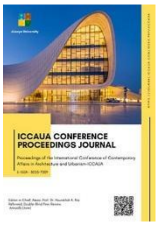

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Nature Based Solutions: A Sustainable Potential for Romanian Cities

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Abstract

This research explores the untapped potential of Romanian cities to become healthier and more resilient through adopting Nature–based Solutions (NbS). The analysis was based on the hypothesis that NbS, through the development of urban green and blue infrastructure (UGBI), influences public health and the quality of life of inhabitants. A qualitative methodology, relying on relevant literature analysis across environmental, health, social, and economic domains, was employed. The analysis classified the main types of NbS, ranging from architectural green infrastructures to blue areas and water–management systems, and identified the benefits they generate. As a result, the methodology highlights relevant advantages, organized according to their impact areas and their potential for the Romanian cities.
Keywords: Nature–based Solutions; urban resilience; sustainability.

1. Introduction

As the effects of climate change become increasingly pronounced, cities are confronted with ever more complex and growing challenges.

Future European cities are expected to expand green space and limit sprawl by densifying compact neighborhoods, while smart spatial and infrastructure design helps mitigate heat island effects, air pollution, and flooding (European Environment Agency et al., 2016). Growing urban challenges, from climate change and increasing car dependency to air pollution and the steady erosion of natural areas, have brought attention to the role of green and blue infrastructure and the ecosystem services it delivers.

Green and blue infrastructure is a consistent recurring theme across the literature, from European Commission policy documents to environmental research, each pointing to natural processes as a viable response to current urban challenges. The concept of green infrastructure first appeared in academic literature in 1995, when initial publications on the topic were recorded in the Scopus and Web of Science databases (Seiwert and Rößler, 2020).

Urban Green and Blue Infrastructure (UGBI) is defined as a strategic, planned network of natural and semi–natural areas, designed and managed to provide a wide range of ecosystem services (Veerkamp et al., 2021, European Environment Agency, 2017). While UGBI represents the network structure, Nature–Based Solutions (NbS) constitute the specific interventions (implementation pillars) that use natural processes to address societal, ecological, and economic challenges while simultaneously generating benefits for biodiversity (United Nations Environment Assembly, 2022).

Romanian context

In Romanian cities, uncontrolled urban expansion has led to a predominance of grey infrastructure (concrete, steel, and asphalt), resulting in an increase in impermeable surfaces (Ungureanu & Șoimoșan, 2023; Cocheci & Petrişor, 2023a, 2023b). Romanian cities are facing increasingly frequent extreme weather events, such as flash floods and prolonged heat waves. A critical issue is the use of outdated urban planning standards, which date back to the 1990s and do not account for built–up density in relation to new climate risks (Badiu et al., 2016).

The uncontrolled expansion of urban areas has led to a massive increase in impervious surfaces (asphalt and concrete), a process that severely disrupts the hydrological cycle and thermal balance (Pochodyła et al., 2021). This structural transformation has severely altered the urban water cycle: in modern cities, only about 10% of precipitation can still naturally infiltrate the soil, with the rest directed toward drainage systems that are often undersized (Pochodyła et al., 2021). This phenomenon accelerates the risk of flash flooding in urban areas and the deterioration of water quality (O'Donnell et al., 2017).

Another problem is the phenomenon of urban heat islands (UHIs): where man–made materials absorb and re–emit solar radiation, raising ambient temperatures (Ibric et al. 2024). Thus, the potential of implementing NbS (such as tree–lined streets and green roofs) can reduce these temperatures by up to 10°C through evapotranspiration and shading (Kumar et al., 2024; Li et al., 2024)

Under current Romanian law, there is no single legal definition of the UGBI, with regulations scattered across numerous legislative acts in fields such as the environment, urban planning, and water management (Ungureanu et al., 2024b), while NbS remain used only by some municipalities, as projects implemented through different EU financing mechanisms (Ungureanu et al., 2024a). Although the concept is mentioned in recent documents such as Romania's Urban Policy 2022–2035, its implementation in operational planning tools remains incomplete and fragmented (Government of Romania, 2022).

The ageing of the population represents a major societal transformation that requires the built environment to be adapted to support the health and well–being of older adults. Older adults are among the most vulnerable groups to extreme weather events, such as heat waves and air pollution (Feddersen and Lüdtke, 2009). Urban design must evolve toward an inclusive approach that integrates the specific accessibility and mobility needs of these vulnerable groups (Gilroy, 2021).

Research Hypothesis, Aim, and Objectives

The research hypothesis is grounded in the premise that the systemic integration of NbS into urban planning documentation will contribute not only to the strengthening of climate resilience but also to the improvement of the urban quality of life. Furthermore, it is assumed that making technical information accessible to non–specialists through digital tools constitutes a critical factor for the successful implementation of these solutions (Popa et al., 2025; Ungureanu et al., 2024b). The aim of the research is to develop a theoretical base for an implementation tool of NbS. This tool is intended to support local authorities and residents in identifying, evaluating, and selecting the most appropriate NbS for their communities (Ungureanu et al., 2024b).

The research objectives of the study are (1) to synthesize the typologies of viable NbS for the Romanian urban environment and to analyze their systemic benefits; (2) to critically analyze the national legislative framework in order to identify the legal and institutional barriers hindering the implementation of urban green and blue infrastructure; (3) to develop the basis for a transparent decision–making framework that could integrate the multiple perspectives of urban stakeholders through participatory e–planning tools for NbS implementation.

