TITLE PAGE

Conceptualising Green Infrastructure and Nature-Based Solutions: Addressing Environmental Challenges in the City of Amman, Jordan

Submitted to the Special Issue: *Culturally Routed and Sustainable Strategies for Regenerating Cities after Crises*

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Abstract

This article explores the applicability of green infrastructure and nature-based solutions to address environmental challenges in the city of Amman, Jordan. They have been championed to help societies address challenges such as climate change, but attention to the Middle East is scarce. We investigate local experts' understanding of these concepts and their applicability to the city of Amman. Although GI and NBS are considered relevant approaches, there is a need for a paradigm shift toward viewing nature as a stakeholder, the enhancement of literacy on NBS, consideration of local biophysical and climatic conditions, and the implementation of pilots.

Keywords: Green infrastructure, Nature-based solutions, urban planning, Jordan, Amman, environmental challenges

1. Introduction

With the concentration of population and economic activities, cities have witnessed various environmental challenges, including air and water pollution, biodiversity loss, the urban heat island effect (UHI), water shortages and urban flooding, among many others (Grimm et al., 2008). Cities have also been recognised as vulnerable locations to the impacts of climate change (IPCC, 2018), a fact that poses the need for sustainable development and adaptation policies across levels and scales (Gómez Martín et al., 2020; Kabisch et al., 2016).

Jordan, like many other Middle East countries, is facing a plethora of environmental challenges. Jordan's climate models predict increased temperatures and lower levels of rainfall (Awad, 2022). The country is listed as one of 17 suffering from extremely high baseline water stress (UN-Water, 2021). This unfolding water crisis suggests that over 90% of Jordan's low-income population will likely experience acute water insecurity by the end of the century (Yoon et al., 2021). Accordingly, Jordan's capital city, Amman, exemplifies many of the challenges witnessed by modern cities. Amman has dramatically expanded over the last decades due to the constant influx of refugees, local population growth and internal rural migration (Greater Amman Municipality (GAM), 2008). The infrastructure and housing needs of the ever-growing population soon went beyond the capacity of local and national authorities (Potter et al., 2009). In addition, Amman historically lacked a robust planning framework for its urban development. Such conditions have significantly shaped the city's 'haphazard' form and expansion patterns and the demise of urban green spaces (Al Rawashdeh & Saleh, 2006; Greater Amman Municipality (GAM), 2008). In this context, Amman is currently witnessing a wide range of environmental challenges, which were effectively addressed in other contexts through implementing green infrastructure (GI) and nature-based solutions (NBS) (Raymond et al., 2017). These environmental challenges include air pollution, the urban heat island effect, water supply shortages, urban flooding, and water pollution (Hadadin & Tarawneh, 2007; Ministry of Water and Irrigation (MWI), 2016).

Against this backdrop, GI and, more recently, the NBS concept have taken centre stage in contemporary urban and environmental planning research putting forward an operational and practical dimension of studies centred on natural processes (Eggermont et al., 2015). Despite the ongoing advances, there is an unequal geographical research spread in GI and NBS. Studies tend to be concentrated in developed regions, mainly in EU member states, followed by Australia, China, and the US (Lemes de Oliveira & Mell, 2019; Li et al., 2021). If GI and NBS are indeed to address urban environmental challenges, and considering that climate change's impacts are likely to be stronger in developing countries, then mainstreaming NBS in such contexts is paramount. Yet, despite the potentiality of the broader

application of these concepts internationally, NBS research in the Middle East, generally, and in Jordan, specifically, is scarce.

As such, this research aimed to conceptualise the applicability of these concepts to address pressing environmental challenges in its capital city, Amman. It addresses the following research questions: (1) what is the understanding of green infrastructure and nature-based solutions of local experts working within academia, public and private sectors in Jordan? And (2) how applicable and relevant are GI and NBS are considered to be in the context of Amman? We endeavoured to (a) identify the most pressing environmental challenges in the city, (b) explore local experts' perception and understanding of GI and NBS, (c) identify the most suitable NBS to tackle the identified environmental challenges, (d) and propose recommendations for the policy and practice of GI and NBS in this context.

The following section discusses the concepts of GI and NBS in the literature. This is followed by a description of the methodological approach employed. Subsequently, the results are presented and discussed. Major themes regarding the current expert understanding and applicability of NBS to Amman are analysed. Finally, the conclusions identify limitations of the study, suggest areas for further research, highlight this study's main findings, and make recommendations for policy and practice of GI and NBS for the Jordanian and similar contexts.

