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Understanding stakeholder preferences for the spatial and temporal distribution of nature-based solution benefits in cities

Alessia Chelli [a,b], Davide Geneletti [b,*]

[a] Department of Economics and Management, University of Trento, via Inama 5, 38122 Trento, Italy
[b] Planning for Ecosystem Services and Urban Sustainability Lab, Department Civil, Environmental and Mechanical Engineering, University of Trento, via Mesiano 77, 38123 Trento, Italy

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ABSTRACT

Stakeholder preferences regarding the spatial and temporal distribution of nature-based solutions (NBS) -namely, the size of the intervention and how its benefits are distributed across space and time-remain largely unexplored in the current literature. This study investigates these preferences and their underlying motivations through ten semi-structured interviews with local stakeholders in the Municipality of Trento. A thematic analysis was conducted to explore the drivers behind preferences for implementing a single large versus several small, distributed NBS, as well as for NBS that deliver benefits in the short-term (within one year) compared to those offering a broader range of benefits over the long-term (6–10 years). Single large NBS was valued for its environmental and socio-cultural impact, while several small interventions were generally preferred due to their accessibility, adaptability, and perceived fairness in benefit distribution. Notably, most stakeholders maintained their preference for several small NBS even after being informed that a single large NBS could generate a higher overall volume of benefits. Long-term NBS were appreciated for their ecological impacts, while short-term interventions were favored for their immediate visibility and greater public support. These findings underscore the importance of explicitly considering both the spatial and temporal distribution of NBS benefits in planning processes.

1. Introduction

Nature-based solutions (NBS) are strategies that use nature and ecosystems to address the effects of climate change, while simultaneously delivering social, environmental, and economic benefits in the form of ecosystem services (ES) [1], and are increasingly gaining attention in urban contexts [2]. NBS encompass a wide range of interventions that can be strategically combined to achieve specific urban goals [3].

NBS interventions can differ significantly in terms of their implementation scale, that is, the physical extent of the intervention [4]. For instance, small-scale interventions may include green roofs or pocket gardens within neighborhoods, while large-scale projects such as urban forests or metropolitan parks can span vast areas and deliver multiple ecological and social benefits. The location where NBS are implemented does not necessarily coincide with the area where the resulting ES are provided and experienced. Different spatial relationships may emerge between the Service Providing Areas (e.g., the NBS themselves) and the Service Benefiting Areas (i.e., the locations where people or ecosystems actually receive the benefits) [5]. These spatial relationships are influenced by multiple factors, such as the type of ecosystem function involved, the specific environmental components [6], and the characteristics of the surrounding built environment [7]. The size of the NBS is another key factor that influences both the intensity and distribution of the ES they generate [8,9]. The relationship between intervention size and ES provision can follow either a linear or a non-linear pattern [6]. Generally, larger interventions tend to generate greater benefits, although under non-linear conditions, and marginal returns may diminish as the size increases. Urban climate studies have shown that parks of 10 hectares or more-with canopy cover above approximately 40%-can produce cooling effects that extend for several hundred meters, whereas parks of two hectares or less typically have cooling impact under 100 m [10–12]. In some cases, a minimum area is necessary to activate the ecological processes required for service provision. For instance, regulating ES such as air purification or carbon sequestration only become effective beyond certain levels of green cover [13,14].

The amount and types of ES generated by NBS can also vary over time, as NBS follow distinct temporal patterns throughout their entire

* Corresponding author.
E-mail address: davide.geneletti@unitn.it (D. Geneletti).

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life cycle. These temporal dynamics depend on several factors, including the time needed for vegetation to establish and mature [15], as well as external biophysical conditions such as geology, soil characteristics, climate, topography, and species composition [16]. As a result, NBS may require a time lag before reaching full effectiveness, with different ES emerging at different stages of development [17–19,3]. While some services can be provided immediately after implementation, others may take years to materialize- or even extend beyond the project's technical lifespan [17,20]. For instance, an urban park can immediately offer recreational opportunities by providing accessible green space to residents. However, its climate regulation functions, such as shading and evapotranspiration, emerge gradually as vegetation grows and reaches a size and density sufficient to influence the microclimate.

Although there is a scientific consensus on the positive impacts of NBS, public acceptance remains essential for their successful implementation. This, in turn, requires a deep understanding of the preferences of stakeholders and residents, as these can influence the NBS development process [21] and help ensure that interventions align with the needs of the community, the characteristics of the specific location, and the urban challenges to be addressed [22,3]. Stakeholders for NBS refer to the individuals, communities, organizations, and government entities that participate in designing, building, and managing NBS projects [23]. Stakeholder and resident engagement enables urban planners to enhance the multifunctionality of NBS, providing valuable insights for their long-term success [24,25]. While the significance of understanding how stakeholders perceive urban challenges, prioritize actions, and value the benefits of NBS is widely acknowledged, research into these interrelationships remains incomplete [26]. Current literature has focused on exploring stakeholders' views on NBS and green infrastructure, by examining perception on specific NBS such as urban trees [27] and NBS for flood management [28], and by investigating the influence of these perceptions on conservation efforts [29] and their role in facilitating sustainable urban transitions [30]. Other contributions have examined stakeholder opinions on the adaptive capacity of NBS in response to climate change [31], their ability to provide ES [32,33], and general perceptions of ES [34]. Additionally, research has addressed stakeholders' views on urban challenges, preferred interventions, and the factors shaping these preferences [21], as well as perceptions of the opportunities and barriers to NBS implementation [35–37].

Nonetheless, limited attention has been paid to stakeholders' preferences and motivations concerning the spatial and temporal distribution of NBS and their benefits [38]. Understanding these preferences is essential because planning decisions involve multiple critical trade-offs across both dimensions [39,40]. From a temporal perspective, delayed benefits can lead to perceptions of risk and uncertainty [41], and create misalignment with political cycles, potentially failing to meet stakeholder expectations [42]. Spatially, decisions about intervention size, location, and distribution determine who benefits, where, and to what extent, raising fundamental questions of accessibility and equity. Without understanding stakeholder preferences across both dimensions, planners risk designing interventions that, while technically sound, fail to gain public support or meet community needs.

The objective of this study is to provide a comprehensive investigation of stakeholders' preferences and underlying motivations for both the spatial and temporal dimensions of urban NBS, using semi-structured interviews and thematic data analysis. Our investigation addresses two complementary aspects that together provide a complete understanding of how these dimensions shape NBS planning decisions. Firstly, we examine how stakeholders perceive and prioritize urban challenges when evaluated at different spatial scales (site, district, urban) and under different temporal horizons (general importance versus immediate urgency). This aspect is essential because these dimensions shape which problems stakeholders believe NBS should address, and consequently, which types of interventions are considered most appropriate. Secondly, we investigate stakeholders' preferences and underlying motivations for the spatial and temporal distribution of NBS interventions and their benefits. Concerning the spatial dimension, we explore preferences regarding the size and distribution of NBS (whether stakeholders favor a single large intervention or several smaller, distributed ones), as well as how stakeholders value the resulting spatial distribution of benefits. Concerning the temporal dimension, we investigate preferences for the timing of NBS benefits, comparing interventions that deliver moderate benefits rapidly (short-term) versus those that provide greater benefits but require longer maturation periods (long-term).