2. Materials and Methods

This study employed a qualitative, literature–based research methodology. It was structured around three complementary analytical layers. These included: (1) a systematic review of scientific literature; (2) a critical analysis of the national legislative and policy framework; and (3) a synthesis of international best practices with applicability to the Romanian urban context. This research employs a multi–layered, mixed–methodology approach designed to bridge the gap between theoretical frameworks and the practical implementation of Nature–based Solutions in Romanian urban environments.

In addition to these analytical layers, the methodology integrates specific research techniques: (1) "Research through Design" Approach: This technique was employed to evaluate NbS prototypes, providing insights into how these natural interventions can be physically integrated into the built environment; (2) Analysis of Urban Development Strategies: This procedure focused on identifying existing urban vulnerabilities—such as the uncontrolled expansion of impermeable surfaces—and searching for opportunities to enhance the connectivity of green and blue infrastructure at a metropolitan scale.

The goal of this methodological framework is to develop a theoretical base for an NbS implementation tool. This tool is intended to function as a transparent decision-making framework, supporting local authorities and residents in identifying, evaluating, and selecting the most appropriate solutions for their communities.

3. Results

3.1 Typology of Nature–based Solutions

The process of identifying and classifying NbS is a direct answer to the specific weaknesses of Romanian cities, including the uncontrolled expansion of impermeable surfaces such as asphalt and concrete, and the increasing frequency of extreme weather events.

The necessity for a clear, localized typology is further underscored by the current reliance on outdated urban planning standards dating back to the 1990s, which fail to account for modern climate risks or built-up density. Additionally, because Romanian regulations for UGBI remain fragmented across various legislative acts, there is a critical need for a unified technical inventory. This classification serves as a theoretical foundation for a decision-making tool intended to help local authorities and residents identify viable solutions adapted to the Romanian climate.

The study identifies thirteen distinct categories of NbS, ranging from architectural green infrastructure to water management systems, each evaluated for its technical diversity and contextual adaptability. The following tables detail these solutions, categorizing them by their primary functional impact (Table 1, Table 2, Table 3, Table 4).

Table 1: Building-Integrated NbS.

Type	Short description	Benefits	Romanian cities adaptability	Source
Green roof	Vegetation installed on building rooftops, typically supported by a thin growing substrate, with irrigation and maintenance requirements that vary depending on the system type	Contribute to improved building thermal performance, energy savings, cooling influence of vegetation through shading and evapotranspiration	A growing number of new commercial and office buildings in Romania feature green roofs	Bocanegra et al., 2024; Fiorentin et al., 2026;
Green wall and facade	A green wall consists of a vertical structure fixed to a wall, designed to support the direct growth of plants on its surface. A green facade is formed by vegetation that climbs and spreads across the outer surface of a wall, with plants generally rooted in the ground below.	Improve environmental performance and support psychological well–being by reducing stress, boosting mood, and enhancing cognitive function, improve the air quality	Are becoming increasingly prevalent in Romania, with a growing number of such systems being implemented across the country.	Husini et al., 2026; Free and Hanseatic City of Hamburg, Ministry for the Environment, Climate, Energy and Agriculture, 2020; Perez et al., 2017;
Green balcony and terraces	Refers to vegetation grown primarily in containers on private outdoor spaces.	Reduce stress, dust capture, reduce building temperatures, promote well–being	Are widespread in Romania at the individual level – especially in collective housing blocks – though no formal policy or programme currently supports them as a NbS.	Priya & Senthil, 2025; Mladenović et al., 2017;

Building-integrated solutions make efficient use of both vertical and horizontal surfaces in high-density urban environments. These interventions play a key role in enhancing energy efficiency by reducing heating and cooling demand while also mitigating the urban heat island effect.

Table 2: Social and Health-Oriented NbS.

Type	Short description	Benefits	Romanian cities adaptability	Source
Community garden	Collectively managed plots dedicated to the cultivation of food plants — including fruits, vegetables, and herbs — intended for the personal consumption of those who maintain them; typically, are maintained by local residents	Support community wellbeing by improving access to fresh food and strengthening social relationships	Community–led gardening initiatives exist in some of Romania's major cities, yet they operate in a legal grey area, as the current regulatory framework does not explicitly permit them	Egli et al., 2016; McKelvey, 2026; URBASOFIA et al., 2023;
Pocket parks	Small green spaces located between and around buildings, featuring ornamental trees, shrubs, and grass; they are commonly found in collective housing areas	Contribute to the health and wellbeing of residents; Time spent in nature has well–documented restorative effects, reducing stress and anxiety, improving concentration and cognitive recovery.	Are not formally recognised as a distinct green space typology under Romanian legislation. Despite this, efforts to promote and implement the concept are emerging	Jing et al., 2026; Kerishnan and Maruthaveera, 2021; Peschardt et al., 2012;
Therapeutic green spaces	A space purposefully designed to support therapeutic, rehabilitative, or skills–based programs	Promote comprehensive well–being, reduce social isolation	Romania's first therapeutic garden was established in 2014 within a healthcare facility. Another initiative involved creating a therapeutic garden at the Bucharest Oncology Institute to improve the patient experience during hospitalization.	Stepansky et al., 2023; Hazen, 1995;

These interventions serve as strategic social infrastructure. These are crucial for building community and offering accessible, restorative spaces that boost residents' mental health and older adults' independence.