2. Green infrastructure and nature-based solutions: global concepts?

Green infrastructure has been defined as a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services (ES) (European Commission, 2013), while nature-based solutions are conceived as actions inspired by, supported by or copied from nature that aim to help societies address a variety of environmental, social and economic challenges in sustainable ways (European Commission, 2015). More recently, the European Commission's definition was amended to emphasise that NBS should be cost-effective, help build resilience and that, as 'living solutions', they must benefit biodiversity. In essence, whilst the GI approach encourages the preservation and enhancement of green networks in urban settings, placing attention on the very interconnectedness of urban green (Benedict & McMahon, 2006) and the proactive delivery of ecosystem services in urban and environmental planning, the concept of nature-based solutions focuses on how nature can support humans in addressing challenges across the three pillars of sustainability (i.e. social, economic and environmental) (Frantzeskaki, 2019).

NBS is often seen as an umbrella concept that accommodates a range of ecosystem-based approaches (European Commission, 2020; Nesshöver et al., 2017; Pauleit et al., 2017), and in meeting various ethical, intellectual and relational challenges, eventually becoming itself a more holistic approach (Eggermont et al., 2015). NBS should be considered from a systemic perspective, be multifunctional, resource-efficient and locally adapted (Cohen-Shacham et al., 2019; Frantzeskaki, 2019). There is consensus that GI and NBS involve actions that harness nature to societies. Furthermore, they can represent more efficient and cost-effective solutions than grey infrastructure approaches (Albert et al., 2019).

Extant literature promotes their ability to help tackle global challenges through the delivery of ecosystem services (O'Sullivan et al., 2020; Venkataramanan et al., 2020). As such, NBS as a socio-ecological concept have gained ground in urban planning. Many studies have attempted to integrate ecosystem services into urban planning frameworks as a shift away from normative to performance-based planning (Cortinovis & Geneletti, 2020; Ronchi et al., 2020). It is argued that NBS can concomitantly help societies address the climate crises, by slowing further warming and through climate adaptation (Frantzeskaki et al., 2019; Kabisch et al., 2017; Pauleit et al., 2017). For instance, many cities have been implementing NBS as part of strategies to cope with the increasing frequency of extreme climatic events such as heavy storms and droughts (Beceiro et al., 2022; Qi et al., 2020). Sustainable Urban Drainage Systems (SUDS), as one of the main typologies of NBS in cities,

contributes to stormwater management and present co-benefits such as enhancing biodiversity (Coutts et al., 2012; Engström et al., 2018). Increasing and supporting urban biodiversity through NBS has been the object of many recent studies. Aerts et al. (2018) has shown that a biodiverse environment benefits both humans and non-humans, and Kowarik (2011) that urban nature can take many forms. Cities are being considered not only as the locus for human inhabitation, but also through a multispecies perspective (Celermajer et al., 2021). While research on NBS have reached a significant level of advancement both in theory and practice (Frantzeskaki et al., 2017; Mahmoud et al., 2022), most of it has been done in developed countries. The simple transfer of knowledge, technologies, tools and approaches from developed countries to other socio-cultural and economic contexts has not proven efficient or effective (Lemes de Oliveira & Mell, 2019). Ecosystem 'disservices' have a higher possibility of emerging should implementation of GI and NBS not be locally constructed. For example, in a context like Amman, some NBS' demand for water may be in competition to existing needs. In addition, the selection of non-adapted plant species (Mestre et al., 2021) and poor design may lead to ecological issues, health risks (e.g. facilitating the hosting of infectious pathogens) (Sharifi et al., 2021) and security issues (Zuniga-Teran et al., 2020). Socio-ecological inequalities can also be exacerbated by GI and NBS, mainly through gentrification processes (Scott et al., 2016; Song et al., 2019; van der Jagt et al., 2020).

Considering that NBS could be a prism through which a potential reconceptualization of urban planning and nature may take place (Scott et al., 2016), challenges such as extreme drought coupled with socio-economic and technological inequalities, require a reconsideration of what NBS can become in diverse contexts (Keeler et al., 2019). This article asks what GI and NBS in the context of a city like Amman imply and may mean.

