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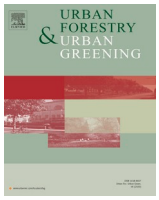

Original article

Perceptions of stakeholders on nature-based solutions in urban planning: A thematic analysis in six European cities

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ABSTRACT

A commonly addressed aspect of urban planning involves the integration of nature-based solutions (NBS). Before applying NBS, acquiring stakeholders' viewpoints, e.g., city councils, local governments, and academia, contributes to the successful application and thus to mitigation of global challenges such as climate change, loss of biodiversity, water, and food scarcity. The present study explores how stakeholders across Europe view the role of NBS in urban planning. A thematic analysis was conducted to identify patterns, themes, and concepts within interview transcripts gathered through semi-structured interviews held in Budapest, Cordoba, Ljubljana, Reykjavik, Vienna, and Zurich. The study resulted in 107 distinctive codes categorized into NBS benefits, challenges, opportunities, NBS actors, and regulations. The frequency of codes (Fr) mentioned by the interviewees showed that NBS benefit cooperation (Fr=125) between individuals, while the most challenging issue obstructing NBS implementation was the lack of NBS knowledge (Fr=93). The need for green areas (Fr=42) was identified as an opportunity that could give rise to NBS applications. This study also provides practical recommendations to overcome some barriers when implementing NBS.

1. Introduction

The effects of climate change in an urban setting, *e.g.,* degradation of ecosystems, depletion of resources, and loss of biodiversity, are amplified by urban development processes. However, urban green and blue areas and infrastructures harness natural processes *via* Nature-Based Solutions (NBS) to mitigate them (Kabisch et al. 2022). According to the European Commission, NBS are actions or infrastructures based on natural processes capable of producing environmental, economic, health, and social benefits for citizens and communities (Cohen-Shacham et al. 2019; Pineda-Martos and Calheiros, 2021). NBS were also defined as concepts that bring nature into cities and solutions that are derived from nature (Langergraber et al. 2021), like treatment wetlands technology (Gholipour et al. 2020). NBS are intended to address and mitigate the severe consequences of climate change by triggering ecosystem services. To accomplish this, NBS are expected to be

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well-integrated into both the social and environmental context of implementation (Wickenberg et al. 2021; Gholipour et al. 2024a). The use of NBS at the urban scale " *emphasizes multifunctionality in terms of services and functions to include drainage management, habitat provision, ecological connectivity, health and well-being, recreational space, energy reduction, and climate change mitigation and adaptation"* (Scott et al., 2016). They are valid solutions for climate change adaptation and urban regeneration requiring different co-creation settings to connect with urban social innovation while a collaborative approach to their planning and implementation is needed (Frantzeskaki, 2019). To effectively coordinate these processes, NBS should be implemented from the earliest stages of urban planning (Dremel et al., 2023). The issues of responsibility and competence of urban planning were raised a few years ago (Christis, 2019), and frameworks to handle the issue have been proposed (Raymond et al., 2017); however, establishing a principle takes time. Furthermore, an integration of social and biophysical values contributes to the continuous function in achieving carbon mitigation and biodiversity outcomes (Raymond et al. 2023).

In recent years, for many European cities, ranging from Linz (Davies et al. 2021) and Turin (Dogan et al. 2023) to Lisbon (Bona et al. 2022; Gholipour et al. 2022) and Hamburg (Scharf et al. 2021), NBS have been the key drivers in developing sustainable planning strategies and policies (Pineda-Martos and Calheiros, 2021). Stimulated by European agencies, policymakers appear to be more reactive and prone to invest resources in the recovery of urban natural spaces and the creation of new ones. Nonetheless, the mainstreaming of NBS in urban planning strategies still appears blurred and scarcely problematized (Cooper et al. 2023), and the potential of NBS to produce prominent policy changes is still lacking (Kauark-Fuentes *et al.* 2023). On the one hand, some municipalities use the concept of NBS as a buzzword for describing elementary interventions in public green areas or a basic readaptation of former industrial spaces (Cilliers, 2019; Rice et al., 2020), while other misinterpret the core principles of NBS and confuse them with grey or blue infrastructure (Fastenrath et al., 2020). NBS can play a pivotal role in providing ecosystem services, particularly cultural services, and elucidating their interconnectedness with other ecosystem management and understanding frameworks (Plieninger et al., 2015; Nesshöver et al., 2017). Furthermore, NBS have been conceptualized as a form of co-evolutionary technology (CET), facilitating the interaction between the techno-sphere and biosphere (Herrmann-Pillath et al., 2022). To untangle this policy knot, recent studies have proposed a common conceptualization and nomenclature to understand what should be considered as NBS (Langergraber et al., 2021; Bianciardi and Cascini, 2023). To this end, looking at the direct consultation of a panel of experts involved in the COST Action CA17133 "Implementing nature-based solutions for creating a resourceful circular city (Circular City)", Castellar et al. (2021) identified 32 NBS which are summarized in two groups: NBS units (NBS_u) and NBS interventions (NBS_i). NBS_i refers to the act of intervening in existing ecosystems and in NBS_u, by applying techniques to support natural processes (Castellar et al. 2021). A new framework was developed by Langergraber et al. (2021) with seven Urban Circularity Challenges (UCCs), and more than fifty NBS units and NBS interventions to address these UCCs. The UCCs are restoring and maintaining the water cycle, water, and waste treatment (Gholipour and Stefanakis, 2021), recovery and reuse (Kisser et al. 2020), nutrient recovery and reuse (Wirth et al. 2021), material recovery and reuse (Pearlmutter et al. 2020), food and biomass production (Seddon et al. 2020; Leimkühler et al., 2024; Canet-Martí et al., 2021), energy efficiency and recovery (Oral et al. 2020), and building system recovery (a visual representation of UCCs addressing NBS can be found in the supplementary materials). Other studies have highlighted the importance of local stakeholders for realizing the full potential of NBS (Bush and Doyon, 2019). Urban actors are seen as crucial filters for turning EU strategies into practical policies aimed at transforming cities into sustainable and climate-resilient ecosystems (Raymond et al., 2017; Ravazzi, 2021).

Local stakeholders play a pivotal function in supporting the implementation of NBS and fitting them to the needs of urban communities (Depietri and McPhearson, 2017). From municipalities to citizens' associations, and from non-governmental organizations (NGOs) to private companies engaged in innovation and environmental sustainability, local actors can decide which NBS are most suited by creating narratives (Voegeli and Finger, 2021; Gholipour et al. 2023). Hence, local stakeholders can determine the failure or success of NBS implementation in cities, by either applying a siloed approach or by interacting in a constructive and cooperative manner (Bryson, 2004; Katsou et al., 2020). Governance models for NBS such as tokenistic approaches, may tend to dominate citizen participation across diverse NBS contexts, whereas collaborative multi-stakeholder models are often perceived as lacking in their ability to enhance ecological functions (Kiss et al. 2022). Hybrid governance in urban NBS presents a promising avenue for scaling up, offering a demand-driven and cost-effective approach to urban green infrastructure; however, its impact on justice outcomes varies, highlighting the need for transparent decision-making and public control (Toxopeus et al. 2020). Bush and Doyon (2019) presented a framework that could guide the implementation of NBS in urban planning, focusing on climate change and ecosystem services. Wickenberg et al. (2021) focused on the process of introducing and managing NBS in urban environments and their effects on social and economic aspects. The keys to NBS implementation are collaboration and co-creation from the very beginning - *i.e.*, from planning, through implementation, and maintenance, to evaluation of the results. Based on a meta-analysis of 36 papers (Kisser et al., 2020), joint efforts and inclusion of the inputs of different stakeholders can support the implementation of NBS and increase economic and social benefits. Kisser et al. (2020) provided a comprehensive review of various approaches and strategies that utilize NBS to recover resources in cities. The article covered a range of topics, including the potential benefits, challenges, and implementation of NBS. A systematic review delved into citizen perception and stakeholder involvement in NBS, examining 142 relevant papers, highlighted a growing recognition of participation's importance, yet identified research gaps (Ferreira et al., 2020). Variations in urban, geographical, and socio-economic contexts were found to impact stakeholder perceptions (Ferreira et al., 2021). Disparities in co-benefits perception and valuation may lead to stakeholder trade-offs, with the inclusion of a time dimension aiding conflict anticipation (Giordano et al., 2020). Citizens' involvement in co-developing NBS actions was found to be limited, while innovative stakeholders had less influence compared to controllers, mainstreamers, and laggards (Mitincu et al., 2023; Castellar et al., 2024). Stakeholders' perceptions illuminate socio-ecological inequalities within NBS, questioning its universal benefits (Nóblega-Carriquiry et al., 2023).