Answering these questions will provide insights on how spatial and temporal dimensions can inform NBS planning, from problem identification through solution design, generating insights for designing NBS that are aligned with the communities' multidimensional expectations.

2. Methods

2.1. Study area

Trento is an Alpine municipality of approximately 120,000 inhabitants, situated in the eastern Italian Alps, representative of medium-sized European cities where NBS planning is increasingly becoming a priority. The administrative area spans over 158 km^2, with forests occupying about 72 km^2 (Fig. 1). Around 70% of the population is concentrated on the valley floor, hosting industrial, commercial, and infrastructural developments.

The city of Trento is divided into 12 administrative districts, each with distinct local responsibilities, population density, types of economic activity, and the presence and accessibility of green and blue spaces [43,44]. Public green spaces occupy only 2% of the urbanized area [45], making Trento representative of land-constrained urban contexts where NBS implementation faces competing spatial demands. Currently, the Municipality of Trento is actively engaged in several projects aimed at increasing green spaces, promoting biodiversity, and developing green infrastructure [45].

Trento is crossed by the Adige River and the Fersina Stream. The Fersina originates from Lake Erdemolo in the upper Fersina Valley of eastern Trentino, at an altitude of around 2000 m, and extends for approximately 30 km. The Stream exemplifies a widespread urban condition of artificially confined urban waterway with high ecological potential, but limited functionality, also in terms of recreational use. Its urban stretch has been transformed into an artificial channel bounded by high embankments, providing minimal ecosystem services and no public accessibility. For this reason, the area has been selected by the BioValue project (https://biovalue-horizon.eu/) to design urban regeneration interventions enhancing biodiversity and the provision of ecosystem services. The artificialization resulting from historical grey infrastructure approaches is representative of numerous degraded urban waterways across Europe [46], making findings relevant to similar restoration contexts.

2.2. Stakeholder selection and mapping

Stakeholder analysis is typically conducted in the early stages of public project planning to understand the broader context and identify key actors who can either support or obstruct decision-making [47]. Clearly defining stakeholders is essential for understanding their needs, expectations, and viewpoints, enabling project planners to anticipate and address potential opposition while also evaluating each group's influence on the project's outcome [48].

We built upon the stakeholder list compiled by the BioValue project, which had already identified and engaged key actors involved in the preliminary planning phases for the Fersina Stream restoration [49]. From this list, we selected participants to ensure diverse perspectives across institutional roles, decision-making power, and sectoral expertise. At least one participant was selected from each of the following categories:

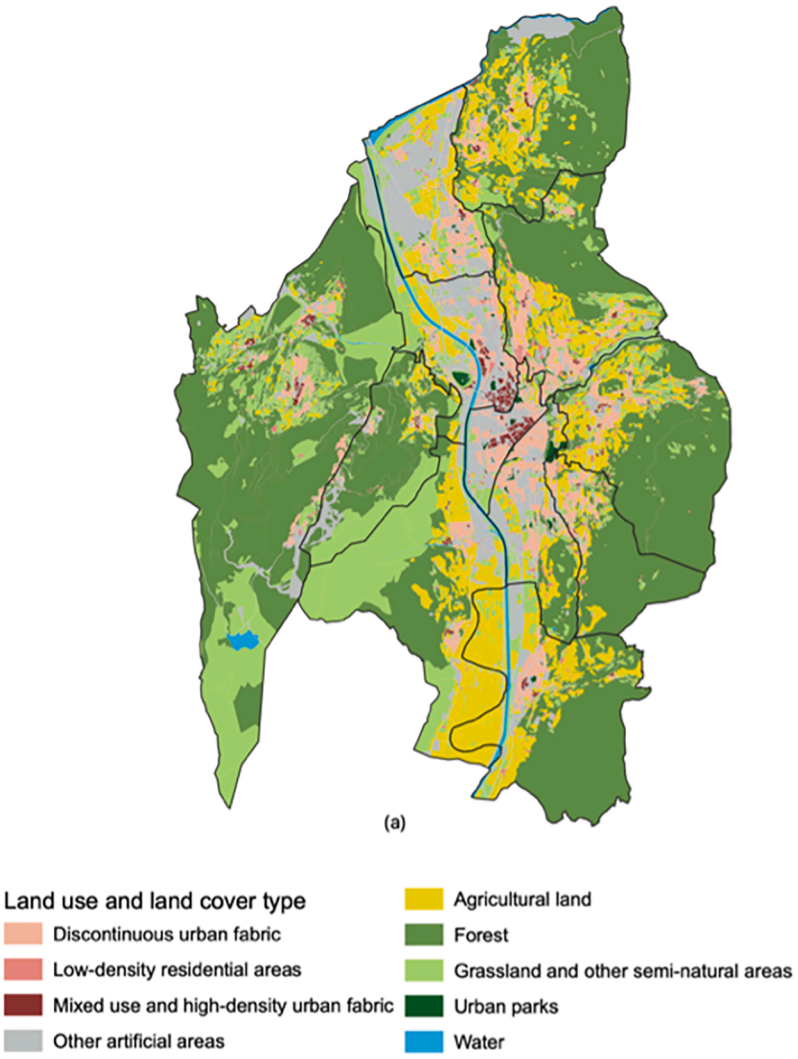

Fig. 1. Mainland uses in Trento.

1. Public administrations: local government officials, including technical staff, responsible for urban development and green area management.
2. Practitioners: urban planners, designers, and technical consultants who contribute specialized expertise.
3. Associations and local communities: local councilors, civil society groups, and members of environmental or social NGOs, whose role is to convey community viewpoints.

Academic researchers were deliberately excluded to maintain focus on stakeholders with direct decision-making or implementation roles in local NBS planning.

This selection approach provided several methodological advantages: (1) stakeholders had demonstrated active interest in NBS through participation in BioValue planning workshops; (2) they possessed contextual knowledge of the site's challenges and opportunities; (3) being already familiar with real-world planning constraints and opportunities for the Fersina area, their responses reflected informed perspectives rather than abstract opinions, enhancing the validity of findings.