Table 3: Stormwater and Hydrological NbS.

Type	Short description	Benefits	Romanian cities adaptability	Source
Rain garden	Address both stormwater runoff and urban biodiversity, making them relevant for dense city environments.	Effective solution for reducing flood risk, managing stormwater runoff, and enhancing biodiversity in urban environments.	The first rain garden in Bucharest will be developed in 2026 in one of the city's major parks. The concept is promoted by specialists in other cities across the country as a solution to problems caused by climate change.	Wu et al., 2026;
Vegetative filter strips	Shallow vegetated swales with a slight gradient, used to filter surface water.	Reduce soil erosion, improve water quality, reduce water pollution	Are not recognized as a distinct typology within Romanian legislation. Additionally, there is a lack of technical design standards specifically adapted to the Romanian urban context.	Luo et al., 2026; Laburda et al., 2025;
Infiltration basins	Broadly used stormwater control measures designed to manage urban runoff	Contribute to multiple ecosystem functions and services	In Romania, infiltration basins are an under–investigated option for urban stormwater management, even as flood risks rise due to rapid urbanization and climate change.	Natarajan & Davis, 2016;
Permeable pavements	Allow rainwater to infiltrate directly through their porous surfaces, without requiring additional land.	Reduce surface water runoff and accumulation, contribute to evaporative cooling of the surrounding area	Are gradually being recognized in Romania as a viable solution for urban stormwater management, particularly in urban flooding that is becoming more common.	Huang et al., 2025; Zhao et al., 2025; Zhou et al., 2024;

Nature-based solutions for managing water sustainably offer an alternative to traditional grey drainage systems. By facilitating natural infiltration and filtration, these solutions significantly reduce the risk of floods and the decline of water quality in Romanian cities.

Table 4: Connectivity and Linear NbS.

Type	Short description	Benefits	Romanian cities adaptability	Source
Green corridor	Interconnected networks that deliver ecological, recreational, and cultural benefits to urban communities.	Connect people with nature, reduce pollution, protect wildlife	Green corridors remain aspirational, present as plans and policy intentions rather than implemented projects, except for a few isolated initiatives.	Aman et al., 2022;
Green transport track	Tram or light rail tracks that are covered with greenery such as grass, or easy–care plants	Improve the aesthetic appeal and visual identity of the cityscape, reduce noise	Are gradually emerging in Romania; for example, the city of Arad has greened 5.5 km of tram corridors using sedum vegetation, covering an area of approximately 3 hectares.	Major et al., 2023; Sikorski et al., 2018;
Riparian buffer zones	Vegetated zones preserved or established alongside rivers and streams	Reduce pollutants, improve water quality, support biodiversity	Romania's riparian zones face ongoing pressure from fragmented land ownership and limited coordination of waterway management.	Dala–Corte et al., 2026; Han et al., 2025;

Linear NbS are important for linking city green and blue spaces. These networks offer urban wildlife refuge and provide people places to relax and enjoy.

3.2 Benefits of Nature–based Solutions organized by impact area

NbS generate a wide, interconnected range of ecosystem services. These services help address the major challenges cities face in sustainable development. This study reviews the literature on NbS and examines its potential in Romanian cities. Four core domains of influence emerged: environmental, public health and well–being, social and economic.

Environmental

The implementation of NbS generates a significant ecological impact, functioning as a critical mechanism for climate change adaptation and mitigation in urban environments. From a thermal perspective, extensive vegetation and tree cover help mitigate the urban heat island effect by providing shade and enhancing evapotranspiration (Ibric et al., 2024). NbS also plays a direct role in carbon sequestration and the enhancement of air quality, as vegetation filters airborne pollutants and traps dust particles, supporting a sustainable local ecological balance.

Public health and well–being

The integration of NbS into urban planning in Romania extends beyond ecological objectives, emerging as a strategic necessity for public health and the systemic well–being of the population. This category holds the largest concentration of direct benefits influencing the everyday quality of life of city residents.

One of the most pressing benefits is the mitigation of the urban heat island effect, whereby abundant vegetation and tree canopies can lower perceived temperatures, thereby reducing the risk of heat–related mortality during extreme heat waves, particularly among vulnerable groups such as children and the elderly (Irfeey et al., 2023; Oleson et al.,2015). The mental health benefits of accessible green spaces, such as pocket parks and community gardens, are well–documented, ranging from reduced anxiety and depression to support for cognitive health in ageing populations (Kabisch et al., 2017; Viti et al., 2022).

Social

The integration of NbS into urban environments acts as an essential catalyst for social cohesion and community well–being, transforming public spaces into active facilitators of interaction and inclusion (Mell, 2019). Community gardens, for instance, transcend their basic food production role, becoming strategic instruments for fostering neighborhood solidarity and community spirit. Beyond direct interaction, NbS contributes to strengthening cultural identities and cultivating a deep sense of belonging, a fundamental dimension of social resilience in the face of accelerating urbanization (Pagano et al., 2019).

Economic

Implementing NbS across Romanian cities demands a broader evaluative framework — one that goes beyond ecological gains to recognize NbS as a fundamental component of urban economic efficiency, capable of generating lasting financial savings and attracting new investment (Popa et al., 2025; Viti et al., 2022). Studies on costs repeatedly indicate that green–blue infrastructure approaches are often cheaper and more sustainable than traditional ‘grey’ methods (Nesshöver et al., 2017). These grey methods, such as oversized drainage systems, impose a substantial financial burden on public budgets due to their construction and maintenance. NbS like green roofs and facades enhance building thermal efficiency, significantly lowering heating and cooling energy costs, while also increasing property values and the aesthetic appeal of urban areas (Perez et al., 2017; Shafique et al., 2018).

