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Original Research Article

Analyzing the Principles and Key Features of Nature-based Solutions (NbS) in Urban Greening (UG): A Systematic Review*

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Abstract

Problem statement: Climate change and its consequences influence all environmental, social, and economic conditions of cities. One of the most important ideas to overcome urban issues is implementing urban greening (UG) to improve the ecology and sustainability of cities; however, the manner of adopting this idea is facing numerous challenges. In recent years, Nature-based Solutions (NbS) have proposed an emerging and comprehensive concept for solving the ecological and social challenges of cities at macro and micro levels.

Research objective: The main goal of the research is to identify and analyze the concept of NbS in solving the challenge of managing urban green structures from both theoretical and practical dimensions. Based on this concept, the current research to answer the question of how and in what dimensions NbS, as a comprehensive concept, may support the process of greening cities.

Research mthod: This study investigates the concepts and principles of NBS and extracts its features by applying the systematic review of theoretical foundations and adopting the analytical method; it is followed by targeting the added values and its conceptual and operational obstacles by addressing the concept of UG.

Conclusion: NbS as a transdisci plinary and collaborative concept, by considering the dynamics of the environment, suggests planning for long-term projects with specific solutions for each place while preserving natural, biological, and cultural values to solve the complex challenges. Most of the features and principles of these solutions overlap with UG concepts, and from the operational aspect, they are a suitable and relatively comprehensive approach for implementing the desired concepts compared to UG approaches. However, a more precise definition is required to address the conceptual nature of NbS, as they are still encountering theoretical and practical obstacles. These conceptual barriers trigger both basic concepts and explanations of perceptual dimensions, while the implementation barriers consist of weak communication between organizations, and between them and the related stakeholders, which includes the temporal-spatial dimensions as well. According to the three-case method ('concept', 'principles & characteristics', and 'implementation processes'), the study mainly focuses on two main categories to remove obstacles: 1) considering the features of entirety and multiplicity to resolve the conceptual obstacles, 2) defining the principles of Realism and the applicability, process-based concept, and acceptability of solutions in eliminating the implementation obstacles.

Keywords: *Urban Greening-based Solutions (NbS), Green Infrastructure, Urban Sustainability, Ecosystem-based Adaptation (EbA).*

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Introduction

Attempt to reduce the consequences of climate change, protecting urban ecosystems and increasing ecosystem services (Li, Cheshmehzangi, Chan & Ives, 2021; Kabisch, Stadler, Korn & Bonn, 2017; Bowler, Buyung-Ali, Knight & Pullin, 2010), have turned green infrastructure and Urban Greening-UG into a potentially sustainable solution with multi-layered ecological-social functions for urban planning and development (European Commission, 2015; ICLEI, 2019; Saboonchi, Abarghouyifard & Motedayen 2018; LIG, 2013;). Green infrastructure has more flexibility and economic advantages than gray infrastructure (Bradley, 1995; Shafer, 1999; Tyrvainen, 2001; Lütz & Bastian, 2002). However, in UG, considering the principles of spatial planning and the way of turning them into practical actions through procedures for documentation and implementation of policies is a challenge ahead. Moreover, the significance of human beings as a part of a holistic interactive ecosystem (Raffaelli & Frid, 2010) and the presence of social challenges arising from the number of ecological problems in cities, have increased the necessity for innovative macro-scale solutions (Wu Ruangpan, Sanchez, Rasmussen, Rene & Vojinovic, 2021). In this regard, NbS is among the emerging and promising concepts for resolving this issue (Scott, Lennon, Haase, Kazmierczak, Clabby & Beatley, 2016; Cohen-Shacham, Andrade, et al., 2019; Nesshöver, et al., 2017; Faivre, Fritz, Freitas, de Boissezon & Vandewoestijne, 2017).

These solutions are an umbrella concept that includes a wide range of Ecosystem-based Adaptation (EbA), which resolves the ecological-social challenges by presenting multiple advantages (Cohen-Shacham, Walters, Janzen & Maginnis, 2016). Among the advantages of NbS, the following can be mentioned: connecting society with nature, strengthening social cohesion, providing physical and mental health (Ghisleni, 2021; Gulsrud, Hertzog & Shears, 2018), reducing the urban heat island (UHI), increasing biodiversity, making sustainable water management (Xing, Jones & Donnison, 2017; Majidi, Vojinovic, Alves, Weesakul, Sanchez, Boogaard & Kluck, 2019), and creating a proper condition for creative and low-cost designs compared to the technical and conventional solutions (Short, Clarke, Carnelli, Uttley & Smith, 2019; van der Jagt, Smith, et al., 2019; Raymond, et al., 2017; Young, Marengo, Coelho, Scofield, de Oliveira Silva & Prieto, 2019; Santoro, Pluchinotta, Pagano, Pengal, Cokan & Giordano, 2019; Han & Kuhlicke, 2021; Taneja, van der Hoek & van Koningsveld, 2020). Examples of this approach include: increasing the level of vegetation and natural buffers for natural disaster risk reduction, construction of sand ponds for water storage, creating porous and permeable surfaces, making green roofs and walls, and restoring rivers and wetlands, which are quite similar to the application and function of green infrastructure and greening measures (Brink, et al., 2016; Tzoulas, Korpela, Venn, Yli-Pelkonen, Kaźmierczak, Niemela & James, 2007; Andreucci, 2013; Fink, 2016).

In this regard, the questions that arise here are as follows:

what are the added values of NbS compared to UG? Is NbS considered aPlease correct to comprehensive solution for implementing g r een measures? To answer these questions, this research, by classifying the principles and characte r istics of NbS, adopts them with their counterpart principles in UG discipline, and discusses t h e prospects of NbS through the clarification o f conceptual challenges and related implementing issues.

