AIMS Environmental Science

AIMS Environmental Science, 10(5): 677–690.
DOI: 10.3934/environsci.2023037
Received: 14 August 2023
Revised: 15 October 2023
Accepted: 23 October 2023
Published: 31 October 2023

http://www.aimspress.com/journal/environmental

Review

A comprehensive review of nature-based solutions: current status and future research

Hongpeng Fu*

School of Engineering, Northeastern University, Seattle, WA, 98122, USA

*** Correspondence:** fuhppku@163.com; Tel: +19292896695.

Abstract: Climate change and the rapid development of cities have brought considerable challenges to the sustainable development of urban and rural areas, and using nature-based solutions to strengthen ecosystems' resilience and response capacity has become a consensus strategy. Natural solutions are the collective name for all solutions that increase the city's resilience while benefiting the environment and humanity. To deepen the theoretical research and practical development of NBS, I reviewed 87 papers on NBS through the Web of Science database. The study found that NBS-related research mostly focuses on five aspects: Concept of ideas, applied technology, implementation guidelines, performance evaluation and platform building. Currently, the emphasis is predominantly on ideas and platform development in developed countries. While the other three domains were also explored, they primarily adhere to conventional methodologies and content within the NBS context. While NBS research covered many areas and boasts an integrative, collaborative approach, it remained fragmented and lacked a cohesive system. On this basis, I proposed a systematic framework to strengthen the systematicity of the NBS system, give full play to the unique advantages of NBS as a comprehensive concept and promote the specific implementation and development of NBS. I examined NBS's progression and benefits, providing a thorough insight into its significance in sustainable urban development. The research introduced a cohesive framework by elucidating NBS's foundational concepts guiding subsequent inquiries. Such findings are pivotal for facilitating informed strategies and enhancing resilience to climate adversities, underscoring a comprehensive approach to sustainability.

Keywords: sustainable development goals; nature-based solutions; sustainable development; Ecosystem services; review

1. Introduction

The combined effects of rapid socio-economic development and climate change, among other factors, pose significant threats to the sustainable development of human societies. Overconsumption of resources, severe environmental pollution and accelerated degradation of ecosystems have all contributed to recognizing urban and rural sustainability as global wicked problems [1]. Due to a lack of effective countermeasures, many scholars advocate for adopting nature and ecosystem-based approaches to transform urban and rural areas, enhancing these systems' resilience and adaptive capacities [2,3]. Scholars have researched and applied numerous ecosystem-based methods to transform urban regions to boost ecological resilience [1]. In the 1980s, the United Nations Brundtland Commission defined "sustainable development"[2], which took a comprehensive approach to environmental conservation and human societal progress. Subsequently, fields of applied ecology and ecological economics introduced the concepts of "natural capital" and "ecosystem services"[3], reinforcing the understanding that humans can benefit from ecosystems. In 2000, the Convention on Biological Diversity presented the ecosystem approach [4]. This concept, together with ecosystem services, underscores that human welfare depends on the multifunctionality and resilience of natural ecosystems [3,4]. Building on this research, the concept of "Nature-Based Solutions" (NBS) emerged, promoting nature as a means to mitigate and adapt to climate challenges [5]. This idea encapsulates developments in related concepts but emphasizes balancing environmental, economic and social benefits in urban development [6].

NBS, which promotes nature as a means to address and adapt to climate challenges [5], is not a novel concept but represents a synthesis and evolution of previous ideas. It primarily focuses on balancing and considering multiple benefits in urban and rural development, including environmental, economic and social factors [3]. NBS has its roots in past concepts like green infrastructure [3,6], natural capital and ecosystem services [7–9], ecological design and design ecology [10,11] and the ecosystem approach [12] while also holding its unique positioning and advantages. NBS's potential to tackle environmental issues and socio-economic challenges is internationally recognized. However, current research on NBS is in its infancy, and a unified concept has not been established. The lack of a cohesive framework has limited the development of NBS [13].

Thus, we reviewed NBS research, outlining the current state of NBS concept perspectives, practical applications and benefit assessments. Based on this, a valuable framework for NBS is constructed, providing references for deepening theoretical research and practical development of NBS. I aim to address the following research questions: 1) How does the research currently define the concept of NBS? 2) On which aspects of NBS do current studies primarily focus? 3) How can the umbrella benefits of NBS be maximized? I delve into the evolution and benefits of NBS, offering a comprehensive understanding of its role in sustainable urban development. Highlighting NBS's historical roots, I present a structured framework that encapsulates its diverse research facets and steers future studies. The insights are crucial for urban and rural development stakeholders, enabling informed decisions and bolstering resilience against climate challenges while championing holistic sustainability.

