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Nature-based solutions for urban challenges: A simple framework based on ecosystem services for a World Heritage City

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ABSTRACT

Urban nature projects are becoming increasingly common in cities as they contribute to reducing the impacts of the climate crisis. In this study, we developed a conceptual framework based on ecosystem services (ESs) to analyse how urban naturalisation actions (nature-based solutions, NBSs) included in urban nature projects contribute to multifunctionality. Here, multifunctionality refers to the capacity to generate multiple simultaneous ESs, indicating the extent to which the challenges identified in a city have been addressed. A multi-criteria analysis based on socioeconomic and environmental criteria, assessed using a series of descriptors linked to ESs, was used to develop a Multifunctionality Nature Project (MuNaP) index. The framework identifies the level of multifunctionality of NBSs and incorporates information for its improvement, if necessary. To validate this proposal, we calculated the multifunctionality of an urban nature project in the World Heritage City of Salamanca, Spain. Among all NBSs used in the project, tree planting was the most multifunctional, whereas the creation of bioretention sites was the least multifunctional. Increasing the values of certain criteria, such as diversity and origins, increased the multifunctionality of the urban nature project. Finally, the MuNaP index has a minimum value that ensures the multifunctionality of an urban nature project, that is, its contributions to biodiversity conservation, provision of multiple ESs, and the well-being of citizens.

1. Introduction

Climate change is among the greatest challenges of our time, and its consequences, including precipitation and temperature extremes, have a major impact on cities (Masson et al., 2020). Therefore, policymakers and urban planners are interested in renaturing cities (Keeler et al., 2019) through the implementation of nature-based solutions (NBSs), urban regeneration, rehabilitation, and sustainable development agendas (Haase, 2017; Ferrari et al., 2019). NBSs are multifunctional actions because they can simultaneously provide environmental, social, and economic benefits while helping build resilience (Sarabi et al., 2022). Thus, according to the World Health Organisation (WHO) European Region (EURO) 2017 report, NBSs must provide multiple ecosystem services (ESs), viz. provisioning (food) (Boada, 2005; Liang and Huang, 2023), regulating (habitat for biodiversity, local temperature regulation, surface water management, and air quality regulation (Baró and Gómez-Baggethun, 2017; Key et al., 2022), and cultural (aesthetics, recreation, and sense of place services (Pauleit et al., 2017), improving health and well-being (WHO/EURO, 2017). Moreover, NBSs represent a more efficient and cost-effective solution than the traditional grey approaches (European Commission, 2015). The knowledge of ESs provided by an NBS enables us to determine the degree to which a solution is nature-based (White et al., 2021), as the ES-based approach offers considerable promise for elucidating where and when NBSs will deliver a suite of ESs (Keeler et al., 2019).

The multifunctionality provided by NBSs can be a useful approach to city planning (Larondelle and Haase, 2013; Spyra et al., 2018). However, multifunctionality is an elusive concept, and little information is available on how it is perceived and implemented by urban planners; hence, scientists need to provide relatively more practice-oriented tools and concepts (Hansen et al., 2019). In this context, different European projects, such as URBAN GreenUP, NATURVATION, OPERAs,

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Nature4Cities, and REGREEN, have recently developed tools to identify and assess NBSs, mainly using multi-criteria analysis (Liquete et al., 2016; Raymond et al., 2017a; Croeser et al., 2021). The study of multifunctionality is an effective strategy to integrate multiple ES assessments with other information on the costs and benefits of planning scenarios, explore diverse stakeholder perspectives, and balance competing objectives rationally and transparently (Cortinovis and Geneletti, 2018). However, several studies have identified research needs on the effectiveness, design approaches, and NBS implementation (Albert et al., 2019; Frantzeskaki, 2019; Goodwin et al., 2023). The International Union for Conservation of Nature (IUCN) has developed a simple framework for the verification, design, and expansion of the use of NBSs on a global scale (IUCN, 2020); however, at an urban scale, such frameworks are scarce. In certain instances, these frameworks may refer to a specific NBS, such as the green roof resilience framework (Saqib et al., 2024) or the assessment of a few ESs (Liquete et al., 2016; Epelde et al., 2022). Nevertheless, strong calls also exist for involving the local population in different processes of co-planning, co-design, and co-management to ensure environmental justice (Pauleit et al., 2017). Some authors have prioritised NBS implementation based on their effectiveness and association with socioeconomic variables using a theoretical framework (Balzan et al., 2021). However, the success of an NBS is contingent upon its adaptation to local conditions, the specific wishes and ambitions of stakeholders (van de Ven et al., 2016; Berland et al., 2017), and the utilisation of local scientific information, such as that related to native species, targeted ESs, or *in situ* measurements (Epelde et al., 2022).

World Heritage Cities differ in characteristics from those of other cities and exhibit an extremely relevant cultural heritage; therefore, most studies have focused on the cultural services provided by these cities (Kosanic and Petzold, 2020). However, they also have a highly impervious surface (Yinshuaia et al., 2024), which makes them extremely vulnerable to the effects of climate change, indicating that they must increase their urban greenspace to the minimum required urban greenspace area recommended by various organisations. Thus, the WHO establishes that having 20 %–30 % green area in relation to the built-up urban area and an urban greenspace of greater than or equal to 0.5 ha at a maximum distance of 300 m from the dwelling is necessary (WHO/EURO, 2016). Moreover, the Nature Restoration Law recommends a minimum of 10 % tree canopy cover for European cities (European Council, 2024). A recent study estimated that increasing tree cover by 30 % could reduce deaths related to the urban heat island effect (Iungman et al., 2023). Therefore, urban greenspaces are critical for addressing sustainability challenges (Fang et al., 2023) related to climate change and human well-being. However, aligning the efforts of urban planners to identify viable solutions across multiple scales, issues, and disciplines using a comprehensive approach is necessary (McPhearson et al., 2022). The ES approach is a useful tool for bringing different disciplines together to identify the heritage value of a landscape from different perspectives (Tengberg et al., 2012), including methodological approaches that can be applied to various issues relevant to city planning (Larondelle and Haase, 2013; Cortinovis and Geneletti, 2018; Spyra et al., 2018). Nevertheless, elucidating which ESs are targeted and which could solve the challenges will help determine which NBSs are most appropriate in each context (Remme et al., 2024), particularly those related to reducing the effects of climate change (Ascenso et al., 2021). Furthermore, the active participation of stakeholders contributes to solving social challenges (Brears, 2020; Dorst et al., 2022) and leads to legitimate and informed planning as it includes the interests and needs of society (Afzalan and Muller, 2014; Wilker et al., 2016). NBSs will be readily accepted if people are informed in a comprehensible manner regarding why and how they contribute to meeting urban challenges (Sheppard, 2012; Sarabi et al., 2022).

Therefore, developing simple decision-support tools to assess the potential of NBS based on their multifunctionality is essential for helping World Heritage Cities evaluate the capacity of an urban nature project to meet urban challenges (Kremer et al., 2016; Babí Almenar et al., 2021). However, assessing multifunctionality, maximising synergies, and limiting trade-offs for the management, design, and planning of urban ESs is challenging (McPhearson et al., 2022). In this study, we aimed to present a simple methodological framework for assessing the multifunctionality of different types of NBSs (tree planting, naturalising non-tree greenspaces, greening buildings, and creating bioretention sites) implemented within urban nature projects using a Multifunctionality Nature Project (MuNaP) index. The calculation of multifunctionality values (MFVs) for each NBS enables us to determine whether an NBS ensures minimum performance, facilitates prioritisation for subsequent projects, and helps identify and enhance an NBS with a relatively low MFV. The proposed methodological framework is intended for utilisation by designers and urban planners involved in the elaboration and implementation of NBSs and was tested in the World Heritage City of Salamanca, Spain.

2. Methods

2.1. Study area

According to the 2021 report of Instituto Nacional de Estadística (INE), Salamanca is a city with a population of 143,954 (INE, 2021) and an area of 3,998 ha, of which 37 % is built-up urban and 12 % of that area is protected by the Management Plan for the Old City of Salamanca (Junta de Castilla y León and Ayuntamiento de Salamanca, 2017). In turn, 51 % was declared as an Asset of Cultural Interest: A Historic Complex by the Junta de Castilla y León. In 1988, Salamanca was added to the UNESCO Heritage List after being declared a World Heritage Site. Since then, an evolution exists in the criteria for cultural asset management, requiring a new understanding of the value of a place from both cultural and environmental perspectives. The heritage area is characterised by a scarcity of green spaces, which is crossed from east to west by the Tormes River and from north to south by the ancestral cattle route *Vía de la Plata*, the current *Camino de Santiago*, the most important of the 14 cattle routes that cross the city. Salamanca was the first World Heritage City to establish a Blue–Green Infrastructure network to address climate change, as defined in its *Special Plan for the Protection of Green Infrastructure and Biodiversity* (PEPIVB 2020–2035). To improve this Blue–Green Infrastructure and the ES it provides, within the *LIFE Vía de la Plata* (LIFE19 CCA/ES/ 001188), six urban nature projects located along the cattle route have been carried out in an area of 261 ha (Fig. 1). The project implemented in the heritage area was selected for the validation of the framework. This project included four types of NBSs: tree planting, naturalising non-tree greenspaces, greening buildings, and creating bioretention sites (Table 1). In these NBSs, a variety of species have been employed, exhibiting characteristics that are outlined in Appendix 1, Table S1.1.

2.2. Development of the methodological framework for assessing multifunctionality

The proposed methodological framework (Fig. 2) for assessing the multifunctionality of each NBS type implemented in an urban nature project is based on a multi-criteria analysis that includes socioeconomic and environmental criteria. The multifunctional value of the urban project is achieved by adding the weighted multifunctional value of each NBS (MuNaP index, range 0–8).

In this case, the multifunctionality of an NBS is based on the capacity of each NBS type to meet multiple socioeconomic and environmental criteria, which help ensure that multiple ESs can be provided. The criteria underpinning this multifunctionality were derived from a comprehensive review of the extant literature and discussed with municipal technicians for each type of NBS (Tables 2 and 3).