We adopted the interest-power matrix as a preliminary tool for mapping stakeholders. The interest-power matrix is a widely used stakeholder analysis approach and is categorized as a top-down method that classifies stakeholders into four groups based on their relative power and interest in the decision-making problem [50]. Stakeholder power refers to the capacity of stakeholders to exert influence to achieve desired outcomes, whereas interest pertains to stakeholders' concerns regarding the specific problem being addressed [51]. The four quadrants represent: (1) high power-high interest (key players requiring close engagement); (2) high power-low interest (influential actors to keep satisfied); (3) low power-high interest (stakeholders to keep informed); and (4) low power-low interest (minimal engagement needed). Understanding this distribution is essential for interpreting how different actors' positions shape their NBS preferences. Stakeholders' positions in the matrix were confirmed through direct questions during interviews about their perceived influence over Fersina Stream planning decisions and their level of interest in the project outcome.

2.3. *Semi-structured interviews*

Semi-structured interviews with both closed- and open-ended questions were conducted with the selected stakeholders from January to March 2024. Semi-structured interviews were preferred because they allow for open-ended questions within a structured and adaptable framework [52,53]. The aim of the interviews was to understand how stakeholders' perceptions of urban challenges to be addressed vary according to spatial scale of reference and when urgency is considered, as well as to explore their preferences and motivations for the spatial

configuration of NBS and the spatial and temporal distribution of the benefits. To this end, we identified three different spatial scales (Fig. 2):

- Urban scale: the entire built-up area of Trento,
- District scale: part of the adjacent neighborhoods of Oltrefersina and San Giuseppe-Santa Chiara,
- Site scale: the immediate surroundings of the Fersina Stream.

The interview was structured into an introductory section and three main sections, associated with the three research questions (see Supplementary Material 1 for full interview script text). The introductory section aimed at describing the objectives, providing key definitions, and understanding the interviewee's level of interest and influence in the study area. This information was used to position the stakeholder within a stakeholder map.

In the first section, participants were presented - for each of the spatial scales - with eight environmental and social challenges and asked to indicate their importance, i.e. how necessary they believed it was to implement interventions to address each challenge, using a 1-to-5 rating system. To investigate how the perceived urgency of these challenges influenced their choices, participants were asked to select and rank the three most urgent challenges for each spatial level, assigning a score based on its rank (3 for the most urgent, 2 for the second, and 1 for the third).

The second section aimed to explore stakeholder preferences and underlying motivations for different spatial configurations of NBS, as well as the extent to which the spatial distribution of benefits from these interventions influenced their choices. This section focused exclusively on site-scale interventions in the area surrounding the Fersina Stream. To this purpose, we selected one type of NBS - urban parks - due to their familiarity and ease of visualization. We presented two illustrative options, each covering the same overall area: (1) a single, large, centralized park ("single large" option); and (2) three smaller parks distributed along the Stream ("several small" option). Participants were first asked to express their preference between the two configurations and to explain the reasoning behind their choice. Next, we provided additional information on how the ES generated by each configuration would be spatially distributed. Specifically, we explained that the single large option could deliver benefits extending beyond its immediate boundaries, while the several small option would offer more localized and evenly spread benefits. After this, participants were asked whether this new information changed their initial preference and, again, to elaborate on the motivations behind their choice.

The final part of the interview focused on understanding stakeholders' preferences and underlying motivations regarding NBS that differ in the timing and magnitude of the benefits they deliver. To this end, we presented two illustrative NBS options, differing in both the time required to realize their full range of benefits and the overall magnitude of those benefits. The first option was a short-term intervention, expected to deliver moderate benefits within one year. The second was a long-term intervention, designed to generate greater benefits, but requiring six to ten years to reach its full potential. As in previous sections, we used a park as a concrete and familiar example to facilitate understanding. Participants were then asked to indicate their preferred option and to explain the reasons for supporting or opposing each of them.

2.4. Data analysis

Data analysis proceeded in two main stages. First, we examined how perceptions of urban challenges to be addressed vary depending on the spatial scale of reference, by calculating the average of the Likert-scale responses for each urban challenge at the three spatial scales. We then compared these results with an analysis of the temporal prioritization of the urban challenges to be addressed to understand how urgency influences perception of importance across different spatial scales. To do so, we calculated the total score for each urban challenge based on individual responses, using a 0 to 3 rating system, where 0 was assigned when a challenge was not considered among the top three priorities, and 3 was assigned when it was given the highest priority.

In the second part of the analysis, we explored stakeholder preferences and their motivations for NBS spatial and temporal configurations through a qualitative thematic analysis, using MAXQDA to systematically organize and interpret the data [54]. The coding process was conducted inductively, meaning that themes and categories emerged through multiple readings of the interview transcripts, and codes were revised throughout the analysis. This iterative approach proceeded through three main steps: (1) initial open coding to identify all justifications provided by stakeholders; (2) consolidation of conceptually similar codes; and (3) hierarchical organization into macro-categories and sub-categories to enable analysis at multiple levels of detail and facilitate identification of both specific motivations and broader thematic patterns. This ensured openness to unexpected findings while allowing us to capture the nuances of participants' perspectives. Whenever a negative viewpoint was expressed about one NBS option, we recoded it as a positive viewpoint for the alternative configuration to maintain analytical consistency. We then conducted a frequency analysis of the codes and analyzed how these motivations varied across

Fig. 2. The three spatial scales used in the interviews: urban (entire city), district (part of Oltrefersina and San Giuseppe-Santa Chiara neighborhoods), and site (Fersina Stream surroundings).

different stakeholder groups.

3. Results

3.1. Stakeholder analysis

Ten stakeholders, with varying degrees of interest and power in the Fersina redevelopment project, were involved. Fig. 3 shows the distribution of stakeholders within the interest-power matrix. Public administrators ($n = 4$) consistently held high power but varied in interest levels, reflecting formal authority over planning decisions with differing degrees of active engagement. Practitioners ($n = 3$) showed the most dispersed positioning across the matrix, spanning from low power-low interest to high interest-medium power, reflecting diverse professional roles. Associations and community representatives ($n = 3$) demonstrated consistently high interest (4–5) but variable power (1–3), with most holding limited formal authority despite strong motivation.

3.2. Spatial scales and urban challenges

Stakeholders rated the importance of each urban challenge on a 1-to-5 Likert scale at each of the three spatial scales and then ranked the three most urgent challenges per scale (see Section 2.3). Fig. 3 shows the average importance scores, while Table 1 compares importance and urgency ratings across scales.

The district level registers the highest average scores for most challenges, in particular for heatwave mitigation, air quality, and recreation, which are all higher than at both the urban and site scale. The urban scale generally shows lower average values except for runoff management, where it records the highest score. The site scale shows mixed values. Its overall total is slightly lower than that of the urban scale, but surpasses it for aesthetic improvement, social cohesion, recreation, and biodiversity. Comparing individual challenges across scales reveals additional patterns. Some challenges, such as heatwave mitigation and biodiversity, maintain consistently high importance regardless of the scale. Others show scale-dependent variations. In particular, air quality improvement ranges from high at the district scale to low at the site scale, and runoff management stands out as a predominantly urban-scale concern. Noise reduction remains at medium importance at the urban and district scales and drops to low at the site level.