2. Materials and methods

2.1. Data source

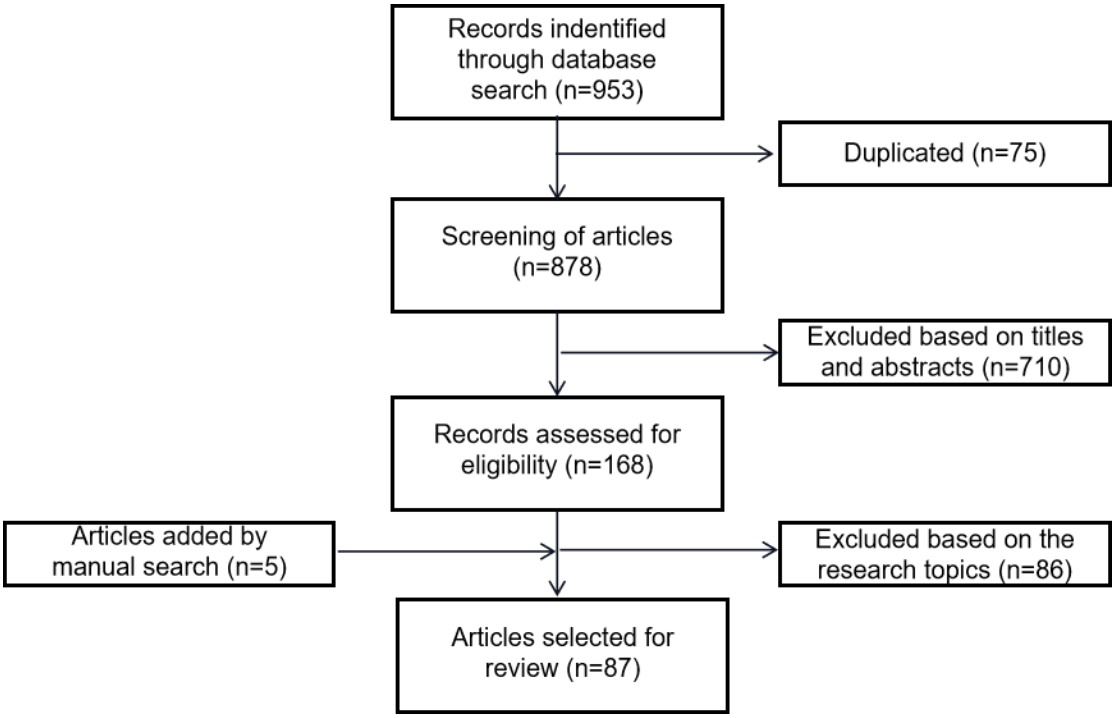

Figure 1. Flow diagram of the review process

The data for this study was sourced from the Web of Science database as of December 2021. Developed by the Institute for Scientific Information, the Web of Science is among the most comprehensive citation databases, featuring wide disciplinary coverage and significant impact [14]. Bibliometrics, utilized in this study, is a standard method in scientific research. An additional search using "nature-based solutions" as the theme and other keywords such as environment, economy, social, landscape and ecology retrieved 953 articles (Figure 1). A total of 168 papers were found with "nature-based solutions" according to the titles. After meticulous screening based on titles, abstracts and conclusions, we eliminated articles related to microbiology, polymer physics, hotel management and those misusing the terms "nature," "based" and "solutions." Ultimately, 87 articles formed the core repository for this study.

Each publication in our database was allocated a distinct identification number. I initially cataloged vital details for each paper, including the publication year, paper title, DOI, research context, focal country and research theme. To holistically understand NBS, this study discerned various aspects: Conceptual Viewpoints, Application Techniques, Implementation Guidelines, Performance Evaluation and Platform Construction. Building on this, I delineated the traits, merits and limitations of current NBS and proposed potential enhancements. In conclusion, the study offers a structured framework, emphasizing the foundational principles of NBS to guide further research.

2.2. Methodology

Bibliometrics offer insights into the dynamism of academic disciplines and is extensively applied to urban studies. CiteSpace is a visualization tool developed by Professor Chaomei Chen of Drexel University, capable of computing research frontier terminologies, identifying co-citation clusters and pinpointing research hotspots. Initially, I employed CiteSpace for visual analytics of critical terms and major participating countries in nature-based solutions research. While domestic scholars have previously delineated NBS trends [15], related concepts, implementation instances and proposed developmental recommendations for NBS [16,17], there remains a lacuna in systematic analyses of the current NBS. Consequently, further in-depth categorization and studies were conducted to discern the conceptual essence, practical applications and current status of NBS.

3. Results

Figure 2. Analysis of the countries of NBS studies.

Based on the analysis presented in Figure 2, which depicts the geographical distribution of NBS-related publications, it is evident that the bulk of NBS research is predominantly carried out in developed nations, with Europe, particularly countries like the UK and Italy, at the forefront of this academic pursuit. However, it is worth noting that developing countries also contribute to this field, though to a lesser extent, showcasing a global interest in NBS topics.