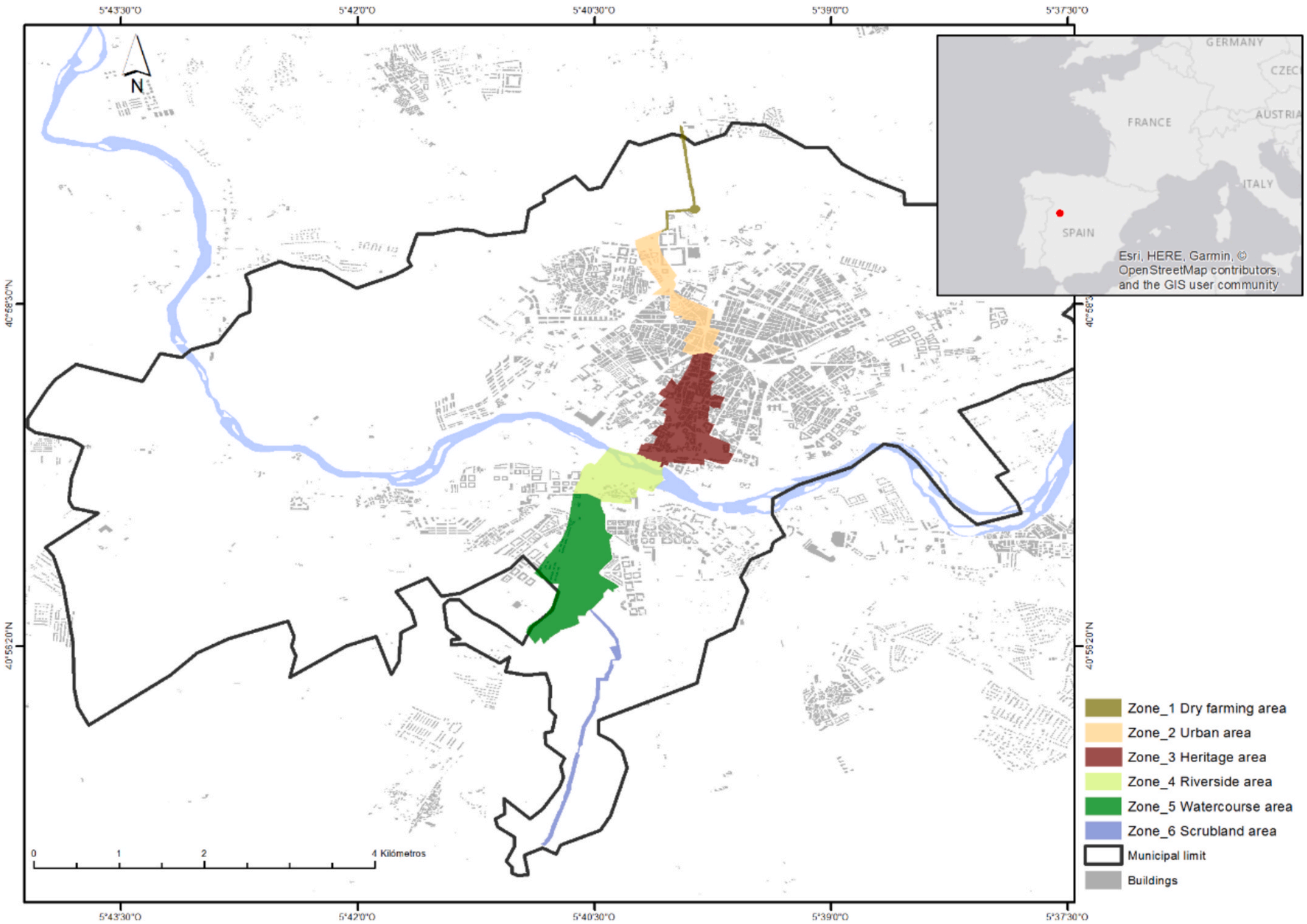

Fig. 1. The geographical location of the study area and the location of the six zones where the urban nature projects were carried out in Salamanca.

Table 1
Type of NBS implemented in the selected urban nature project within LIFE *Vía de la Plata* in Salamanca.

Type of NBS	Description
Planting of Trees	Street trees planting: individual trees planted in rows on a tree pit on the pavement. The planting distances in rows ranged from 4 to 7 m. Clustered trees planting: Group of trees planted in green areas / meadows (stands).
Naturalisation of non-tree greenspaces	They consisted on the replacement of small lawn patches, which are frequently mowed and require large volumes of water, with carpet plants or shrubs.
Greening of buildings	They consisted on the development of green walls with climbing plants or vines naturally attached to the wall that extract water and nutrients directly from the ground (ground-based greening).
Creation of bioretention sites	They are typically designed as shallow vegetated depressions that can intercept, infiltrate, divert, change volume and velocity, and treat stormwater flow (World Bank, 2021). Two types were implemented: draining paving (permeation of impermeable pavement in car parks, zebra crossings or on pavements) and rain gardens. To create these sites, the concrete was broken up and structural ground was added. In the case of rain gardens, a base of boulders was added with a mixture of sand, compost and top ground on which vegetation was planted.

2.2.1. *Socioeconomic criteria*

The socioeconomic assessment was based on three criteria and five descriptors: challenge (challenge identification and objectives), impact on the local economy (local employment and economic costs), and active participation of citizens (type of participation) (Table 2). The criteria for active citizens' participation were based on those proposed by Kiss et al. (2022). However, the five levels were reduced to the following four forms of participation, considering the real difficulties of including citizens' proposals in the NBSs: None, when there is no participation; Non-cooperative, the NBS is merely explained to the public, that is, informed in public presentations; Cooperative, the NBS is presented to and consulted with the citizens and inputs are registered (notably, citizens are not involved in NBS implementation); and Co-design, citizens collaborate on the design of the NBS. The designers and urban planners are involved in co-decision-making. The final value for socioeconomic criteria was obtained by summing up the results of the five descriptors for each NBS type evaluated.

2.2.2. *Environmental criteria*

The environmental assessment included seven environmental criteria directly related to the provision of 17 ESs, based on existing literature (Table 3): diversity, type of actions (how an NBS will be implemented), environment, connectivity, size, origins, and components. These criteria were aggregated into four groups: the characteristics of the NBS, location, extension, and the characteristics of the species used. The assessment of these criteria employed descriptors, such as the number of species or individuals of each species, the percentage of NBSs that satisfy specific criteria, the area occupied by the

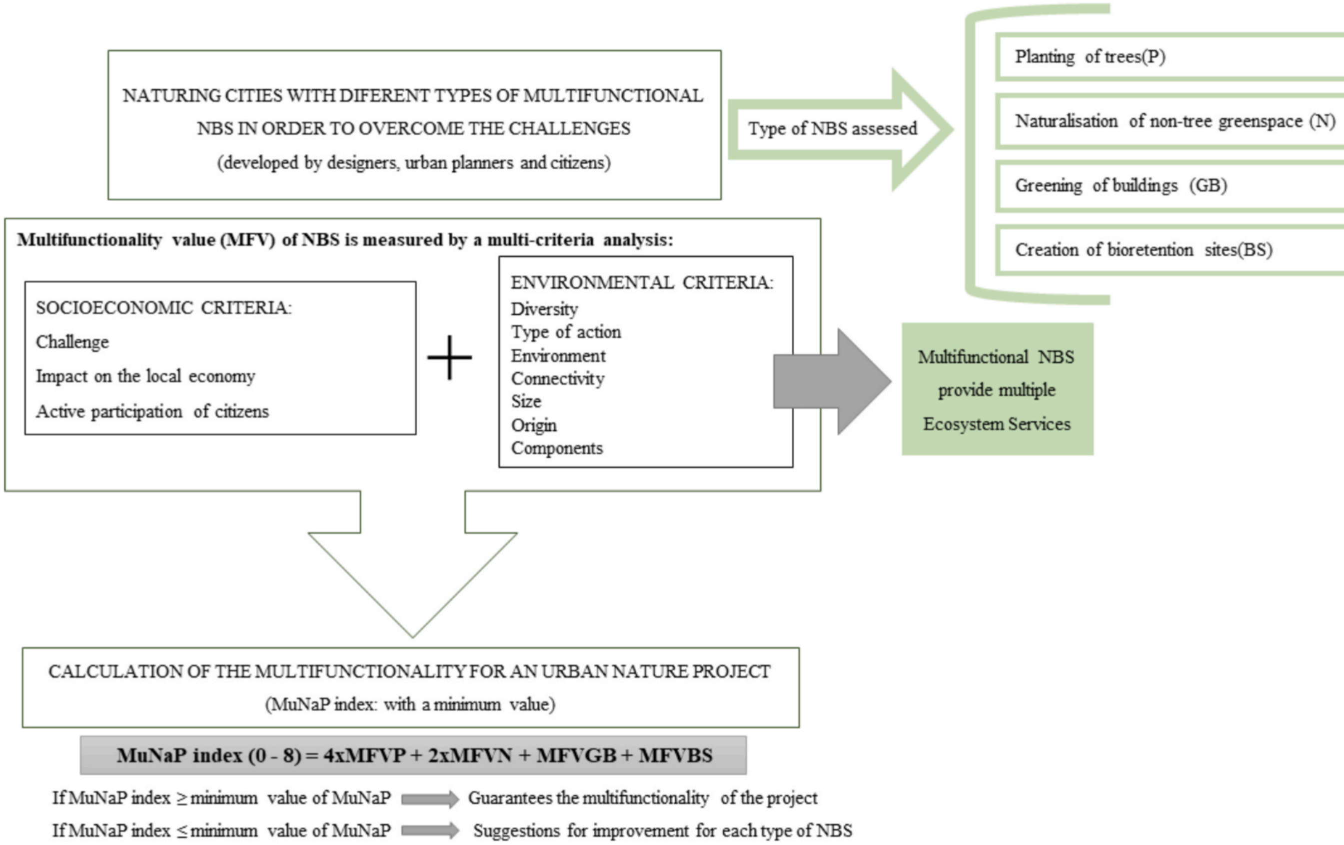

Fig. 2. The methodological framework to assess the multifunctionality of the different types of NBS (planting of trees, naturalisation of non-tree greenspaces, greening of buildings, and creation of bioretention sites) implemented within urban nature projects using a multifunctionality index called MuNaP (Multfifunctionality of Nature Project).

NBSs, the species employed, and the proximity of the NBSs to an educational centre (Table 4). The rating ranges for the different descriptors were based on the literature (Table 4). The final environmental value was obtained by adding the results of the descriptors for each type of NBS evaluated.

2.3. Multifunctionality index of urban nature project

The MuNaP index was calculated by summing up the MFV of each NBS type used in the project and weighted using Equation (1) as follows:

$$MuNaP\ index = 4MFVP + 2MFVN + MFVGB + MFVBS, \quad (1)$$

where MFVP, MFVN, MFVGB, and MFVBS are the MFVs of tree planting, naturalising non-wooded greenspaces, greening buildings, and creating bioretention sites, respectively.

The different NBS types were assigned a weighting based on their capacity to provide ESs. Tree planting was assigned the highest weight due to its capacity to provide a substantial number of ES (Berland et al., 2017; Davies et al., 2017; Pataki et al., 2021; Suchocka et al., 2023) and to mitigate the negative impacts of climate change (Rötzer et al., 2019). Moreover, they contribute particularly to the urban challenges in Salamanca, such as heat mitigation (Schwaab et al., 2021; Cortinovis et al., 2022) and urban surface water runoff reduction (Armson et al., 2013). The naturalisation of non-wooded greenspaces also contributes at a relatively low level; however, its contribution exceeds that of greening buildings and creating bioretention sites, thereby assigning it an intermediate weighting value. Hence, the maximum attainable value for the MuNaP is 8.

2.4. Ensuring the minimum performance of an NBS

To ensure that an NBS performs to the required standard for the anticipated challenges, the following conditions must be fulfilled: 1) socioeconomic criteria must reach a minimum value, which has been calculated based on the minimum performance indicated in Table 2; and 2) to achieve improved self-sustainability (White et al., 2021), the environmental criteria must be assigned a minimum value, which has been calculated based on the minimum performance indicated in Table 3. Therefore, diversity, origin, and certain descriptors of the components directly related to the challenges identified in the city should reach the value of 1. For the remaining descriptors, a minimum value of 0.5 is proposed (Appendix 1, Table S1.3).

2.5. Validation of the methodological framework

The urban nature project implemented in the heritage area was used for validation (Fig. 1). The area exhibited a high degree of waterproofing on the surface, characterised by narrow pedestrian streets and modest green spaces adjacent to the built heritage site, making it vulnerable to the effects of climate change. The overarching objective of the project was to mitigate the heat island effect and surface runoff, which were identified as the main environmental challenges in the city. To achieve this objective, four types of NBSs were implemented (Table 5).

Notably, these NBSs were designed before the validation of the framework, although improvements were implemented based on feedback from a citizen-participatory process (Appendix 1, Table S1.5). This process was carried out through seven workshops in 2021, involving 74 citizens from diverse neighbourhoods of Salamanca. Participants represented various stakeholder groups, including neighbourhood associations, university students, and businesses.