The present manuscript analyses NBS in urban planning in relation to sustainable urban water management, resource recovery, urban agriculture, climate change mitigation and adaptation, and the built environment. It aims to understand how local actors (municipalities, public institutions, enterprises, research institutions and universities, civic organizations, and NGOs) in six European cities, namely Budapest, Cordoba, Ljubljana, Reykjavik, Vienna, and Zurich, identify and integrate NBS in urban planning. A scoping review (Peters et al., 2015) was conducted to understand if and to what extent urban stakeholders' practices and perceptions differ from what has been suggested so far in the literature on urban planning and NBS policies. The analysis of the findings is based on a short scoping review exploring the use of NBS in urban planning by analyzing relevant documents and interviewing urban practitioners. The selection of case study cities across Europe was deliberate, aiming to encompass geographical diversity and present a spectrum of NBS implementation practices. Despite the abundance of studies on NBS and its integration into urban planning, there remains a significant gap in our understanding of how various stakeholder groups perceive NBS within the urban landscape and whether they actively contribute to its inclusion in planning processes. This manuscript seeks

to address this gap by delving into the main challenges and benefits arising from the incorporation of NBS into urban plannings. Our primary objective is to contribute to filling this knowledge void by focusing on three overarching research questions:

I. Identification of common NBS examples and definitions: Through semi-structured interviews with various stakeholders, we aim to discern the most prevalent examples and guiding definitions of NBS within the context of urban planning.

II. Stakeholder expectations, benefits, and challenges: We seek to investigate the diverse perspectives of stakeholder groups. By elucidating their expectations, perceived benefits, and encountered challenges regarding the utilization of NBS, we aim to gain insights into the complexities of stakeholder dynamics and their implications for NBS implementation.

III. Identification of key actors in urban planning and NBS implementation: Lastly, we aim to identify the key actors involved in urban planning processes and their respective roles in the implementation and management of NBS initiatives. By mapping out the landscape of urban planning stakeholders and delineating their contributions to NBS implementation, we aim to shed light on the distribution of decision-making power and resources within this domain.

In summary, this manuscript endeavors to contribute to the existing body of literature by providing a comprehensive examination of NBS applications through the eyes of stakeholders in the context of urban planning in Europe. By addressing these research questions, we aim to offer valuable insights for policymakers, practitioners, and researchers seeking to enhance the integration of NBS into urban planning.

2. Methodology

The perception of stakeholders about NBS in urban planning was explored through interviews in which stakeholders stated their experiences and expertise. The case studies were six European cities, namely Budapest (Hungary), Cordoba (Spain), Ljubljana (Slovenia), Reykjavik (Iceland), Vienna (Austria), and Zurich (Switzerland). The results stemmed from six Short-Term Scientific Missions (STSM) in frame of Cost Action 17133 conducted by co-authors. Among types of case studies, *i.e.*, exploratory, explanatory, and descriptive (according to Yin, 2014), the design of this research followed an exploratory approach on multiple case studies to understand how local actors perceive NBS implementation in cities (Iqbal and Mansell, 2021; Frantzeskaki et al., 2020; Chausson et al., 2020). Exploratory studies (Fig. 1) in urban planning and public policy offer essential insights into issues that are still poorly covered in the literature and by policy makers (Wolfram, 2018). The multiple case studies approach (Hunziker et al., 2021) involves an in-depth analysis of individual cases and the combination of the individual findings to reach cross-case conclusions without comparing the different case studies which here refer to the six cities.

The profiles of the cities were cross analyzed before the scientific missions in order to ensure that the city mix covered the spectrum of the seven Urban Circularity Challenges (UCCs) identified by Atanasova et al. (2021) and Langergraber et al. (2021). The matching of case studies with the UCCs is presented in Fig. 2. Data collection in the six case study cities involved conducting semi-structured interviews (Kvale, 1994) from August to September 2021. The interviews covered five main topics corresponding to Working Groups (WG) of the COST Action: (i) built environment (WG1), (i) water management (WG2); (ii) resource recovery (WG3); (iii) urban farming (WG4); (iv) built environment (WG1); and (v) climate change mitigation and adaptation (WG5).

The semi-structured interviews had a common structure based on the same interview guide, which was designed to be applicable across all cities and topics (in the supplementary materials). In semi-structured interviews, the interaction between the interviewer and interviewee is flexible, but still guided (Kvale, 1994). Apart from the core questions, the interviewer can explore additional topics based on the interviewee's responses. This approach fosters a cooperative atmosphere, encouraging sincere and thus potentially valuable insights. Both parties contribute to the exchange of information, leading to a deeper exploration of the topic. The interviewees were asked to briefly present their organization and discuss the role of implementing NBS and urban planning in their daily operations. Details of their opinions and ideas about UCCs and NBS were also requested. They were encouraged to freely express their

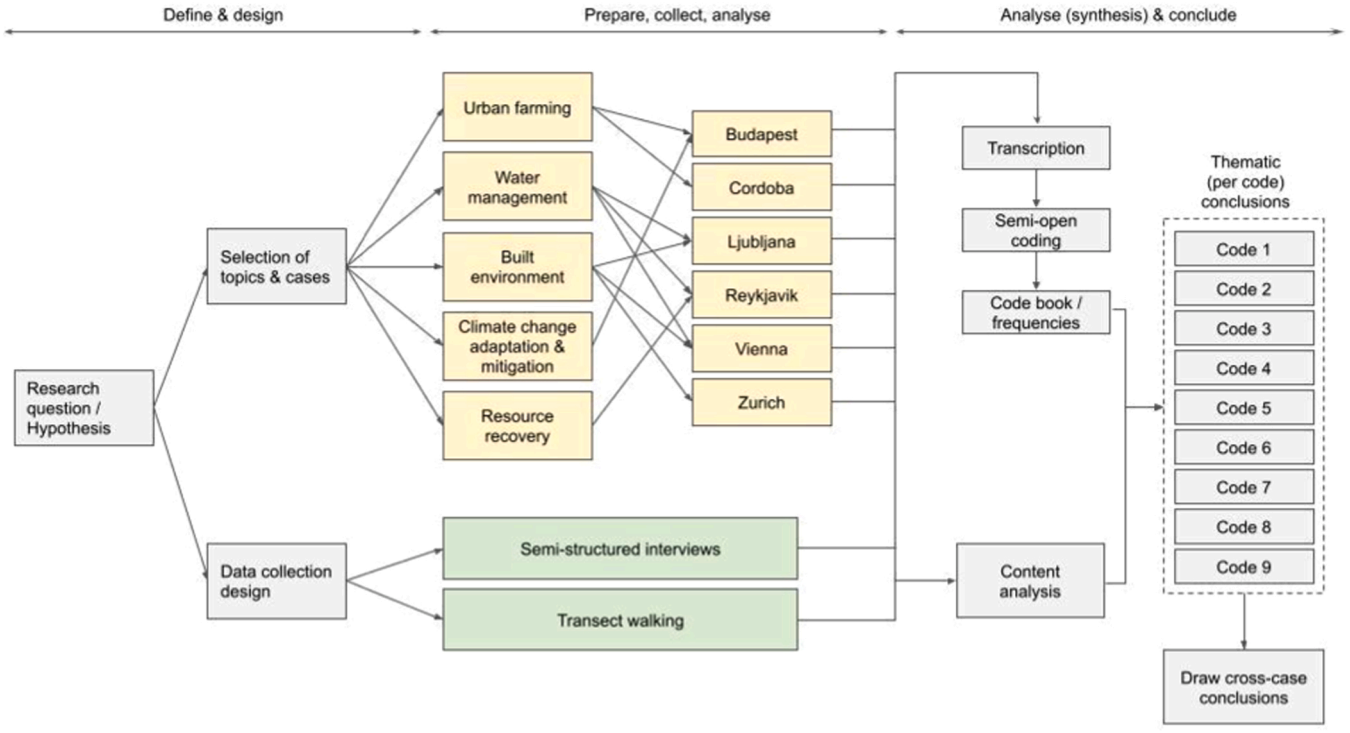

Fig. 1. Multiple case study design (adapted from Yin, 2014).