3.1. Conceptual analyses of natural-based solutions

Scholars have evident differences in the content and terminology of the NBS concept and definition. The International Union for Conservation of Nature (IUCN) initially defined NBS as "actions taken to protect, manage and restore natural or modified ecosystems that can effectively and adaptively address societal challenges while benefiting human well-being and biodiversity"[18]. In

2015, a multi-disciplinary expert team centered on the European Commission (EC) defined NBS as "solutions originating from and relying on nature, addressing various challenges adaptively and efficiently, ensuring simultaneous economic, social and environmental benefits"[3]. Besides natural protection and restoration, this definition emphasizes active nature management to obtain comprehensive benefits. Subsequently, other scholars also explored the concept of NBS. For instance, Van der Jagt defined NBS as multi-functional green interventions that achieve sustainable social, economic and environmental development [19]. Kronenberg believed that NBS is "deliberately using nature to help urban residents solve various problems and address environmental, social and economic challenges [20]." Among the many definitions, the ones proposed by IUCN and EC are frequently cited, with each emphasizing a different aspect. IUCN's definition stresses the importance of natural conservation and restoration, while the EC's definition considers the three pillars of sustainability, highlighting that economic development and ecological protection are not contradictory. The ambiguity in NBS concepts has made it challenging to establish standards and guidelines, hindering global implementation and assessment. In the future, there is an urgent need to integrate different perspectives to form a unified definition and connotation.

Table 1. Comparison of various definitions.

	IUCN	EC	Van der Jagt	Kronenberg	Maes
Rely on and utilize nature	√	√	√	√	√
Proactive management intervention	√	√	√		
Advocate human primacy		√		√	
Achieve comprehensive benefits	√	√	√	√	

Even though scholars currently do not have a unified definition for NBS, the core content is consistent, showcasing the advancement of the NBS concept (Table 1). This is mainly reflected in the following four aspects:

(1) Relying on and utilizing nature, natural-based solutions can supplement or replace human or industrial solutions. By sustainably investing in natural capital, climate change can be mitigated, human welfare improved and this approach is more efficient and sustainable than previous ones.

(2) Proactive management intervention. Unlike the previous concepts of natural restoration and protection, NBS emphasizes proactive management, making cities more resilient to climate change and disasters while realizing human well-being.

(3) Advocate for human primacy. Unlike the full coverage of previous planning and management, NBS is a concept centered on pursuing human interests and well-being, focusing on urban and rural areas where human activity is concentrated, with more targeted intervention and nature manipulation to seek human welfare.

(4) Achieve comprehensive benefits. NBS aims to introduce natural ecosystem service functions to repair, restore or even enhance urban ecological infrastructure, addressing the sustainable development challenges faced by cities, bringing beneficial results for urban economic development, environmental improvement and human health and realizing comprehensive benefits in society, economy and ecology.

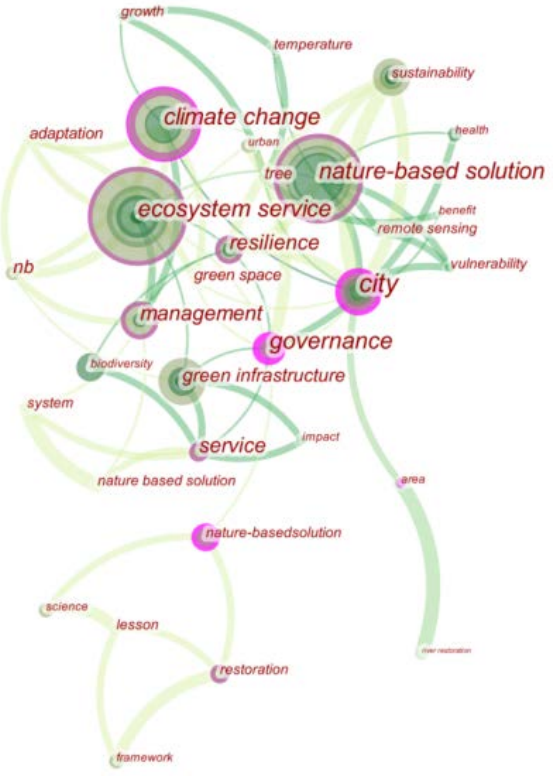

Figure 3. Keyword clustering analysis of NBS.