Table 2
Socioeconomic criteria evaluated, the conceptual framework on which they are based, the descriptors included in the methodological framework for each evaluated criterion, and the assessment of each one. The minimum performance value of multifunctionality within the framework is also included.

Socioeconomic criteria	Conceptual framework	Descriptors	Minimum performance
Challenge	The first step in designing an NBS is to identify the challenge you want to address, orient your design towards it, and link project objectives to specific actions (Raymond et al., 2017b; Albert et al., 2019).	Challenge identification:Have the challenge(s) for which the action has been designed been identified? Challenges have not been identified: 0 • Challenges are identified jointly by urban planners and citizens: 1 • Challenges are identified only by urban planners: 0.5 • No challenges identified: 0	Challenges are identified jointly by urban planners and citizens.
		Objectives: Have the objectives of the NBS been linked to the type of action? • Action is linked to all the objectives: 1 • Action is linked to at least one objective: 0.5 • Action is not linked to the objectives: 0	Action is linked to at least one objective.
Impact on the local economy	NBSs can boost business development by creating new jobs (ILO et al., 2022). In addition, using local raw materials to boost the local economy important.	Local employment: Does the action have an impact on the local economy by generating local employment or using local raw materials? • % local suppliers (<100 km of Salamanca)	At least 50 % of suppliers must be local.
	NBS contribute to reducing economic costs, e.g. sanitation costs due to extreme heat (Borg et al., 2023; Chen et al., 2023) or pollution due to increased urban vegetation (Hirons and Sjöman, 2019).	Economic costs: Does the action contribute to reducing the economic costs of water and energy consumption in the city? • Action reduces energy and water consumption: 1 • Action reduces energy or water consumption: 0.5 • Not calculated: 0	Action must entail a reduction of at least one economic cost.
Active participation of citizens	The active participation of citizens, particularly in the design of the NBS, is essential for its success (Laurenz et al., 2021) as the local community must be aware of the relevance of the NBS to be implemented.	Type of participation: What type of citizen participation has been included? • Co-design: 1 • Cooperative: 0.75 • Non-cooperative (just informed): 0.5 • None: 0	Citizens included in the implementation of the NBS (cooperative).

Two technicians from the Salamanca City Council validated the framework, one agricultural technical engineer from the urban planning office specialising in green areas and another from the environmental department. The validation process involved completing Excel-based questionnaire addressing the socioeconomic and environmental criteria.

3. Results

3.1. Multifunctionality of each NBS type

In terms of the socioeconomic criteria descriptors, the challenges identified by the technical staff were as follows: increasing biodiversity, mitigating heat, and reducing urban surface water runoff. However, objectives of the project were not linked to the type of NBS. Thus, its value was the lowest (0.25) for all NBS. In relation to the impact on the local economy, some suppliers have been contracted out to local companies, although not all of them. Nonetheless, no economic costs have been calculated for any NBS regarding their environmental impact in the city. Therefore, the greening of buildings exhibited the highest value for this criterion (0.50), with all providers being local (Table 6 and Appendix 2, Table S2.1), whereas tree planting exhibited the lowest value (0.30) as most of the suppliers were not local. Finally, the type of citizens' participation was cooperative as some of the citizens' proposals were incorporated into the implementation of NBSs, and all NBS types exhibited the highest value (0.75) for this criterion.

The socioeconomic criteria values for the greening of buildings and the other NBS types were 0.50 and 0.46, respectively (Table 6). However, the minimum performance value for these criteria was estimated to be 0.67 for all NBS types (Appendix 1, Table S1.3), and none of the different NBS types touched the minimum value.

In the case of environmental criteria descriptors (Table 6 and Appendix 2, Table S2.2), diversity and connectivity showed the highest values for the naturalisation of non-wooded greenspaces (0.5 and 0.71, respectively) as they exhibited a high diversity of species. Many of these species boasted showy flowers and fleshly fruits or possessed aromatic characteristics. Regarding the types of actions, the greening of buildings exhibited the highest value (1.00), considering the high level of vegetation cover; nonetheless, it exhibited null values for species diversity, origin, and components as it employed only the naturalised species *Hypericum calycinum*. For environment, origin, and components, tree planting exhibited the highest values (1.00, 0.95, and 0.55, respectively).

The estimated values for the environmental criteria were 0.62, 0.53, 0.37, and 0.36 for tree planting, naturalising non-wooded greenspaces, greening buildings, and creating bioretention sites, respectively (Table 6). None of these values touched the minimum performance value for these criteria, that is, 0.74 for tree planting, 0.68 for naturalising non-wooded greenspaces, and 0.71 for greening buildings and creating bioretention sites (Appendix 1, Table S1.3). Although tree planting exhibited the highest value, it was not enough to achieve the minimum performance value.

Finally, the highest MFV corresponded to tree planting (0.53), followed by those for naturalising non-wooded greenspaces (0.49), greening buildings (0.44), and creating bioretention sites (0.41) in decreasing order (Table 6), and none of them reached the minimum multifunctionality (0.71, 0.67, 0.69, and 0.69, respectively). Therefore,

Table 3
Conceptual framework of the environmental criteria for each NBS type (P: Planting of Trees; N: Naturalisation of non-wooded greenspaces; GB: Greening of buildings; and BS: Creation of bioretention sites) and ES that help deliver based on the Common International Classification of Ecosystem Services (CICES v5.1 code) (Appendix 1, Table S1.2). The minimum performance value of multifunctionality within the conceptual framework is also indicated.

Environmental criteria	NBS type		Conceptual framework	Ecosystem Services (CICES v5.1 code)*	Minimum performance
Characteristics of the NBS	*Diversity*	All	Diversity is a determinant of multifunctionality (Hector and Bagchi, 2007; Isbell et al., 2011). Higher plant species diversity increases habitat for faunal species, improves pest and disease resistance (Johnston et al., 2011; Vogt et al., 2017), and enhances landscape aesthetics (Peña et al., 2015). Santamour (1990) recommends the 10/20/30 rule (no species should exceed 10 %, no genus 20 %, and no family 30 % of the urban tree population). To maximally mitigate the risks associated with environmental stress, other authors suggested the 5/10/15 rule (Galle et al., 2021).	2.2.2.3 2.2.3.1 2.2.3.2 3.1.2.4	High species diversity.
	Types of actions	P	Street trees: Planting must be individual, and tree pits must be as large as possible to allow for ample growing space for the roots of a tree (New York City, 2016). Moreover, it helps to reduce surface runoff if the area occupied by a tree pit is more than 4.8 m^2 (Grey et al., 2018). For example, in New York City, the standard size of a street tree pit is 4.5 m^2. Hard (impermeable) materials, such as paving, disturb the tree environment and make them susceptible to pests and diseases (Sjöman and Busse Nielsen, 2010). Thus, the most optimal choice would be tree pits that are uncovered and with a permeable ground that provides habitat for beneficiary insects for pest control (Alonso Martínez et al., 2019) and pollination (Lundquist et al., 2022), increases the amount of water available for trees, and assists in stormwater capture and management (New York City, 2016). Planting of trees can be in single (street trees) or double row (boulevards). The canopies of the opposing trees often form an almost closed canopy, which favours the area between the double row of trees to be shaded, cooling the air temperature (Dubovik et al., 2022). Clustered trees: Trees planted in groups within 6 m of each other provide relatively more shade and available ground volume and cause less evapotranspiration, ground compaction, and exposure to reflective heat (New York City, 2016). Thus, clustered trees provide a high contribution to cooling and runoff mitigation (de Manuel et al., 2021).	2.2.1.3 2.2.2.1 2.2.2.3 2.2.3.1 2.2.6.2	Trees in doubled rows or in groups and on continuous living pits.
		N	Non-compacted ground: Compacted grounds, as opposed to non-compacted, reduce ground infiltration and drainage, increasing the likelihood of waterlogging, even after minor rainfall events (Hirons and Sjöman, 2019). Permeable ground: Sealed grounds, as opposed to permeable grounds, have a strong negative effect on the richness of bird species as they hinder the movement of birds within the urban landscape (Schütz and Schulze, 2015). Such grounds have relatively less surface moisture available for evapotranspiration than available in natural grounds, contributing to high surface and air temperatures (EPA, 2008). However, permeable grounds can absorb and store considerable amounts of rainwater (Pataki et al., 2021).	2.2.1.3 2.2.2.3 2.2.6.2	Non-compacted and permeable grounds.
		GB	Presence of vegetation in buildings implies several potential benefits, such as reducing the temperature, increasing water retention, habitat provision, and improving aesthetics (Eisenberg and Polcher, 2019).	2.2.1.3 2.2.2.3 2.2.6.2 3.1.2.4	Presence of abundant vegetation.
		BS	Presence of vegetation at these sites increases their capacity to provide ESs (Mak et al., 2017). The type of vegetation is among the factors determining the efficiency and treatment capacity of a bioretention site (World Bank, 2021).	2.2.1.3	Presence of trees and abundant vegetation.
Location of the NBS	*Environment*	All	WHO/EURO (2016) recommends that greensapces must be accessible to children within a proximity of 300 m to facilitate their healthy development. In addition, the proximity of NBSs to educational centres or cultural or environmental trails helps the environmental education service (Davies et al., 2017). NBSs are an opportunity to add value to assets of cultural interest (Coombes and Viles, 2021) as they can provide a cultural identity service or sense of belonging and enhance the landscape if located in environments of cultural interest. NBSs enhance outdoor	3.1.1.1 3.1.1.2 3.1.2.2 3.1.2.3	Proximity to educational centres, a cultural heritage site, and a natural/cultural route.

(*continued on next page*)

Table 3 (*continued*)