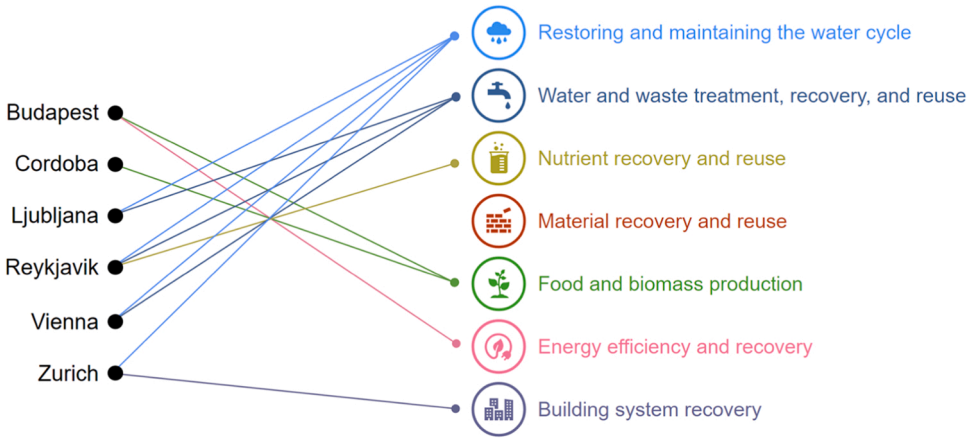

Fig. 2. The seven Urban Circularity Challenges (UCCs) explored through case studies.

thoughts on the topic, allowing for the interpretation of their ideas on NBS. The interview guide was used flexibly to explore their opinions, values, and attitudes, with topics defined and new topics introduced in line with the interview's inner logic. The main objective was not merely to collect information but also to comprehend how NBS manifest or do not manifest in urban planning.

The selection of interviewees was based on stakeholder mapping (Reed at al., 2009) to cover the groups: municipality representatives (environmental and urban planners, directors of urban and environmental units), public institutions (transport, urban planners, etc.), private enterprises (engineers, resource recovery specialists, waste management), research institutions, civic organizations and citizen representatives, and NGOs. The final list of interviewees was supplemented using the snowball technique *i.e.*, the interviewees were asked to provide recommendations of relevant stakeholders to perform further interviews. The number of interviews ranged from five (Zurich) to 24 (Budapest), with an average of 12 interviews per city depending on the availability of the stakeholders. A total of 76 interviews were conducted, involving all stakeholder groups (Fig. 3.a) and main thematic topics (Fig. 3.b).

The interviews, typically lasting one hour, were recorded and transcribed. A semi-open coding method was used to analyze the interviews, with each interview being coded by two researchers to enhance the validity of the results. A semi-open coding method (Urquhart, 2022, Charmaz, 2014) is a variation of coding used in qualitative research, particularly for analyzing interview data to identify new categories of outcomes (Kolb, 2012). It lies between open and focused coding, offering a balance between flexibility and structure in the coding process. In semi-open coding, the researcher (interviewer) starts with a set of predetermined or predefined codes. In the present paper, the main categories were pre-established based on existing theories and prior research of the COST Action (Voegeli and Finger, 2021; Gholipour et al., 2023) while the codes emerged from the text of the interviews (Castellar et al., 2024). These initial codes provided a basic framework for organizing and analyzing the data. Unlike fully structured coding methods, semi-open coding allows additional codes to emerge from the data during the analysis process. During the analysis, if the data does not fit into any of the predefined codes, the researcher can create new codes or adapt existing ones to capture the emerging concepts. At the outset, 86 codes were identified, and organized into nine overarching categories by the research team. Various aspects of NBS, including their definition, perceived benefits, encountered challenges, potential opportunities, as well as the key actors involved in urban planning and NBS management and implementation processes, were encompassed by these categories. These codes were instrumental in structuring the analysis and provided a systematic framework for examining stakeholder perspectives on NBS. By categorizing the findings into thematic areas, an exploration of perceptions of NBS of different stakeholders were enabled and how these perceptions may shape their attitudes, decisions, and actions related to NBS implementation in urban contexts. Thus, the organization and interpretation of the data were facilitated by these codes, and a lens through which the nuanced relationships between stakeholder perceptions and the broader landscape of NBS practices and policies could be investigated was provided. In essence, the backbone of the analytical approach was formed by them, enabling a comprehensive exploration of the multifaceted dimensions of NBS within urban planning. During the

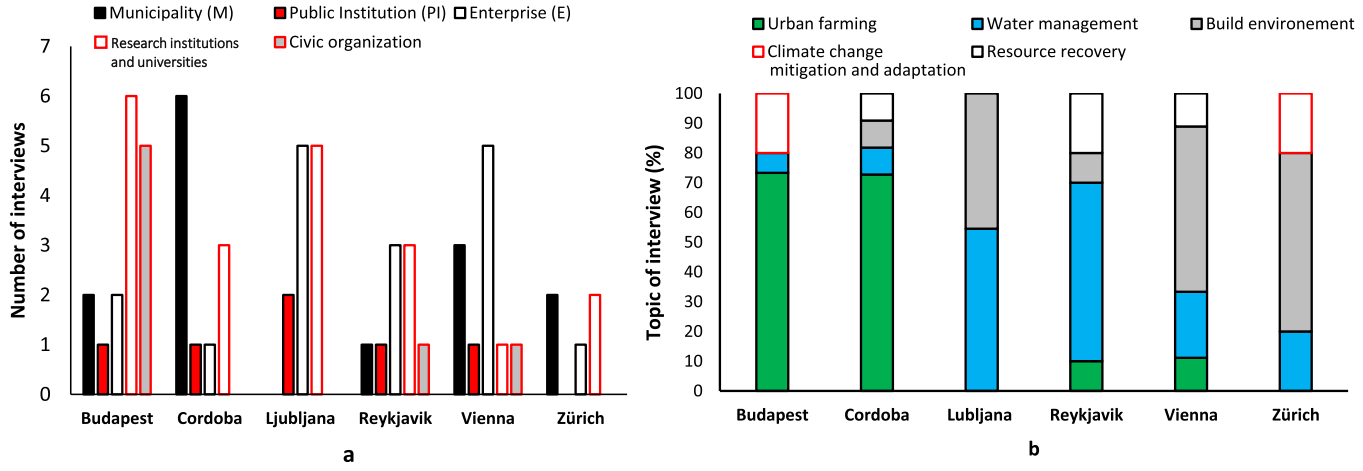

Fig. 3. Summary of semi-structured interviews in six European cities: a) the number of interviews conducted per organization, b) the main thematic topics covered.

analysis of the interviews, 21 new codes were added Therefore, 107 codes were used to create a codebook, which served as the main tool for analyzing the semi-structured interviews (in the supplementary materials). Eleven of these codes were about NBS examples and topics, and 25 codes were related to NBS benefits. Other codes were related to NBS challenges (29), opportunities (9), planning actors (9), managing actors (6), implementation actors (6), regulations (11), and ungrouped codes (4). Fig. 4 illustrates the high-level codes identified in this study, with each code representing a description of the perception of NBS.

A codebook allows researchers to systematize and document the coding process in qualitative research, specifically for analyzing interview data collected by different teams, as in this case. It comprises a comprehensive list of codes with clear definitions and examples, representing different concepts or themes found in the data (Theron, 2015). By offering transparent instructions and comments, the codebook enhances the rigor of the research analysis, reduces bias, and ensures the replicability of the study's findings. Sharing the codebook with more researchers further validates the research process and strengthens the credibility of the results.

In the codebook (MS Excel), the interviews were coded per interviewee. Each transcript interview was screened to identify and record any of the 107 codes and their frequencies. The codes were grouped into nine overarching categories. In parallel to code frequency reporting, selected quotations from each interview were also documented in the codebook. The codes were analyzed using frequency analysis, which involves counting how often certain concepts or patterns appear and presenting the results in tables or graphs (Voegeli and Finger, 2021; Gholipour et al., 2023). It complements qualitative research by identifying dominant themes, comparing their prevalence, supporting findings, and informing subsequent research steps. To ensure a comprehensive understanding of the data, frequency analysis can be used alongside qualitative methods, aiming to capture the depth and context of qualitative responses. Therefore, the frequencies of each code were summed up for all interviews, a total of codes frequencies per category of codes was also calculated, and this information, together with the quotations, forms the basis of the results and discussions. To avoid biases while counting the frequency of each code, it was agreed not to count a code used twice or more in the same context and sentence.