NBS encompasses existing conceptual frameworks and methods, demonstrating comprehensive and integrative advantages. NBS has evolved from existing concepts such as "blue-green infrastructure," "natural capital" and "ecosystem services," establishing a more extensive platform on the foundations of various concepts. The keyword clustering analysis of NBS (Figure 3) indicates that many scholars approach it from pre-existing concepts, comparatively analyzing the strengths and weaknesses of NBS. Principles and methods from existing concepts, such as sustainable development and blue-green infrastructure, serve as significant references for NBS. Moreover, there are opportunities for further application after integration based on principles and methodologies embedded within ecological adaptation, water catchment engineering and ecological engineering. Ecosystem services and ecosystem methods have unique emphases, with their principles and methods still needing further practical testing and evaluation. Essentially, principles and methods from various existing concepts are consolidated into one system. Integrating these methods can facilitate interdisciplinary collaborations, addressing societal issues holistically and proposing systematic solutions. However, the lack of integration among different methodologies leads to a complex and chaotic theoretical landscape, challenging its cohesive application and practice, thereby limiting NBS's genuine implementation in real-world scenarios.

Regarding potential implementation, NBS spans various sectors, involves diverse stakeholders and offers holistic benefits. Still, its practicality needs further validation and assessment. Many scholars have begun to explore the potential of NBS's subsequent implementation from its domains, stakeholders and benefits. NBS addresses ecological and societal challenges in various fields, aiming for human well-being. Its system touches upon food security, climate change mitigation and adaptation, urban sustainability, disaster risk management and enhancing ecosystem resilience. Some scholars

have preliminarily discussed the potential applications of NBS in coastal city development, water pollution, infrastructure and built environment needs and residents' mental health. Concerning stakeholders, it is emphasized that NBS should consider various factors from different stakeholders, promote interdisciplinary cooperation, and ensure its inclusivity. In terms of benefits, the academic community widely acknowledges the social, economic and ecological advantages of NBS, recognizing its potential to optimize synergies between nature, society and the economy. This approach creates more sustainable, economically competitive and inclusive solutions. Nonetheless, existing issues in NBS concepts and methods have limited its practicality. New research is urgently needed to understand its pros and cons better, improve its practicality and encourage its timely introduction to the field for in-depth evaluations.

3.2. Technical application of natural-based solutions

NBS, integrating previous technical methods, has shown potential in green infrastructure planning, urban renewal and ecological restoration. First, in refining green infrastructure planning with NBS, research continues from existing green infrastructure methodologies, incorporating biological and hydrological factors. For example, McFarland et al. used SWMM runoff simulations for Detroit, Michigan and Addis Ababa, Ethiopia, emphasizing the need to consider site biophysical characteristics, watershed positions and connectivity of existing urban water systems [21]. Second, using NBS to guide urban renewal, a study utilized the Data Envelopment Analysis model to assess the vulnerability of natural disasters in Chongqing's districts [22]. However, applying NBS as a technical method is only evident in its implementation. Furthermore, in adopting NBS as a pathway for ecological restoration, some scholars stress that ecological restoration should cater to benefits like flood protection and welfare improvement. For instance, based on NBS theories, Marie Luise Blau proposed that the Albufeira River restoration must satisfy such socio-economic advantages. However, while certain projects have showcased the viability of harnessing NBS, there's an observable stagnation in many technical applications [23]. Rather than breaking new ground, these applications often mirror methodologies from earlier studies that did not incorporate NBS. This stagnation is further exacerbated by the absence of robust, actionable technical guidelines, a palpable knowledge gap among those orchestrating projects, a lack of standardized evaluative metrics and an overarching inertia in the broad-scale adoption of NBS.

3.3. Implementation guidelines of nature-based solutions

Guidelines represent a critical aspect of NBS implementation. Many scholars have focused on developing guidelines for the application of NBS. These generally fall into two categories: Those that emphasize holistic benefits and those specific to implementation levels. Guidelines grounded in holistic benefits aim to amplify the composite effects across different stages, facets and actors involved in NBS implementation. Some scholars, for instance, underline the need to structure the NBS implementation process across various stages, as exemplified by Raymond's proposal of a seven-stage operational guideline for urban-scale NBS implementation and evaluation [24]. Frantzeskaki analyzed the implementation of 15 types of NBS across 11 European cities, suggesting guidelines for the different stages of urban NBS realization, which effectively promote NBS implementation [25]. Additionally, other studies emphasized the content of the NBS implementation guidelines, highlighting

various vital segments, such as van der Jagt's collation of successful factors from EU case studies, leading to a set of guidelines that range from goals and regulations, municipal support, fiscal resources and social capital to local community-building promoters [26]. Lastly, the participation and decision-making of funders, researchers, policymakers and practitioners in the NBS implementation process represent significant research directions. Nesshover, after summarizing the essence and features of NBS, proposed an operational guideline from the perspectives of these stakeholders [27]. Some studies present specific guidelines at the NBS implementation level, guiding NBS applications in subsystems, such as water resource management for sub-sectors like cities, food production, hydropower and flood control [28], guidelines pushing biodiversity and ecosystem service-driven NBS implementation [29] and those for architectural environment design and retrofitting [30]. In summary, although existing research on NBS implementation guidelines offers insights into holistic benefit enhancement and localized performance optimization, there is a lack of synergy and integration among these guidelines. Consequently, the comprehensive and collaborative principles of NBS are not fully realized, hindering the implementation and evaluation of NBS's practicality and innovation.