Environmental criteria	NBS type		Conceptual framework	Ecosystem Services (CICES v5.1 code)*	Minimum performance
			recreation opportunities (Cortinovis and Geneletti, 2018). The proximity of NBSs to recreational routes facilitates social cohesion (Babí Almenar et al., 2021). NBSs contribute to making cities relatively more liveable and attractive to tourists and visitors (Rice, 2019).		
	Connectivity	All	Loss of connectivity through landscape fragmentation or habitat loss has detrimental effects on biodiversity and ES delivery, both in quantity and quality, such as pollination and pest control (Mitchell et al., 2013; Pal et al., 2021). Vega and Küffer (2021) classified urban greenspaces into three groups based on their size, that is, small (<20 m^2), medium (20 – 300 m^2), and large (>300 m^2), and indicated that connecting them is essential to exploit their potential as habitats. In addition, they pointed out that spaces occupying more than 4 m^2, such as street trees, can support a high diversity of species, particularly in areas where large greenspaces cannot be created, as patch richness is positively affected by surrounding habitats within 50–200 m distances. The boulevards favour connectivity as they can act as greenways (Walmsley, 1995). The development of corridors (greenways) or stepping stones can improve connectivity in urban environments, with corridors being relatively more efficient in supporting biodiversity but more costly to implement (Lynch, 2019). Urban trees are stepping stones for the movement of birds across the urban matrix (Han and Keeffe, 2021). Increasing the area of habitat patches and creating a network of corridors is the most crucial strategy for maintaining high levels of urban biodiversity (Beninde et al., 2015). Therefore, the implemented NBSs act as a greenway or stepping stone to facilitate the mobility of bird species, thus contributing to their connectivity with other urban greenspaces. Moreover, the NBSs considered greenways must be at least 10 m wide (Dean Austin, 2012), and the stepping stones must be evaluated following Vega and Küffer (2021).	2.2.2.1 2.2.2.3 2.2.3.1	Contribution to the greenway or stepping-stone connectivity: a minimum size of 20 m^2 and maximum distance of 200 m between the spaces.
Extension of the NBS	*Size*	All	WHO proposed 0.5–1 ha as the minimum size of greenspace required to generate the expected benefits (WHO/EURO, 2017), and English Nature proposed a minimum size of 2 ha (Natural England, 2003).	Has a positive impact on all the identified ESs	Minimum mean size: 0.5 ha
Characteristics of the species used in NBS	*Origin*	All	Native plants increase biodiversity by providing resources for urban animals (Berthon et al., 2021), particularly for pollinators (Paudel and States, 2023), improve pest and disease control efficacy (Buckland et al., 2020) and ground quality (Rojas et al., 2022), contribute to the distinctiveness of a place by favouring a sense of place (Forristal et al., 2014), and generally need relatively less irrigation (Lehmann, 2021). However, non-native trees can produce undesired effects, such as fire proneness or pollen allergenicity (Castro-Díez et al., 2019).	2.2.2.1 2.2.3.1 2.2.3.2 2.2.4.2 3.2.1.1	Native species
	Components	P	Tree crown: Trees with large and dense canopies are the most effective for cooling and rainfall interception (Brink et al., 2016) and filtering of fine particulars (Pretzsch et al., 2015). Tree leaf: Deciduous trees are very effective for cooling as they provide shade during the summer and not blocking light in winter (EPA, 2008; Lee and Mayer, 2018). Flower: Trees with flowers in the urban landscape are a favourable habitat for pollinators (Melathopoulos et al., 2020). The presence of large flowers improves the aesthetics of the urban landscape (Goodness et al., 2016). Fruit: A few species provide food for animals and people (Boada, 2005; Liang and Huang, 2023) and feeding on them helps seed dispersal (Egerer et al., 2018). Drought tolerance: Periods of drought and ground moisture deficits can lead to high mortality among species (Owuor et al., 2022). Pollen: Allergies caused by urban vegetation have a negative impact on human health (Escobedo and Seitz, 2009); however, exposure to airborne pollen can be reduced using plant species and genotypes with low allergenic potential (Ogren, 2000).	1.1.5.1 2.2.1.3 2.2.2.1 2.2.2.2 2.2.2.3 2.2.3.2 2.2.6.2 3.1.2.4 3.2.2.1	Selecting species with dense crowns. Deciduous tree promotion. Encouraging the presence of different types and sizes of flowers. Promoting trees with fleshy fruits. Selecting drought-tolerant species. Selecting species with low allergenic potential.

(*continued on next page*)

Table 3 (*continued*)

Environmental criteria	NBS type	Conceptual framework	Ecosystem Services (CICES v5.1 code)*	Minimum performance
	N GB BS	Flower: Diverse flower patches can be an effective tool to attract a higher diversity of beneficial insect groups, which provide crop pollination and pest control services (Campbell et al., 2012). Floristically diverse swards favour the abundance of pollinators, food resources, and pest predators, among other benefits (Melathopoulos et al., 2020). Aromatic species: The use of aromatic species could be important for increasing pollination functions (Semeraro et al., 2022) and also as part of traditional knowledge (Youga et al., 2022). Fruits: Fruits are a food resource for wildlife (Jordano, 2014), particularly wintering birds (Hernández, 2007).	2.2.2.1 2.2.2.3 2.2.3.1 3.1.2.1	Selecting species with diverse, aromatic flowers and fleshy fruits.

the implementation of future NBSs must be improved from a socioeconomic and environmental perspective.

3.2. Multifunctionality of an urban nature project: MuNaP index

The calculated MuNaP index was 3.95 (Table 6), indicating a range of improvement from 4.05 to a maximum of 8. This value did not touch the minimum value proposed for the index, which is 5.52 (Appendix 1, Table S1.6), as neither the socioeconomic nor environmental criteria reached the minimum value proposed for the project to be multifunctional, that is, to provide multiple ESs and contribute to the identified urban challenges.

4. Discussion

4.1. Improving multifunctionality in an urban nature project

The MuNaP index, easily understandable by urban planners, enables improving the multifunctionality of NBS in an urban nature project by identifying which aspects of the NBS design do not meet the minimum values needed to generate multiple ESs. In our case, the value of MuNaP is 3.95 and does not reach the minimum of 5.55, which creates a warning to the designers and urban planners to make improvements in the design of the NBS to make the project truly multifunctional. Other studies use models or mapping methods to assess ESs and multifunctionality, which are difficult for urban planners to understand and use (Balzan et al., 2021; Sciuto et al., 2025).

The socioeconomic criteria valuation was low as the objectives of this urban nature project have not been linked to the different NBS types, essential actions required to evaluate the effectiveness of the NBS have not been taken (Raymond et al., 2017b), and the economic costs have not been considered. For example, trees can reduce costs associated with stormwater management infrastructure, health impacts of air pollution (Pataki et al., 2021), energy consumption (Roy et al., 2012; Mullaney et al., 2015), and impacts related to the promotion of mental and physical health (Tyrväinen et al., 2005). Other NBSs could also provide relevant economic benefits, for example, by creating green jobs (Raymond et al., 2017b) and even improving local economies through nature-based tourism by rewilding gardens (Lehmann, 2021). These economic aspects (cost–benefits) are poorly recognised and documented in the case of NBSs (Debele et al., 2023). On the contrary, the collaborative participation of citizens was notable, as citizens' proposals were considered in the implementation of all NBSs studied, addressing social equity issues (Goodwin et al., 2023); however, the level of co-design was not reached. In addition, the framework includes an environmental criterion, the location of the NBS, which helps to achieve an equitable distribution, that is, easier access to urban green areas for children and elderly (Wolch et al., 2005). Higher levels of citizen participation could address the social inclusion challenges in NBS but are difficult to achieve because of various constraints, such as inherent institutional structures owing to the scarce communication among the departments involved or lack of trust among stakeholders (Kiss et al., 2022).

In the case of the environmental assessment, none of the NBS reached the minimum values of the proposed environmental criteria. The NBSs exhibited the minimum values for diversity and size, indicating that these descriptors need to be improved in these NBSs to increase species diversity and the size of new greenspaces (Anguelovski et al., 2018). Therefore, unlike previous frameworks (IUCN, 2020; Saqib et al., 2024), the framework proposed herein identifies improvements that can increase multifunctionality. Particularly, for tree planting, using a similar number of individuals per species would have resulted in a diversity value of 0.5, and replacing *Taxus baccata* with *Sambucus nigra* would have improved values for leaf type and cooling capacity (Lee and Mayer, 2018). Furthermore, the cooling effect and connectivity would have been relatively high if the trees had been planted preferably in groups and double rows (Walmsley, 1995; Dubovik et al., 2022). This possibility implies that the proposed methodological framework can help identify the combination of tree species with the highest multifunctionality, thereby facilitating improvement in multifunctionality even before an urban nature project is conducted. Species selection is essential, and care must be taken to avoid planting invasive species that could spread and outcompete native species in surrounding natural habitats (Vogt et al., 2017) or cause allergic reactions (Castro-Díez et al., 2019). Therefore, tree species should be selected to ensure long-term ecological well-being rather than merely short-term aesthetic appeal, although potential risk factors must also be taken into account (Cimburova and Berghauser Pont, 2021). The NBS with the highest range of improvement in the environmental criteria was the greening of buildings and bioretention sites, particularly in terms of diversity, origin, and species characteristics, as they only used one species. Moreover, if the creation of bioretention sites had been combined with the planting of trees, the values would have been relatively high and multifunctionality would have increased (Stevens et al., 2023). For long-term sustainability in urban planning, an analysis of the characteristics of the trees to be planted is necessary to integrate species-specific benefits into the urban design process, and urban planners should be able to select appropriate tree species to maximise specific ES (Xie et al., 2011; Amini Parsa et al., 2019).

4.2. Sustainable practices in NBSs in a World heritage City

Over the last century, urban nature projects have become increasingly common in cities because they are particularly vulnerable to extreme weather events, which are predicted to increase with climate change (Masson et al., 2020). For example, Amsterdam (Netherlands) and Barcelona (Spain) are greening schoolyards (Cartalis Constantinos, 2021; Giezen and Pellerey, 2021), and Friedburg (Germany) has made considerable progress in urban design improving accessibility to public

Table 4
List of descriptors used to assess the environmental criteria for each NBS type. *Species belonging to the *Lamiaceae* family are considered aromatic.

Environmental criteria	Descriptors	Planting of trees	Naturalisation of non-wooded greenspaces	Greening of buildings	Creation of bioretention sites
Characteristics of the NBS	*Diversity* £	Number of individuals of each species			Number of species
	Type of actions §	%NBS in a continuous pit %NBSs in a living pit/natural ground %NBSs in double line or a group	%NBSs on non-compacted ground %NBSs on permeable ground		%NBSs covered by vegetation
Location of the NBS	*Environment* Ω	NBSs close to an educational centre NBSs in the surroundings of a cultural heritage site NBSs in a cultural or natural or both kinds of tours			
	Connectivity β	Acts as a corridor Acts as stepping stones Distance to the nearest green neighbour			
Extension	*Size* ¥	Area of NBS			
Characteristics of NBS species used	*Origins* α	Native/Naturalised			%Native species
	Components ∞	Crown density Leaf type Presence of showy flowering species Presence of fruit as food for wildlife Drought tolerance Allergenicity			% of species with showy flower % of species with fleshy fruit % of aromatic species*

The assigned values are:

£ : Planting of trees: if it meets the 5/10/15 rule = 1 (Galle et al., 2021), if it meets the 10/15/20 rule = 0.5 (Santamour, 1990), and if it does not meet any rule = 0. Naturalisation of non-wooded greenspaces: high diversity (16–21 spp.) = 1, medium diversity (9–13 spp.) = 0.5, low diversity (3–4 spp.) = 0.25, and no diversity (<3 spp.) = 0 (Norton et al., 2019). Greening of buildings: high diversity (15 spp.) = 1, medium diversity (7 spp.) = 0.5, low diversity (3–4 spp.) = 0.25, and no diversity (<3 spp.) = 0 (World Bannk, 2021; Dubovik et al., 2022). Creation of bioretention sites: high diversity (26 species) = 1, medium diversity (13 spp.) = 0.5, low diversity (6–7 spp.) = 0.25, and no diversity (<6 spp.) = 0 (Bjørn and Howe, 2023).

§ : Mean value of descriptors.

Ω : Yes = 1; No = 0. Mean value of descriptors.

β : Stepping stones were classified by size as follows: small (<20 m^2) = 0.25, medium (20–300 m^2) = 0.5, and large (>300 m^2) = 1. In addition, the distance between the NBS and the nearest green neighbour was considered as follows: >200 m = 0, 200–50 m = 0.5, <50 m = 1. This criterion is described in detail in Appendix 2. The final value was the mean value of the characteristics considered.

¥ : Low size (<0.25 ha) = 0.25, medium size (0.25–0.5 ha) = 0.5, high size (≥0.5 ha) = 1.

α : Native species = 1, naturalised species (non-invasive species adapted to the conditions of the environment and frequently used in the area) = 0.5, and allochthonous species = 0. For tree planting, the value was multiplied by the number of individuals per species.

∞ : Mean value of descriptors. See Appendix 1, Table S1.2 for assessing the characteristics of the tree species based on the bibliography and Appendix 1, Table S1.3 for different valuation options for tree planting according to the selected species in the heritage area. Each value was multiplied by the number of individuals of each species.

transport (Lin et al., 2021). Other World Heritage Cities also need to address this issue by developing urban nature projects, as exemplified by the case of Salamanca. Thus, they need to improve multifunctionality, both regulatory (habitat maintenance, cooling, runoff reduction, pollination, and pest control) and cultural services, which are very relevant in World Heritage Cities (Hilbert et al., 2019; Kosanic and Petzold, 2020). These projects should be carefully designed to create synergies

Table 5
Interventions performed for each NBS type within the heritage area urban nature project inside the *LIFE Vía de la Plata* in Salamanca.