Table 1 illustrates how the introduction of the urgency dimension influences the perceived importance of addressing urban challenges across different spatial scales. The comparison between the importance and the urgency scores reveals that the two dimensions do not always align. Some challenges maintain consistently high urgency across scales. Air quality improvement ranks among the top two most urgent challenges at all three levels, despite receiving heterogeneous importance scores ranging from low at the site scale to high at the district scale. Heatwave mitigation also shows high urgency at the urban and district levels, where it ranks first, but is prioritized less at the site scale. Conversely, other challenges exhibit urgency patterns that diverge markedly from their importance ratings. Social cohesion, despite being rated as highly important at all scales, consistently receives low urgency scores. Biodiversity is deemed highly urgent exclusively at the site scale, where it ranks first, while maintaining moderate urgency at the district level and low urgency at the urban level. Noise reduction, a medium-importance challenge at the urban and district scales, gains relevance in urgency only at the district level. Finally, some challenges show stable patterns across both dimensions. Runoff mitigation maintains consistently low urgency scores across all scales, in line with its generally low-to-medium importance ratings, and recreation remains among the least urgent challenges at all levels.

3.3. Stakeholders' preferences on NBS spatial configuration

Eight out of ten interviewees initially opted for several small parks, while two preferred the single large park option. All stakeholders, regardless of their final choice, expressed both positive and critical opinions about both options, recognizing a set of common advantages and disadvantages. Table 2 presents the results of the thematic analysis of the motivations underlying the two typologies of NBS, while Fig. 4 illustrates how these motivations are distributed across various stakeholder groups and whether they target several small or single large NBS. The resulting codes were classified into six macro-categories: ecological, socio-cultural, planning, implementation and management, urban, and economic. A detailed description of these codes and categories is provided in Table A1 of the Supplementary Material. Overall, associations and local communities tend to emphasize social and environmental

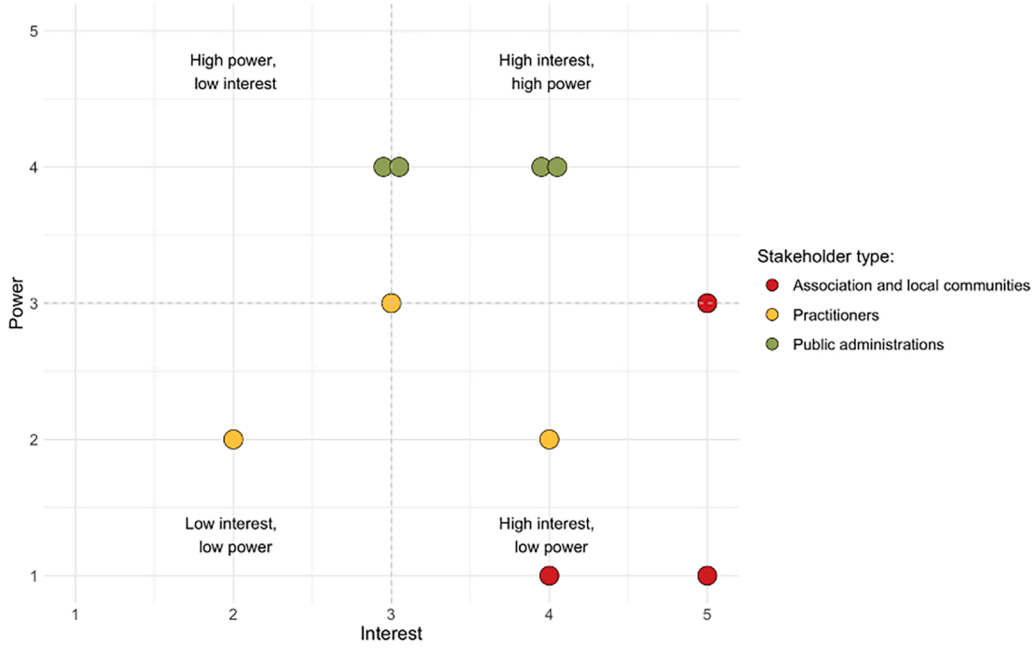

Fig. 3. Stakeholders' distribution in the interest-power matrix. Each circle represents a single stakeholder, positioned according to their level of interest and power.

Table 1
Perceived importance and urgency of urban challenges at the urban, district, and site scale. Importance scores are based on the average of the 1–5 Likert scale responses: low refers to average scores below 2.5, medium to scores between 2.5 and 3.49, and high to scores of 3.5 and above. Urgency scores were calculated by assigning 3 points to the most urgent challenge, 2 to the second, and 1 to the third, and summing these scores across all participants.

Urban challenge	Importance			Urgency		
	Urban scale	District scale	Site scale	Urban scale	District scale	Site scale
Air quality improvement	Medium	High	Low	11	12	13
Heatwave mitigation	High	High	High	18	16	8
Runoff mitigation	Medium	Low	Low	3	3	3
Noise reduction	Medium	Medium	Low	0	8	1
Biodiversity	High	High	High	7	9	16
Recreation	Medium	Medium	Medium	2	3	6
Social cohesion	High	High	High	9	2	6
Aesthetic improvement	High	High	High	10	7	1

impacts. Practitioners, by contrast, consider a broad range of factors but give less attention to economic aspects, whereas public administrators address most dimensions but place slightly less emphasis on ecological considerations (Fig. 5).

Most motivations in favor of several small NBS relate to their better integration into a fragmented urban context with architectural constraints. Some interviewees highlighted that small interventions have the advantage of being implemented in unused areas and that, in general, they can better adapt to the specific characteristics of the territory and make more efficient use of public land. In contrast, the creation of a single large NBS might require the expropriation of private land. They claim that, from both ecological and social perspectives, several small NBS are especially valued because they allow for a broader distribution of ES across multiple sections of the Stream. This configuration increases accessibility, promotes a more equitable allocation of green spaces, and supports ecological connectivity, thereby facilitating wildlife movement throughout Trento's existing green areas. Additionally, it was noted that the development of several small NBS could support the creation of thematic green areas, strengthening local identity and responding to the specific needs of each neighborhood.