3.4. Performance evaluation of nature-based solutions

The superiority and efficacy of NBS need to be verified through extensive practice. Post-implementation performance assessment based on standardized metrics is crucial for enhancing the acceptance of NBS. Simultaneously, feedback from these evaluations can guide the development of NBS more effectively. Articles on NBS evaluation have various focuses, categorizing them into potential application assessments and implementation outcome evaluations. On the one hand, some scholars theoretically assess the performance and application potential of NBS. This generally falls into two major areas: Assessment of benefits from different thematic angles, such as green infrastructure, ecosystem services and climate change adaptation and mitigation strategies [31–33], and evaluations of engineering techniques that can be employed in NBS implementations, focusing on the impact of man-made interventions on ecosystems [34,35]. On the other hand, utility evaluations based on specific NBS implementations are also essential. Scholars have employed traditional evaluation methods like field studies and the Analytic Hierarchy Process- to assess NBS outcomes, providing feedback to refine NBS applications, as seen in studies by Schaubroeck and Liquete [36,37]. Given the trans-scalar and cross-departmental characteristics of NBS interventions, traditional evaluation methods may fall short in holistically assessing NBS's performance and impact. Thus, some researchers have revamped these traditional methods. Wendling, for instance, combined NBS evaluation frameworks with Sustainable Development Goals (SDGs), enhancing synergy between assessment schemes and maximizing operational efficiency [38]. Similarly, Calliari integrated traditional methods like water resource capacity evaluations with NBS, introducing the new Water Resource-Water Environment Carrying Capacity evaluation system [39]. Current evaluation articles in both research and practice are diverse in their scopes and methods, reflecting the comprehensive benefits of NBS across ecological, social and economic dimensions. However, due to the varied evaluation standards employed across different disciplines and fields, challenges arise in quantifying and standardizing the synergistic benefits of NBS. This disparity hinders the lateral comparison of benefits from different research projects or specific initiatives. Nonetheless, a universally standardized evaluation system might also have limitations, being less flexible and lacking criteria specific to particular phases.

3.5. Stakeholder collaboration and platform development for nature-based solutions

NBS focuses on interdisciplinary and cross-domain communication and cooperation. Perfecting platforms for stakeholder communication can provide better support for further development and implementation. Since 2019, various stakeholders and academic experts have increasingly recognized the importance of collaborative platforms. Current research primarily falls into two categories:

On the one hand, some scholars put more emphasis on balancing the perceptions of multiple stakeholders. Platform construction is a complex process. Initially, it involves different interpretations by stakeholders about the project, with inevitable divergent expectations of outcomes, risk assessment and implementation challenges. Therefore, researchers have begun collecting information and data from the public, stakeholders and experts [40] to effectively enhance communication among all parties, resolve differences, establish information exchange platforms and promote collaborative decision-making [41].

On the other hand, efforts are also being made to integrate traditional methods with the NBS approach to update and establish new communication platforms. Using past conventional governance methods, some scholars combine them with the NBS philosophy to make decisions and collaborate. For instance, Santoro shifted the focus of Melbourne's Urban Forest Strategy from technical strategies to socio-ecological principles under the NBS framework [42] and, based on this, revised management systems to promote joint decisions and cooperation. Some studies, considering the specific characteristics of projects, have begun innovatively constructing communication platforms. For example, Gulsrud, N, considering Mexico's specifics, established a government-led, public participation multi-center governance model platform to negotiate with stakeholders and propose feasible decisions [43]. Furthermore, the water management project in the southern Cotswolds, UK, encompasses ecologists, farmers, forest landowners and local community residents within a single framework. Through multi-party cooperation meetings, knowledge-sharing groups and other forms, they regularly communicate and provide feedback, aligning their objectives in practice. These platforms each have unique features, opening new paths for NBS communication, collaboration and feedback sharing, and have demonstrated positive results during implementation.

Overall, research on NBS platform construction remains nascent. While each platform has unique characteristics, making horizontal evaluations and comparisons is challenging, and there is no unified methodology yet. The experiences and advantages are difficult to exploit in more practical applications. Moreover, the role of platforms should span theoretical research, practical application and benefit evaluation, ensuring timely information sharing and feedback. However, most platform constructions are concentrated on the practical part, with other aspects remaining relatively weak.

4. Conclusions

In summary, preliminary studies and explorations have been conducted on NBS in various areas, such as conceptual viewpoints, application techniques, implementation guidelines, performance evaluations and platform construction. This research demonstrates the comprehensive, collaborative and integrative nature of the NBS field. However, there are gaps in the development of NBS across these areas. This study provides a comparative summary of each area's content, strengths and weaknesses (Table 2).

