

NATURE-BASED SOLUTIONS FOR THE SUSTAINABLE DEVELOPMENT OF GREEN AND BLUE INFRASTRUCTURE IN ROMANIA

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Abstract

Romania faces challenges related to climate change, such as rising temperatures, floods, and droughts, while urban areas struggle with air and water pollution. The growing public awareness of sustainability and environmental protection creates a favorable context for the large-scale implementation of such infrastructure across the country. This research provides a detailed classification of green and blue infrastructure types, highlighting their diversity and the specific functions each fulfills in improving urban life. Green and blue areas are essential for improving urban life quality and protecting the environment. The growing significance of green and blue infrastructure is reflected in Romania's urban laws and policies, highlighting a shift towards sustainable development and city resilience. However, implementing this is difficult due to the lack of a single legal definition, causing inconsistent use and confusion. Additionally, there is no cohesive national strategy, and legal frameworks addressing different aspects are uncoordinated. Local authorities also need clearer guidelines and better methods for planning, designing, and managing these infrastructures effectively.

Key words: climate change, environmental quality, sustainability.

INTRODUCTION

Currently, over half of the global population (55%) resides in urban areas, and this percentage is projected to rise in the coming years (United Nations, 2019). Cities are increasingly confronting various risks, with escalating heat stress driven by rising temperatures being one of the most pressing challenges (Sari Kovats & Hajat, 2007). As urban areas grow, the heat island effect amplifies heat stress, reducing quality of life and increasing heat-related mortality, particularly among vulnerable groups like the elderly, children, and those with health conditions (Oleson et al., 2015; Argüeso et al., 2015). These factors make it necessary for cities to implement effective adaptation strategies to mitigate the health risks associated with extreme heat, including nature-based solutions by integrating green and blue infrastructure.

Nature-based solutions (NBS) and green-blue infrastructure (GBI) are key components of sustainable urban development and environmental policies. By integrating green

spaces and water bodies into the urban landscape, GBI helps cities address today's challenges, providing practical solutions to mitigate the impact of climate change, biodiversity loss, and the rapid expansion of urban areas. Nature-based solutions and the responsible management of natural resources are acknowledged as fundamental elements of sustainable development (Martin et al., 2020). Our studies have found that many documents and research investigations, including reports by the European Commission and studies by environmental organizations, feature nature-based solutions as a cross-cutting topic, proposing the use of natural processes to address urban challenges such as climate change, pollution reduction, or increasing the resilience of cities. European documents establish the general framework for integrating nature-based solutions and green-blue infrastructure into environmental, urban planning, and economic development policies (European Parliament, 1998; 2015; 2018). At the national level, Romania's legislation details how these

principles are implemented, with specific laws like Law no. 24/2007 for the regulation and administration of green spaces, Emergency Ordinance no. 114/2007 for flood risk management, and the National Strategy for Sustainable Development of Romania 2030 for urban regeneration (The Government of Romania, 2007). At the European level, the general direction regarding green and blue infrastructure focuses on integrating nature-based solutions into environmental, urban planning, and economic development policies. The European Union promotes a holistic approach that emphasises biodiversity protection through initiatives like the Natura 2000 network, climate change adaptation by implementing emissions reduction targets, and the creation of more resilient and sustainable cities through funding programs for green infrastructure projects. European programs and strategies like the European Green Deal and the 2030 Agenda for Sustainable Development highlight coordinated efforts to enhance quality of life, decrease pollution, and manage natural resources efficiently.

We have observed that NBS has different definitions that vary based on cultural and regional contexts, but the overall goal remains consistent: to harness the power of nature to address environmental challenges. Thus, our research uses the encompassing definition provided by the European Commission's Report on NBS as those actions that enhance existing natural processes and develop innovative approaches that leverage nature's ability to store carbon and regulate water, contributing to disaster risk reduction, well-being, and green growth. The European Commission recognises that the concept aligns with ecosystem-based approaches and emphasises sustainable alternatives inspired by ecological principles (European Commission, 2015).

Romanian legislation has adopted European principles regarding the protection of green spaces, flood risk management, and urban regeneration by adopting and transposing European Union directives and strategies into its national regulatory framework (Ungureanu et al., 2024). In the context of current global challenges such as climate change, biodiversity loss, and rapid urbanization, nature-based solutions and sustainable management of natural

resources are recognized as an integral part of sustainable development at both the European and national levels.

MATERIALS AND METHODS

NBS and GBI have become integral to environmental policy and urban planning at the European and national levels. The world's climate change, biodiversity loss, and urbanization challenges have made it imperative for governments to prioritize nature-based solutions and green infrastructure in order to create more sustainable and resilient cities.