4. Discussions. How to implement NbS and UGBI in the Romanian context?

Romania is undergoing a transition from a sectoral regulatory model towards an integrated one, with national efforts increasingly orientated towards alignment with the European Green Deal and the EU Biodiversity Strategy for 2030 (European Commission, 2020; Ciot, 2021). Programmatic documents such as Romania's Urban Policy 2022–2035 actively promote the concept of resilient cities; however, their transposition into operational legal instruments remains fragmented across urban planning, environmental, and water resource management authorities (Ungureanu aet al., 2024a). A significant impetus is provided by the conditionalities attached to the National Recovery and Resilience Plan (Component 10), which require the integration of urban green and blue infrastructure in GIS format within the processes of updating urban planning documentation.

On institutional and legislative challenges, our research has identified the absence of a unified legal definition for NbS and UGBI within the national legislation. We have identified relevant concepts dispersed across normative acts that employ inconsistent terminology. For example, a future legislative act, the Code for Spatial Planning, Urbanism, and Construction (CATUC) introduces the definition for ‘green network’, but its scope remains limited, with explicit references to ecosystem services and public health missing. Moreover, the current quantitative standards (e.g., 6–15 sqm of green space per inhabitant), based on norms developed prior to 2000, are considered outdated in relation to contemporary climate risks (Wokan et al., 2026; Badiu et al., 2016).

Barriers to Adoption: Financial and Technical Constraints

On an international level, the implementation of NbS is constrained by the scarcity of demonstration pilot projects capable of providing local evidence on cost–effectiveness relative to conventional grey infrastructure (O'Donnell et al., 2017; Perales–Momparler et al., 2017). Local authorities remain cautious due to the long–term maintenance costs associated with technology–intensive solutions such as green facades and green roofs (Suszanowicz and Kolasa–Więcek, 2019). At a national level, we also identified the data fragmentation and the absence of a nationally interoperable GIS system, which together impede strategic planning and the active monitoring of urban natural heritage (Popa et al., 2025; Ungureanu et al., 2024a; Ungureanu, 2019).

Recommendations for Policy and Planning

The transition from a fragmented regulatory model to an integrated one requires immediate normative action. Urban green and blue infrastructure along with NbS must be transformed from a theoretical concept into an operational instrument. Our study has shown that current quantitative and qualitative standards require fundamental revision. The outdated norms prescribing 6 to 15 square meters of green space per inhabitant should be replaced by standards that correlate built density with local climate risks (Bertassello et al., 2026). Based on European examples, our recommendations are in favor of the adoption of the 3–30–300 rule: three visible trees from every dwelling, thirty per cent canopy cover at the neighborhood level, and a maximum distance of three hundred meters to the nearest green space. This would help ensure an equitable distribution of benefits across urban areas. Ecological performance indicators must also be embedded within the regulatory framework. Local Urban Regulations associated with General Urban Plans and Zonal Urban Plans should incorporate mandatory parameters (Ungureanu and Șoimoșan, 2023). Some of the important parameters we observed and present potential for the Romanian local context are the permeability coefficient, stormwater retention capacity, and the percentage of stratified vegetation cover.

Digitalization and GIS–based monitoring represent a further priority. In accordance with the conditionalities of the National Recovery and Resilience Plan, integrating urban green and blue infrastructure and NbS in GIS format within urban planning documentation is imperative. The integrations would enable real–time monitoring of urban green areas and the analysis of the ecosystem services they provide (Tache et al., 2023a; Tache et al., 2023b).

For the future, we consider the importance of legal clarification within the next Code for Spatial Planning, Urbanism, and Construction. Definitions such as that of the "green network" or NbS must be refined to encompass urban health and climate resilience. Doing so would provide predictability for both public and private stakeholders.

Considering NbS and UGBI from a social and health aspect for Romanian cities

Urban green and blue infrastructure must be recognized not merely as ecological infrastructure but as critical social infrastructure and an integral aspect of public health strategies.

Our research has identified 3 main aspects that should be taken in account when implementing NbS with social and health in mind: (1) *ageing–in–place* and child health strategies have to integrate NbS and be part of UGBI, elements such as shaded pathways, strategically placed seating, and accessible ramps not only support the independence of older adults and help counteract social isolation but also contribute to a better quality of life (Feddersen and Lüdtke, 2009; Gilroy, 2021); (2) *community engagement* has been identified as an important aspect in the success of NbS implementation, the social acceptance of non–specialists implies the clear understanding of benefits NbS can bring in their neighborhood (O'Donnell et al., 2017); (3) implementing *pilot projects* can serve a dual function, on one part we have the educational aspect, where small–scale interventions raise community awareness of ecosystem service value but also encourage active participation (Rueda, 2019), but they also present a potential for the replicability of certain successful NbS into the city where outlet projects are tested.

5. Conclusions

The approach to implementing Nature–Based Solutions (NbS) and Urban Blue–Green Infrastructure (UGBI) in the Romanian urban context requires conceptual rigor and a solid scientific foundation, given the complexity of ecosystem services and the fragmented legislative framework.