Methodology

This research examines NbS in relation to UG approach by performing a systematic review and comparative analysis method. Initially, the concept of UG and its basic principles were explained; later, the principles of NbS were defined and a systematic review was adopted as a method for addressing this issue, to find the features of this concept. In the next step, the related characteristics were classified based on a three-case model consisting; of 1) basis of concepts 2) principles-characteristics, and 3) classified executive processes and procedures (Fig. 1) and comparing the principles and characteristics of NbS with their counterparts in UG to specify the similarities and differences between these two concepts. Finally, the challenges and the conceptual and operational obstacles in NbS discipline were discussed to explain the limitations of these solutions and their conceptual characteristics.

The concept of UG has been frequently studied in articles, books, guidelines, scientific websites, and official reports of international organizations. To present and define the principles of NbS the systematic review method and Scopus search engine have been used. The related terms and keywords[1] were reviewed between the years 2015 and 2021. A number of 498 published articles between 2015-2019 were reported, while from 2020 to the end of 2021, 1076 articles and books were published, which shows the growing literature on this concept. Most of the research studies were from the United Kingdom and the United States, and the most research area (20% out of all) was related to the climate change issue. In the first step of the research, a number of 1137 studies were extracted. After reviewing the abstracts, those articles that were focused mostly on the technical aspects of NbS (for instance, biophysical subjects or earth sciences) were removed from the initial data, so the total number of reviewed articles reached 487 cases. After screening and reviewing the subjects, only those articles that referred to at least one of the target principles, functional potentials, or the issue of implementation were selected. Finally, 114 articles were chosen as the main articles.

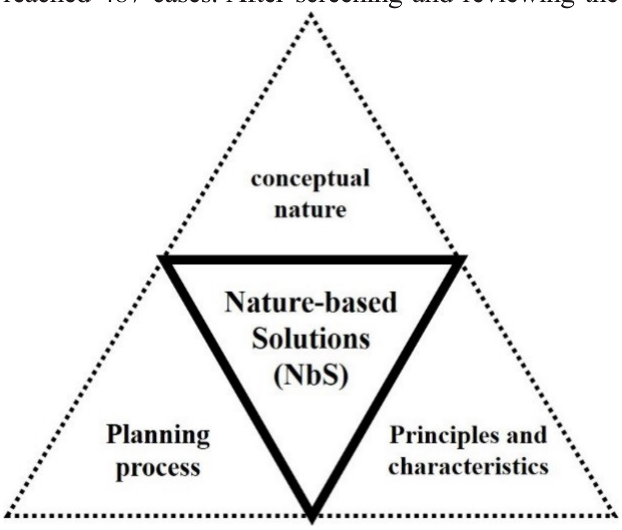

Fig. 1. The three main components of NbS. Source: Masnavi, Motedayen, Saboonchi & Hemmati, 2021.

Theoretical Foundations

• Urban Greening (UG)

UG is defined as a set of actions for returning Nature to urban textures by protecting, managing, and making quantitative and qualitative green structures. The planning and design of these structures are being applied as a network of natural or semi-natural areas to lead urban planning toward sustainable land use (Ahern, 2007). Greening includes the proceedings such as creating parks, green-blue corridors, rain gardens, porous surfaces, and green roofs (Addas & Maghrabi, 2021). Various approaches such as ecosystem-based adaptation (EbA), landscape ecology, landscape ecological urbanism (Steiner, 2011), biophilic urbanism, and other related areas explain the theoretical and practical aspects of this concept. Today, greening is an essential and basic infrastructure in urban planning, which includes not only a set of physical and environmental measures for increasing green spaces but also consists of a multi-functional concept with an identical application, which by creating a unique network of green-blue spaces, help to understand the perception of the natural environment and semantic integration (Saboonchi et al., 2018). Eight important principles define the requirements of UG from different aspects (U1-U8) (Li, Wang, Paulussen & Liu, 2005; Monteiro, Ferreira & Antunes, 2020; Young, 2010; Jim & Chen, 2003; Reeve, Desha, Hargreaves & Hargroves, 2015; Alvey, 2006; Xing et al., 2017):

U1-Structure and performance: modification in performance by changing the green structure, an integrated green network.

U2- Clarity and consistency of the green space system: a long-term perspective, landscape units as an integrated whole.

U3-Functional and environmental diversity: multifunctionality and visual experience.

U4-Biodiversity and environmental facilities:

quality and diversity of green space, protection of plant species.

U5-Access for the Public: a network of pedestrian paths linking recreational areas with public transport.

U6- Distribution of Green Space: creating public parks with ecological advantages close to residential areas.

U7-Integration and Development: integration of green network elements, considering growth and change.

U8- Adoption and Implementation: public participation, public awareness, green space development as an essential strategy; use of legal mechanisms and financial support.

- **Nature-based Solutions (NbS)**

NbS is not necessarily a novel idea. The creation of parks and tree-lined streets to decrease the harm caused by separation from the natural world are related examples (Hall, 1998). According to the United Nations report in 2005, this concept is defined actively in relation to the protection, restoration, and sustainable management of ecosystems by the stakeholders to benefit from the advantages of nature (Millennium Ecosystem Assessment, 2005). As stated by the International Union for Conservation of Nature (IUCN), NBS is a kind of 'action to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges[2] effectively and adaptively' (IUCN, 2013), while simultaneously providing human well-being and biodiversity benefits (Maes & Jacobs 2017; Seddon, Chausson, Berry, Girardin, Smith & Turner, 2020; Fedele, Locatelli, Djoudi & Colloff, 2018; Lafortezza, Chen, Van Den Bosch & Randrup, 2018). According to this definition, NbS can be classified into 1) ecosystem restoration approaches, 2) issue-specific ecosystem-related approaches, 3) infrastructure-related approaches 4) ecosystem-based management approaches, and 5) ecosystem protection approaches (Fig. 2).