Conversely, the motivations supporting the single large NBS focused on its potential to serve as a high-impact green space, generating positive effects on the local economy. This includes benefits for businesses in the area, an increase in surrounding property values, and greater opportunities to leverage economies of scale. Some stakeholders also pointed out that concentrating resources in one area could simplify management, and maintenance, allowing for more efficient planning and the creation of complementary services, such as sports facilities or event spaces. Such spaces would also ensure better oversight to prevent vandalism and inappropriate behavior, which often occur in small parks that *"tend to be less monitored and risk becoming the neighborhood's dumping ground."* (Stakeholder 4). From an ecological and social perspective, these areas were recognized for their greater ability to provide psychological well-being, as they allow people to immerse themselves in nature, away from the urban environment. Additionally, a single large NBS could support the implementation of multiple ecosystems with high biodiversity value, enhancing both environmental and recreational benefits.

After receiving more details about the possible distribution of environmental and social benefits from both spatial configurations-such as the potential for several small NBS to create a more distributed but locally limited impact compared to the broader but concentrated impact of a single large NBS-only two of the several small NBS supporters changed their preference. Their reasoning was that "*When planning NBS interventions, it is crucial to maximize the environmental and social benefits that can be derived. If a large park allows for the generation of amplified, synergistic benefits, it is more efficient to invest in this solution rather than in small-scale interventions, which, although easier to distribute and manage, may not achieve the same overall impact."* (Stakeholder 6). For these stakeholders, the distribution of benefits proved to be a decisive factor in reconsidering their initial choice. Conversely, those who maintained their preference for several small NBS emphasized the importance of providing more equitable and widespread access to ecosystem functions, as well as greater adaptability to local needs. In some cases, it was noted that socio-economic differences between neighborhoods and the limited presence of green spaces in certain areas of the city made a distributed model preferable. Conversely, none of the respondents who initially preferred single large NBS changed their opinion.

3.4. Stakeholders' preferences on temporal distribution of NBS benefits

A preference for long-term NBS was expressed by six out of ten respondents, while the remaining four favored short-term solutions. As with spatial preferences, all respondents, regardless of their final choice, provided both supporting and opposing motivations for each alternative.

Table 3 presents the results of the thematic analysis on the motivations supporting the two typologies of NBS, while Fig. 6 illustrates how these motivations are distributed across various stakeholder groups and whether they target short-term or long-term NBS. The resulting codes were grouped into five macro-categories: impacts, urban planning, operational aspects, economic, and public and institutional support. This thematic structure differs from the one of spatial configuration (Table 2), reflecting distinct decision-making dimensions. For example, while spatial analysis generated more detailed ecological and socio-cultural subcategories reflecting the importance of physical distribution and equity in benefit provision, temporal configuration analysis uniquely includes the "Public and institutional support" category that captures stakeholders' concerns about maintaining political commitment and funding stability over multi-year timeframes. A detailed description of these codes and categories is provided in Table A2 of the Supplementary Material. Overall, associations and local communities tend to emphasize the social and environmental impacts of NBS, as well as public acceptance and support. Practitioners, by contrast, focus on impacts alongside urban and operational considerations, whereas public administrators address all the dimensions.

Respondents who preferred the short-term option often stressed the urgency of providing immediate solutions to environmental and social needs, emphasizing that this approach would better address the concerns of residents who are worried about the growing impacts of climate change and would like to see a quick response from the Municipality. One interviewee pointed out how rapidly visible outcomes can encourage further interventions *"We need immediate responses to improve urban quality of life and mitigate climate change effects. A short-term NBS can produce visible results and encourage further investments"* (Stakeholder 2). Respondents also highlighted that these types of NBS might gain more support from policymakers who need to demonstrate tangible results from the investment and initiatives they support. However, many of these stakeholders also raised concerns about the resilience of an ecological system designed for quick impact, fearing it might be more vulnerable and less biodiverse *"A fast intervention might work to address immediate problems, but its longevity and ability to regenerate over time are*

Table 2
Motivations for supporting "single large" versus "several small" NBS reported by the interviewees and divided by thematic area (in brackets the number of interviewees).

Motivations		Spatial configuration	
Area	Sub-area	Several small NBS	Single large NBS
Ecological	*Ecological quality*	• Distribution of ecosystem services (4)	• High biodiversity & ecosystem services (3) • Multiple ecosystems (1) • Perception of naturalness (2)
	Ecological connectivity	• Ecological connectivity (2)	
Socio-cultural	*Accessibility and inclusiveness*	• Distributed accessibility (2) • Inclusiveness for vulnerable groups (2)	
	Aggregation	Distributed meeting points (1)	Broader social gathering capacity (2) Social cohesion (3)
	Cultural and recreational functions	• Event manageability (1) • Thematic design (1)	• Multipurpose space (1) • Cultural hub (1) • Environmental education (2) • Local institutions partnerships (1)
	Value and identity	• Local identity (1)	• City identity (1) • Community value (2) • Aesthetic impact (4) • Tourist value (2)
	Well-being		• Psychological well-being (3) • Urban isolation (2)
Planning, implementation and management	*Planning and implementation*	• Planning flexibility (2) • Implementation feasibility (1) • Stakeholders' coordination (2)	• Unified planning (1)
	Operational management	• Risk diversification (1) • Risk management flexibility (2) • Flow management (2) • Reduced infrastructure requirements (2)	• Operational efficiency (1) • Centralization of management operations (1) • Enhanced safety and behavior control (2)
	Maintenance	• Localized maintenance (1)	• Simplified maintenance (1)
Urban planning	*Urban feasibility*	• Minimized urban constraints (1) • Adaptation to the urban context (1) • Urban feasibility (1) • Use of public land (1) • Urban integration (3)	
	Urban connectivity	• Green network (5)	
	Urban regeneration	• Sustainable mobility (2) • Urban regeneration (1)	
Economic aspect	*Costs*		• Economies of scale (3)
	Economic impact		• Local economic impact (1) • Investment attraction (1)

uncertain" (Stakeholder 9).

On the other hand, supporters of the long-term option highlighted the added value of an NBS intervention that gradually evolves into a more complex and resilient ecosystem, finally resulting in greater benefits for the environment and society. According to some respondents, this slower pace of ecological maturation is part of the intervention's appeal, showcasing the beauty of nature's evolution and reinforcing the connection between people and their environment. For some, the prospect of waiting several years to see full results was not a limitation but rather an opportunity to carefully plan management and governance aspects, develop more structured local participation mechanisms -educating the population about natural growth cycles and actively involving them in monitoring the evolution of benefits over time while respecting the rhythm of nature. *"If we want lasting change, we must be willing to wait and build a project that integrates stably into the urban ecosystem"* (Stakeholder 7). In this vision, gradual growth allows for the experimentation of innovative solutions and adaptation to changing urban or climatic conditions, although this approach entails a slower return for the community and may be less politically attractive. Additionally, several interviews highlighted how the delay in the provision of benefits can influence the availability of financial resources and the stability of institutional support. While long-term solutions are perceived as more impactful and more beneficial for future generations, they may face greater challenges in securing funding and maintaining stakeholder interest throughout the entire maturation process. "*There is always a risk that a long-term project will be abandoned or lose political support over time, and this is something to consider"* (Stakeholder 3). Moreover, long-term interventions may require investments in complementary measures to address urban challenges during the period when benefits are still materializing, ensuring that the transition to a more resilient ecosystem does not leave immediate needs unmet.