Type of NBS	Intervention
Planting of trees	Number of interventions: 24 A total of 94 individuals of 12 tree and shrub species were planted in an area of 0.04 ha. All species except *Syringa vulgaris* were native (Appendix 1, Table S1.4). They were located within less than 300 m of an educational centre.
Naturalisation of non-tree greenspaces	Number of interventions: 8 Approximately 0.052 ha of meadows have been sown. Nine species have been planted (four native and three naturalised) in these meadows (Appendix 1, Table S1.6). Approximately 0.028 ha was on non-compacted ground and 0.023 ha was on permeable ground.
Greening of buildings	Number of interventions: 3 Two green walls and one pergola were installed within an area of 0.004 ha. *Parthenocissus tricuspidata* was the only used species, which is non-native (Appendix 1, Table S1.6).
Creation of bioretention sites	Number of interventions: 33 Approximately 0.034 ha of the area were intervened, creating rain gardens with *Hypericum calycinum* (68 m^2), a naturalised species (Appendix 1, Table S1.6), and installing permeable pavements (281 m^2) on zebra crossings and parking areas. They were located within less than 300 m of an educational centre. Areas without vegetation are considered unsuitable for connectivity (0).
All	They were in a cultural heritage site or on the cultural route *Vía de la Plata*, and they acted as stepping stones.

and reduce or avoid trade-offs among ESs, as well as multiple aspects of ecosystem health should be considered (Key et al., 2022). To this end, the proposed methodological framework is useful as it helps select the NBS type that will be more effective in addressing the identified challenges, such as coping with the impacts of climate change in the present case, during the design and planning phase. Moreover, monitoring and evaluation of the NBS are crucial to ensure its success (Ascenso et al., 2021) and to identify the most efficient NBS that can be extrapolated to other World Heritage Sites. However, to ensure its success, implementing sustainable management practices, such as using recycled water for irrigation, reducing fertiliser use, limiting the frequency of annual mowing, reducing pruning, pruning at the right time, and promoting the recycling of organic residues via composting, is necessary.

The NBS carried out in the heritage area of Salamanca clearly increased multifunctionality, particularly cooling and runoff reduction. However, they could be improved by considering the environmental criteria proposed in this study, as it is clear that greenspaces and trees provide cooling to mitigate urban heat (Schwaab et al., 2021); however, considering size, type, and structure (Park et al., 2017) in their design is relevant. In addition, the implemented NBSs will help manage stormwater at its source, focusing on infiltration-based technologies that include rain gardens and tree or shrub planting (Berland et al., 2017), as opposed to traditional stormwater management that relies on grey infrastructure. According to a study conducted in the USA, the removal of 2,990 m^2 of urban tree cover resulted in an increase in runoff volume of 198 m^3 (Selbig et al., 2022), highlighting the need to plant trees in cities. Various studies have shown that urban tree planting and proper management are relevant for securing, maintaining, and supporting the provision of a wide range of urban ESs (Amini Parsa et al., 2019; Rötzer et al., 2021; Cortinovis et al., 2022) in cities, where space is, by definition, at a premium (Vogt et al., 2017).

4.3. Strengths and limitations

The proposed framework for calculating the MuNaP index, based on multi-criteria analysis (socioeconomic and environmental criteria), is a

Table 6
Values for socioeconomic criteria, environmental criteria and the multifunctionality value (MFV) for each type of NBS and the value for MuNaP index of the urban nature project in the heritage area of Salamanca.

		Type of NBS			
		Planting of trees	Naturalisation of non-tree greenspaces	Greening of buildings	Creation of bioretention sites
Socioeconomic criteria					
Challenge		0.25	0.25	0.25	0.25
Impact on the local economy		0.30	0.37	0.50	0.37
Active participation of citizens		0.75	0.75	0.75	0.75
Environmental criteria					
Characteristics	*Diversity*	0.22	0.50	0.00	0.00
	Types of actions	0.69	0.50	1.00	0.19
Location	*Environment*	1.00	0.67	0.67	1.00
	Connectivity	0.65	0.71	0.67	0.23
Extension	*Size*	0.25	0.25	0.25	0.25
Characteristics of species	*Origin*	0.95	0.61	0.00	0.50
	Components	0.55	0.44	0.00	0.33
Final values					
Values for socioeconomic criteria		0.43	0.46	0.50	0.46
Values for environmental criteria		0.62	0.53	0.37	0.36
Multifunctionality value (MFV) (0–1)		0.53	0.49	0.44	0.41
MuNaP index (0–8)		3.95			

simple tool for assessing the multifunctionality of an urban nature project, which includes the NBS types evaluated in this proposal. Moreover, it defines the minimum value of multifunctionality to be achieved by the project. In this way, designers will know if they need to improve the multifunctionality of the project. In such cases, the MuNaP index identifies which aspects of the NBS require modification. Contrarily, as the framework assesses each NBS individually, it allows us to know the multifunctionality of each one of them.

The framework includes criteria related to biodiversity and habitat connectivity, which are not usually considered in the design of NBS (Key et al., 2022), that contribute to the protection and enhancement of ecosystems and biodiversity (Remme et al., 2024; Stuhlmacher and Kim, 2024). It allows us to select the most appropriate species for each site, which can have a profound impact on ES provision as the selection of native species can help support and enhance biodiversity (Dubovik et al., 2022), whereas non-native species can have negative impacts, which is not always considered in the design of NBS (Key et al., 2022). On the contrary, the framework considers disservices, namely allergies and excessive water demand by trees, which is an important aspect when designing an NBS (Perera et al., 2024).

The main limitation of the proposed framework is the imbalance between the socioeconomic and environmental criteria. Future research should include additional descriptors to assess the extent to which citizens' and stakeholders' inputs are incorporated into NBS design and implementation, such as the percentage of associations or social groups involved or the percentage of actions wherein citizens' proposals have been incorporated. Clearly distinguishing stakeholders and their different roles in different aspects of NBS is imperative (Kiss et al., 2022). Furthermore, the framework does not link socioeconomic criteria to ESs, which would aid in planning relatively more inclusive and equitable cities (Calderón-Argelich et al., 2021). By contrast, the economic cost descriptors are straightforward as this type of assessment is rarely conducted in NBS (Debele et al., 2023) but remains an area for future research.

5. Conclusions

Nowadays, urban renaturation through the implementation of multifunctional NBS is becoming increasingly adopted as a solution to addresss the impacts of climate change and biodiversity loss. However, the extent to which such NBSs are efficient in performing these tasks is often unknown. In this study, we present a methodological framework that facilitates the identification of those aspects of the four NBS types commonly used in urban restoration projects that can be improved from a socioeconomic and environmental perspective to increase multifunctionality. Furthermore, this framework makes it possible to calculate whether the NBS proposed in the project meets the minimum MFVs, thus ensuring that each type of NBS can contribute to the enhancement of biodiversity and ESs. It also considers the connectivity of NBS, an aspect not usually considered in this type of project.

Finally, this framework has been validated by the municipal technical staff in Salamanca, a World Heritage City. This validation supports its applicability in other cities of this type that face different urban challenges, such as climate change and biodiversity loss. As a result, urban planning can be enhanced to promote achieve urban resilience, increase sustainability, and improve citizen's well-being.

CRediT authorship contribution statement

B. Fernández de Manuel: Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Investigation, Conceptualization. **L. Peña:** Writing – review & editing, Methodology, Investigation. **A. Berreteaga:** Visualization, Validation, Methodology. **B. Diosdado:** Validation. **J. Laso:** Validation, Methodology. **I. Ametzaga-Arregi:** Writing – review & editing, Investigation, Project administration, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecoser.2025.101746.

Data availability

Data will be made available on request.

References

Afzalan, N., Muller, B., 2014. The Role of Social Media in Green Infrastructure Planning: a Case Study of Neighbourhood Participation in Park Siting. J. Urban Technol. 21 (3), 67–83. https://doi.org/10.1080/10630732.2014.940701.

Albert, C., Schröter, B., Haase, D., Brillinger, M., Henze, J., Herrmann, S., Gottwald, S., Guerrero, P., Nicolas, C., Matzdorf, B., 2019. Addressing societal challenges through nature-based solutions: how can landscape planning and governance research