The European Union defines NbS as a kind of action inspired by, supported by, or copied from nature that addresses various societal challenges in an efficient and resource-friendly way that provide simultaneously economic, social, and environmental benefits (European Commission,

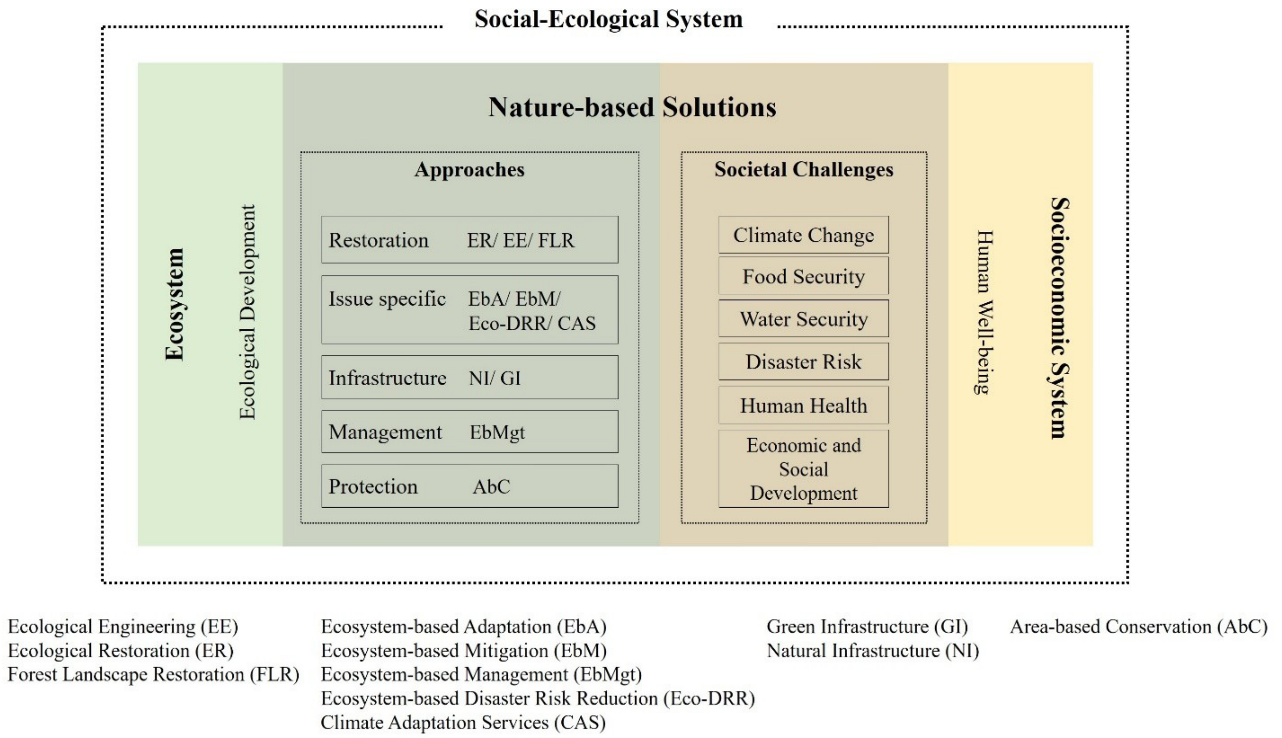

Fig. 2. NbS provides a wide range of ecosystem management, which connects ecosystem protection to human well-being for implementing sustainable development. Source: Cohen-Shacham et al.

2015). Unlike the first definition, which emphasizes the protection and restoration of the ecosystem, the EU definition supports all three aspects of sustainable development. Due to the cooperation of IUCN and the Commission on Ecosystem Management (CEM), eight principles for NbS have been defined below (N1-N8):

N1- Protection of essential ecosystem processes, resources and biodiversity is a priority and it is required to avoid the decline of the current state of the available ecosystems (Lennon & Scott, 2016).

N2- NbS provides a full range of ecosystem-based services, in combination with green infrastructure planning, which can compete and be replaced with gray infrastructure (Davies & Lafortezza, 2019; Dutta, Torres & Vojinovic, 2021). By joining with gray components, they can increase the effectiveness of actions in a completely flexible manner (Anderson & Renaud, 2021; Ramírez-Agudelo, de Pabl & Roca, 2021; Nika, Gusmaroli, Ghafourian, Atanasova, Buttiglieri & Katsou, 2020; O'Hogain & McCarton, 2018). The application of NbS has different types and scales of urban interventions and nature involvements (Eggermont, et al., 2015):

- Type I: This type of measure is based on the principle of protection and minimal interventions in the ecosystems (Thorslund, et al., 2017).
- Type II: At this level, there are more interventions than type 1. A set of management rules is defined that corresponds to the development of sustainable and multifunctional ecosystem-based services in a better way; for instance, by implementing integrated water resources management programs (Artmann & Sartison, 2018).
- Type III: The ecosystems management programs are more intensive than the two previous types, as there are efforts to create even new ecosystems in this type of action (van der Jagt, Szaraz, Delshammar, Cvejić, Santos, Goodness & Buijs, 2017; Frantzeskaki, 2019; Droste, Schröter-Schlaack, Hansjürgens & Zimmermann, 2017; Fink, 2016; Fan, Ouyang, Basnou, Pino, Park & Chen, 2017; Andersson, Borgström & McPhearson, 2017; Fig. 3).