The research highlights thirteen distinct categories of NbS—including green roofs, rain gardens, and riparian buffer zones—that demonstrate significant contextual adaptability for Romanian cities. These interventions have the potential to generate a wide range of interconnected benefits across four core domains: environmental (climate adaptation), public health (heat mitigation and mental well-being), social (community cohesion), and economic (cost-effectiveness over traditional grey infrastructure). However, a persistent implementation gap exists due to fragmented legislation and the absence of unified legal definitions for NbS within national frameworks like the current building codes.

Despite these constraints, the research identifies significant opportunities. Romania's National Recovery and Resilience Plan (Component 10) and its adherence to the European Green Deal and the EU Biodiversity Strategy for 2030 offer the necessary authority and funding to speed up the shift to integrated urban green–blue infrastructure. Implementing performance–based standards, like the 3–30–300 rule, could represent one possible operational framework.

The findings support the study's initial hypothesis that the systemic integration of NbS into urban planning is critical to strengthening climate resilience and improving quality of life. By achieving the research objectives, this study: (1) Synthesized viable typologies for the Romanian context, providing a technical inventory for practitioners; (2) Identified institutional barriers, specifically the reliance on outdated 1990s quantitative standards that fail to account for modern climate risks; (3) Established conceptual criteria that may support the future development of a transparent decision-making tool intended to support local authorities in selecting appropriate interventions.

By integrating a "research through design" approach with legislative analysis, the study provides a multidimensional framework that addresses the unique socio-economic and regulatory landscape of Romania and may provide insights applicable to other Eastern European nations facing similar urban challenges.

Future Research Directions

As seen in our study, the current Romanian quantitative and qualitative standards for urban green space, many of which date from the 1990s, are no longer adequate. We aim to further research the opportunity of implementation of new norms that correlate built density with local climate risks and the demand for ecosystem services. These new standards should move beyond the usual quantitative metrics, such as area–per–capita and reflect the importance of NbS and UGBI as key infrastructure in the urban system.

Another possible research direction we have identified involves the performance management and integrated design of NbS. In order to inform and convince the public about the benefits of NbS, there is a need for long–term monitoring of NbS and UGBI projects. Continuous performance tracking enables the assessment of technical outcomes and allows maintenance strategies to be adapted on the basis of field results. Without such systems, it remains difficult to determine whether interventions are meeting their intended goals.

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Conflicts of Interest

The authors report no conflicts of interest.

Data Availability Statement

No new data were created or analyzed in this study; all sources are cited within the article.

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Reference

Aman, A., Rafiq, M., Dastane O., & Sabir, A. A. (2022). Green corridor: A critical perspective and development of research agenda. *Frontiers in Environmental Science*, 10. https://doi.org/10.3389/fenvs.2022.982473

Badiu, D. L., Iojă, C. I., Pătroescu, M., Breuste, J., Artmann, M., Niță, M. R., Grădinaru, S. R., Hossu, C. A., & Onose, D. A. (2016). Is urban green space per capita a valuable target to achieve cities' sustainability goals? Romania as a case study. *Ecological Indicators*, 70, 53–66. https://doi.org/10.1016/j.ecolind.2016.05.044

Bertassello, L. E., van der Velde, M., Maes, J., Liu, S., Brandt, M., & Feyen, L. (2026). Assessing European cities with the 3–30–300 rule underscores the need for enhanced urban greening efforts. *Nature Communications*, 17, 4846. https://doi.org/10.1038/s41467–026–71523–8

Bocanegra, J. A., Scarpa, F., Bianco, V., & Tagliafico, L. A. (2024). Feasibility of green roofs in the mediterranean region: A stochastic study using a Monte–Carlo financial model. *Energy*, 309, 132995. https://doi.org/10.1016/j.energy.2024.132995

Ciot, M.–G. (2021). On European Green Deal and sustainable development policy (the case of Romania). *Sustainability*, 13(21), 12233. https://doi.org/10.3390/su132112233

Cocheci, R.–M., & Petrișor, A.–I. (2023a). Extended suburbanisation and land cover dynamics in post–socialist metropolitan areas: Evidence from Romania. d*isP – The Planning Review*, 59(2), 88–102. https://doi.org/10.1080/02513625.2023.2257490

Cocheci, R.–M., & Petrișor, A.–I. (2023b). Assessing the negative effects of suburbanization: The urban sprawl restrictiveness index in Romania's metropolitan areas. *Land*, 12(5), 966. https://doi.org/10.3390/land12050966

Dala–Corte, R. B., Giam, X., & Wilcove, D. S. (2026). Assessing the effectiveness of riparian buffers in protecting biodiversity: a meta–analysis. *Nature Communications*, 17(1), 4155. https://doi.org/10.1038/s41467–026–70191–y

Egli, V., Oliver, M., & Tautolo, E. S. (2016). The development of a model of community garden benefits to wellbeing. *Preventive Medicine Reports*, 3, 348–352. https://doi.org/10.1016/j.pmedr.2016.04.005

European Commission. (2020). *EU biodiversity strategy for 2030: Bringing nature back into our lives* (COM (2020) 380 final). EUR-Lex.

European Environment Agency. (2016). *Urban adaptation to climate change in Europe 2016: Transforming cities in a changing climate*. Publications Office of the European Union. https://doi.org/10.2800/021466

European Environment Agency. (2017). *Green infrastructure and flood management: Promoting cost–efficient flood risk reduction via green infrastructure solutions* (EEA Report No. 14/2017). Publications Office of the European Union.