contribute? Landsc. Urban Plan. 182, 12–21. https://doi.org/10.1016/j.landurbplan.2018.10.003.
Alonso Martínez, P., Escuer, L., Francolí, A., Martí, I., 2019. Proyecto piloto del control biológico por conservación en alcorques de la ciudad de Barcelona.
Amini Parsa, V., Salehi, E., Yavari, A.R., van Bodegom, P.M., 2019. Evaluating the potential contribution of urban ecosystem service to climate change mitigation. Urban Ecosystems 22 (5), 989–1006. https://doi.org/10.1007/s11252-019-00870-w.
Anguelovski, I., Connolly, J., Brand, A.L., 2018. From landscapes of utopia to the margins of the green urban life. City 22 (3), 417–436. https://doi.org/10.1080/13604813.2018.1473126.
Armson, D., Stringer, P., Ennos, A.R., 2013. The effect of street trees and amenity grass on urban surface water runoff in Manchester UK. Urban Forestry & Urban Greening 12 (3), 282–286. https://doi.org/10.1016/j.ufug.2013.04.001.
Ascenso, A., Augusto, B., Silveira, C., Rafael, S., Coelho, S., Monteiro, A., Ferreira, J., Menezes, I., Roebeling, P., Miranda, A.I., 2021. Impacts of nature-based solutions on the urban atmospheric environment: a case study for Eindhoven, the Netherlands. Urban For. Urban Green. 57, 126870. https://doi.org/10.1016/j.ufug.2020.126870.
Babí Almenar, J., Elliot, T., Rugani, B., Philippe, B., Navarrete Gutierrez, T., Sonnemann, G., Geneletti, D., 2021. Nexus between nature-based solutions, ecosystem services and urban challenges. Land Use Policy 100, 104898. https://doi.org/10.1016/j.landusepol.2020.104898.
Balzan, M., Zulian, G., Maes, J., Borg, M., 2021. Assessing urban ecosystem services to prioritise nature-based solutions in a high-density urban area. Nature-Based Solutions. 1, 100007. https://doi.org/10.1016/j.nbsj.2021.100007.
Baró, F., Gómez-Baggethun, E., 2017. Assessing the potential of Regulating Ecosystem Services as Nature-based Solutions in Urban areas. In: Kabisch, N., Korn, H., Stadler, J., Bonn, A. (Eds.), Nature-Based Solutions to Climate Change Adaptation in Urban Areas: Linkages between Science, Policy and Practice (issue Book, Section. Springer International Publishing, pp. 139–158. https://doi.org/10.1007/978-3-319-56091-5_9.
Beninde, J., Veith, M., Hochkirch, A., 2015. Biodiversity in cities needs space: a meta-analysis of factors determining intra-urban biodiversity variation. Ecol. Lett. 18 (6), 581–592. https://doi.org/10.1111/ele.12427.
Berland, A., Shiflett, S.A., Shuster, W.D., Garmestani, A.S., Goddard, H.C., Herrmann, D. L., Hopton, M.E., 2017. The role of trees in urban stormwater management. Landsc. Urban Plan. 162, 167–177. https://doi.org/10.1016/j.landurbplan.2017.02.017.
Berthon, K., Thomas, F., Bekessy, S., 2021. The role of 'nativeness' in urban greening to support animal biodiversity. Landsc. Urban Plan. 205, 103959. https://doi.org/10.1016/j.landurbplan.2020.103959.
Bjørn, M.C., Howe, A.G., 2023. Multifunctional bioretention basins as urban stepping stone habitats for wildflowers and pollinators. Urban Forestry & Urban Greening, 90 (Journal Article), 128133. https://doi.org/10.1016/j.ufug.2023.128133.
Boada, M., 2005. Arbolado urbano. Importancia Desde El Punto De Vista De La Biodiversidad y La Mejora De La Calidad De Vida. [Conferencia].
Borg, M.A., Xiang, J., Anikeeva, O., Ostendorf, B., Varghese, B., Dear, K., Pisaniello, D., Hansen, A., Zander, K., Sim, M.R., Bi, P., 2023. Current and projected heatwave-attributable occupational injuries, illnesses, and associated economic burden in Australia. Environ. Res. 236, 116852. https://doi.org/10.1016/j.envres.2023.116852.
Brears, R.C., 2020. Nature-based solutions to 21st century challenges. Routledge. https://doi.org/10.4324/9780429294600.
Brink, E., Aalders, T., Ádám, D., Feller, R., Henselek, Y., Hoffmann, A., Ibe, K., Matthey-Doret, A., Meyer, M., Negrut, N.L., Rau, A.L., Riewerts, B., von Schuckmann, L., Törnros, S., von Wehrden, H., Abson, D.J., Wamsler, C., 2016. Cascades of green: a review of ecosystem-based adaptation in urban areas. Glob. Environ. Chang. 36, 111–123. https://doi.org/10.1016/J.GLOENVCHA.2015.11.003.
Buckland, A., Sparrow, K., Handley, P., Hill, D., Doick, K.J., 2020. Valuing Newport's Urban Trees. A Report to Newport City Council and Welsh Government.
Calderón-Argelich, A., Stefania B., Isabelle A., James J.T.C., Johannes L., Francesc B., 2021. Tracing and building up environmental justice considerations in the urban ecosystem service literature: A systematic review, Landscape and Urban Planning, Volume 214, 2021, 104130, ISSN 0169-2046, .
Campbell, A.J., Biesmeijer, J.C., Varma, V., Wäckers, F.L., 2012. Realising multiple ecosystem services based on the response of three beneficial insect groups to floral traits and trait diversity. Basic Appl. Ecol. 13 (4), 363–370. https://doi.org/10.1016/j.baae.2012.04.003.
Cartalis Constantinos, 2021. Project GBG_AS2C - Blue, Green & Grey_Adapting Schools to Climate Change Barcelona, Spain Topic Climate adaptation Upscaling with a vision - The school yard as a school. Expert Article - Project GBG_AS2C - Blue, Green & Grey_ Adapting Schools to Climate Change. https://uia-initiative.eu/en/news/upscaling-vision-school-yard-school.
Castro-Díez, P., Vaz, A.S., Silva, J.S., van Loo, M., Alonso, Á., Aponte, C., Bayón, Á., Bellingham, P.J., Chiuffo, M.C., DiManno, N., Julian, K., Kandert, S., La Porta, N., Marchante, H., Maule, H.G., Mayfield, M.M., Metcalfe, D., Monteverdi, M.C., Núñez, M.A., Godoy, O., 2019. Global effects of non-native tree species on multiple ecosystem services. Biol. Rev. 94 (4), 1477–1501. https://doi.org/10.1111/brv.12511.
Chen, F., Zhang, X., Chen, Z., 2023. Behind climate change: Extreme heat and health cost. Struct. Chang. Econ. Dyn. 64, 101–110. https://doi.org/10.1016/j.strueco.2022.12.007.
Cimburova, Z., Berghauser Pont, M., 2021. Location matters. a systematic review of spatial contextual factors mediating ecosystem services of urban trees. Ecosyst. Serv. 50, 101296. https://doi.org/10.1016/J.ECOSER.2021.101296.
Coombes, M.A., Viles, H.A., 2021. Integrating nature-based solutions and the conservation of urban built heritage: challenges, opportunities, and prospects. Urban For. Urban Green. 63, 127192. https://doi.org/10.1016/j.ufug.2021.127192.
Cortinovis, C., Geneletti, D., 2018. Mapping and assessing ecosystem services to support urban planning: a case study on brownfield regeneration in Trento Italy. One Ecosystem 3, e25477. https://doi.org/10.3897/oneeco.3.e25477.
Cortinovis, C., Olsson, P., Boke-Olén, N., Hedlund, K., 2022. Scaling up nature-based solutions for climate-change adaptation: potential and benefits in three European cities. Urban For. Urban Green. 67, 127450. https://doi.org/10.1016/j.ufug.2021.127450.
Croeser, T., Georgia, G., Roshan, S., Alessandro, O., Sarah, B., 2021. Choosing the right nature-based solutions to meet diverse urban challenges, Urban Forestry & Urban Greening, Volume 65, 2021, 127337, ISSN 1618-8667, https://doi.org/10.1016/j.ufug.2021.127337.
Davies, H., Doick, K., Handley, P., O'Brien, L., Wilson, J., 2017. Delivery of ecosystem services by urban forests. Forestry Commission.
Dean Austin, G., 2012. Multi-functional ecological corridors in urban development. Spaces & Flows: an International Journal of Urban & Extra Urban Studies 2 (3), 211–228.
Debele, S.E., Laura, S.L., Prashant, K., Jeetendra, S., Joy, O., Edoardo, B., Saša, V., Milan, K., Zahra, A., Irina, P., Mohammad, A.R.S., Alejandro, G.-O., Silvana, D.S., 2023. Nature-based solutions can help reduce the impact of natural hazards: A global analysis of NBS case studies, Science of The Total Environment, Volume 902, 2023, 165824, ISSN 0048-9697, https://doi.org/10.1016/j.scitotenv.2023.165824.
de Manuel, B.F., Méndez-Fernández, L., Peña, L., Ametzaga-Arregi, I., 2021. A new indicator of the effectiveness of urban green infrastructure based on ecosystem services assessment. Basic Appl. Ecol. 53, 12–25. https://doi.org/10.1016/j.baae.2021.02.012.
Dorst, H., van der Jagt, A., Toxopeus, H., Tozer, L., Raven, R., Runhaar, H., 2022. What's behind the barriers? Uncovering structural conditions working against urban nature-based solutions. Landsc. Urban Plan. 220, 104335. https://doi.org/10.1016/j.landurbplan.2021.104335.
Dubovik, M., Rinta-Hiiro, V., Laikari, A., Zu Castell-Rüdenhausen, M., Wendling, L., Jakstis, K., Fischer, L., Spinnato, P., Jermakka, J., Fatima, Z., Ascenso, A., Miranda, A., Roebeling, P., Martins, R., Mendonça, R., Vela, S., Cioffi, M., Mok, S., Botto, S., Gambucci, E., 2022. Nature-based Solutions Implementation Handbook. UNaLab-Urban Nature Labs. https://unalab.eu/system/files/2024-01/d55-nbs-implementation-handbook2024-01-04.pdf.
Egerer, M.H., Fricke, E.C., Rogers, H.S., 2018. Seed dispersal as an ecosystem service: frugivore loss leads to decline of a socially valued plant Capsicum Frutescens. Ecological Applications 28 (3), 655–667. https://doi.org/10.1002/eap.1667.
Eisenberg, B., Polcher, V., 2019. Nature Based Solutions -Technical Handbook. https://doi.org/10.13140/RG.2.2.24970.54726.
EPA (Environmental Protection Agency), 2008. Trees and Vegetation. In: Reducing Urban Heat Islands: Compendium of Strategies. https://www.epa.gov/heat-islands/heat-island-compendium.
Epelde, L., Mendizabal, M., Gutiérrez, L., Artetxe, A., Garbisu, C., Feliu, E., 2022. Quantification of the environmental effectiveness of nature-based solutions for increasing the resilience of cities under climate change, Urban Forestry & Urban Greening, Volume 67, 2022, 127433, ISSN 1618-8667, https://doi.org/10.1016/j.ufug.2021.127433.
Escobedo, F., Seitz, J., 2009. The Costs of Managing an Urban Forest. EDIS, FOR217. https://doi.org/10.32473/edis-fr279-2009.
Commission, E., 2015. Towards an EU research and innovation policy agenda for nature-based solutions & re-naturing cities – final report of the Horizon 2020 expert group on 'Nature-based solutions and re-naturing cities'. Publications Office. https://doi.org/10.2777/479582.
Council, E., 2024. Nature restoration law: Council gives final green light. Press Release. https://www.consilium.europa.eu/en/press/press-releases/2024/06/17/nature-restoration-law-council-gives-final-green-light/.
Fang, X., Li, J., Ma, Q., 2023. Integrating green infrastructure, ecosystem services and nature-based solutions for urban sustainability: a comprehensive literature review. Sustain. Cities Soc. 98, 104843. https://doi.org/10.1016/j.scs.2023.104843.
Ferrari, B., Quatrini, V., Barbati, A., Corona, P., Masini, E., Russo, D., 2019. Conservation and enhancement of the green infrastructure as a nature-based solution for Rome's sustainable development. Urban Ecosystems 22 (5), 865–878. https://doi.org/10.1007/s11252-019-00868-4.
Forristal, L.J., Lehto, X.Y., Lee, G., 2014. The contribution of native species to sense of place. Curr. Issue Tour. 17 (5), 414–433. https://doi.org/10.1080/13683500.2012.723679.
Frantzeskaki, N., 2019. Seven lessons for planning nature-based solutions in cities. Environ. Sci. Policy 93, 101–111. https://doi.org/10.1016/j.envsci.2018.12.033.
Galle, N.J., Halpern, D., Nitoslawski, S., Duarte, F., Ratti, C., Pilla, F., 2021. Mapping the diversity of street tree inventories across eight cities internationally using open data. Urban For. Urban Green. 61, 127099. https://doi.org/10.1016/j.ufug.2021.127099.
Giezen, M., Pellerey, V., 2021. Renaturing the city: Factors contributing to upscaling green schoolyards in Amsterdam and the Hague. Urban For. Urban Green. 63, 127190. https://doi.org/10.1016/j.ufug.2021.127190.
Goodness, J., Andersson, E., Anderson, P.M.L., Elmqvist, T., 2016. Exploring the links between functional traits and cultural ecosystem services to enhance urban ecosystem management. Ecol. Ind. 70, 597–605. https://doi.org/10.1016/j.ecolind.2016.02.031.
Goodwin, S., Olazabal, M., Castro, A.J., et al., 2023. Global mapping of urban nature-based solutions for climate change adaptation. Nat Sustain 6, 458–469. https://doi.org/10.1038/s41893-022-01036-x.

Grey, V., Livesley, S.J., Fletcher, T.D., Szota, C., 2018. Tree pits to help mitigate runoff in dense urban areas. J. Hydrol. 565, 400–410. https://doi.org/10.1016/j.jhydrol.2018.08.038.

Haase, A., 2017. The Contribution of Nature-based Solutions to Socially Inclusive Urban Development– some Reflections from a Social-environmental Perspective. In: Kabisch, N., Korn, H., Stadler, J., Bonn, A. (Eds.), Nature-Based Solutions to Climate Change Adaptation in Urban Areas. Theory and Practice of Urban Sustainability Transitions. Springer, Cham. https://doi.org/10.1007/978-3-319-56091-5_13.

Han, Q., Keeffe, G., 2021. Promoting climate-driven forest migration through large-scale urban afforestation. Landsc. Urban Plan. 212, 104124. https://doi.org/10.1016/j.landurbplan.2021.104124.