N3- The source of evidence for NbS is scientific documents, traditional knowledge, or a combination of these two solutions (Cohen-Shacham et al., 2019). They should be compatible with local conditions and challenges and also be resilient to possible changes (Ignatieva, Haase, Dushkova & Haase, 2020). Since these solutions are limited to a specific location (Albert, et al., 2019; Colléony & Shwartz, 2019; Mubeen, Ruangpan, Vojinovic, Sanchez Torrez & Plavšić, 2021), integrating them with local knowledge can be efficient; as the indigenous knowledge related to perceptions, skills and developed philosophies of the societies with a long history (Hiwasaki, Luna & Shaw, 2014), which has been transformed into place-based local knowledge through 'physical', 'functional' and 'semantic' dimensions by understanding the context and adopting resource management (Saboonchi & Abarghouei Fard, 2020).

N4- One of the disadvantages of Ecosystem-based adaptation (EbA) approaches is its mere focus on engineering and economic benefits instead of social aspects, and the presence of interactions between stakeholders (Triyanti & Chu, 2018). NBS approaches mostly focus on the participation of different stakeholders from design to project implementation; The following are relevant examples in this regard: the attitude in integrated management of water resources or integrated management of coastal areas (ICZM) (Brandolini & Disegna, 2015; Blázquez, García & Bodoque, 2021). This approach causes the creation of common interests, promotion of public communication (Kabisch, et al., 2016), provision of learning conditions, transfer of knowledge, increasing awareness and motivation (Pagano, Pluchinotta, Pengal, Cokan & Giordano, 2019; Neumann & Hack, 2020), and finally the promotion of knowledge production through participatory processes (Frantzeskaki, 2019; Wickenberg, McCormick & Olsson, 2021). Participation facilitates transdisciplinarity as a boundary object and allows stakeholders to find a common language for collaboration (Dorst, van der

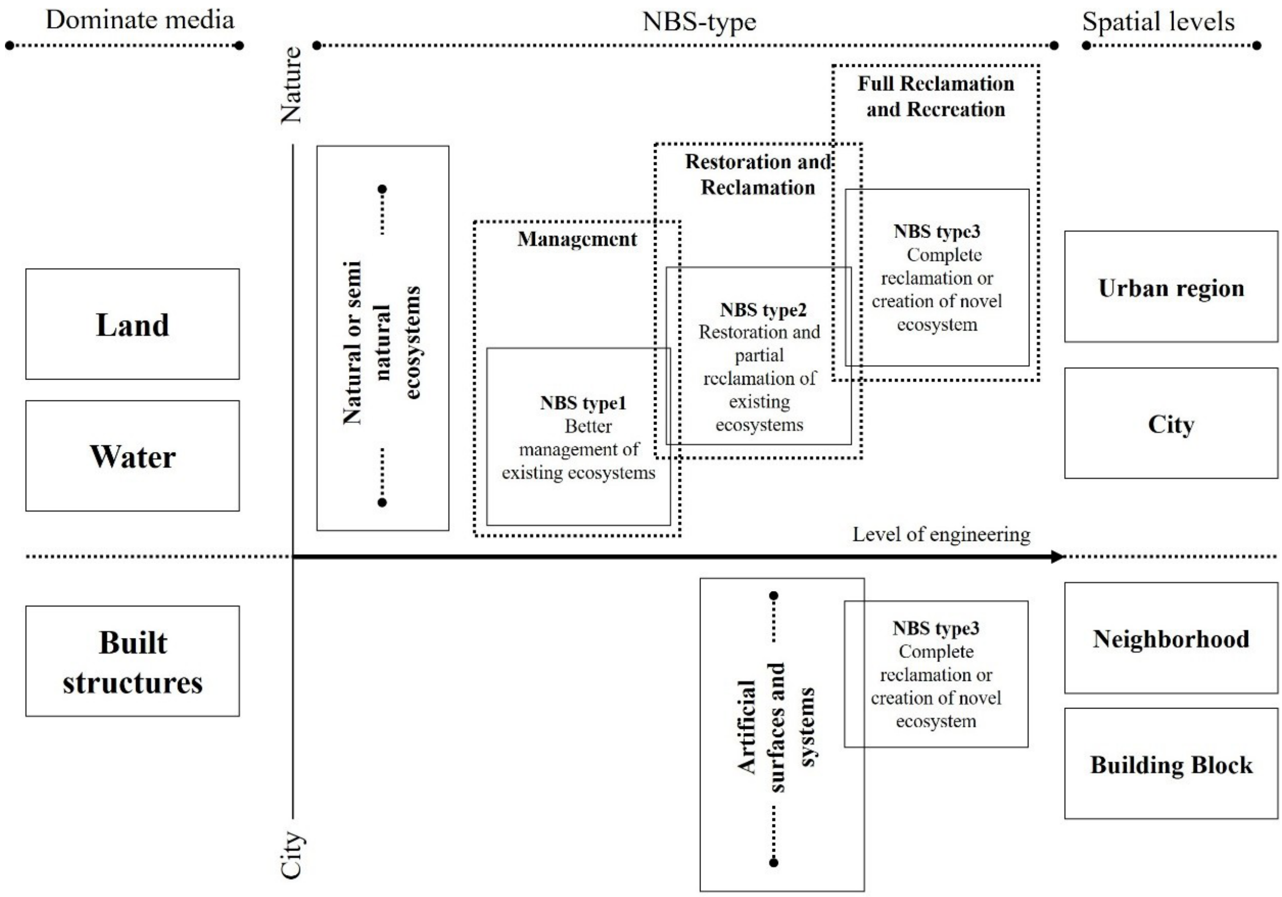

Fig. 3. The Conceptualization of NbS. Source: Roggema, Tillie & Keeffe, 2021.