Feddersen, E., & Lüdtke, I. (2009). *Living for the elderly: A design manual*. Birkhäuser. https://doi.org/10.1515/9783035609769

Fiorentin, D. P., Rafael, S., & Quinteiro, P. (2026). Environmental sustainability of green roofs in urban areas. *Environmental Impact Assessment Review,* 118, 108270. https://doi.org/10.1016/j.eiar.2025.108270

Free and Hanseatic City of Hamburg, Ministry for the Environment, Climate, Energy and Agriculture. (2020). *Manual green walls: On the walls – ready – green! Façade greening in Hamburg*. https://www.hamburg.com/resource/blob/1057970/2e371f779846efd8f7b012ab2f4d63fc/d–manual–green–walls–data.pdf

Gilroy, R. (2021). *Planning for an ageing society.* Lund Humphries.

Government of Romania. (2022). National Strategy for Integrated Urban Development for Resilient, Green, Inclusive and Competitive Cities 2022–2035: Romania's Urban Policy. Government of Romania.

Han, H., Yan, X., Li, X., Huang, Z., Yan, X., & Xia, Y. (2025). Significant differences in optimal riparian buffer zone on water quality between different segments within the same river. *Journal of Environmental Management*, 381, 125306. https://doi.org/10.1016/j.jenvman.2025.125306

Hazen, T. (1995). Therapeutic garden characteristics. *American Horticultural Therapy Association Newsletter*, 41(2). https://irp.cdn–website.com/c876b665/files/uploaded/therapeuticgardencharacteristics_ahtareprintpermission.pdf

Huang, P., Zhang, K., & Chui, T. F. M. (2025). Hydrologic performance of permeable pavements under extreme and regular rainfall conditions. *Journal of Hydrology*, 652, 132653. https://doi.org/10.1016/j.jhydrol.2024.132653

Husini, E. M., Idris, M. M., Manaf, A. A., Ismail, N. H., & Khasanov, A. (2026). Green wall facade and IOT–based system for optimal indoor environment of 'sakinah'in living. *Planning Malaysia*, 24. https://doi.org/10.21837/pm.v24i41.2004

Ibric, A., Bostenaru Dan, M., & Crăciun, C. (2024). Adapting street profile design by using Nature–Based Solutions in new neighbourhoods and the retrofit of buildings. *Buildings*, *14*(7), 1920. https://doi.org/10.3390/buildings14071920

Irfeey, A. M. M., Chau, H. W., Sumaiya, M. M. F., Wai, C. Y., Muttil, N., & Jamei, E. (2023). Sustainable mitigation strategies for urban heat island effects in urban areas. *Sustainability*, 15(14), 10767. https://doi.org/10.3390/su151410767

Ishimatsu, K., Ito, K., Mitani, Y., Tanaka, Y., Sugahara, T., & Naka, Y. (2017). Use of rain gardens for stormwater management in urban design and planning. *Landscape and Ecological Engineering*, 13, 205–212. https://doi.org/10.1007/s11355–016–0309–3

Jing, C., Zhou, W., Huang, G., Zhang, Z., Yan, J., Jiang, Y., & Xu, Z. (2026). Beyond urban parks: Integrating residential greenspaces to address greenspace inequality. *Cities,* 168, 106432. https://doi.org/10.1016/j.cities.2025.106432

Kabisch, N., van den Bosch, M., & Lafortezza, R. (2017). The health benefits of nature–based solutions to urbanization challenges for children and the elderly – A systematic review. *Environmental Research,* 159, 362–373. https://doi.org/10.1016/j.envres.2017.08.004

Kerishnan, P. B., & Maruthaveeran, S. (2021). Factors contributing to the usage of pocket parks―A review of the evidence. *Urban Forestry & Urban Greening*, 58, 126985. https://doi.org/10.1016/j.ufug.2021.126985

Kumar, P., Debele, S. E., Khalili, S., Halios, C. H., Sahani, J., Aghamohammadi, N., Andrade, M. de F., Athanassiadou, M., Bhui, K., Calvillo, N., Cao, S.–J., Coulon, F., Edmondson, J. L., Fletcher, D., Freitas, E. D. de, Guo, H., Hort, M. C., Katti, M., Kjeldsen, T. R., … Jones, L. (2024). Urban heat mitigation by green and blue infrastructure: Drivers, effectiveness, and future needs. *The Innovation*, 5(2). https://doi.org/10.1016/j.xinn.2024.100588

Laburda, T., Zumr, D., Devátý, J., Ray, S. S., Koudelka, P., Krása, J., Dostál, T., & Schwartz, J. S. (2025). Efficiency of vegetative filter strips in mitigating soil erosion and surface runoff. *Land Degradation and Development*, 36(14), 4845–4859. https://doi.org/10.1002/ldr.5671

Li, H., Zhao, Y., Wang, C., Ürge–Vorsatz, D., Carmeliet, J., & Bardhan, R. (2024). Cooling efficacy of trees across cities is determined by background climate, urban morphology, and tree trait. *Communications Earth & Environment,* 5(1), 754. https://doi.org/10.1038/s43247–024–01908–4

Luo, M., Pan, C., & Xiao, L. (2026). Experimental study on sediment trapping by vegetated filter strips under successive runoff events: effects of pre–existing sediment deposition. *Hydrology Research,* 57(3), 566–585. https://doi.org/10.2166/nh.2026.165

Major, Z., Szigeti, C., & Czédli, H. M. (2023). "Green" Tram Tracks for the Sustainability of the Urban Environment. *Chemical Engineering Transactions*, 107, 289–294. https://doi.org/10.3303/CET23107049

McKelvey, B. (2026). *Community Gardening Toolkit: a resource for planning, enhancing and sustaining your Community Gardening Project (MP906).* University of Missouri Extension.