Hansen, R., Olafsson, A.S., van der Jagt, A.P.N., Rall, E., Pauleit, S., 2019. Planning multifunctional green infrastructure for compact cities: what is the state of practice? Ecol. Ind. 96, 99–110. https://doi.org/10.1016/j.ecolind.2017.09.042.

Hector, A., Bagchi, R., 2007. Biodiversity and ecosystem multifunctionality. Nature 448 (7150), 188–190. https://doi.org/10.1038/nature05947.

Hernández, A., 2007. Alimentación de aves frugívoras en setos y bordes de bosque del norte de España: Importancia de algunas especies de plantas en invierno y primavera. Ecología 27, 145–156. https://www.mapa.gob.es/ministerio/pags/Biblioteca/Revistas/pdf_REPN%2FECO_2007_21_145_156.pdf.

Hilbert, D.R., Koeser, A.K., Roman, L.A., Hamilton, K., Landry, S.M., Hauer, R.J., Campanella, H., McLean, D., Andreu, M., Perez, H., 2019. Development practices and ordinances predict inter-city variation in Florida urban tree canopy coverage. Landsc. Urban Plan. 190, 103603. https://doi.org/10.1016/j.landurbplan.2019.103603.

Hirons, A., Sjöman, H., 2019. Tree species selection for green infrastructure: a guide for specifiers (issue 1.3). Trees & Design Action Group. https://www.tdag.org.uk/tree-species-selection-for-green-infrastructure.html.

ILO, UNEP and IUCN, 2022. Decent Work in Nature-based Solutions 2022. Geneva. ISBN: 9789220389721.

INE, 2021. Instituto Nacional de Estadística. https://www.ine.es/.

IUCN (2020). Global Standard for Nature-based Solutions. A user-friendly framework for the verification, design and scaling up of NbS. First edition. Gland, Switzerland: IUCN. ISBN: 978-2-8317-2058-6 DOI: https://doi.org/10.2305/IUCN.CH.2020.08.en.

Isbell, F., Calcagno, V., Hector, A., Connolly, J., Harpole, W.S., Reich, P.B., Scherer-Lorenzen, M., Schmid, B., Tilman, D., van Ruijven, J., Weigelt, A., Wilsey, B.J., Zavaleta, E.S., Loreau, M., 2011. High plant diversity is needed to maintain ecosystem services. Nature 477 (7363), 199–202. https://doi.org/10.1038/nature10282.

Iungman, T., Cirach, M., Marando, F., Pereira Barboza, E., Khomenko, S., Masselot, P., Quijal-Zamorano, M., Mueller, N., Gasparrini, A., Urquiza, J., Heris, M., Thondoo, M., Nieuwenhuijsen, M., 2023. Cooling cities through urban green infrastructure: a health impact assessment of European cities. Lancet 401 (10376), 577–589. https://doi.org/10.1016/S0140-6736(22)02585-5.

Johnston, M., Nail, S., James, S., 2011. Natives versus Aliens - the relevance of the debate to urban forest management in Britain. https://doi.org/10.13140/2.1.1340.3844.

Jordano, P., 2014. Fruits and frugivory. In Seeds: the ecology of regeneration in plant communities (pp. 18–61). CABI. https://doi.org/10.1079/9781780641836.0018.

Junta de Castilla y León (Dirección General de Patrimonio Cultural) y Ayuntamiento de Salamanca, 2017. PLAN DE GESTIÓN DE LA CIUDAD VIEJA DE SALAMANCA, 2017. ORDEN FOM-59-2007, de 22 de enero, sobre la Revisión del Plan General de Ordenación Urbana de Salamanca (BOCYL núm. 16, de 23 de enero de 2007).

Keeler, B.L., Hamel, P., McPhearson, T., Hamann, M.H., Donahue, M.L., Meza Prado, K.A., Arkema, K.K., Bratman, G.N., Brauman, K.A., Finlay, J.C., Guerry, A.D., Hobbie, S.E., Johnson, J.A., MacDonald, G.K., McDonald, R.I., Neverisky, N., Wood, S.A., 2019. Social-ecological and technological factors moderate the value of urban nature. Nat. Sustainability 2 (1), 29–38. https://doi.org/10.1038/s41893-018-0202-1.

Key, I.B., Smith, A.C., Turner, B., Chausson, A., Girardin, C.A.J., Macgillivray, M., Seddon, N., 2022. Biodiversity outcomes of nature-based solutions for climate change adaptation: characterising the evidence base. Front. Environ. Sci. 10. https://doi.org/10.3389/fenvs.2022.905767.

Kiss, B., Sekulova, F., Hörschelmann, K., Salk, C.F., Takahashi, W., Wamsler, C., 2022. Citizen participation in the governance of nature-based solutions. Environ. Policy Gov. 32 (3), 247–272. https://doi.org/10.1002/eet.1987.

Kosanic, A., Petzold, J., 2020. A systematic review of cultural ecosystem services and human wellbeing. Ecosyst. Serv. 45, 101168. https://doi.org/10.1016/j.ecoser.2020.101168.

Kremer, P., Hamstead, Z.A., McPhearson, T., 2016. The value of urban ecosystem services in New York City: a spatially explicit multicriteria analysis of landscape scale valuation scenarios. Environ Sci Policy 62, 57–68. https://doi.org/10.1016/j.envsci.2016.04.012.

Larondelle, N., Haase, D., 2013. Urban ecosystem services assessment along a rural–urban gradient: a cross-analysis of European cities. Ecol. Ind. 29, 179–190. https://doi.org/10.1016/j.ecolind.2012.12.022.

Laurenz, J., Belausteguigoitia, J., de la Fuente, A., Roehr, D., 2021. Green urban (RE) generation: a research and practice methodology to better implement green urban infrastructure solutions. Land 10 (12), 1376. https://doi.org/10.3390/land10121376.

Lee, H., Mayer, H., 2018. Maximum extent of human heat stress reduction on building areas due to urban greening. Urban For. Urban Green. 32, 154–167. https://doi.org/10.1016/j.ufug.2018.04.010.

Lehmann, S., 2021. Growing biodiverse urban futures: renaturalization and rewilding as strategies to strengthen urban resilience. Sustainability 13 (5), 2932. https://doi.org/10.3390/su13052932.

Liang, D., Huang, G., 2023. Influence of urban tree traits on their ecosystem services. A Literature Review. Land 12 (9). https://doi.org/10.3390/land12091699.

Lin, B.B., Ossola, A., Alberti, M., Andersson, E., Bai, X., Dobbs, C., Elmqvist, T., et al., 2021. Integrating solutions to adapt cities for climate change. The Lancet Planetary Health 5 (7), e479–e486. https://doi.org/10.1016/S2542-5196(21)00135-2.

Liquete, C., Udias, A., Conte, G., Grizzetti, B., Masi, F., 2016. Integrated valuation of a nature-based solution for water pollution control. Highlighting Hidden Benefits. Ecosystem Services 22, 392–401. https://doi.org/10.1016/j.ecoser.2016.09.011.

Lundquist, M.J., Weisend, M.R., Kenmore, H.H., 2022. Insect biodiversity in urban tree pit habitats. Urban For. Urban Green. 78, 127788. https://doi.org/10.1016/j.ufug.2022.127788.

Lynch, A.J., 2019. Creating Effective Urban Greenways and Stepping-stones: four critical Gaps in Habitat Connectivity Planning Research. J. Plan. Lit. 34 (2), 131–155. https://doi.org/10.1177/0885412218798334.

Mak, C., Scholz, M., James, P., 2017. Sustainable drainage system site assessment method using urban ecosystem services. Urban Ecosystems 20 (2), 293–307. https://doi.org/10.1007/s11252-016-0593-6.

Masson, V., Lemonsu, A., Hidalgo, J., Voogt, J., 2020. Urban Climates and climate change. Annu. Rev. Environ. Resour. 45 (1), 411–444. https://doi.org/10.1146/annurev-environ-012320-083623.

McPhearson, T., Cook, E.M., Berbés-Blázquez, M., Cheng, C., Grimm, N.B., Andersson, E., Barbosa, O., Chandler, D.G., Chang, H., Chester, M.V., Childers, D.L., Elser, S.R., Frantzeskaki, N., Grabowski, Z., Groffman, P., Hale, R.L., Iwaniec, D.M., Kabisch, N., Kennedy, C., Troxler, T.G., 2022. A social-ecological-technological systems framework for urban ecosystem services. One Earth 5 (5), 505–518. https://doi.org/10.1016/j.oneear.2022.04.007.

Melathopoulos, A., Bell, N., Danler, S., Detweiler, A.J., Kormann, I., Langellotto, G., Sánchez, N., Stoven, H., Smitley, D., 2020. Enhancing urban and suburban landscapes to protect pollinators. Oregon State University. https://extension.oregonstate.edu/sites/default/files/documents/em9289.pdf.

Mitchell, M.G.E., Bennett, E.M., Gonzalez, A., 2013. Linking Landscape connectivity and ecosystem service provision: current knowledge and research gaps. Ecosystems 16 (5), 894–908. https://doi.org/10.1007/s10021-013-9647-2.

Mullaney, J., Lucke, T., Trueman, S.J., 2015. A review of benefits and challenges in growing street trees in paved urban environments. Landsc. Urban Plan. 134, 157–166. https://doi.org/10.1016/j.landurbplan.2014.10.013.

Natural England, 2003. Accessible Natural Green Space Standards in Towns and Cities: A Review and Toolkit for their Implementation (ENRR526). .

New York City, 2016. Street Tree Planting Standards for New York City. https://www.nycgovparks.org/pagefiles/53/Tree-Planting-Standards.pdf.

Norton, B.A., Bending, G.D., Clark, R., Corstanje, R., Dunnett, N., Evans, K.L., Grafius, D.R., Gravestock, E., Grice, S.M., Harris, J.A., Hilton, S., Hoyle, H., Lim, E., Mercer, T.G., Pawlett, M., Pescott, O.L., Richards, J.P., Southon, G.E., Warren, P.H., 2019. Urban meadows as an alternative to short mown grassland: effects of composition and height on biodiversity. Ecol. Appl. 29 (6), e01946. https://doi.org/10.1002/eap.1946.

Ogren, T.L., 2000. Allergy-free gardening : the revolutionary guide to healthy landscaping. Internet Archive. Ten Speed Press, Berkeley.

Owuor, J.A., Whitehead, I., De Vreese, R., 2022. Unlocking the Potential of Urban Forests: Developing a Local Urban Forestry Plan. Erasmus+ Project Uforest Deliverable 3.4. ISBN 978-952-7426-28-9 https://www.uforest.eu/news/project-updates/urban-forestry-action-plan/.

Pal, S., Singha, P., Lepcha, K., Debanshi, S., Talukdar, S., Saha, T.K., 2021. Proposing multicriteria decision based valuation of ecosystem services for fragmented landscape in mountainous environment. Remote Sens. Appl.: Soc. Environ. 21, 100454. https://doi.org/10.1016/j.rsase.2020.100454.

Park, J., Kim, J.-H., Lee, D.K., Park, C.Y., Jeong, S.G., 2017. The influence of small green space type and structure at the street level on urban heat island mitigation. Urban For. Urban Green. 21, 203–212. https://doi.org/10.1016/j.ufug.2016.12.005.

Pataki, D.E., Alberti, M., Cadenasso, M.L., Felson, A.J., McDonnell, M.J., Pincetl, S., Pouyat, R.V., Setälä, H., Whitlow, T.H., 2021. The Benefits and limits of urban tree planting for environmental and human health. Front. Ecol. Evol. 9. https://doi.org/10.3389/fevo.2021.603757.

Paudel, S., States, S.L., 2023. Urban green spaces and sustainability: Exploring the ecosystem services and disservices of grassy lawns versus floral meadows. Urban For. Urban Green. 84, 127932. https://doi.org/10.1016/j.ufug.2023.127932.