Jagt, Raven & Runhaar, 2019; Wamsler, et al., 2020). Systematic participation and the presence of classified planning orders, in addition to better utilization of complementary services, will create equitable benefits for all stakeholders and local opportunities (Albert,et al., 2020).

N5- NbS to promote sustainability of ecosystem services is required to be compatible with the living condition and time-based complexity of ecosystems, and be resilient against future environmental changes (Bush & Doyon, 2019; Calliari, Staccione & Mysiak, 2019). This all requires adaptive management and future work and also considering the uncertainties (Morris, Konlechner, Ghisalberti & Swearer, 2018). Considering the long-term nature of the future-based approaches and the necessity to examine the efficiency of ecosystem services and social benefits, the implementation and evaluation of NbS requires more time to be influential compared to the rigid technical and engineering solutions (Maes & Jacobs, 2017; Guerrero, Haase & Albert, 2018).

N6- The effectiveness of NbS is presented in the form of interconnected networks of multiple habitats or (semi) natural areas (Loiseau, et al., 2016; Arkema, Griffin, Maldonado, Silver, Suckale & Guerry, 2017) at the landscape scale. Despite affecting short-term challenges at the micro-scale, these solutions may not have the same effectiveness at larger scales or in long-term approaches (Geneletti & Zardo, 2016); For instance, NbS is more effective for low-risk events, but for larger events, it is required to be joined with different types of actions (Vojinovic, Alves, Gómez, Weesakul, Keerakamolchai, Meesuk & Sanchez, 2021; Kuwae & Crooks, 2021), however, even in micro scales, they can influence larger scales through the interconnected network (Hankin, Page, McShane, Chappell, Spray, Black & Comins, 2021). Therefore, NbS provides an integrated multiscale hierarchical approach.

N7- NbS is trans-sectoral (Wendling, Huovila, zu Castell-Rüdenhausen, Hukkalainen & Airaksinen, 2018) and able to provide future solutions with a combination of technical, commercial, financial, governmental, monitoring, and societal innovations (European Commission, 2015; Raymond et al., 2017; Xing et al., 2017). Multiple objectives and common environmental, social, and economic interests are pursued in these solutions (Haase,et al., 2017; Martin, Giordano, Pagano, van der Keur & Costa, 2020a; Song, Kirkwood, Maksimović, Zheng, O'Connor, Jin & Hou, 2019).

N8- NbS is a kind of integrated approach, beyond a mere green communication tool for exploiting natural resources (Ershad Sarabi, Han, Romme, de Vries & Wendling, 2019; Dushkova & Haase, 2020). Providing simple solutions is one of the reasons for their widely adopted NbS, which facilitates opportunities for integrating different sectors and stakeholders (Van Ham & Klimmek, 2017) and thereupon strengthens their participation. NbS approaches, in the widespread adoption of governance models, while organizing a societal planning process (Song et al., 2019; van der Jagt, Raven, Dorst & Runhaar, 2020), provide more communication tools with policymakers and assist to create promotions or regulatory mechanisms, in multilateral or global structures (Faivre et al., 2017; Strosser, Delacámara, Hanus & Williams, 2015; MacKinnon, Dudley & Sandwith, 2011; MacKinnon, Sobrevila & Hickey, 2008).

Discussion

UG and NbS are classified into three aspects of 'concept', 'features', and 'planning processes', and they can be adopted with each other from below aspects:

- **Conceptual Aspect**

Evaluating the double-sided relationship between human-being and the environment is the most significant component of the concept in UG and NbS. Both approaches have an equal description of the environment in the form of the ecosystem, but in terms of the human concept and the type of relationship with the environment, the UG approach under the U 2 principle emphasizes more on the conceptual relationship and the individual perception of the landscape. Creating a unique perceptual image of a stable landscape in green networks is defined as the characteristic of stability in U2, while in NBS, the interpretation of the problem from the stakeholder's perspective and their understanding of the environment is not clearly explained, as the role of individuals has been limited to the executive factor and the implementation of decisions.

- **Principles and intrinsic characteristics**

The characteristic of integration is discussed under the topic of U[1] on green spaces from two aspects of 'form' and 'function', and also in principles of NBS in terms of applied methods, concepts, and stakeholders under the titles of N2-N3-N7-N8. The systematic approach, meaning the change of performance, resulting from its components, is one of the other features related to U1. This feature is expressed with a similar concept, under the title of N6-U7, from NbS and under the influence of the comprehensive view, by focusing on the effect of the micro-scale on the macro-scale, from which the multi-scale feature can also be interpreted. Although UG does not directly refer to the scale, the principles of N1-N 2 and the U5-U6-U 7 indirectly refer to the macro and micro-scales accordingly. The same issue is expressed with the concept of hierarchy under the subjects of the amount and manner of intervention in the natural environment, the cooperation of stakeholders, and the effects of proceedings from part to whole under the principles of N2-N4-N 6 from NbS.