4. Discussion

4.1. Spatial scale effects on the challenge importance and urgency

Our results confirm that the spatial scale of reference and the introduction of the urgency component influence stakeholders' perceptions of the urban challenges to be addressed. This aligns with previous research demonstrating that spatial scale influences ES valuation [55–57]. In general, at a finer spatial scales (site and district), challenges that are more easily observable such as biodiversity and aesthetic improvement tend to be emphasized, while at a broader scale, less tangible and more diffuse needs, such as air quality improvement, become more salient. The influence of spatial scale on the prioritization of ES by stakeholders had already been demonstrated by Langemeyer & Baró [58]. Our findings extend this understanding to a finer spatial scales (urban, neighborhood, local), reinforcing the need a of multi-scale approach in NBS planning, which are currently rare [58]. Planning interventions based solely on local needs risks producing fragmented solutions that, while addressing site-specific challenges, may fail to tackle

Fig. 4. Importance of the urban challenges to be addressed at the urban, district, and site level.

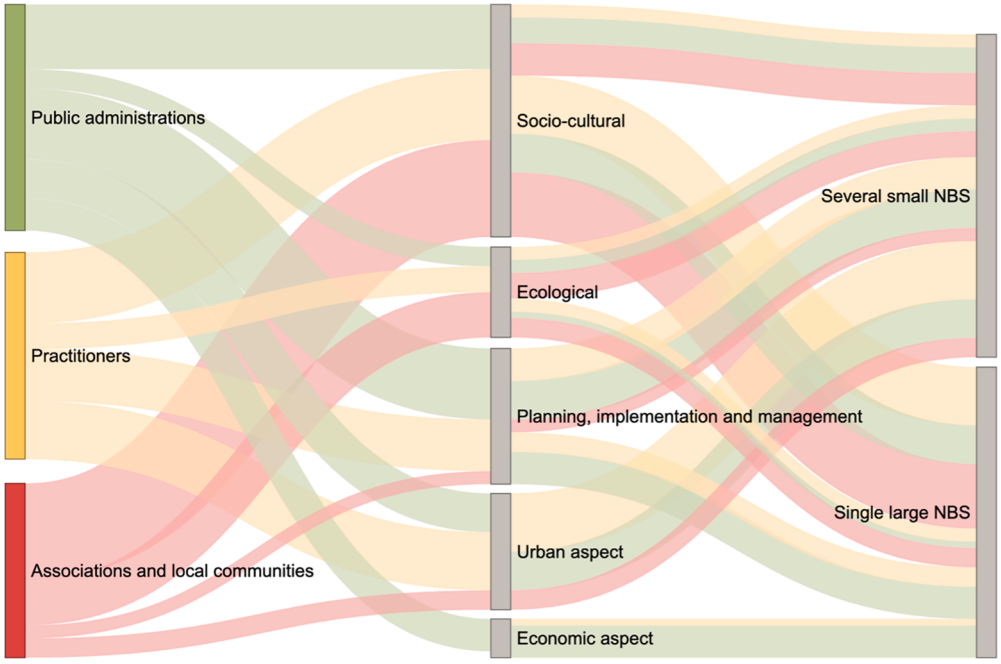

Fig. 5. Distribution of motivations supporting the two NBS spatial configuration among stakeholder groups.

broader urban issues, potentially generating spatial trade-offs and hindering wider urban goals [59,60].

According to our results, perception of importance and urgency do not always align. In particular, when asked to identify the challenges that should be addressed "as soon as possible", challenges that have an impact on the mitigation of public health risks were prioritized. Specifically, air quality improvement - which received heterogeneous importance scores across scales - rose to second place across in urgency at all three spatial scales, and heatwaves remained among the top urgent concerns. This suggests that, when establishing temporal priorities, stakeholders prioritize public health risks over challenges initially considered important. These findings have direct implications for NBS planning: interventions addressing immediate health concerns are likely to receive stronger stakeholder support and political commitment than those targeting social or aesthetic objectives, even if the latter are valued as generally important.

4.2. *Stakeholders' preferences on NBS spatial configurations*

Eight out of ten stakeholders preferred the implementation of several small NBS over a single large intervention, aligning with previous evidence suggesting that residents often favor a network of smaller green

Table 3
Motivations for supporting "short-term" versus "long-term" NBS reported by the interviewees and divided by thematic area (in brackets the number of interviewees).

Motivations		Temporal distribution	
Area	Sub-area	Short-term NBS	Long-term NBS
Impacts	*Social*	• Awareness of the importance of green areas (3)	• Awareness of the importance of green areas (1) • Participatory monitoring (2) • Environmental education (2) • Intergenerational sustainability (5)
	Environmental		• Synergies with ecosystems and biodiversity (2) • Environmental quality improvement (4)
	Response to urban needs	• Immediate response (7)	• Significant response (8)
Urban planning	*Urban regeneration*	• Immediate regeneration (2)	
	Urban coherence	• Maintenance of land use (3)	• Alignment with urban planning objectives (2)
	Ecological approach		• Valorization of natural capital (4) • Integration of complex natural elements (1) • Strengthening the ecological network (3)
Operational aspect	*Technical-administrative feasibility*	• Administrative complexity (1) • Data requirement (1) • Reduced governance continuity requirement (2)	
	Experimental character	• Iterative adaptation (3) • Input for future interventions (6)	
	Operational efficiency		• Efficient use of resources (5) • Avoiding additional interventions (1) • Avoid postponing necessary interventions (2)
Economic aspect	*Economic efficiency*	• Perceived cost-effectiveness (1) • Rapid return of investment (3) • Dynamic budget management (1)	• Prevention of future costs (3) • Cost reduction in urban infrastructures (2)
Public and institutional support	*Public perception*	• Response to current public concerns (3) • Perception of tangible results (5)	• Avoiding temporary satisfaction (3)
	Political advantage	• Alignment with political objectives (4) • Demonstration of environmental commitment (3)	• Demonstration of long-term commitment (1)

spaces over a single large one, as the latter may not adequately meet the needs of a complex and diverse community [61,62].