3. Results

3.1. NBS definition

At the start of the interview, participants were prompted to define "NBS" and indicate their familiarity with established definitions from the European Union, the International Union for Conservation of Nature (IUCN), the United Nations Environment Assembly (UNEA), and the COST Action Circular City, emphasizing NBS within the framework of circularity. As anticipated, academics and researchers demonstrated familiarity with various NBS definitions. Throughout their responses, most interviewees not only defined NBS but also referenced related terms falling under its umbrella, including GI (green infrastructure), BGI (blue-green infrastructure), SUDs (sustainable urban drainage systems), LID (low impact development), BMP (best management practices), WSUD (water sensitive urban design), and sponge cities. Quote 1 elucidates the varied interpretations of NBS across different contexts, emphasizing the diverse definitions based on the field of study. This is exemplified by the definition within urban drainage for sustainable water management. Similarly, Quote 2 underscores the importance of improved categorization despite the shared characteristics among definitions.

Quote 1. *: "The terminology used depends on the origin of the speaker. SUDs, LID and BMP, WSUD, Sponge Cities. It is essentially the same, the same elements are used. Just different phrasing for the same concepts and elements. […] But all of this is a subgroup of NBS, which has a wider scope, not only urban drainage. The aim of the rest is to save the urban drainage system from water, to make it more sustainable."*

Quote 2. : *"There are many definitions like GI, BGI, NBS are almost the same. But there would be value in separating the terms and be more precise in*

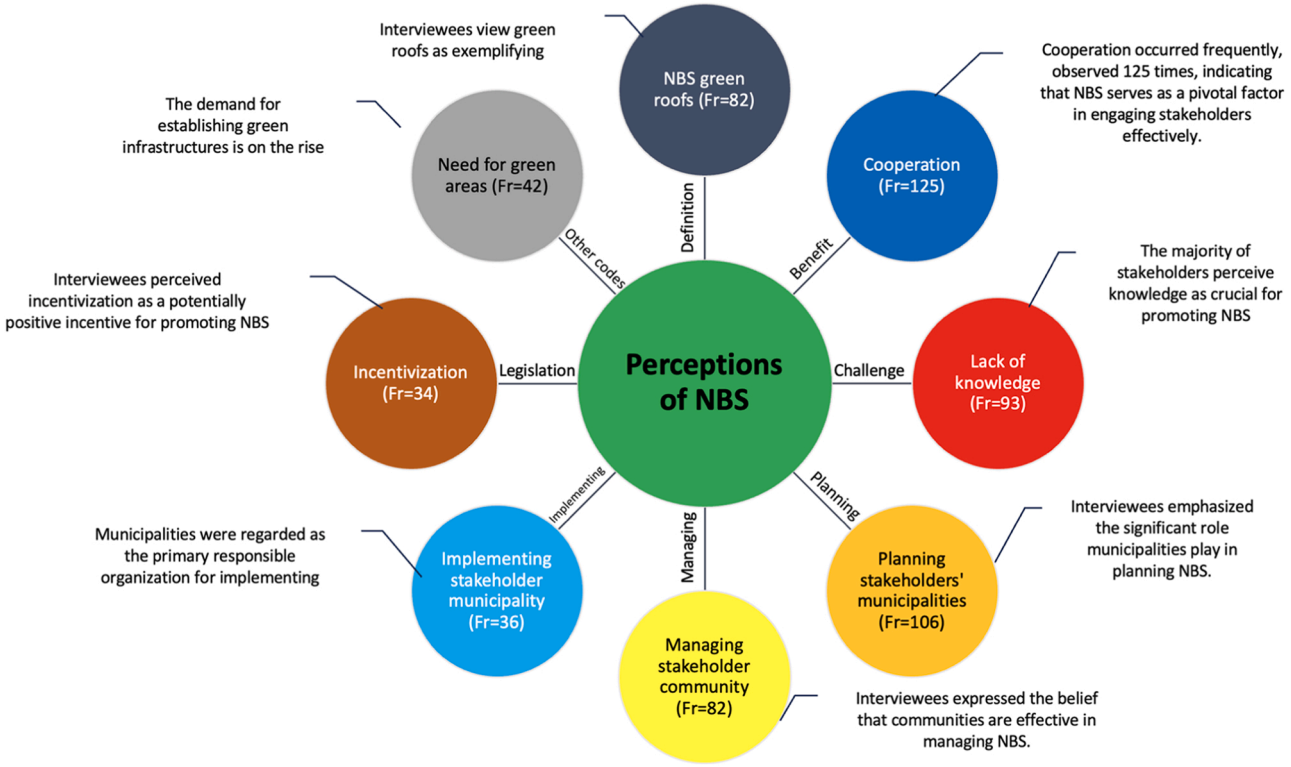

Fig. 4. High-level codes of the study and the frequencies (Fr) of their mention.

using them."

An important observation emerged: the use of diverse terminology across disciplines, such as engineering and landscape architecture, often led to nuanced interpretations of NBS when discussing specifics. While delving into NBS definitions, interviewees highlighted the need for clear definitions not just for NBS alone but also for associated terms. They emphasized the importance of precision in their usage, enabling practitioners to communicate effectively as explained by an interviewee in Ljubljana in Quotes 3 and 4. Quotes underscore a range of definitions, notably encompassing green infrastructure as a subset of NBS. Highlighting the necessity for standardizing terminologies, further research is essential to streamline understanding and application within this domain.

Quote 3. : *"For me, NBS is* something *related to water management but for a landscape architect everything green is an NBS. There can be a completely different approach between an engineer and a landscape architect. The concept is very wide so we must describe it well and explain what we mean. Otherwise, we can also confuse it with GI, BGI.*"

Quote 4. : "*I prefer the* term *NBS. The term GI has a different meaning for other people and for landscape architects, like bigger systems which are connected.*"

Among these terms, GI was frequently mentioned and compared to NBS. Some interviewees regarded them as synonymous, while others emphasized distinct differences but acknowledged similar functionalities. For instance, certain participants viewed NBS as intricate, small-scale solutions requiring heightened engineering complexity compared to GI. They emphasized that when integrated into a network of small-scale solutions, NBS can complement grey infrastructure, effectively addressing significant challenges like flood risk and the urban heat island effect. Overall, interviewees conveyed that the term NBS encapsulates a wide array of solutions and technologies, representing abundant opportunities. This was also found in previous studies through the NBS typology conducted by da Rocha, (2017). Respondents from Ljubljana defined NBS and articulated their benefits as follows:

Quote 5. : "*NBS is a* systematic *approach for solving urban challenges. They are not just a solution on a micro scale, for example, rain gardens, green roofs, and so on. These small-scale solutions can solve bigger issues such as flooding or the heat island effect."*

Quote 6. : *"I* think *NBS are in small scales, in smaller dimensions, more technical."*

Quote 7. : *"Blue-green infrastructure is something completely different to green infrastructure. It is like it is designed in a special way."*

Fig. 5 presents the thematic breakdown of interviewee discussions regarding the definition of NBS and its corresponding examples. When prompted about NBS definitions and examples, interviewees primarily steered the conversation towards two main tracks: either articulating a clear, individual interpretation of the term based on their expertise and understanding or illustrating NBS concepts through practical examples to clarify their definition.

The majority of interviewees (16.9%) focused on discussing NBS concerning green roofs, highlighting their significance. Water management, considered a vital aspect in urban planning, garnered 13.0% of the comments as examples of NBS applications. Green walls received considerable attention at 12.2%, followed closely by NBS projects (10.9%), NBS ideas (9.3%), and community gardens (9.3%). Additionally, interviewees elaborated on various NBS examples, including wastewater management (7.6%), green terraces (6.4%), green gardens (4.9%), NBS green resting areas (4.7%), and NBS for soil improvement (4.5%). In essence, the discussions predominantly revolved around NBS implementations for enhancing energy efficiency and addressing water management challenges, which are the key components identified as critical in the urban circularity context by Langergraber et al. (2021).

3.2. NBS benefits

The interviewees identified 25 benefits of NBS (Fig. 6). The perceived importance of the benefits by frequency (Fr) ranged between 2 and 125 of which cooperation was the most frequently mentioned. Knowledge (knowledge sharing) (Fr=105), improvement (Fr=64), biodiversity enhancement (Fr=54), finance (Fr=50), circularity (Fr=53), and the advantage of community gardens (Fr=50) were the other frequently identified benefits. Interviewees in Budapest and Zurich stated their perceptions about cooperation. As per Quotes 8 and 9, prioritizing communication and collaboration to advance NBS emerges as pivotal. Furthermore, establishing a synergy between grey, blue, and green infrastructures holds the potential to enhance the overall functionality of NBS.