The characteristic of diversity depends on the two factors of form and function presented under the title of U 3 due to its ability for manifesting visual richness and its multi-functional feature. This characteristic is also discussed in NbS under the principles of N2-N3-N 5 which supports diversity in solutions (natural-technical), diversity in concepts and knowledge (scientific-traditional), biodiversity, and cultural diversity. Under the principle of N7, from NbS a multifunctional approach is introduced, but contrary to greening ones, which focuses mostly on ecological benefits, these solutions emphasize the simultaneous provision of benefits.

The green network and promoting elements in U1-U 7 emphasize the dynamic feature. The issue of development and complexity is also discussed in N5. In contrast to dynamism, the issue of physical stability can also be observed under the title of preservation in the principle of U4-U5-U 7 and N[1] from NbS. In order to preserve ecosystems, UG explains that while maintaining access, there should be connection and integration among green infrastructure components, and also between them and the gray infrastructure (Saboonchi et al., 2018); For example, through transportation corridors, railway lines, canals and intermittent rivers or waterways. Moreover, in U6, the manner of distribution and spreading of green space and the location of this space has been discussed. The issue of place and context is also proposed under the principle of N3, which introduces NbS as a specified, non-generalizable, and place-based concept, besides emphasizing natural and cultural values and the knowledge of local communities.

- **Planning process**

Implementation and execution of greening strategies have been mentioned under the principle of U[8] in the form of participation, awareness, involvement of different stakeholders and acceptance of programs by them, and also definition of legal and financial instruments. Under the principle of N4, the two characteristics of participation and the existence of different stakeholders have been stated, which creates a systematic process for agreement and transparency among groups to facilitate the transfer of knowledge and increase the level of education and awareness (Ruangpan, et al., 2021). On the other hand, the involvement of multiple stakeholders promotes NbS toward a multidisciplinary field. The title of N[8] states that NbS should be comprehensive and an integral part of planning the policies and actions. According to the principle of N3, acceptance of adaptive management, resilience, and flexibility of solutions are other significant points when implementing NbS. Considering the time scale and defining long-term projects is one of the principles emphasized in U 2 of greening and N 5 of NbS; However, according to NbS the long-term goals are required to be related to future planning and essential for the effectiveness of EbA. To follow the dynamics and intrinsic developments of green networks, NbS addresses the components affecting the ecosystem such as political and economic factors (McQuaid, Kooijman, Rhodes & Cannon, 2021) as external influencers and emerging uncertainties, besides the internal developments of the system (Giordano, Costa, Pagano, Rodriguez, Zorrilla-Miras, Gomez & Lopez-Gunn, 2021).

The comparison between the two mentioned principles displays that, dissimilar to UG, NbS less considers the perceptive conceptual issues of the stakeholders and their interpretation of the environment, as they mostly provide a wide range of practical measures to solve the challenges. NbS has more specific solutions for the planning process, the manner of management, and establishing macro strategies with a flexible and feature-based approach, as the effort to create a suitable context for transforming basic concepts into executive actions by implementing EbA approaches. However, to understand the form and function of ecosystems, and for implementing NbS approach, the subset of these solutions, including ecological engineering, Catchment Systems Engineering should be addressed. UG approaches similarly proposes principles for implementing the projects, but in long run consider green spaces and networks as the ultimate goal; however, the use of natural components and the preservation of ecosystems in NbS is not a mission, but rather a tool for solving the ecological-social challenges is addressed. The mentioned goals in this solution-based approach are achieved by considering the functional, physical, and time-based dimensions. However, the most significant advantages of NbS compared to the UG are as below:

Time dimensions and consideration of planning processes as a dynamic phenomenon with continuous improvements: these solutions implement the desired current planning based on past experiences and local awareness to provide solutions for current issues; they consider the future and predictions necessary to overcome the challenges and encountering the uncertainties.

- Place dimensions: these solutions cannot be generalized, as they are defined depending on the conditions and requirements of each place.
- Flexibility and future-based aspect: NbS when is designed flexibly, can complete the previous strategies and provide significant economic benefits (Iloka, 2016; Rahman, Sakurai & Munadi, 2017). The ability to adapt and coordinate local knowledge can also provide innovative and resilient methods.
- Multifunctional feature: Along with overcoming social challenges, is able to create multiple benefits for integrating decisions.

Participation: Attempting to create commonalities and agreement among stakeholders (making common issues) is one of the significant principles of these kinds of solutions.

The Challenges of NbS

In spite of the growing research on NbS (Solheim, Capobianco, Oen, Kalsnes, Wullf-Knutsen, Olsen, ... & Strout, 2021; Wolf, Pham, Matthews & Bubeck, 2021), there are two categories of conceptual and operational obstacles for this approach as follow:

- **Conceptual obstacles**

A lack of proposing a clear definition of social and environmental interactions (Tzoulas, et al., 2021), creates a gap between the plan and implementing NbS in a non-human-based attitude, which can reduce the commonalities of humans and non-human beings, known as environmental justice (Pineda-Pinto, Frantzeskaki & Nygaard, 2021). In defining the principles of NbS, the perceptual dimensions are mostly ignored, while the environmental interpretation of stakeholders and their perceptual idea on this issue is the basis of decision-making and planning processes. Considering the wide range of stakeholders' perceptions, NbS does not provide a solid concept, as different structures can be defined for them. Therefore, recognizing and reinterpreting the manner of the relationship between humans and the environment, and having a holistic view to understand physical and non-physical dimensions is highly required here. This whole characteristic can explain the tangible and objective concepts of NbS, the role of individuals in ecosystems, and the way they affect the environment.