This preference persisted even after stakeholders were informed that a single large NBS could generate a higher overall volume of ES [6,63]. In contrast, several smaller parks offer a broader spatial distribution of benefits, albeit in smaller quantities. This distinction between the magnitude and spatial distribution of benefits allowed us to understand how stakeholders weigh these dimensions in relation to other relevant factors. Only two respondents changed their preference upon learning about the magnitude difference, indicating that for most stakeholders, maximizing total ES provision was less important than other considerations. The main reason was the desire for a fairer distribution of ecosystem and recreational services, helping to reduce inequalities between neighborhoods. In line with this rationale, evidence shows that having many small green spaces in close proximity can be more effective in supporting day-to-day restoration and social interaction [64], and such spaces often record high visitation rates [65]. This preference also resonates with emerging urban planning paradigms, such as the "15-minute city" and its 10- and 5-minute variants [66,67], as well as the 3–30–300 rule [68], and with the principles of distributive environmental justice [69].

Adaptability to the urban context emerged as another key driver. Stakeholders noted that several small interventions integrate more easily into fragmented urban areas without requiring land expropriation, minimize conflicts with competing land uses, and reduce implementation risks [70,71]. Large NBS were perceived as ambitious but uncertain projects vulnerable to delays or abandonment, leading stakeholders to prefer more modest but guaranteed benefits. Additionally, several small NBS were seen as easier to plan, manage and maintain. They were also perceived as more resilient, since if one intervention fails, others continue functioning independently.

Although several small NBS were generally preferred, all stakeholders acknowledged advantages associated with a single large intervention. From a practical perspective, the main arguments included the concentration of resources in a single area, enabling economies of scale, unified implementation, and streamlined maintenance. In addition, a single large NBS was seen as an opportunity to create multifunctional green hubs capable of hosting cultural and sports events, attracting tourism, and increasing property values in surrounding areas. From an ecological standpoint, stakeholders emphasized that a single large intervention could support higher levels of biodiversity and provide a "nature immersion" experience rarely achievable in smaller urban areas. However, existing literature challenges the assumption that only large NBS can deliver such ecological value [10,72,73]. This suggests stakeholders' perceptions may reflect incomplete information, highlighting the importance of providing comprehensive ecological evidence during the planning process.

In summary, our findings suggest that preferences for NBS configurations are not solely determined by the ES produced, but reflect a broader set of considerations. However, better understanding of how small green spaces provide ES and how to enhance this capacity remains essential for aligning planning decisions with both social preferences and ecological performance [10].

4.3. Stakeholders' preferences on NBS temporal configurations

Six out of ten respondents expressed a preference for long-term NBS. This finding is significant, given that the time lag required to produce benefits is often perceived as a barrier to NBS adoption [74,75], typically leading to a preference for grey infrastructures that provide immediate outcomes [76]. However, our findings suggest that delayed benefits are not necessarily seen as a limitation, as long as the social and environmental impacts are significant. This aligns with findings from a participatory GIS study conducted among the citizens of Trento [38]. These findings are particularly relevant given that current NBS management practices often prioritize short-term achievements over

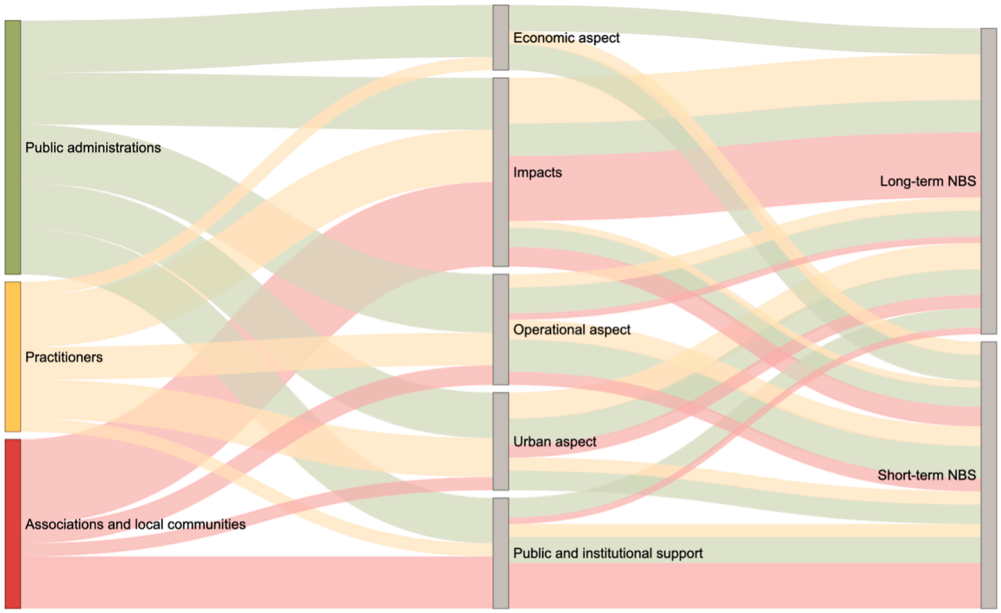

Fig. 6. Distribution of motivations supporting the two types of NBS temporal configuration among stakeholder groups.

long-term needs [77]. So far, the temporal dimension has received limited attention in both NBS planning and academic research, and studies that accurately quantify the time-related performance curves of NBS remain scarce [42].

The preference for long-term solutions raises an important methodological issue concerning the selection of the appropriate discount rate in the economic evaluation of NBS. Standard CBA practice typically applies constant discount rates, which tend to reduce the present value of benefits that materialize in the long term, potentially undervaluing precisely those NBS that stakeholders prefer. A declining discount rate, which assigns progressively greater weight to future benefits over time could better reflect these preferences [78,79]. However, a review of cost-benefit analyses (CBA) on urban NBS by Chelli et al. [38] found that only two out of 114 CBAs used a declining discount rate [80,81]. In light of these considerations, future CBA studies should more carefully reflect on stakeholders' temporal preferences and explore whether these preferences justify the adoption of lower discount rates to better capture the value of long-term benefits.

The implementation of both short- and long-term NBS presents limitations that often require complementary measures. Short-term solutions may fall short of ecological needs and need scaling-up interventions, while long-term projects leave an initial gap in service delivery, requiring interim actions such as traffic reduction for air quality improvements. Several stakeholders see this need for supplementary measures as a drawback due to higher costs and management complexity. These challenges highlight the importance of clearly defining the objectives and context of each intervention, including estimating both the time needed for benefits to emerge and when they are most needed. Building future scenarios based on the properties of NBS, their timeframes, and expected system responses is crucial to support anticipatory planning [82,83]. Distinguishing between short- and long-term priorities is essential. For instance, parks with limited tree cover may suffice to expand recreational opportunities in the short term, while areas exposed to increasing heat stress require immediate urban reforestation, even if cooling benefits will materialize only over time. Delays in NBS implementation have been identified as major barriers to climate change mitigation [84], and recent studies recommend early action to avoid growing impacts and opportunity costs [85].

