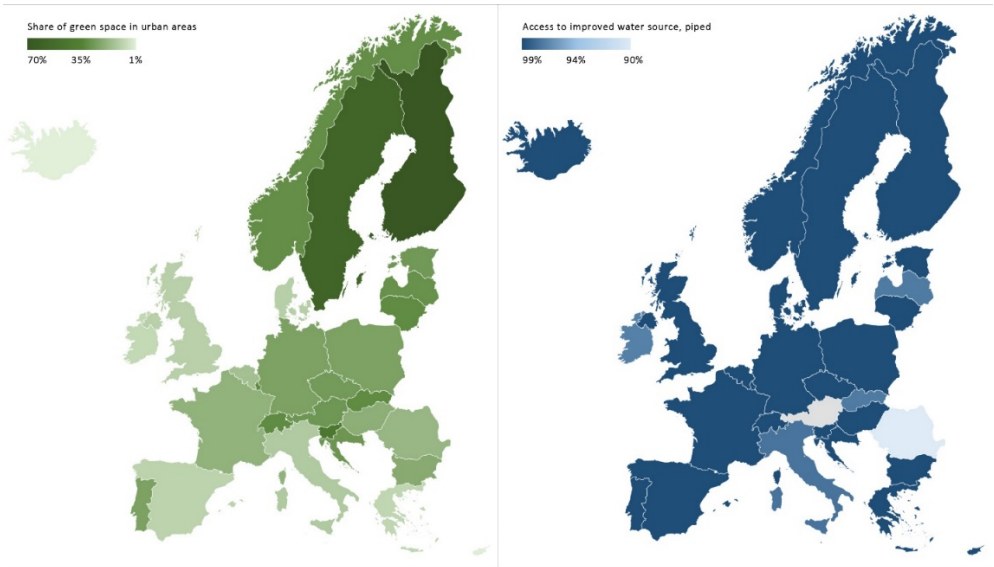
Source of data: (Faivre et al., 2017; United Nations, 2015b). *Table made by the author.*

The 2020 results of the Institute of European Environmental Policy (Sustainable Development Solutions Network & Institute for European Environmental Policy, 2020) show that any European country has not achieved the SDG 11 yet. In general, countries in Southern Europe perform worse than another sub-region.

Within the SDG 11, the targets related to the average share of urban green spaces and forests as a percentage of the land area and the percentage of the urban population with access to improved drinking water piped on-premises are analysed in-depth (Sustainable Development Solutions Network & Institute for European Environmental Policy, 2020). Figure 2 shows the map for shared urban spaces and blue-shades in green-shades, which is the "improved" drinking-water source.

On one side, both targets primary outcomes are a great success for the Nordic countries (the best-performing European subregion). On the other side, some countries are performing better in one indicator than the other, such Greece or Iceland, where access to the improved water source is wholly guaranteed but, on the contrary, the green spaces still lack. However, countries as Italy are still behind to meet both targets.

Figure 2: *European maps about SDG 11 and its targets. Green-shades for the percentage of the average share of urban green spaces and forests and blue-shades for the urban population's percentage with access to improved drinking water piped on-premises.*



Source of data: Insitute of European Environmental Policy. Visualisation made by the author.

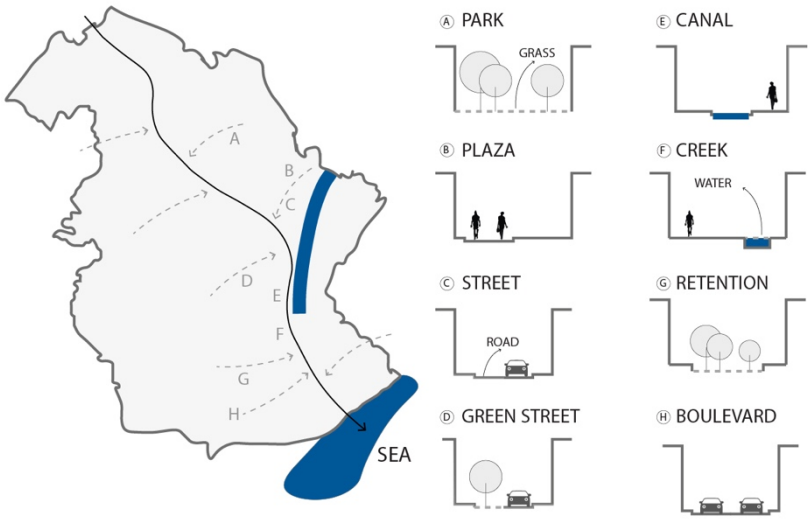
The special report issued by the Intergovernmental Panel of Climate Change (IPCC) (IPCC, 2018) about Global Warming on 1.5°C shows how climate change is influencing the severity of flooding and other hazards (such as wildfires, droughts, storms, etc.) with consequent negative impacts on livelihoods and the ability to reach the SDGs by the countries.
IPCC scenarios concerning the limitation of climate change rely on land-use mitigation methods, increasing the usage of renewable resources and decreasing the greenhouse gasses (GHGs) emission; the potential contribution of NbS in this concern is meaningful to the scope of safeguarding of biodiversity (European Commission, 2020b). By including resilient, climate-smart thinking into disaster risk management, climate change adaption, and development agendas, countries can ensure that these disaster events' impacts do not weaken the SDGs.
NbS are a fundamental part of the climate and biodiversity, also described by the Paris Agreement's Climate Change goals (United Nations, 2015a) and the European Green Deal (European Commission, 2019). NbS can deliver over one-third of the cost-effective climate mitigation required between now and 2030 to stabilise warming to below 2° C, achieving a nature mitigation potential of 10-12 gigatons of CO_2 year. Hence, they are an essential component of decarbonisation, reducing climate change risks and establishing resilient climate societies (United Nations Global Compact, 2019).