The documents selected for this study cover various regulations and strategies that support environmental protection, sustainable development, and urban regeneration. They underscore the critical importance of incorporating NBS and GBI into local and national policy frameworks.

Our analysis examined legislative and strategic documents, offering a comprehensive view of the regulations and policies related to green and blue infrastructure at the European and national levels. These documents cover a wide array of issues, from environmental protection and sustainable resource management to biodiversity conservation, water quality, natural disaster risk reduction, urban regeneration, and sustainable development.

Romania's national legislation outlines the implementation of these principles, focusing on the protection and management of green spaces, flood risk reduction, and urban regeneration efforts.

RESULTS AND DISCUSSIONS

A total of 18 legislative and strategic documents were carefully analysed in the reviewed studies. Among these, 13 were European Union (EU) documents, comprising strategies, directives, and conventions that outline the general framework for green and blue infrastructure and nature-based solutions. Five national documents from Romania were analysed, including laws, emergency ordinances, and national strategies that incorporate European principles into the Romanian framework. One national bill proposal has been examined (Draft Law, 2024).

European Legislation regarding NBS

The European Union places significant emphasis on integrating nature-based solutions into its environmental, urban planning, and economic development policies. This holistic approach aims at biodiversity protection, adaptation to climate change, and the creation of more resilient and sustainable cities. We have identified a series of documents and strategies that support and promote the use of nature-based solutions in the urban environment:

- ***The Green Infrastructure Strategy, 2013*** aims to promote investments in ecological solutions and avoid costly gray solutions. This encourages the use of green infrastructure to protect ecosystems and reduce costs through natural and sustainable solutions (European Commission, 2013). It offers recommendations for using nature-based solutions to replace or complement grey infrastructure, emphasizing that green infrastructure is a planned network of natural and semi-natural areas that contribute to increased resilience and significant savings.
- ***Strategic Research and Innovation Agenda Biodiversa*** supports research in biodiversity and natural solutions to address ecological, climate, and social crises, promoting innovation (Eggermont et al., 2021).
- ***The amendments adopted on October 5, 2023, regarding wastewater treatment*** propose measures to reduce emissions from wastewater treatment and encourage the use of nature-based solutions for water management (European Parliament and the Council, 2015).
- ***The review of progress regarding the implementation of the EU strategy for green infrastructure (2019)*** highlights that green infrastructure is an important tool for ensuring ecosystem services, reducing costs, and supporting biodiversity. It also provides guidance for integrating green infrastructure into spatial planning and sustainable development (European Commission, 2019).
- Major European strategies, such as the ***European Green Deal*** and ***The 2030 Agenda for Sustainable Development***, emphasize the need for concerted actions to

improve quality of life, reduce pollution, and use natural resources efficiently (European Commission, 2020; UN, 2015).

Romanian Legislation regarding NBS

Romania has made progress in implementing European principles on green space protection, flood risk management and urban regeneration through the adoption of specific legislation and national strategies, although the implementation and mainstreaming of concepts such as green-blue infrastructure still requires coordinated efforts and a unified approach at local and national level.

Regarding the protection of green spaces, Romania has adopted a legal framework that reflects European concerns for biodiversity conservation and the improvement of quality of life in urban areas. Law no. 24/2007 regarding the regulation and administration of green spaces within urban areas establishes the legal framework for the protection and management of these spaces, including regulations for administration, protection, and penalties for deterioration (Parliament of Romania, 2007). This law was amended and supplemented by Emergency Ordinance no. 114/2007 and Law no. 47/2012, with the aim of the continuous protection of green spaces and the prohibition of changing the destination of green lands (The Government of Romania, 2007; Parliament of Romania, 2012). Moreover, the Technical Norms for the Development of the Local Register of Green Spaces provide guidelines for the inventory, management, and expansion of urban green spaces, establishing criteria for their monitoring (Ministry of Regional Development and Tourism, 2010). These initiatives are in line with European strategies that emphasize the role of expanding green and blue networks to support ecosystems and create connections between natural and urban areas.

In the field of flood risk management, Romania has implemented relevant European directives, such as the Water Framework Directive 2000/60/EC and the Floods Directive (2018/2019). These directives require member states to assess and manage flood risks, encouraging the implementation of ecosystem-based measures and green infrastructure. The Water Framework Directive regulates the protection of water resources, setting standards

for the quality and quantity of water for sustainable uses. The Directive on the assessment and management of flood risks improves cooperation between member states in the assessment and management of flood risks, with an emphasis on green infrastructure.