Quote 8. : *"But we have* common *areas, and we have to communicate, and we have to talk, and we have to decide what will work for you."*

Quote 9. : *"They are beginning to understand this. I think it's important to create this combination of grey, blue, and green infrastructures, this communal thinking*".

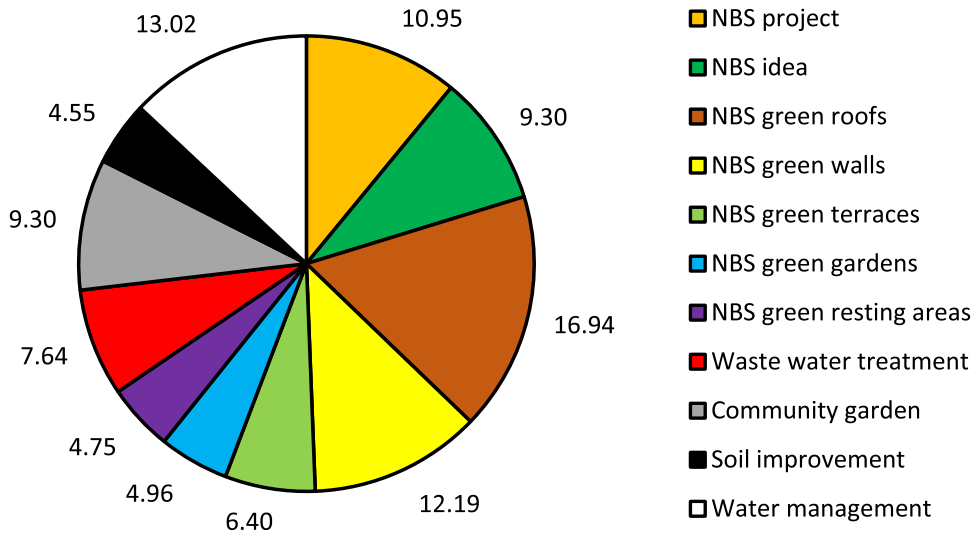

Fig. 5. Classification of NBS definition and examples.

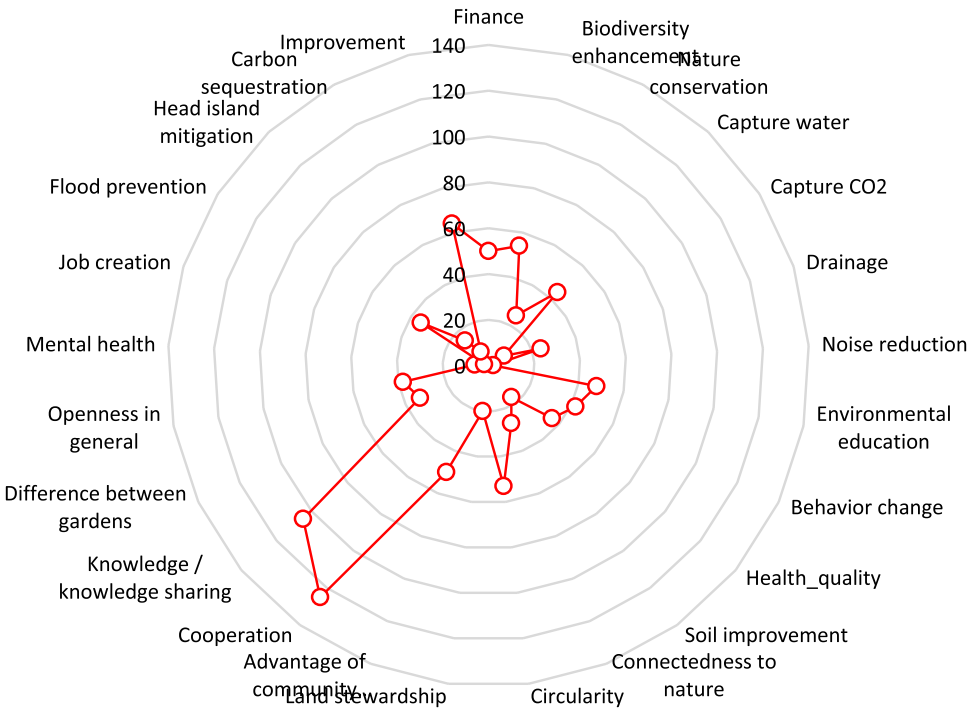

Fig. 6. NBS benefits. In terms of water management, the identified NBS benefits were related to water capture (Fr=44), drainage (Fr=24), and flood prevention (Fr=35). Atmospheric-related benefits include urban heat island (UHI) effect mitigation (Fr=15), CO2 capture (Fr=8), carbon sequestration (Fr=7), and noise reduction (Fr=2). Interviewees also mentioned NBS benefits related to behavioral change (Fr=42), health quality (Fr=36), connectedness to nature (Fr=27), and mental health (Fr=6). An interviewee in Vienna highlighted additional benefits of NBS, illustrating their potential to influence a wide range of areas such as energy, water, and ecosystems.

Likewise, local governments seem to share these viewpoints with NGOs about the benefits of NBS, as stated by an interviewee in Budapest:

Quote 10. *: "We would also like to follow good examples. So, I think it is more like a partnership around cooperation between the municipalities."*

Enhancing the role of municipalities involves fostering stronger inter-community connections through the establishment of a collaborative platform. This tool facilitates the exchange of knowledge and experiences among municipalities (Cohen-Shacham et al., 2019), ultimately boosting the effectiveness of NBS implementation. By fostering better inter-municipal communication, the platform can strengthen collaborative governance dynamics and mitigate the risks of NBS functionality failures (Anderson and Renaud, 2021).

Quote 11. : "*NBS in the built environment such as green terraces can provide as well a 'biodiversity hotspot,' and they act as a buffer to collect and evapotranspiration partly the rainwater through the plants. The thermal isolation effect of green facades in the building turns out to be beneficial in reducing costs in electricity bills*".

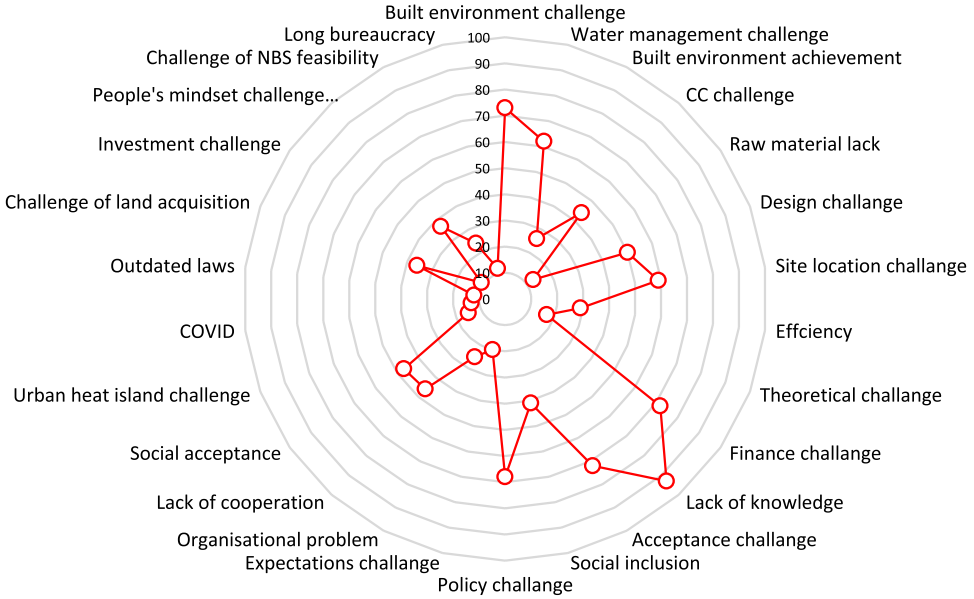

Fig. 7. NBS challenges identified from the analyses of the interviews.