These natural solutions are becoming more and more important in international agreements and policy frameworks; for instance, both the UN Framework Convention on Climate Change and the Convention on Biological Diversity are increasingly recognising, debating and promoting the potential of NbS to help reach their more ambitious goals and targets over the next decade. Moreover, among the EU calls on ecosystem-based approaches, specifically under the umbrella of Horizon 2020 (2014-2020), Oppla (Oppla.eu, 2020) and Think Nature (Think Nature.eu, 2020) are two notable outcomes. The first is an open platform repository of NbS, and the second is a multi-stakeholder communication platform supporting the understanding and promotion of NbS; both funded by the European Union's Horizon 2020 research and innovation programme.

4. Relevant Results

The main ambition of research and innovation policy is to place the EU as a leader in innovating natural solutions to achieve more sustainable and resilient cities and communities (European Commission, n.d.). As mentioned previously, within the EU platform Oppla, many worldwide NbS application case studies are collected and continuously updated. This EU sort of database is a great outcome from the Research and Innovation programme since it permits architects and designers to study a series of NbS applications already in-use in different cities to face various flood hazard levels. For instance, the Cloudburst management plan was designed in 2012 to mitigate the effects of climate change in Copenhagen's city following the 2011 heavy floods (Miljo Metropolen, 2011). One of the main strategies adopted by this plan was creating a toolkit with potential measures that might also be applicable in other contexts, incentivizing the transferability of the results (Figure 3).

Figure 3: *Design principles of Cloudburst management plan (toolkit) for Copenhagen, Denmark.*



Source of data: (Miljo Metropolen, 2011; Oppla.eu, n.d.). *Visualization made by the author.*

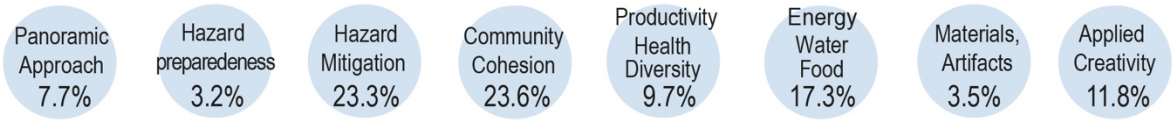
These solutions are now implemented in Copenhagen's local plans, where synergy projects are encouraged between municipalities, water utilities, and philanthropists as catalysts for development.

4.1. Resilience assessment tools

Due to the increasing amount of shocks owed by climate change, cities adopt different strategies (Sellberg et al., 2017), from NbS as corrective actions to the resilience assessment method as preventive measures. The importance of developing tactics for improving resilience and minimising negative impacts caused by unforeseen hazards events has been recognised and broadly accepted (Nan & Sansavini, 2017). Indeed, the US Green Building Council, administrator of the Leadership in Energy and Environmental Design (LEED) certification (USGBC, 2019), made resilience a policy priority, writing RELi, a tool entirely focused on resilience for homes, neighbourhoods, and infrastructure (USGBC, 2018). Figure

4 shows the categories present in the Resilience Action List Credit Catalogue. The resilience rating system helps to understand which preventive solutions can be taken into account to minimise the damage caused by disaster events (e.g. storms, flood, landslide, earthquakes, etc.).

Figure 4: *RELi assessment categories and their relative weightings. Section Hazard Mitigation leads to requirements to protect cities and communities from floods - for example, the design of defences from power outages from the grid due to flooding phenomena.*



Source of data: USGBC, 2018 and (Felicioni et al., 2020).
Visualisation made by the author.

Another tool used to combine resilience indicators with sustainability in the United States is Envision V3 (Institute for Sustainable Infrastructure, 2018a). This protocol provides guidelines on sustainable best practices to users and helps design and evaluate infrastructure projects once completed (Institute for Sustainable Infrastructure, 2018b). It considers a holistic process that analyses the location, climate, and natural hazards in different geographic areas. Furthermore, Envision v3 reflects the life-cycle economic approach for enhancing decision making by encouraging the effective management of resources and assessing that finally lead to more resilient and sustainable projects.