For urban regeneration, Romania has adopted legislative and strategic measures that align with European objectives for sustainable development and improving the quality of life in urban and rural communities. Emergency Ordinance no. 183/2022 regarding the establishment of measures for the financing of urban regeneration projects regulates the financing of these projects from non-reimbursable funds and establishes the eligibility criteria (The Government of Romania, 2022). This ordinance emphasizes the necessity of conserving and expanding green spaces within urban areas as an integral part of urban policies. The National Strategy for Sustainable Development of Romania 2030 represents the strategic framework for the implementation of the 2030 Agenda in Romania and highlights the need for a transition towards more responsible economic and social practices, aligned with global and European objectives (The Government of Romania, 2018). This includes objectives related to sustainable urban development and the integration of sustainability principles into public policies (Parliament of Romania, 2022).

Nature based solutions as tools for sustainable urban developments

By examining the key documents at both the European and Romanian levels, we have identified the legislative and strategic frameworks that guide the implementation of Nature-Based Solutions (NBS). These policies define the integration of green and blue infrastructure within urban regeneration initiatives, water management systems, and overarching sustainability strategies. The findings underscore the advancements achieved and the obstacles that persist in integrating NBS into policy frameworks, providing insights on how cities can more effectively utilise nature to tackle current urban and environmental issues (Bockarjova et al., 2017).

Green and blue spaces are vital in sustainable urban development, significantly affecting the

environment, public health, and residents' quality of life. Integrating them into urban infrastructure offers numerous advantages: better biodiversity, reduced urban heat island effects, and improved stormwater management. Additionally, their contributions help conserve aquatic ecosystems, creating healthier, more enjoyable community environments. Green and blue infrastructure are crucial for building sustainable, climate-resilient cities. These spaces provide numerous environmental and social benefits, enhancing ecological balance and residents' well-being (Semeraro et al., 2021).

Bockarjova et al. (2017) developed a key tool for understanding and quantifying the financial and economic benefits of nature-based solutions in urban contexts. The tool relies on a transdisciplinary classification framework and data from previous research. Based on this research, we utilised and extended this classification, integrating the previously examined local documents, as shown in Table 1. This study presents a detailed classification of green and blue infrastructure and its contributions to better urban living.

Table 1. Nature based solutions as tools for sustainable urban developments throughout types of Green and Blue Urban Infrastructures

Nature based solutions as tools for sustainable urban developments	
Green Infrastructure	Blue Infrastructure
Urban park or forest <ul style="list-style-type: none"> have many benefits for the city's quality of life: environmental benefits, economic benefits, social and psychological benefits, and planning and design (Sadeghian & Vardanyan, 2013). 	Lake/pond <ul style="list-style-type: none"> the shores can be developed into recreational spaces, becoming areas for relaxation, recreational activities, and ecological education platforms.
Pocket park <ul style="list-style-type: none"> neighborhood green spaces, including pocket parks of less than 5000 m², contribute to the health and well-being of residents (Baur & Tynon, 2010; Peschardt et al., 2012; Kerishnan & Maruthaveeran, 2021). 	River/ Estuary <ul style="list-style-type: none"> flowing water bodies with freshwater aquatic communities (or, in the case of estuaries, both freshwater and saltwater).
Botanical garden <ul style="list-style-type: none"> showcase plant species from different regions, providing a rich diversity of 	Sea coast <ul style="list-style-type: none"> area of contact between the sea and land, with diverse characteristics (e.g., sandy