3.3. NBS challenges

Fig. 7 shows the challenges that urban practitioners indicated regarding NBS implementation and mainstreaming. The result of the interview analyses suggests that lack of knowledge (Fr=93) is the most crucial barrier for NBS implementation, as emphasized by interviewees in Reykjavik and Zurich:

Quote 12. *: "I think we should get to know that there is really a lack of knowledge in society."*

Quote 13. *: "The fear of new systems they do not know yet—the fear of a thousand things. Moreover, I believe that if we manage to learn together what we need for the future, then we can order it, pay for it, and realize it (NBS). I think a lot of educational work is needed".*

Quotes 12 and 13 underscore the significance of having a comprehensive understanding of NBS as a fundamental aspect. Furthermore, they draw attention to the challenge of effectively disseminating this knowledge within the communities engaged in NBS, highlighting the need for further research in this area. Other NBS challenges are related to the built environment (Fr=73), acceptance (Fr=72), finance (Fr=72), policy (Fr=68), water management (Fr=62), site location (Fr=59), and design (Fr=50).

Among the NBS challenges, the availability of space was stated by an interviewee in Budapest:

Quote 14. *: "The problem is that we do not have a lot of space left and that's the problem of every urban environment. So, of course, it should be the restoration of green spaces."*

The issue of space emerges as a prominent challenge in NBS implementation, necessitating a re-evaluation of prioritization strategies to move beyond conventional approaches (Bianciardi and Cascini, 2023). In terms of NBS market, it is believed that the NBS market does not exist and the knowledge about it is not well-known, as stated by an interviewee in Reykjavik:

Quote 15. *: "The challenges is that we don't really know the market because such a marketplace you do not know if exists already."*

In addition, interviewees declared that policies supporting NBS in urban gardening are not available, as stated by an interviewee in Budapest. Drawing from these insights, it becomes evident that policy and market dynamics serve as pivotal elements in NBS implementation (Castellar et al., 2024). Especially in urban planning policies, where there are standard toolkit that can work in any implementation context; a systematic approach is essential to effectively influence the application of NBS in practice.

Quote 16. *: "So there is, this is like, the biggest problem is that there is no universal framework, policy for urban gardening in Budapest."*

For urban gardening or agriculture in Vienna there is already a successful scheme for maintenance which involves citizens on a volunteer basis. Citizens apply for a parcel of land which they can use for two years. This NBS not only provides fruits and vegetables, but also promotes social interaction, and educates younger generations.

Meanwhile, lack of cooperation, organizational problems, outdated laws, people's mindset, investment challenges, challenges of land acquisition, social inclusion, efficiency, and theoretical challenges were perceived as other NBS challenges.

In Zurich, it was stated that the long bureaucracy is another crucial challenge that NBS face: Quote 17: *"I have the feeling that planning processes are slow".*

3.4. NBS opportunities

Although NBS may encounter challenges, there are opportunities that were considered by the interviewees, such as the need for green areas, new people, innovation, composting, biogas, urban farming, climate conditions, built environment diversity, and loneliness. Fig. 8 shows NBS opportunities.

Quote 18. *: "Climate change already impacted the planet, and I would think the need for greeneries in urban area will surge and provide more opportunities to the community".*

Another opportunity of NBS was stated by an interviewee from Ljubljana in which the presence of natural green spaces presents a valuable opportunity to develop well-defined NBS within communities, leveraging existing resources for sustainable initiatives.

Quote 19. *: "There are many NBS opportunities in Ljubljana because we have quite a lot of green spaces. And that's a very big opportunity I see."*

NBS were also mentioned as a driver to boost innovations by a Zurich interviewee:

Quote 20. : *"You need the administration to come up with good ideas, you need research like you're doing now that examines approaches".*

Research on NBS, as highlighted by Gholipour et al. (2023), plays a crucial role in enhancing traditional methods and fostering innovation.

3.5. Actors involved in NBS planning

Interviewees mentioned various actors involved in NBS planning, as shown in Fig. 9. They believed that the stakeholders could be related to society, public authorities, science, private sector, NGOs, state of natural environment, policymakers, communities, and municipalities. Among the NBS planning actors, municipalities were mentioned most frequently (Fr=106) while society was considered as the second most important actor (Fr=53). One of the interviewees stressed the role of civil society in all the main climate change mitigation policies:

Quote 21. *: "So I think it's good that there is diversity and that we have a fragmented local government system because if you have one or just a few good mayors, district mayors in Budapest they have power to support it. But I believe they are very progressive in the involvement of the civil society and the citizens in their decision."*

Highlighting the diverse stakeholders involved in NBS implementation underscores the fragmented nature of governmental bodies, hindering cohesive promotion of NBS initiatives.

3.6. Actors involved in NBS implementation and management

Interviewees also considered other groups of actors closely connected to the implementation and management of NBS (Fig. 10.a). They recognized urban planning actors, society, science, private sector, NGOs, and community as important actors in NBS implementation. Among NBS actors, municipalities (Fr=36) played the most important role as stated by the interviewees.

Fig. 10.b outlines the actors involved in NBS management as recognized by the interviewees. The most frequently mentioned actors are the stakeholders relevant to the community (Fr=82), as expressed in by an interviewee in Budapest:

Quote 22. *: "On the other hand, these people who were part of this growth curve are very much committed. My opinion is that these challenges related to the two moving, like really strengthened the community."*

An interviewee in Ljubljana mentioned the importance of cooperation in cities and communities to improve a better understanding of NBS:

Quote 23. : *"Cities, communities, neighborhoods do not have an understanding about this level of complexity yet (NBS and circularity). They still function based on the sectorial approach. More cooperation is needed. NBS can be the umbrella to achieve this".*

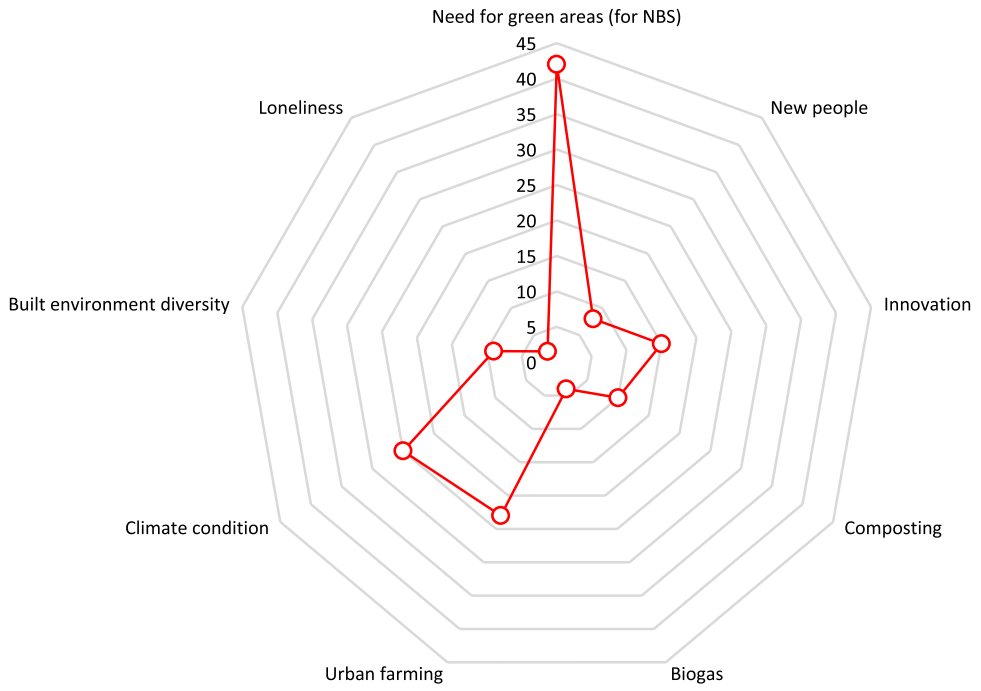

Fig. 8. NBS opportunities. The need for green areas (Fr=42) was the most frequent perceived factor among NBS opportunities, which was connected to the climate change challenge, as stated by an interviewee in Reykjavik:.

Fig. 9. Actors involved in NBS planning and the frequency of their mention by the interviewees.