Another obstacle is the unspecified term "solution". The complex nature of managing ecosystems can stop forming a definitive agreement (Game, Meijaard, Sheil & McDonald-Madden, 2014), while the word "solution" implies that difficulties and necessities are presumably approved by all stakeholders. The feature of multiplicity in relation to the concept of environment (Abarghouei Fard et al,. 2023) by accepting diverse methods and ideas facilitates a higher level of adaption and a better definition of inter and intra connections of communities and ecosystems through establishing discourse and democratic negotiation about the desired concepts to maintain social-environmental justice.

- **Implementation obstacles**

the implementation of NbS can be associated with various obstacles as below: lack of integration and cooperation between foundations, complications of financial funding, lack of effective regulation, support for the development of gray infrastructure lack of awareness of the NbS benefits (Sarabi, Han, Romme, de Vries, Valkenburg & den Ouden, 2020; Dorst, Van Der Jagt, Runhaar & Raven, 2021; Coletta, Pagano, Pluchinotta, Fratino, Scrieciu, Nanu & Giordano, 2021; Watkin, Ruangpan, Vojinovic, Weesakul & Torres, 2019), lack of sufficient knowledge base to accelerate adoption and absorption (Vojinovic et al., 2021), and the conflict of economic and political interests between foundations (Han & Kuhlicke, 2021; Giordano, Pluchinotta, Pagano, Scrieciu & Nanu, 2020).

The manner the foundations communicate and cooperate with other stakeholders is another issue. In other words, the level of acceptability of these solutions and a complete understanding of motivational reasons related to public perception has not been considered in the process of participation. In NbS, it is assumed that the opinions of the local communities and other stakeholders are aligned with the planned decisions and projects, while these decisions may conflict with the living interests of different stakeholders; this issue may adversely trigger the integrity of the ecosystem and human well-being (Gann,et al., 2018). For example, wetland restoration for flood prevention may have positive effects on ecosystems but adverse effects on the lives of local farmers (Nesshöver et al., 2017). In these conditions, the projects might not be convincing and feasible. Agreeing on a common issue can build resilience in many economic and ecological fields to provide conditions for long-term development (Gunn, Rica, Zorrilla-Miras, Vay, Mayor, Pagano, ... & Giordano, 2021). So there are challenges that are required to turn into operational measures from conceptual ideas: defining the role of mediators in the participation process and establishing a discourse among stakeholders (Frantzeskaki & Bush, 2021) to make an agreement, prioritize issues and provide solutions to finally create common vision and awareness, and founding the manner of cooperation among local communities.

Among the existing obstacles, the following can be mentioned as difficulties that make this discipline remain unclear, without accuracy in operation (Schaubroeck, 2017; Kumar, et al., 2020; Mendes, Fidélis, Roebeling & Teles, 2020) which hinder investment in these areas:

Physical and place limitations, delay in the time expected for observing the effectiveness and efficiency of this approach (Wolf et al., 2021; Pagano et al., 2019), time limitations due to external pressures to quickly overcome problems (Liu & Jensen, 2017), the existence of limited knowledge and evidence in implementation and the existence of challenges in monitoring and evaluation areas (Turconi, Faccini, Marchese, Paliaga, Casazza, Vojinovic & Luino, 2020; Kumar, et al., 2021), lack of Information about the certainty of NbS in the long run (Mayor,et al., 2021).

To overcome these obstacles, the below principles could be effective: continuity and process-based approaches (for monitoring and inspecting projects), evaluating the Realism and applicability of projects, and creating conditions for stakeholders to accept the recommended situations. Monitoring and inspection following the design, planning, and implementation of the project to evaluate the effectiveness should be performed in a developed and process-based cycle, to assist in better implementation of the projects and create a strong execution knowledge of NbS by performing the necessary feasibility studies (Debele, et al., 2019). To achieve the acceptability of plans, the following actions could have a significant role in facilitating the process of participation, acceptance, and bottom-up planning approaches, to promise the implementation of the programs as follow: setting principles in accordance with the needs and roles of the stakeholders, decentralizing policies, and more support from governance and local states (Table 1); (Fig. 4).

Conclusion

In this study, it was found that the two concepts of UG and NbS include different approaches, strategies, and a range of practical ecosystems-based arrangements that provide social, environmental, and economic benefits for overcoming challenges with the common goal of sustainable development. These two approaches have many similarities and overlap concepts in strategies, characteristics, and practical principles for managing green infrastructures. However, in NBS approach, contrary to UG, less attention has been paid to the precise conceptual manner of the human-environmental system, the related perceptual principles, and conceptual aspects. NbS approaches are mainly focused on implementation processes and defining principles such as preservation of the ecosystem, participation, adaptive management, awareness, and future-based concepts, "that makes NbS concept- as a solution based approach- to adopt comprehensive strategies." Unlike UG principles, NbS approaches try to overcome the social-ecological challenges together in a practical manner, and thereupon, they can provide suitable solutions for implementing green plans and policies.

However, multi-stakeholders, the complexity of the planning process, and the necessity of comprehensive governance approaches have encountered the intervention and proposed solutions of NbS approaches with conceptual and practical obstacles. In this regard, the main conceptual obstacle is the lack of a clear definition of individual perception of human-environmental communication. Another obstacle is ignoring the multiple perceptions of stakeholders and their various interpretations of the problem, which can create a serious challenge in accepting programs. These two characteristics of inclusion and multiplicity can be a response to these challenges. The most significant challenges for implementing NbS approaches is also arising from political and organized obstacles in the manner these foundations communicate with stakeholders, and the time-based or place-based limitations. Evaluating the realism and the applicability of decisions, considering the characteristics of process-based and

Table 1. Comparing the principles of NbS and UG approaches based on the classification of intrinsic characteristics, and according to the planning process. Source: Authors.