The motivations emerging from the interviews suggest how perceived strengths can be strategically leveraged to support NBS planning and compensate for the limitations of different temporal configurations. For short-term NBS, the most cited advantage - the ability to deliver tangible results quickly - can be used to build public support. Quick interventions in degraded areas immediately showcase the social and aesthetic value of urban green spaces, encouraging acceptance of further investments. Small early successes can act as "proofs of concept", unlocking additional funding and encouraging the replication of more ambitious solutions, reinforced by the prospect of rapid economic returns. For long-term NBS, stakeholders emphasized strengths that can be actively incorporated into planning. Continuous community engagement through citizen-science initiatives maintains public attention, supports adaptive management, and promotes environmental education-practices increasingly adopted by cities [10,70]. Moreover, long-term projects help prevent future costs by enhancing urban resilience, reducing the need for expensive corrective actions. They also signal institutional commitment to long-term sustainability. Systematically highlighting these advantages during participatory processes and communication efforts can facilitate the adoption of both short- and long-term strategies. Overall, the findings underscore the need for further research on how temporal preferences influence NBS planning, including studies in different territorial contexts and the use of diverse methodologies, such as discrete choice experiments to quantify trade-offs between timing and benefit magnitude, or participatory scenario-planning workshops to capture collective temporal visions.

4.4. Limitation of the study

This study presents several limitations that should be acknowledged. First, the stakeholder sample was limited in size and context-specific, consisting of only ten participants from a single urban area. Although the interviews offered valuable insights, the small and localized nature of the sample restricts the generalizability of the findings. Future studies should replicate this approach in different urban contexts and involve a broader range of stakeholders to improve the robustness and applicability of results.

Second, the NBS typology used in the interviews relied on necessary simplifications. We distinguished between "several small" and "single large" interventions and framed the associated ES accordingly. Smaller NBS were presented as offering fewer but more widely distributed benefits, while larger NBS were framed as providing higher but more spatially concentrated benefits. While this helped participants engage with the trade-offs more easily, it overlooks the complexity of ES

dynamics, which are influenced by various factors such as vegetation type, spatial layout, and socio-ecological conditions [9]. Future research should consider more nuanced NBS classifications that better reflect the multidimensional nature of ES provision.

Third, the temporal categories also represent a simplification. We assumed that short-term interventions provide fewer benefits than long-term ones, implying a trade-off between immediacy and magnitude. However, ES do not always follow linear or uniform temporal patterns - some benefits may appear rapidly, others more gradually, and some may fluctuate or peak at different times [42]. While this simplification was necessary to make the concept more accessible to interviewees, future studies could refine this approach by incorporating more detailed temporal patterns and using dynamic simulation tools. Such tools would help stakeholders better understand the evolving nature of ES provision and explore different scenarios over time.

5. Conclusions

This study investigated how the spatial and temporal dynamics of NBS influence stakeholder preferences for their implementation in urban areas. Drawing on ten semi-structured interviews with local stakeholders in the city of Trento, we examined preferences and underlying motivations related to different spatial (several small vs. single larger) and temporal (short- vs. long-term) configurations of NBS and their expected benefits. The findings reveal a general preference for several small NBS and for long-term interventions. Small-scale NBS were generally preferred due to their equitable accessibility, adaptability to dense urban contexts, and ease of implementation. While a single large NBS was acknowledged for its socio-economic potential and ecological capacity, it was often perceived as more complex and riskier to implement. These findings have several implications for future NBS planning. They underline the importance of adopting multi-scalar approaches, as stakeholders' perceptions of urban challenges and priorities varied significantly across spatial levels. They also highlight the need to explicitly address temporal trade-offs in planning-especially the gap between short-term needs and long-term benefits-and to design complementary strategies that mitigate transitional vulnerabilities. Finally, our findings offer insights for the economic valuation of NBS, suggesting that stakeholder acceptance of long-term interventions may support the use of a decreasing discount rate in CBA, an aspect that deserves further investigation.

6. NBS impacts and implications

6.1. Summary of the study

This study explores how urban stakeholders perceive and prioritize different configurations of nature-based solutions (NBS) in terms of their spatial characteristics—namely, the size of the intervention and the spatial distribution of its benefits—and their temporal characteristics, referring to when those benefits materialize. Ten semi-structured interviews were conducted with local actors in Trento, Italy, to understand their preferences and motivations regarding several small versus single large NBS, and short-term versus long-term interventions. The analysis highlights how perceptions of equity, feasibility, and risk influence support for different NBS strategies.

6.2. Impacts

Findings reveal that interviewees generally preferred several small, distributed NBS over single large interventions, emphasizing their perceived accessibility, flexibility, and equitable distribution of ecosystem services. Participants also tended to favor long-term NBS that gradually deliver more substantial ecological and social benefits, despite delayed outcomes. These results demonstrate that the acceptance of NBS depends not only on their type but also on how their benefits are distributed across space and time.

The study advances understanding of public preferences and social acceptability of NBS by revealing how stakeholders perceive the role of spatial scale and timing in shaping planning choices. Interviewees emphasized that distributed, smaller-scale NBS can provide significant cumulative impacts when connected through green networks, while long-term interventions are viewed as key to ensuring ecological resilience and intergenerational sustainability.

6.3. Implications for policy and practice

Urban planners and decision-makers should explicitly incorporate spatial and temporal trade-offs in NBS planning and financing frameworks. A multi-scalar approach—connecting neighborhood, district, and city levels—can prevent fragmented implementation and promote fairer benefit distribution.

Stakeholders' willingness to support long-term NBS suggests an opportunity for policies that sustain funding and governance beyond short political cycles. Economic evaluation tools, such as cost–benefit analysis, should reflect these preferences by applying lower or declining discount rates that better account for future ecosystem service benefits.

Early and continuous stakeholder engagement can enhance perceived fairness and adaptability, while transparent communication of both short- and long-term benefits can strengthen public trust and encourage broader participation in NBS implementation.

6.4. Implications for research

Future studies should apply this approach in other urban contexts and with larger, more diverse samples to test the generalizability of these patterns. Quantitative and participatory methods—such as discrete choice experiments or scenario co-design—can help assess trade-offs between spatial scale, timing, and perceived value of NBS benefits. This would support more inclusive, evidence-based planning that aligns ecological performance with social acceptance.

Declaration of generative AI and AI-assisted technologies in the manuscript preparation process

During the preparation of this work the author(s) used ChatGPT in order to refine written content. After using this tool/service, the author (s) reviewed and edited the content as needed and take(s) full responsibility for the content of the published article.

CRediT authorship contribution statement

Alessia Chelli: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Davide Geneletti:** Writing – review & editing, Supervision, Methodology, Conceptualization.

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.

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Supplementary materials

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Data availability

Data will be made available on request.

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