Pauleit, S., Zölch, T., Hansen, R., Randrup, T. B., Konijnendijk van den Bosch, C., 2017. Nature-Based Solutions and Climate Change – Four Shades of Green (pp. 29–49). https://doi.org/10.1007/978-3-319-56091-5_3.

Peña, L., Casado-Arzuaga, I., Onaindia, M., 2015. Mapping recreation supply and demand using an ecological and a social evaluation approach. Ecosyst. Serv. 13, 108–118. https://doi.org/10.1016/j.ecoser.2014.12.008.

Perera, C., Toxopeus, H., Klein, S., Merfeld, K., 2024. Enabling justice for nature-based solutions in real estate development. Nature-Based Solutions 6, 100148. https://doi.org/10.1016/j.nbsj.2024.100148.

Pretzsch, H., Biber, P., Uhl, E., Dahlhausen, J., Rötzer, T., Caldentey, J., Koike, T., van Con, T., Chavanne, A., Seifert, T., du Toit, B., Farnden, C., Pauleit, S., 2015. Crown size and growing space requirement of common tree species in urban centres, parks, and forests. Urban For. Urban Green. 14 (3), 466–479. https://doi.org/10.1016/j.ufug.2015.04.006.

Raymond, C.M., Berry, P., Breil, M., Nita, M.R., Kabisch, N., de Bel, M., Enzi, V., Frantzeskaki, N., Geneletti, D., Cardinaletti, M., Lovinger, L., Basnou, C., Monteiro, A., Robrecht, H., Sgrigna, G., Munari, L., Calfapietra, C., 2017a. An Impact Evaluation Framework to Support Planning and Evaluation of Nature-Based Solutions Projects. United Kingdom.

Raymond, C.M., Frantzeskaki, N., Kabisch, N., Berry, P., Breil, M., Nita, M.R., Geneletti, D., Calfapietra, C., 2017b. 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.
Remme, R.P., Meacham, M., Pellowe, K.E., Andersson, E., Guerry, A.D., Janke, B., Liu, L., Lonsdorf, E., Li, M., Mao, Y., Nootenboom, C., Wu, T., van Oudenhoven, A.P.E., 2024. Aligning nature-based solutions with ecosystem services in the urban century. Ecosyst. Serv. 66, 101610. https://doi.org/10.1016/j.ecoser.2024.101610.
Rice, L., 2019. Nature-based solutions for urban development and tourism. International Journal of Tourism Cities 6 (2), 431–448. https://doi.org/10.1108/IJTC-05-2019-0069.
Rojas, J.A., Dhar, A., Naeth, M.A., 2022. Urban green spaces restoration using native forbs, site preparation and soil amendments—a case study. Land 11 (4), 498. https://doi.org/10.3390/land11040498.
Rötzer, T., Moser-Reischl, A., Rahman, M.A., Hartmann, C., Paeth, H., Pauleit, S., Pretzsch, H., 2021. Urban tree growth and ecosystem services under extreme drought. Agric. For. Meteorol. 308–309, 108532. https://doi.org/10.1016/j.agrformet.2021.108532.
Rötzer, T., Rahman, M.A., Moser-Reischl, A., Pauleit, S., Pretzsch, H., 2019. Process based simulation of tree growth and ecosystem services of urban trees under present and future climate conditions. Sci. Total Environ. 676, 651–664. https://doi.org/10.1016/j.scitotenv.2019.04.235.
Roy, S., Byrne, J., Pickering, C., 2012. A systematic quantitative review of urban tree benefits, costs, and assessment methods across cities in different climatic zones. Urban For. Urban Green. 11 (4), 351–363. https://doi.org/10.1016/j.ufug.2012.06.006.
Santamour, F. S. Jr., 1990. Trees for Urban Planting: Diversity, Uniformity, and Common Sense. Proc. 7th Conf. Metropolitan Tree Improvement Alliance (METRIA) , 57–65.
Saqib, A., Khan, M., Ullah, S., Irfan, R., 2024. Bridging nature and urbanity through green roof resilience framework (GRF): a thematic review. Nature-Based Solutions. 6, 100182. https://doi.org/10.1016/j.nbsj.2024.100182.
Sarabi, S., Han, Q., de Vries, B., Romme, A.G.L., 2022. The nature-based solutions planning support system: a playground for site and solution prioritization. Sustain. Cities Soc. 78, 103608. https://doi.org/10.1016/j.scs.2021.103608.
Schütz, C., Schulze, C.H., 2015. Functional diversity of urban bird communities: effects of landscape composition, green space area and vegetation cover. Ecol. Evol. 5 (22), 5230–5239. https://doi.org/10.1002/ece3.1778.
Schwaab, J., Meier, R., Mussetti, G., Seneviratne, S., Bürgi, C., Davin, E.L., 2021. The role of urban trees in reducing land surface temperatures in European cities. Nat. Commun. 12 (1), 6763. https://doi.org/10.1038/s41467-021-26768-w.
Sciuto, L., Licciardello, F., Giuffrida, E.R., Barresi, S., Scavera, V., Verde, D., Barbagallo, S., Cirelli, G.L., 2025. Hydrological-hydraulic modelling to assess Nature-Based Solutions for flood risk mitigation in an urban area of Catania (Sicily, Italy), Nature-Based Solutions, Volume 7, 100210, ISSN 2772-4115, https://doi.org/10.1016/j.nbsj.2024.100210.
Selbig, W.R., Loheide, S.P., Shuster, W., Scharenbroch, B.C., Coville, R.C., Kruegler, J., Avery, W., Haefner, R., Nowak, D., 2022. Quantifying the stormwater runoff volume reduction benefits of urban street tree canopy. Sci. Total Environ. 806, 151296. https://doi.org/10.1016/j.scitotenv.2021.151296.
Semeraro, T., Scarano, A., Pandey, R., 2022. Ecosystem services analysis and design through nature-based solutions in urban planning at a neighbourhood scale. Urban Sci. 6 (1). https://doi.org/10.3390/urbansci6010023.
Sheppard, S.R.J., 2012. Visualizing climate change: a guide to visual communication of climate change and developing local solutions. Routledge.
Sjöman, H., Busse Nielsen, A., 2010. Selecting trees for urban paved sites in Scandinavia – a review of information on stress tolerance and its relation to the requirements of tree planners. Urban For. Urban Green. 9 (4), 281–293. https://doi.org/10.1016/j.ufug.2010.04.001.
Spyra, M., Kleemann, J., Cetin, N.I., Vázquez Navarrete, C.J., Albert, C., Palacios-Agundez, I., Ametzaga-Arregi, I., La Rosa, D., Rozas-Vásquez, D., Adem Esmail, B., Picchi, P., Geneletti, D., König, H.J., Koo, H., Kopperoinen, L., Fürst, C., 2018. The ecosystem services concept: a new Esperanto to facilitate participatory planning processes? Landsc. Ecol. 34 (7), 1715–1735. https://doi.org/10.1007/s10980-018-0745-6.
Stevens, P.J., Stevens, A.J., Ferranti, E.J.S., Sharifi, S., James, S., 2023. First steps in Urban Water. a Trees and Design Action Group (TDAG) Guidance Document. London, UK.
Stuhlmacher, M., Kim, Y., 2024. The unequal connectivity of parks and tree canopy in 10 U.S. cities. Urban Forestry & Urban Greening, 96 (Journal Article), 128332. https://doi.org/10.1016/j.ufug.2024.128332.
Suchocka, M., Heciak, J., Błaszczyk, M., Adamczyk, J., Gaworski, M., Gawłowska, A., Mojski, J., Kalaji H. M., Kais, K., Kosno-Jończy, J., Wojnowska Heciak, M., Comparison of Ecosystem Services and Replacement Value calculations performed for urban trees, Ecosystem Services, Volume 63, 2023, 101553, ISSN 2212-0416, .
Tengberg, A., Fredholm, S., Eliasson, I., Knez, I., Saltzman, K., Wetterberg, O., 2012. Cultural ecosystem services provided by landscapes: assessment of heritage values and identity. Ecosyst. Serv. 2, 14–26. https://doi.org/10.1016/j.ecoser.2012.07.006.
Tyrväinen, L., Pauleit, S., Seeland, K., de Vries, S., 2005. Benefits and Uses of Urban Forests and Trees. In: Konijnendijk, C., Nilsson, K., Randrup, T., Schipperijn, J. (Eds.), Urban Forests and Trees: A Reference Book. Springer, Berlin Heidelberg, pp. 81–114. https://doi.org/10.1007/3-540-27684-X_5.
van de Ven, F.H.M., Snep, R.P.H., Koole, S., Brolsma, R., van der Brugge, R., Spijker, J., Vergroesen, T., 2016. Adaptation Planning support Toolbox: Measurable performance information based tools for co-creation of resilient, ecosystem-based urban plans with urban designers, decision-makers and stakeholders. Environ Sci Policy 66, 427–436. https://doi.org/10.1016/j.envsci.2016.06.010.
Vega, K.A., Küffer, C., 2021. Promoting wildflower biodiversity in dense and green cities: the important role of small vegetation patches. Urban For. Urban Green. 62, 127165. https://doi.org/10.1016/J.UFUG.2021.127165.
Vogt, J., Gillner, S., Hofmann, M., Tharang, A., Dettmann, S., Gerstenberg, T., Schmidt, C., Gebauer, H., Van de Riet, K., Berger, U., Roloff, A., 2017. Citree: a database supporting tree selection for urban areas in temperate climate. Landsc. Urban Plan. 157, 14–25. https://doi.org/10.1016/j.landurbplan.2016.06.005.
Walmsley, A., 1995. Greenways and the making of urban form. Landsc. Urban Plan. 33 (1–3), 81–127. https://doi.org/10.1016/0169-2046(95)02015-L.
White, C., Collier, M.J., Stout, J.C., 2021. Using ecosystem services to measure the degree to which a solution is nature-based. Ecosyst. Serv. 50, 101330. https://doi.org/10.1016/j.ecoser.2021.101330.
WHO/EURO, 2016. Urban green spaces and health. WHO Regional Office for Europe,. .
WHO/EURO, 2017. Urban green spaces: a brief for action. https://www.who.int/europe/publications/i/item/9789289052498.
Wilker, J., Rusche, K., Rymsa-Fitschen, C., 2016. Improving participation in green infrastructure planning. Plan. Pract. Res. 31 (3), 229–249. https://doi.org/10.1080/02697459.2016.1158065.
a. Wolch, J., Wilson, J.P., Fehrenbach, J., 2005. Parks and park funding in Los Angeles: An equity-mapping analysis. Urban Geogr. 26 (1), 4–35. . B.World Bannk, 2021. A Catalogue of Nature-based Solutions for Urban Resilience. .
Xie, Q., Zhou, Z., Chen, F., 2011. Quantifying the beneficial effect of different plant species on air quality improvement. Environ. Eng. Manag. J. 10 (7), 959–963. https://doi.org/10.30638/eemj.2011.137.
Yinshuaia, L., Nan, J., Chenglong, Y., Ruishan, C., 2024. Transition of land use/cover in world heritage cities under climate crisis. Ecol. Ind. 169 (112972). https://doi.org/10.1016/j.ecolind.2024.112972.
Youga, M.K.D., Njiméli, P.S., Kenfack, C.P., Taffo, J.B.W., Tacham, W.N., Fonkou, T., 2022. Knowledge and traditional uses of some aromatic and cosmetic plants species in the western highlands of cameroon. Open Journal of Applied Sciences 12 (10), 1698–1718. https://doi.org/10.4236/ojapps.2022.1210116.