Principles		UG	NbS
Intrinsic Characteristics	Integrity	U1-U7	N2-N3-N7-N8
	Dynamism	U1-U7	N5
	Systematic approach	U1	N6-N7
	Diversity	U3	N2-N3-N5
	Multi-functional	U3	N7
	Physical dimensions (accessibility, connection, distribution)	U5-U6	-
	Integration	U4-U5-U7	N2-N3
	Multi-stakeholders	U8	N4
	Multi-scale	U1-U2-U5-U6-U7	N3-N6
	Place-based	-	N3
	Transdisciplinary	-	N4
	Hierarchy	-	N2-N4-N6
	Perception as an integrated whole	U2	-
	Multiplicity	-	-
Planning Processes (policy-making and implementation)	Preservation	U4	N1
	Participation	U8	N4-N8
	Development of knowledge, awareness, and learning	U8	N4
	Inclusive strategy	U8	N8
	Adaptive management and resilience	-	N3-N5
	Flexibility	-	N2-N3-N4
	Future-based and uncertainty	-	N5
	Long-term planning	U2	N5
	Applicability and Realism	-	-
	Continuity and process-based	-	-
	Acceptability	U8	-

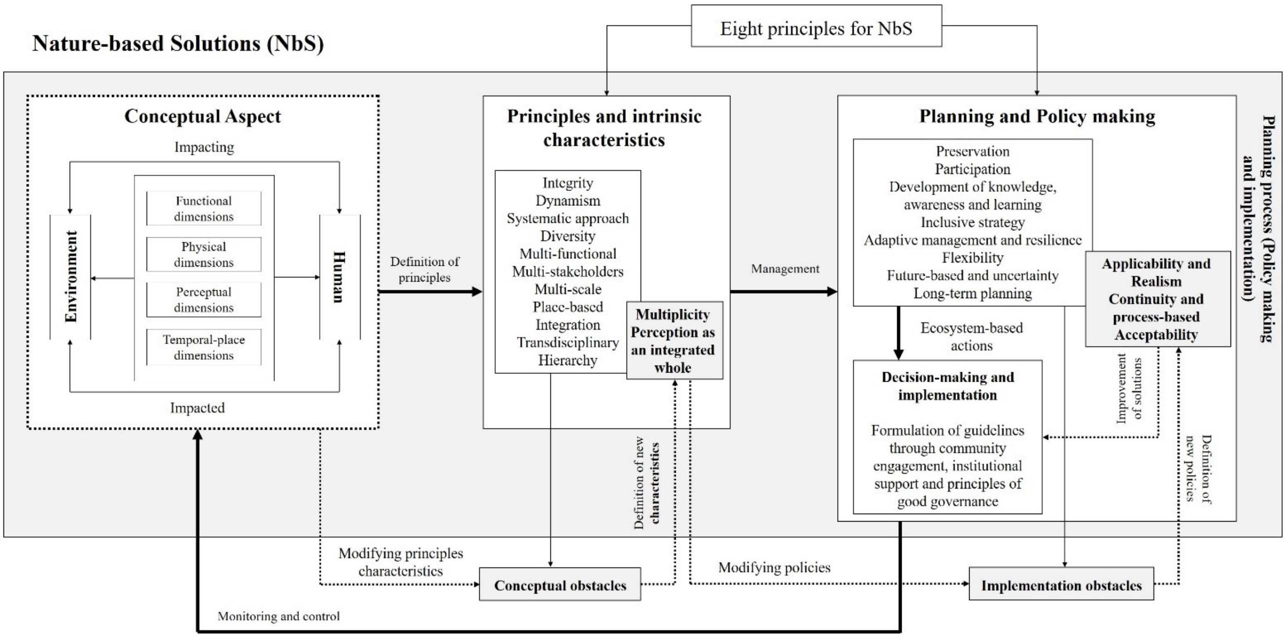

Fig. 4. Analyzing the NbS approach based on the three-case model of 'concept', 'principles-characteristics', and 'planning processes'. Source: Authors.

acceptability in operational aspects of projects to identify and accept plans are other complementary principle. Prior to these proceedings, it is required to define precisely the basic concept of this approach together with temporal-place dimensions in a perceptual manner, besides targeting its physical and functional dimensions.

Therefore, NbS not only supports the theoretical aspects of greening concepts but also provides numerous practical solutions; however, targeting the NbS principles and its conceptual outlines requires more complete investigations and discussions in future research.

Endnotes

1. TITLE-ABS-KEY (nature-based AND solutions).
2. TITLE-ABS-KEY (nature-based AND solutions AND barriers), TITLE-ABS-KEY (nature-based AND solutions AND principles)

For instance, climate change (New Climate Economy, 2014; Kabisch et al., 2016), food and water security (Mohamed-Katerere & Smith, 2013; Kumar, Saint-Laurent, Begeladze & Calmon, 2015; Muthee, Duguma, Nzyoka & Minang, 2021; Ozment, DiFrancesco & Gartner, 2015), human health (Hartig, Mitchell, de Vries & Frumkin, 2014; Thompson Coon, Boddy, Stein, Whear, Barton & Depledge, 2011; Stolton & Dudley, 2009), disaster risk reduction (Duncan, Dash & Tompkins, 2014; Depietri & McPhearson, 2017; Senhoury, Niang, Diouf & Thomas, 2016; Anderson& Renaud, 2021; Martin, Costa & Máñez, 2020b; IUCN, 2019; Han & Kuhlicke, 2021; Gooden & Pritzlaff, 2021).

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