Table 2. Advantages and disadvantages of different NBS research types.

Content	Conceptual Viewpoints	Application Techniques	Implementation Guidelines	Performance Evaluation	Platform Construction
Content	Nature-based management; human-centric approach; achieving holistic benefits	Technologies supporting green infrastructure, urban renewal techniques, ecological restoration techniques	Guidelines emphasizing holistic benefits and specific implementation directives	Comprehensive benefits; complex evaluation frameworks	Balancing interests of multiple stakeholders in platform construction
Strengths	Comprehensive and integrative; diverse stakeholders	Demonstrated operability in various directions	Enhances NBS's overall and specific outcomes	Variety of evaluation methods; broad application fields; emphasizes comprehensive benefits	Unique platform constructions facilitate collaboration, feedback sharing and joint decision-making.
Limitations	Lack of a precise and unified concept; lack of integrated methods	Disjointed recommendations; lack of systematic guidelines and experienced personnel	Lack of integration and coordination between different guidelines	Absence of cooperative yet flexible evaluation standards	Difficulty in cross-comparison; lack of a standardized methodology

Table 2 shows that current NBS research is fragmented and lacks a systematic approach. The research-practice-evaluation sequence has not yet formed a cohesive system, which might be a major reason for the underutilization of NBS's unique strengths. Based on this, it is imperative to establish a refined guiding framework to bolster the advancement of NBS. By enhancing the systematic nature of NBS and maximizing its unique advantages, a robust NBS framework can be realized.

The proposed NBS guiding framework encompasses five pillars: Conceptual viewpoints, application techniques, implementation guidelines, performance evaluations and platform construction. The conceptual foundation of NBS ensures its successful implementation. Hence, clarifying definitions, content and advantages is paramount for guiding practices. Building on this, collating various NBS-related techniques and corresponding guidelines will ensure comprehensive and efficient applications. Performance evaluation is essential for feedback and refinement. The framework must continuously evolve through iterative learning, adaptation and enhancement loops. This system's creation and operation depend on multi-disciplinary and multi-stakeholder platforms, fostering collective communication and collaborative decision-making.

In light of this NBS research overview, the study recommends the following for implementing nature-based solutions and deepening the theoretical and practical advancements of NBS: Conceptually, a unified and precise NBS definition should be adopted domestically to guide its application. Concurrent theoretical advancements and practical applications are necessary for refining the NBS system. Technically, NBS studies should prioritize using technological guidelines, personnel training and technology verification standards, thereby constructing an organized, actionable technical guide. For implementation guidelines, emphasis should be on optimizing connections between different levels, ensuring a clear hierarchy. Performance evaluation should integrate various discipline-specific standards, establishing a unified macro-assessment system. Specialized evaluation systems should also be created to assess NBS's benefits comprehensively. Platform construction requires the collaboration of various departments, disciplines and stakeholders. Under government leadership, the essential idea of platform construction should be realized and multi-level platform systems should be established. The platform's role should be extended throughout the NBS process.

By focusing on the evolution, applicability and benefits of NBS, this research contributes to a deeper understanding of how such solutions can holistically promote the environmental, economic and social aspects of urban development. It also extends the knowledge of NBS's roots in past concepts, shedding light on its unique positioning in sustainable urban and rural development. By constructing

a functional framework based on the insights from the review, the study not only organizes and presents the multifaceted nature of NBS research but also offers a structured method to guide future studies in this area. On the practical front, the insights derived from this study are invaluable for urban planners, policymakers, environmentalists and stakeholders involved in urban and rural development. By emphasizing the multiple benefits of NBS and proposing a structured implementation guide, this research paves the way for more strategic and informed decisions in urban development practices. It serves as a beacon for cities and regions seeking to fortify their resilience against climate challenges while aiming for holistic, sustainable development. This research also has limitations, as it did not fully apply the proposed framework, which presents an avenue for future studies to explore and enhance.

Use of AI tools declaration

The author declare that he has not used Artificial Intelligence (AI) tools in the creation of this article.

Conflict of interest

The author declares no conflicts of interest.