3. Materials and Methods

3.1 Background of the study area

Jordan is an upper-middle-income country (United Nations, 2012) located on the northern side of the Arabian Peninsula with an area of 89,318 km^2. Around 78.4% of the country is semi-desert, yet the weather in Jordan is predominately Mediterranean, characterised by cool wet winters and hot dry summers. The average daily mean temperature is between 2ºand 8ºC in January and 26ºC in August (Farhan & Alnawaiseh, 2018). The country is highly urbanised (Jordan Ministry of Environment, 2009), with the highest population living in Amman (Jordan Department of Statistics, 2021), its economic and industrial hub (Younis et al., 2016) (Figure 1). The average annual rainfall in the city ranges from 290 to 473 mm (Farhan & Alnawaiseh, 2018). Jordan has three climatic regions, and Amman is located within the central one. Incised intermittent valleys constituting hills (each locally called "jebel") and steep side slopes (Farhan & Al-Shawamreh, 2019; Masri, 1963) dissect this region.

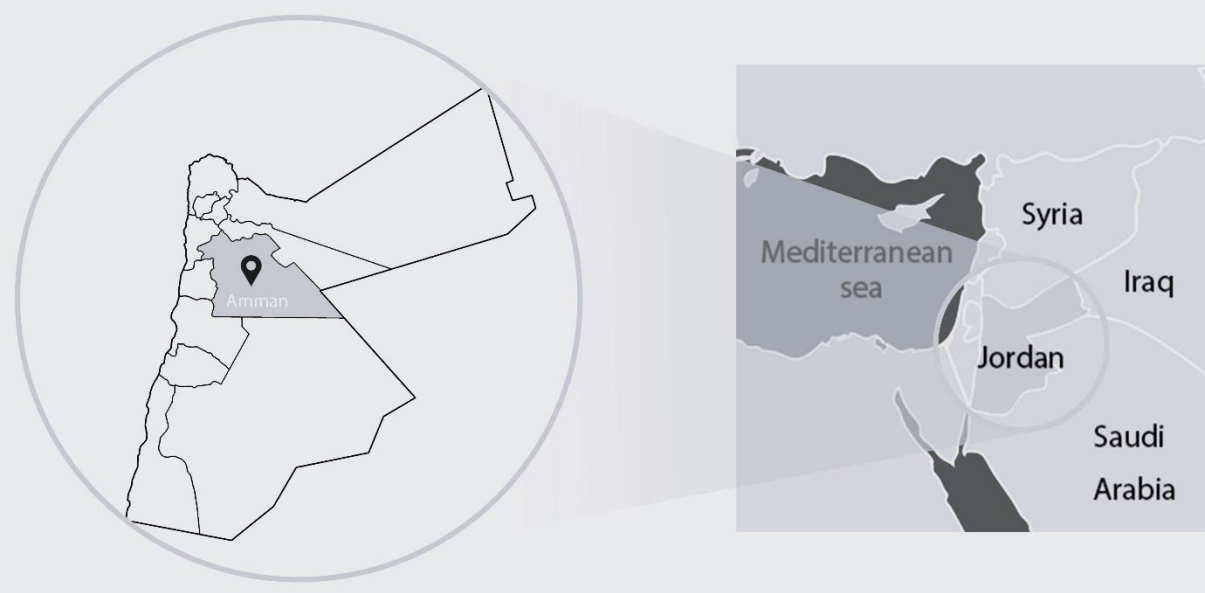

Figure 1.Amman's location

The old city centre of Amman is located at the base of seven jebels, 750 m above sea level. Hydrologically, the capital was historically known for its water resources, such as streams, springs, artesian wells, and reservoirs spread along its valleys. Today, this connection to water has faded due to urbanisation and processes of stream coverage (Gharaibeh et al., 2019).

While Amman's urban growth was initially concentric, it became axial following political and economic drivers, mainly towards the north-east, north-west, south-west, and south of the city (Ababsa, 2013). Amman transformed from a village of 3,000-5,000 inhabitants in the 1920s to a city of over 4,500,000 in 2020, counting 42% of the country's total population (Jordan Department of Statistics, 2021). Currently, Amman is distributed over 19 hills and 801 km^2 and is governed by the Greater Amman Municipality (GAM). Jordanian people live in densely populated urban areas characterized by a lack of green spaces. leading to various environmental issues that negatively impact urban living standards and the quality of life. Moreover, many reports, research findings and studies highlight the advantages of urban green infrastructure (UGI) in mitigating environmental problems in crowded cities. However, UGI development remains deficient in numerous Arab nations, including Jordan. Previous studies have indicated that the primary obstacles affecting the implementation of UGI in Jordan are the limited availability of irrigation water and the absence of incentive programs from local authorities (Zeadat, 2022).