3.7. Regulation issues related to NBS

Multiple regulations issues related to NBS were mentioned (Fig. 11). Incentives and regulation tools for NBS appeared frequently in the interviewees' comments with Fr=34 for each of them. In addition, the role of state, application (how, when and where the regulation is applied), leadership, drive for focusing on objectives, taxation, competition, laws proficiency, international agreements, and environmental certification were also perceived as relevant to NBS. In this context, an interviewee in Vienna stated:

Quote 24. *: "And then soon you need a lawyer, like somebody who really understands well the environmental law!".*

NBS are often linked to highly innovative fields that do not yet have clear regulations. This vacuum in legal and administrative terms creates uncertainty that can discourage urban actors from experimenting and developing their ideas. Moreover, the uncertainty can make municipalities avoid the risk and stop NBS at the early stage, as stated by an interviewee in Budapest:

Quote 25. *: "So if municipality, and I somehow happen to have the capacity to take a political risk, and I have the money, even if I have everything, I don't know, what are the rules I need to go with? So, it's difficult, it's very complicated. [analyzing water] And they don't know what the indicators are they need to check, because there are no guidelines for that in Hungary".*

This suggests that the studied cities face a notable absence of NBS regulations and support systems, potentially serving as significant barriers to implementation. Conversely, interviewees from Reykjavik and

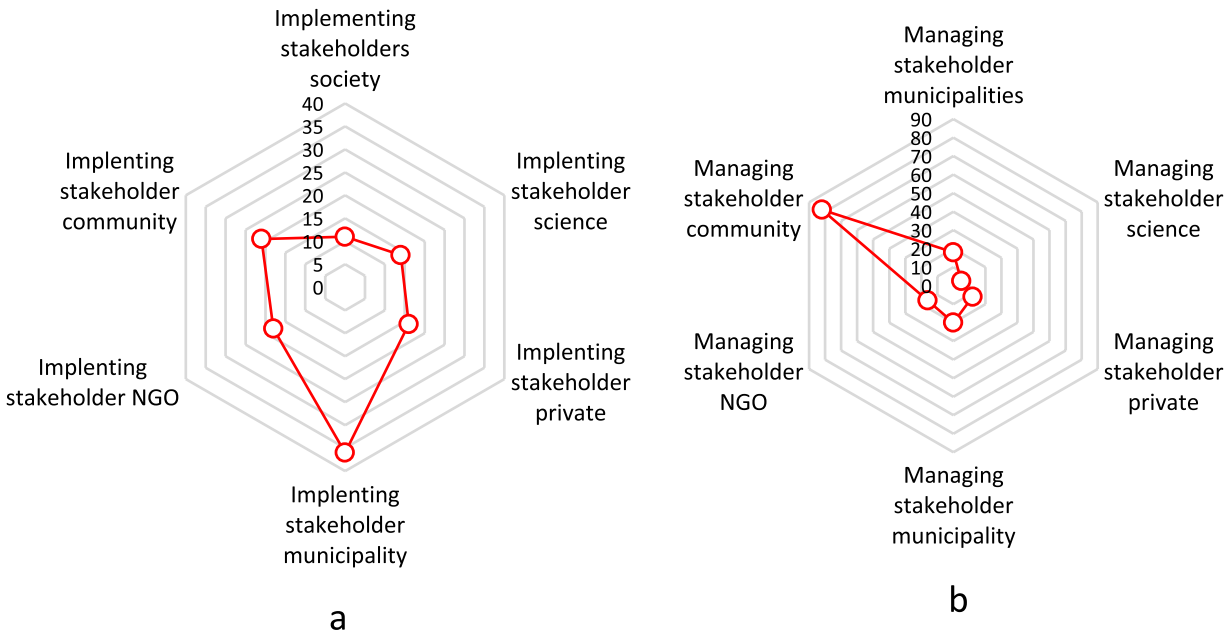

Fig. 10. Actors involved in NBS a) implementation, and b) management.

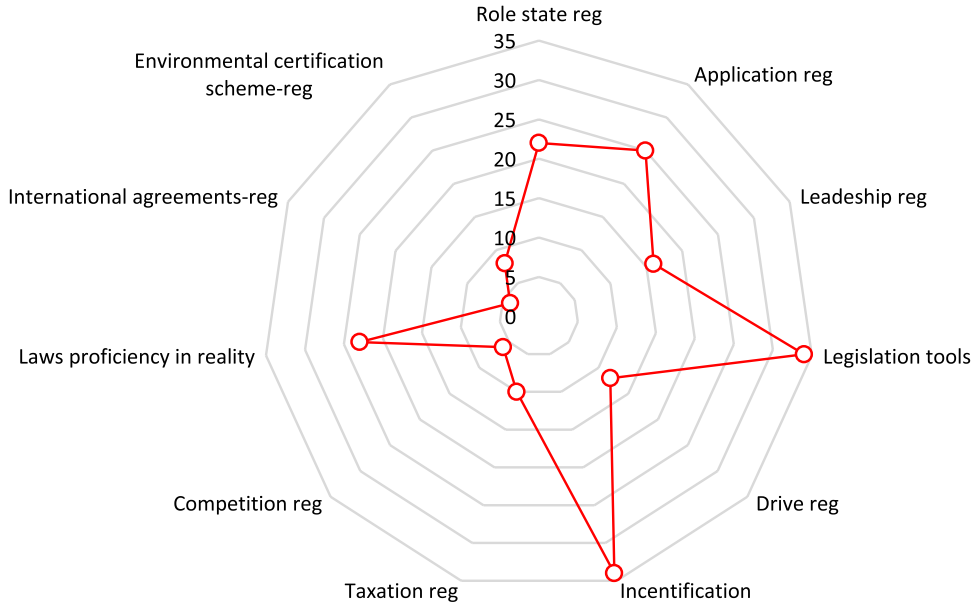

Fig. 11. Regulation issues related to NBS and the frequency of their mention in interviews.

Zurich offered insightful solutions to address these challenges.

Quote 26. *: "The policy should come in the regulations with time. I would argue that the policies are already there, the goals are there but there is always a big historical converting battle into regulations".*

Quote 27. *: "If we think about it very carefully, we can often even avoid introducing NBS to correct our mistakes, because we could have proper planning policies, such as zoning restrictions or things like prohibiting building within 100 or 200m of a riverbank or something like that. Such policies will affect future land use, which in turn will affect nature and the way the city branches out around nature".*

In addition, an interviewee in Ljubljana mentioned the fundamental effect of regulations in the implementation of NBS:

Quote 28. *: "My impression in general is that the inclusion of NBS in strategies is very limited. Even if something is written, it does not have like, you know, practical approaches or something".*

3.8. Other codes

Within this study, interviewees frequently referenced additional codes related to NBS in urban planning, highlighting the interconnection of green areas and the utilization of green roofs as rainwater storage, noted 24 and 11 times, respectively. Additionally, discussions on the definition of success for NBS projects emerged as another significant code, mentioned 7 times.

Their views turned out to be key to understanding how sustainable NBS are marketed and how they can be an attractive field of investment for private actors. In Córdoba and Zurich, the selection process resulted in contacting mainly municipal officials and managers involved in urban

planning. The insights of local government representatives proved to be of pivotal relevance in understanding how NBS fit into broader policy strategies geared toward mitigating climate change and fostering urban regeneration. Civil society was extensively engaged in Budapest, Vienna, and Reykjavik. In these cities, citizen committees, and environmental associations offered important insight into how NBS are used by urban planning, perceived by citizens and how they can respond to the real needs of local communities.

4. Discussion

The study aimed to gather the viewpoints of stakeholders engaged in urban planning regarding the importance of NBS. The discussion encompassed various domains, including the built environment, urban water systems, resource recovery, urban farming, and climate change adaptation. The findings revealed that stakeholders perceive numerous social and ecological advantages associated with NBS, notably fostering cooperation within communities. This cooperation manifested at different levels, encompassing empowerment, collaborative decision-making, cooperation, consultation, and information sharing (Kabisch et al., 2016; Kiss et al., 2022). Additionally, knowledge sharing emerged as a valuable advantage, facilitating the exchange of scientific and practical experiences related to NBS implementation, challenges, and applications among urban planners, users of urban spaces, and researchers. It is suggested that simplifying knowledge-sharing through narratives of NBS, particularly addressing impacts on individual lives and local areas, could enhance stakeholder engagement in promoting NBS (Frantzeskaki, 2019) and at the same time the use of NBS in urban planning. Furthermore, this study identified additional co-benefits of NBS, such as behavior change and improved health, within the context of urban planning, aligning with findings from previous studies (Raymond et al., 2017; Viti et al., 2022). NBS appear to catalyze unconventional dialogues, prompting diverse actors to collaborate on NBS. This extends to cooperation between municipalities, as highlighted in interviews where local governments viewed NBS as potential solutions for complex urban challenges across diverse European contexts; these results are also supported by Frantzeskaki et al. (2019). The array of diverse perceptions significantly contributes to shaping a robust and inclusive definition of NBS. This study embraces a wide spectrum of urban stakeholders engaged in experimenting and managing NBS, including urban planners, local decision-makers, entrepreneurs, and researchers. In cities like Budapest and Ljubljana, responses were predominantly provided by experts and academics from research institutes, whose profound theoretical insights enriched our understanding of NBS characteristics, potential, and technical constraints. Conversely, in Vienna, the snowball sampling strategy facilitated the inclusion of numerous business representatives, shedding light on how NBS are perceived and approached from a commercial standpoint.