References

1. Head BW, Xiang WN (2016) Working with wicked problems in socio-ecological systems: More awareness, greater acceptance, and better adaptation. *Landsc Urban Plan* 154: 1–3. https://doi.org/10.1016/j.landurbplan.2016.07.011
2. Scott M, Lennon M, Haase D, et al. (2016) Nature-based solutions for the contemporary city: insights from practice in Fingal, Ireland. *Plan Theory Pract* 17: 267–300. https://doi.org/10.1080/14649357.2016.1158907
3. Lafortezza R, Chen J, van den Bosch CK, et al. (2018) Nature-based solutions for resilient landscapes and cities. *Environ Res* 165: 431–441. https://doi.org/10.1016/j.envres.2017.11.038
4. Wang Z, Fu H, Jian Y, et al. (2022) On the comparative use of social media data and survey data in prioritizing ecosystem services for cost-effective governance. *Ecosyst Serv* 56: 101446. https://doi.org/10.1016/j.ecoser.2022.101446
5. Cohen-Shacham E, Andrade A, Dalton J, et al. (2019) Core principles for successfully implementing and upscaling Nature-based Solutions. *Environ Sci Policy* 98: 20–29. https://doi.org/10.1016/j.envsci.2019.04.014
6. C Mell I (2015) Establishing the rationale for green infrastructure investment in Indian cities: is the mainstreaming of urban greening an expanding or diminishing reality? *AIMS Environ Sci* 2: 134–153. https://doi.org/10.3934/environsci.2015.2.134
7. Millennium Ecosystem Assessment (MEA), 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.
8. Wang Z, Jie H, Fu H, et al. (2022) A social-media-based improvement index for urban renewal. *Ecol Indic* 137: 108775. https://doi.org/10.1016/j.ecolind.2022.108775
9. Russo A, Escobedo FJ, Zerbe S (2016) Quantifying the local-scale ecosystem services provided by urban treed streetscapes in bolzano, italy. *AIMS Environ Sci* 3: 58–76. https://doi.org/10.3934/environsci.2016.1.58

10. Atanasova N, Castellar JAC, Pineda-Martos R, et al. (2021) Nature-Based Solutions and Circularity in Cities. *Circ Econ Sustain* 1: 319–332. https://doi.org/10.1007/s43615-021-00024-1
11. Sgroi F (2021) Landscape management and economic evaluation of the ecosystem services of the vineyards. *AIMS Environ Sci* 8: 393–402. https://doi.org/10.3934/environsci.2021025
12. Jiang Q, Wang Z, Yu K, et al. (2023) The influence of urbanization on local perception of the effect of traditional landscapes on human wellbeing: A case study of a pondscape in Chongqing, China. *Ecosyst Serv* 60: 101521. https://doi.org/10.1016/j.ecoser.2023.101521
13. Sarabi SE, Han Q, Romme AGL, et al. (2019) Key enablers of and barriers to the uptake and implementation of nature-based solutions in urban settings: A review. *Resources* 8. https://doi.org/10.3390/resources8030121
14. Liu Y, Wu YC, Fu H, et al. (2023) Digital intervention in improving the outcomes of mental health among LGBTQ+ youth: a systematic review. *Front Psychol* 14: 1242928. https://doi.org/10.3389/fpsyg.2023.1242928
15. Fu H, Wang Z, Jie H, et al. (2021) Emotional Characteristics and Influencing Factors of Urban Park Users: A Case Study of South China Botanical Garden and Yuexiu Park. *Beijing Daxue Xuebao (Ziran Kexue Ban)/Acta Scientiarum Naturalium Universitatis Pekinensis* 57: 1108–1120.
16. Seddon N, Chausson A, Berry P, et al. (2020) Understanding the value and limits of nature-based solutions to climate change and other global challenges. *Philos Trans R Soc B Biol Sci* 375. https://doi.org/10.1098/rstb.2019.0120
17. Nelson DR, Bledsoe BP, Ferreira S, et al. (2020) Challenges to realizing the potential of nature-based solutions. *Curr Opin Environ Sustain* 45: 49–55. ttps://doi.org/10.1016/j.cosust.2020.09.001
18. IUCN (2016).The IUCN Programme 2013-2016, Gland (2016), 25-30.
19. van den Bosch M, Ode Sang (2017) Urban natural environments as nature-based solutions for improved public health – A systematic review of reviews. *Environ Res* 158: 373–384. https://doi.org/10.1016/j.envres.2017.05.040
20. Kronenberg J (2015) Betting against Human Ingenuity: The Perils of the Economic Valuation of Nature's Services. *Bioscience* 65: 1096–1099. https://doi.org/10.1093/biosci/biv135
21. McFarland AR, Larsen L, Yeshitela K, et al. (2019). Guide for using green infrastructure in urban environments for stormwater management. *Environ Sci Wat Res Technol* 5: 643–659. https://doi.org/10.1039/C8EW00498F
22. Xiang P, Wang Y, Deng Q (2017) Inclusive nature-based solutions for urban regeneration in a natural disaster vulnerability context: A case study of Chongqing, China. *Sustainability (Switzerland)* 9. https://doi.org/10.3390/su9071205
23. Blau ML, Luz F, Panagopoulos T (2018) Urban river recovery inspired by nature-based solutions and biophilic design in Albufeira, Portugal. *Land (Basel)* 7. https://doi.org/10.3390/land7040141
24. Raymond CM, Frantzeskaki N, Kabisch N, et al. (2017) A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas. *Environ Sci Policy* 77: 15–24. https://doi.org/10.1016/j.envsci.2017.07.008
25. Frantzeskaki N, McPhearson T, Collier MJ, et al. (2019) Nature-based solutions for urban climate change adaptation: Linking science, policy, and practice communities for evidence-based decision-making. *Bioscience* 69: 455–466. https://doi.org/10.1093/biosci/biz042