Mell, I. (2019). *Green infrastructure planning: Reintegrating landscape in urban planning*. Lund Humphries Publishers Ltd.

Mladenović, E., Lakićević, M., Pavlović, L., Hiel, K., & Padejčev, J. (2017). Opportunities and benefits of green balconies and terraces in urban conditions. *Contemporary Agriculture*, 66(3–4), 38–45. https://doi.org/10.1515/contagri–2017–0017

Natarajan, P., & Davis, A. P. (2016). Ecological assessment of a transitioned stormwater infiltration basin. *Ecological Engineering*, 90, 261–267. https://doi.org/10.1016/j.ecoleng.2016.01.029

Ndubisi, F., DeMeo, T., & Ditto, N. D. (1995). Environmentally sensitive areas: a template for developing greenway corridors. *Landscape and Urban Planning*, 33(1–3), 159–177. https://doi.org/10.1016/0169-2046(94)02016-9

Nesshöver, C., Assmuth, T., Irvine, K. N., Rusch, G. M., Waylen, K. A., Delbaere, B., Haase, D., Jones–Walters, L., Keune, H., Kovacs, E., Krauze, K., Külvik, M., Rey, F., van Dijk, J., Vistad, O. I., Wilkinson, M. E., & Wittmer,

H. (2017). The science, policy and practice of nature–based solutions: An interdisciplinary perspective. *Science of The Total Environment,* 579, 1215–1227. https://doi.org/10.1016/j.scitotenv.2016.11.106

O'Donnell, E. C., Lamond, J. E., & Thorne, C. R. (2017). Recognising barriers to implementation of Blue–Green Infrastructure: A Newcastle case study. *Urban Water Journal*, 14(9), 964–971. https://doi.org/10.1080/1573062X.2017.1279190

Oleson, K. W., Monaghan, A., Wilhelmi, O., Barlage, M., Brunsell, N., Feddema, J., Hu, L., & Steinhoff, D. F. (2015). Interactions between urbanization, heat stress, and climate change. *Climatic Change*, 129, 525–541. https://doi.org/10.1007/s10584–013–0936–8

Pagano, A., Pluchinotta, I., Pengal, P., Cokan, B., & Giordano, R. (2019). Engaging stakeholders in the assessment of NBS effectiveness in flood risk reduction: A participatory System Dynamics Model for benefits and co–benefits evaluation. *Science of The Total Environment*, 690, 543–555. https://doi.org/10.1016/j.scitotenv.2019.07.059

Perales–Momparler, S., Andrés–Doménech, I., Hernández–Crespo, C., Vallés–Morán, F., Martín, M., Escuder–Bueno, I., & Andreu, J. (2017). The role of monitoring sustainable drainage systems for promoting transition towards regenerative urban built environments: a case study in the Valencian region, Spain. J*ournal of Cleaner Production*, 163, S113–S124. https://doi.org/10.1016/j.jclepro.2016.05.153

Pérez, G., Coma, J., Sol, S., & Cabeza, L. F. (2017). Green facade for energy savings in buildings: The influence of leaf area index and facade orientation on the shadow effect. *Applied Energy*, 187, 424–437. https://doi.org/10.1016/j.apenergy.2016.11.055

Peschardt, K. K., Schipperijn, J., & Stigsdotter, U. K. (2012). Use of Small Public Urban Green Spaces (SPUGS). Urban *Forestry & Urban Greening*, 11(3), 235–244. https://doi.org/10.1016/j.ufug.2012.04.002

Pochodyła, E., Glińska–Lewczuk, K., & Jaszczak, A. (2021). Blue–green infrastructure as a new trend and an effective tool for water management in urban areas. *Landscape Online*, 92, 1–20. https://doi.org/10.3097/LO.202192

Popa, A.–C., Ungureanu, T., Dragomir, C–S., & Tache, A.–V. (2025), Nature–Based Solutions for the Sustainable Development of Green and Blue Infrastructure in Romania, *Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering*, 14, 578-585.

Priya, U. K., & Senthil, R. (2025). Influence of balcony greenery on indoor temperature reduction in tropical urban residential buildings. *Energy and Buildings,* 343, 115915. https://doi.org/10.1016/j.enbuild.2025.115915

Rueda, S. (2019). Superblocks for the design of new cities and renovation of existing ones: Barcelona's case. In M. Nieuwenhuijsen & H. Khreis (Eds.), Integrating human health into urban and transport planning (pp. 135–153). Springer. https://doi.org/10.1007/978–3–319–74983–9_8

Seiwert, A., & Rößler, S. (2020). Understanding the term green infrastructure: origins, rationales, semantic content and purposes as well as its relevance for application in spatial planning. *Land Use Policy*, *97*, 104785. https://doi.org/10.1016/j.landusepol.2020.104785

Shafique, M., Kim, R., Rafiq, M. (2018). Green roof benefits, opportunities and challenges – A review, *Renewable and Sustainable Energy Reviews*, 90, 757–773. https://doi.org/10.1016/j.rser.2018.04.006