On the other hand, in Europe, some countries are developing guidelines (Smart Mature Resilience, 2018a) suitable for facing natural disaster events, such as the Risk Systemicity Questionnaire (Smart Mature Resilience, 2018b) and the Resilience Maturity Model (Smart Mature Resilience, n.d., 2017), two H2020 funded projects. The Risk Systemicity Questionnaire purposes of supporting cities by enhancing their risk assessment through an advanced focus on the relations between different types of risks that are evaluated within ten main topics (e.g. climate change, air pollution, and flooding). On the contrary, the Resilience Maturity Model enables cities to evaluate their maturity stage and find measures to permit the city to evolve and towards a resilient way. In the well-known building sustainability certification systems like Building Research Establishment Environmental Assessment Method (BREEAM) (BREEAM, 2018) or the Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB) (DGNB, 2018), some criteria focused on resilience enhancement are considered. Still, their weightings are very light compared to their other topics (such as energy or CO_2 emission).

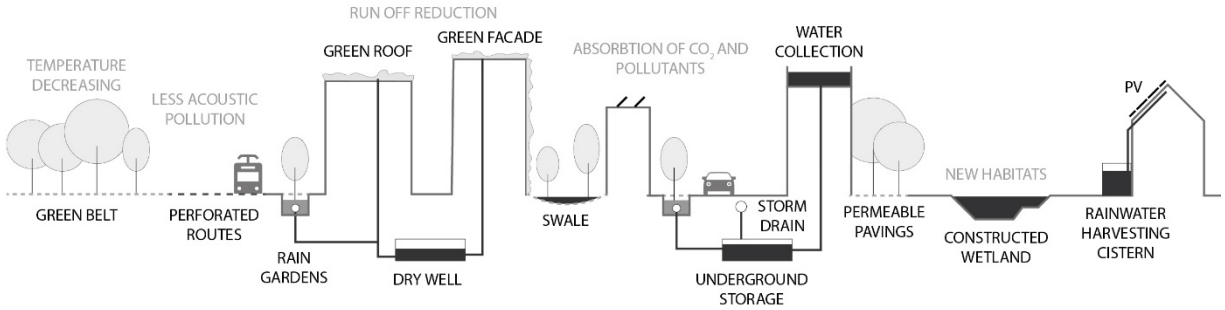
Conclusion and Future Developments

Nature-based solutions directly address a potentially unsustainable over-reliance on grey infrastructure. The “old” infrastructure problem is double – it often uses unrecyclable and finite resources, usually temporary. As climate hazard increases and intensifies, these solutions will need to be improved or replaced. On the other side, NbS similarly need to be maintained and sometimes refurbished, but not at the same frequency; thus, they can be more versatile than their grey counterparts.

NbS includes natural, green, and integrated infrastructure, combining all three elements. Figure 5 shows a visual compilation of design principles for multifunctional green

infrastructure and NbS and provides information on green spaces effectiveness to deliver ecosystem services. These design principles focus on various ecosystem amenities that contribute to more healthy and attractive cities, such as temperature decreasing, air quality regulation, flood prevention, noise reduction and recreation.

Figure 5: *Nature-based Solutions (NbS) and green and blue infrastructure diagram. Some potential solutions are highlighted in black, and there are some consequent benefits to the built and urban environment in grey.*



Visualization made by the author.

One of the most critical impacts for the cities is water regulation. The effectiveness of NbS is the reduction of rainwater runoff and prevention of pluvial flooding, and it depends on rainfall intensity and frequency, vegetation and soil characteristics. NbS and green infrastructure's main contribution is through rainwater's infiltration into permeable soils underneath vegetation. As Copenhagen Cloudburst plan proposed with creating a toolbox, a strategic flood management plan might be seen as an opportunity to safeguard the city while providing the basics for a high-quality urban environment. Resilient urban eco-friendly waterscapes are the grounds for attractive public spaces that are culturally and socially meaningful and contribute to the economic longevity, quality of life, and cities' well-being.

In conclusion, NbS present innovative solutions to deliver resilient climate infrastructure and meet quicker the SDGs. One pivotal aspect is the lower costs (reduced upfront investments and maintenance); in fact, NbS become self-sustaining over time as living systems. They are multifunctional and can generate co-benefits such as increasing resilience, improving human well-being, and mainly improving biodiversity.

Nomenclature:

BREEAM	Building Research Establishment Environmental Assessment Method
DGNB	Deutsche Gesellschaft für Nachhaltiges Bauen
EU	European Union
IPCC	Intergovernmental Panel on Climate Change
LEED	Leadership in Energy and Environmental Design
NbS	Nature-based Solutions
R&I	Research and Innovations
SDGs	Sustainable Development Goals
UHI	Urban Heat Islands

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