26. van der Jagt APN, Szaraz LR, Delshammar T, et al. (2017) Cultivating nature-based solutions: The governance of communal urban gardens in the European Union. *Environ Res* 159: 264–275. https://doi.org/10.1016/j.envres.2017.08.013
27. Nesshöver C, Assmuth T, Irvine KN, et al. (2017) The science, policy and practice of nature-based solutions: An interdisciplinary perspective. *Sci Total Environ* 579: 1215–1227. https://doi.org/10.1016/j.scitotenv.2016.11.106
28. Boelee E, Janse J, Le Gal A, et al. (2017) Overcoming water challenges through nature-based solutions. *Water Policy* 19: 820–836. https://doi.org/10.2166/wp.2017.105
29. Faivre N, Fritz M, Freitas T, et al. (2017) Nature-Based Solutions in the EU: Innovating with nature to address social, economic and environmental challenges. *Environ Res* 159: 509–518. https://doi.org/10.1016/j.envres.2017.08.032
30. Xing Y, Jones P, Donnison I (2017) Characterisation of nature-based solutions for the built environment. *Sustainability* 9. https://doi.org/10.3390/su9010149
31. Panno A, Carrus G, Lafortezza R, et al. (2017) Nature-based solutions to promote human resilience and wellbeing in cities during increasingly hot summers. *Environ Res* 159: 249–256. https://doi.org/10.1016/j.envres.2017.08.016
32. Cariñanos P, Casares-Porcel M, Díaz de la Guardia C, et al. (2017) Assessing allergenicity in urban parks: A nature-based solution to reduce the impact on public health. *Environ Res* 155: 219–227. https://doi.org/10.1016/j.envres.2017.02.015
33. Tomao A, Quatrini V, Corona P, et al. (2017) Resilient landscapes in Mediterranean urban areas: Understanding factors influencing forest trends. *Environ Res* 156: 1–9. https://doi.org/10.1016/j.envres.2017.03.006
34. Lin Z, Qi J (2017) Hydro-dam – A nature-based solution or an ecological problem: The fate of the Tonlé Sap Lake. *Environ Res* 158: 24–32. https://doi.org/10.1016/j.envres.2017.05.016
35. Chen E, Bridgeman T (2017) The reduction of Chlorella vulgaris concentrations through UV-C radiation treatments: A nature-based solution (NBS). *Environ Res* 156: 183–189. https://doi.org/10.1016/j.envres.2017.03.007
36. Schaubroeck T (2018) Towards a general sustainability assessment of human/industrial and nature-based solutions. *Sustain Sci* 13: 1185–1191. https://doi.org/10.1007/s11625-018-0559-0
37. Liquete C, Udias A, Conte G, et al. (2016) Integrated valuation of a nature-based solution for water pollution control. Highlighting hidden benefits. *Ecosyst Serv* 22: 392–401. https://doi.org/10.1016/j.ecoser.2016.09.011
38. Wendling LA, Huovila A, zu Castell-Rüdenhausen M, et al. (2018) Benchmarking nature-based solution and smart city assessment schemes against the sustainable development goal indicator framework. *Front Environ Sci* 6. https://doi.org/10.3389/fenvs.2018.00069
39. Calliari E, Staccione A, Mysiak J (2019) An assessment framework for climate-proof nature-based solutions. *Sci Total Environ* 656: 691–700. https://doi.org/10.1016/j.scitotenv.2018.11.341
40. Mabon L (2019) Enhancing post-disaster resilience by 'building back greener': Evaluating the contribution of nature-based solutions to recovery planning in Futaba County, Fukushima Prefecture, Japan. *Landsc Urban Plan* 187: 105–118. https://doi.org/10.1016/j.landurbplan.2019.03.013
41. Wild TC, Dempsey N, Broadhead AT (2019) Volunteered information on nature-based solutions — Dredging for data on deculverting. *Urban For Urban Green* 40: 254–263. https://doi.org/10.1016/j.landurbplan.2019.03.013

42. Santoro S, Pluchinotta I, Pagano A, et al. (2019) Assessing stakeholders' risk perception to promote Nature Based Solutions as flood protection strategies: The case of the Glinščica river (Slovenia). *Sci Total Environ* 655: 188–201. https://doi.org/10.1016/j.scitotenv.2018.11.116
43. Gulsrud NM, Hertzog K, Shears I (2018) Innovative urban forestry governance in Melbourne?: Investigating "green placemaking" as a nature-based solution. *Environ Res* 161: 158–167. https://doi.org/10.1016/j.envres.2017.11.005

AIMS Press