Nature based solutions as tools for sustainable urban developments		Nature based solutions as tools for sustainable urban developments	
Green Infrastructure	Blue Infrastructure	Green Infrastructure	Blue Infrastructure
flora (Primack & Miller-Rushing, 2009).	beaches, cliffs, dunes).	there are green spaces on both banks of the river (Heggem et al., 2000).	2013).
Green parking lots <ul style="list-style-type: none">can be considered small heat islands and sources of pollutants from vehicles (Hahn & Pfeifer, 1994; Onishi et al., 2010).can lead to lower temperatures, improved water management, and better air quality.	Delta <ul style="list-style-type: none">as a complex aquatic ecosystem, the delta is vital in conserving biodiversity and providing shelter for numerous plant and animal species (Bánáduc et al., 2016).	Green balcony <ul style="list-style-type: none">it refers to plants on balconies and terraces, primarily planted in pots.	Daylighting streams <ul style="list-style-type: none">uncovering buried urban streams and restoring them to a natural state (e.g., Cheonggyecheon Stream in Seoul) (Hwang, 2004).
Community garden <ul style="list-style-type: none">is established in urban, suburban, or rural areas and is close to schools, hospitals, or residential areas (American Community Gardening Association, 2014);	Wetland <ul style="list-style-type: none">is essential for water purification and flow regulation, filtering pollutants, preventing floods by controlling water levels, and reducing soil erosion (Erwin, 2009).	Street trees <ul style="list-style-type: none">streets with tree alignments can be up to 10 degrees cooler in the summer, and a mature, healthy tree has a cooling effect equivalent to two air conditioning units running 20 hours a day (Voinescu, 2020).	Riverbank stabilization with vegetation <ul style="list-style-type: none">using plants to prevent erosion instead of concrete embankments.
Green corridor <ul style="list-style-type: none">network that provides the community ecological, recreational, and cultural benefits (Ndubisi et al., 1995).	Swale <ul style="list-style-type: none">is relatively inexpensive to construct and maintain (Dillaha et al., 1986, cited by Delgado et al., 1995). Their primary purpose is to reduce water pollution by capturing and filtering heavy metals and chemicals.	Green playground/ school ground <ul style="list-style-type: none">the conversion of paved schoolyards by adding green spaces brings children closer to nature, stimulates daily physical activity, and supports social well-being (Raney et al., 2019).	Canal <ul style="list-style-type: none">help manage water flow to reduce flood risks and address drought conditions effectively.
Green roof <ul style="list-style-type: none">is classified into four categories: intensive, semi-intensive, single-layer extensive, and multi-layer extensive (Shafique et al., 2018).	Rain garden <ul style="list-style-type: none">is recommended as an effective solution for managing stormwater runoff and enhancing biodiversity in urban environments (Ishimatsu et al., 2017).	House garden <ul style="list-style-type: none">include areas around private homes, mainly cultivated for ornamental purposes or non-commercial food production.	Mangroves <ul style="list-style-type: none">protect coastlines from erosion and provide nursery habitats for marine species.
Green wall and facade <ul style="list-style-type: none">the „greening” of building facades represents one of the most effective solutions for energy savings in buildings and reducing the urban heat island effect (Perez et al., 2017).	Permeable pavements <ul style="list-style-type: none">are ideal for a range of applications, including residential, commercial, and industrial settings (Scholz & Grabowiecki, 2007).	Vertical greeneries (walls, ceilings) <ul style="list-style-type: none">plant selection must consider climate, building design, and context (Manso & Castro-Gomez, 2015).	Eco-friendly seawall <ul style="list-style-type: none">are designed to minimize environmental impact and enhance habitat potential compared to traditional designs (Fish Habitat Network, 2019).
Institutional green space <ul style="list-style-type: none">improve urban aesthetics by creating a pleasant contrast between vegetation and the architecture of the buildings.	Rainwater harvesting <ul style="list-style-type: none">in urban areas, rainwater harvesting involves capturing, collecting, storing, and treating rainwater from rooftops, terraces, courtyards, and other impervious surfaces for on-site use (Campisano et al., 2017)		
Riverbank green <ul style="list-style-type: none">a river with a width of 35 m can lead to a temperature decrease of approximately 1–1.5°C, and this decrease can be more pronounced if	Green roofs with water retention <ul style="list-style-type: none">help manage water flow to reduce flood risks and address drought conditions effectively (Graceson et al.,		

CONCLUSIONS

The analysis of the documents reveals the importance of nature-based solutions for the sustainable development of green and blue infrastructure in Romania. The analyzed legislative and strategic documents provide a comprehensive overview of the regulations and policies related to green and blue infrastructure, highlighting the importance of integrating it into local and national policies. This is recognised as a central element in environmental and urban planning policies at both the European and national levels in the context of global

challenges such as climate change and biodiversity loss.

The documents emphasise the role of green and blue infrastructure in protecting biodiversity, reducing natural risks, and improving quality of life. European strategies and national legislation promote the integration of these solutions into territorial planning and urban development. Even though not all local strategies explicitly mention the terms nature-based solutions, green infrastructure, or blue infrastructure, the concern for environmental issues and the sustainable use of natural resources is evident.

For a sustainable and resilient future in Romania, it is imperative to embrace and expand a variety of green and blue infrastructure types such as urban parks, wetlands, and green roofs. These solutions effectively manage water, enhance biodiversity, and contribute to sustainable urban development.

Therefore, it is necessary to emphasize the need for an integrated and multidimensional approach to urban development, which prioritises the protection of natural resources and the extensive implementation of nature-based solutions, thus coherently promoting green and blue infrastructure. The efficient integration of NBS in the urban environment brings significant ecological benefits, contributing to biodiversity conservation, sustainable water management, pollution reduction, and climate change mitigation. From an economic perspective, NBS and GBI can stimulate investments in ecological solutions, reduce costs through natural alternatives for grey infrastructure, and support the development of sustainable tourism. Last but not least, the social benefits should be considered in Romanian cities, including the improvement of quality of life through the creation of green spaces for recreation, the promotion of public health, and the increase of urban community resilience. Adopting a holistic perspective that combines environmental protection with economic and social considerations is fundamental to ensuring a sustainable and prosperous urban future in Romania.

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