Sikorski, P., Wińska–Krysiak, M., Chormański, J., Krauze, K., Kubacka, K., & Sikorska, D. (2018). Low–maintenance green tram tracks as a socially acceptable solution to greening a city. *Urban Forestry & Urban Greening*, 35, 148–164. https://doi.org/10.1016/j.ufug.2018.08.017

Stepansky, K., Delbert, T., & C. Bucey, J. (2023). Therapeutic Impact of Engagement in Green Spaces. In Urban Horticulture – Sustainable Gardening in Cities. *IntechOpen eBooks*. https://doi.org/10.5772/intechopen.1001148

Suszanowicz, D., & Kolasa Więcek, A. (2019). The impact of green roofs on the parameters of the environment in urban areas. *Atmosphere*, *10*(12), 792. https://doi.org/10.3390/atmos10120792

Tache, A.–V., Popescu, O.–C., & Petrişor, A.–I. (2023a). Conceptual model for integrating the green–blue infrastructure in planning using geospatial tools: Case study of Bucharest, Romania metropolitan area. *Land*, 12(7), 1432. https://doi.org/10.3390/land12071432

Tache, A.–V., Popescu, O.–C., & Petrişor, A.–I. (2023b). Analytical model of green–blue connectivity in the metropolitan area of Bucharest. *Present Environment and Sustainable Development,* 17(2), 153–164. https://doi.org/10.47743/pesd2023172012

United Nations Environment Assembly. (2022). *Resolution 5/5: Nature-based solutions for supporting sustainable development (UNEP/EA.5/Res.5)*. United Nations Environment Programme.

Ungureanu, T., Popa, A.–C., Tache, A.–V., & Simion, A. (2024a). Integration of nature and city: A strategic approach to green–blue infrastructure in Râmnicu Vâlcea. *Proceedings of the Conference on Construction Research, Construction Economics, Urban Planning, and Land Use Planning*, *26*, 57–62.

Ungureanu, T., Popa, A. C., & Dragomir, C.–S. (2024b). Evaluating green and blue infrastructure in urban areas in Romania: A methodological approach. *Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering*, 13, 362-371.

Ungureanu, T., & Șoimoșan, T. M. (2023). An integrated analysis of the urban form of residential areas in Romania. *Buildings,* 13(10), 2525. https://doi.org/10.3390/buildings13102525

Ungureanu, T. (2019). The potential of City Information Modeling (CIM) in understanding and learning from the impact of urban regulations on residential areas in Romania. *Conference Proceedings of eLearning and Software for Education (eLSE)*, *15*(1), 422–428. https://doi.org/10.12753/2066–026X–19–057

URBASOFIA, ADI Zona Metropolitană Cluj, Asociația Societatea Organizată Sustenabil – S.O.S., Asociația Clujul Sustenabil, & Roman A. (2023). Local public policy proposal for community gardens [in Romanian]. proGIreg Horizon 2020 Project. https://www.clujmet.ro/wp–content/uploads/2024/04/PPP–gradinarit–urban.pdf

Veerkamp, C. J., Schipper, A. M., Hedlund, K., Lazarova, T., Nordin, A., & Hanson, H. I. (2021). A review of studies assessing ecosystem services provided by urban green and blue infrastructure. *Ecosystem Services*, 52, 101367. https://doi.org/10.1016/j.ecoser.2021.101367

Viti, M., Löwe, R., Sørup, H. J. D., Rasmussen, M., Arnbjerg–Nielsen, K., & McKnight, U. S. (2022). Knowledge gaps and future research needs for assessing the non–market benefits of Nature–Based Solutions and Nature–Based Solution–like strategies. *Science of The Total Environment*, 841, 156636. https://doi.org/10.1016/j.scitotenv.2022.156636

Watkin, L. J., Ruangpan, L., Vojinovic, Z., Weesakul, S., & Torres, A. S. (2019). A Framework for Assessing Benefits of Implemented Nature–Based Solutions. *Sustainability*, 11(23), 6788. https://doi.org/10.3390/su11236788

Wokan, A., Iordache, M., Gaica, I., & Herbei, M. V. (2026). Proximity–based accessibility of urban green spaces using WHO indicators in Timișoara, Romania: Spatial distance, walking time, and green space area per capita. *Sustainability*, *18*(3), 1651. https://doi.org/10.3390/su18031651

Wu, Z., Li, S., Liu, Y., Mattoon, E. C., Al–Farsi, M. Z., Her, Y., Chen, J., Feng, X., & Jaber, F. H. (2026). Improvement of simulating rain gardens to advance sustainable stormwater management. *Journal of Environmental Management,* 401, 128853. https://doi.org/10.1016/j.jenvman.2026.128853

Zhao, J., Lu, J., Ge, J., Fan, Y., Wang, H., Gu, M., Xue, Y., Zhao, Y., Lv, G., Lin, H., Zhao, K., & Luo, X. (2025). Influences of permeable pavements with different hydraulic properties on evaporative cooling and outdoor thermal environment: Field experiments. *Building and Environment,* 270, 112525. https://doi.org/10.1016/j.buildenv.2025.112525

Zhou, J., Pang, Y., Du, W., Huang, T., Wang, H., Zhou, M., & Liu, J. (2024). Review of the development and research of permeable pavements. *Hydrological Processes*, 38(6), e15179. https://doi.org/10.1002/hyp.15179