The study highlights several challenges as perceived by stakeholders associated with implementing NBS, despite their increasing utilization. One notable challenge is the lack of knowledge among different categories of urban stakeholders, encompassing various aspects discussed in prior research (Hofstad et al., 2022). This knowledge gap primarily concerns understanding the long-term benefits of NBS and their potential contributions to enhancing urban resilience against climate change and other emerging challenges (Naumann et al., 2015). Additionally, there is a need to enhance understanding of the feasibility of implementing NBS in urban areas, including identifying potential barriers and evaluating their effectiveness (Kabisch et al., 2016). Another challenge identified relates to the built environment, encompassing the efficacy, robustness, and performance of natural materials used in NBS (Frantzeskaki et al., 2019). Addressing the acceptance of NBS requires action at individual, societal, and institutional levels, including the incorporation of disaster risk reduction measures (Anderson and Renaud, 2021). To enhance NBS acceptance, raising awareness about their benefits and fostering effective communication and collaboration are recommended according to our results, and also according to Wickenberg et al. (2021). Addressing financial obstacles is another important aspect found in this study, and as a solution, it was suggested that implementing a new financing system for recreational infrastructure and providing short-term financial incentives could help overcome the investment shortage (Fredman and Tyrväinen, 2010; Woroniecki et al., 2020). In terms of policy, it is crucial to integrate NBS into policymaking and implement approaches that address political and regulatory deficiencies (Dhyani et al., 2020). From local to global levels, policymakers need to be aware of the socio-ecological benefits of NBS and consider them in policy-making processes. However, the need for sound knowledge seems to represent a barrier for more consistent policies at a city scale. As stressed by recent literature, the findings of our case studies confirm that the vacuum of knowledge mainly concerns on the one hand political-administrative aspects related to the capability of policymakers and urban planners to incorporate NBS into long-term policies (Raymond et al., 2017) and, on the other hand, the lack of NBS knowledge is intertwined with the technical skills required for the management and maintenance of NBS, involving engineering and agronomic aspects, such as water reuse systems, regenerated soils or aquaponics, as other papers also stated (Ascione et al., 2021; Gholipour et al., 2024b).

The findings of the study also indicated that NBS offer wide opportunities for upscaling, such as the creation of green spaces and urban farming ranging from former industrial districts to brownfields along riverside areas. Previous research has also demonstrated the societal and environmental advantages of NBS, including their potential to support urban gardening, expand green areas, and enhance crop production (Sekulova et al. 2021). Additionally, NBS have been found to be relevant for addressing climate change impacts by mitigating changes, which can be considered in the context of socioeconomic vulnerability and the specific type of climate change (Seddon et al., 2020). The study identifies key actors shaping the planning, implementation, and management of NBS, highlighting the pivotal roles of stakeholders from society and municipalities. While individual actors and organizations can influence NBS, their collective impact underscores the necessity of establishing collaborative frameworks for synergistic action (Nesshöver et al., 2017). Beyond governmental bodies, significant contributors include NGOs, academic communities, civil societies, private sectors, and international organizations, each bringing unique expertise and resources to the table (Nesshöver et al., 2017). Governmental actors are crucial in formulating supportive policies and regulations for NBS implementation, while NGOs foster community engagement and advocacy for NBS adoption. Research institutions contribute by advancing NBS concepts and approaches, while planners integrate natural elements into urban environments and enhance NBS design and functionality (Kabisch et al., 2016). Civil society plays a vital role in ensuring NBS initiatives align with community needs and priorities through active participation and local knowledge (Nesshöver et al., 2017). At a broader scale, international organizations play a significant role in NBS projects by providing funding, technical support, and coordination. Regulation plays a crucial role in the context of NBS, as highlighted in this study. This includes the use of incentives, legislative tools, and addressing practical challenges in real-world implementation. NBS governance refers to the laws, regulations, and policies that vary across countries, depending on the specific environmental challenges and climate conditions they face (Faivre et al., 2017). The primary objectives of NBS regulation are to establish a legal framework and provide guidance for planning, implementing, and managing NBS projects. This involves addressing aspects such as funding mechanisms, permitting processes, land-use planning, environmental impact assessments, and the monitoring and evaluation of NBS initiatives (Lechner et al., 2020). Furthermore, NBS regulation often aligns with broader policy frameworks and strategies, including climate action plans, sustainable development goals, and national biodiversity strategies (Mansuy et al., 2022). This study primarily focused on European cities, potentially limiting generalizability. Secondly, reliance on qualitative methods may

introduce biases. Additionally, not all possible stakeholder perspectives were explored. Future research should aim to include diverse perspectives from broader geographic regions and employ mixed method approaches for a more comprehensive understanding of NBS in urban planning contexts. Moreover, it is important to acknowledge that not all possible stakeholder perspectives were explored in this study. The inclusion of a broader range of stakeholders, such as community members, industry representatives, and policymakers at different levels of governance, could provide additional insights into the complexities of NBS adoption and implementation. To address these limitations, future research endeavors should aim to include diverse perspectives from broader geographic regions. Employing mixed method approaches that combine qualitative and quantitative methods can offer a more comprehensive understanding of NBS in urban planning contexts. By integrating multiple data sources and analytical techniques, researchers can triangulate findings and enhance the validity and reliability of their conclusions.

5. Conclusions

This study investigated stakeholder perceptions of nature-based solutions for urban planning in six European cities, Budapest (Hungary), Cordoba (Spain), Ljubljana (Slovenia), Reykjavik (Iceland), Vienna (Austria), and Zurich (Switzerland). Using semi-structured interviews and the snowball sampling method, we interviewed key individuals and began by seeking their thoughts on NBS definitions and examples. Subsequently, stakeholders were given the option to choose a specific topic for further exploration, enabling a comprehensive understanding of their perspectives. The findings revealed a plethora of insights, resulting in 107 distinct codes relevant to NBS for urban planning. These codes encompassed various aspects, including 11 codes on NBS topics, 25 on benefits, 26 on challenges, 9 on opportunities, 9 on actors involved in planning, 6 on management, and 6 on implementation. Additionally, 11 codes pertained to legislation associated with NBS. Among the 25 identified NBS benefits, a notable advantage was the potential enhancement of cooperation among individuals. NBS are perceived as key drivers to promote creativity among urban planners to think out of the box of traditional policy toolkits and respond to climate change with alternative solutions. Furthermore, NBS are perceived as prominent collaborative devices to create cross-coalition between different policy actors interested in cooperating and exchanging resources to promote a common model of urban sustainability. On the other hand, lack of awareness and knowledge about NBS emerged as a significant challenge hindering their implementation. Public acceptance and financing of NBS projects within the built environment also faced notable obstacles. However, stakeholders recognized the need for green spaces as a driving force behind NBS opportunities. The study identified the municipality as a pivotal actor in NBS planning and implementation, while the community was perceived as crucial for effective NBS management. Additionally, stakeholders suggested that incentives could play a crucial role in fostering NBS compliance and integration within legislation. In conclusion, this study underscores the importance of seizing opportunities to promote NBS in urban planning. Addressing challenges head-on and establishing supportive legislations are equally critical to ensuring effective NBS management. By encouraging intra-community cooperation, NBS can flourish, maximizing their impact on urban environments and empowering individuals to contribute to sustainable and resilient cities.

CRediT authorship contribution statement

Dragan Milosevic: Writing – review & editing, Visualization, Supervision, Investigation, Formal analysis. **Ranka Junge:** Writing – review & editing, Supervision, Project administration, Methodology, Formal analysis, Conceptualization. **Rocío Pineda-Martos:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Conceptualization. **Eriona Canga:** Writing – original draft, Validation, Investigation, Formal analysis, Data curation. **Federico Cuomo:** Writing – original draft, Visualization, Investigation, Formal analysis, Data curation. **Violeta Zihlmann:** Writing – original draft, Visualization, Investigation. **Alexandra Tsatsou:** Writing – original draft, Visualization, Validation, Investigation, Formal analysis, Data curation. **Amir Gholipour:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Boldizsár Megyesi:** Writing – review & editing, Visualization, Supervision, Methodology, Formal analysis, 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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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ufug.2024.128344.

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