According to Amman spatial profile report (2022), the report show that Amman faces several significant natural hazards, including flash floods, earthquakes, soil erosion, the urban heat island effect, and drought. A flood hazard assessment reveals that Amman's neighborhoods are particularly affected to flash floods due to the growing population and a high concentration of Syrian refugees, placing pressure on social services and critical infrastructure for water and sanitation, drainage, and waste management. Additionally, the heavy rainfall, which is increasingly common, frequently leads to flooding in low-lying areas of the city. Furthermore, the city's elevation exposes it to hazardous blizzards, which impact schools, transportation, the power grid, and access to essential services. The present environmental challenges worsen the vulnerabilities of the most underprivileged segments of both the Jordanian population and Syrian refugees. (UN-Habitat, 2022)

Research on urban environmental challenges and management facing Amman growing city , highlights that Amman set a pioneering example among Arab cities by being the first to implement a climate

plan aimed at addressing environmental issues like inefficient land utilization and the cost of imported energy. In response to its rapid urban expansion, the environmental governance of Amman has observed serious improvements, encompassing urban planning, the establishment of governing bodies, the formulation of regulations and laws, the implementation of mitigation measures, and the development of action plans in order to mitigate adverse effects. (Abdeljawad & Nagy, 2021)

The degradation of the environment due to sprawl is an aspect widely identified by previous studies. For example, Al Rawashdeh and Saleh (2006) revealed that the city's constant expansion between 1918 and 2002 resulted in 23% of agricultural land loss. The need to preserve existing green spaces and reintroduce natural features in the city have become key objectives in Amman's Master Plan (GAM, 2008), which aspires for Amman to evolve as *"A Green, Sustainable City"*. In addition, the Amman Green City Action Plan (AECOM, 2021) foresees developing a green infrastructure strategy to mitigate the urban heat island effect and carbon emissions in the city and using nature-based solutions for water management.

3.2 Study Design and Methods

Given the growing international understanding of how nature-based approaches to urban development and management can help address global challenges, supporting both human and non-human life, and the contrasting lack of such studies for the Jordan context, this article explores the current conceptualisations of green infrastructure and nature-based solutions in the country and their perceived relevance and applicability by experts. Ultimately, the article seeks to suggest pathways and strategies for the implementation of nature-based solutions to help address major environmental challenges.

The study is qualitative and employed a literature review, a two-round Delphi Survey and interviews. A literature search on GI and NBS in Jordan (and Amman) showed a very limited number of publications. Searches were conducted on Scopus in February (and then updated in July) 2022. The queries and relevant returns were as follows: (Jordan AND "Green infrastructure" = 3), (Jordan AND "nature-based solution*=2). Replacing Jordan with Amman did not provide extra returns. For both "Jordan" and "Amman" replacing the second term with "ecosystem services" returned 21 relevant entries. The latter were included in the review as proxies to characterise the state-of-the-art further.

The Delphi technique, a structured method applying multiple rounds of questioning to collect and analyse experts' opinions to explore ideas and help in problem-solving, has been widely used in urban planning research (Alawadi, 2017; Cortinovis et al., 2021; Musa et al., 2019). In this study, experts encompassed academics, policymakers, governmental officers, and practitioners working in NGOs and the private sector (Table 1). They were selected from disciplines related to the built environment (i.e. urban planning, architecture, landscape architecture and civil engineering) and environmental sciences (i.e. ecology, geosciences and climate sciences). Snowballing sampling was employed from the original list of experts. The inclusion criteria for participation were: (1) a PhD (completed or in progress) or an equivalent degree or experience, (2) a proven high level of engagement in environmental leadership or relevant policy-making at national and international levels, (3) a record of publications, projects, or activities, (4) working actively in the built environment or environmental fields for at least the last five years, and (5) expertise in the Jordanian context or the broader region. The open-source suite of tools for field data collection KoBoToolbox was utilised. Experts were contacted by email. The survey was disseminated through two rounds. The responses were anonymous, and confidentiality was preserved. Participation was voluntary.

Main area of expertise	Round 1	Round 2
Architecture	26	16

Stakeholder position/ affiliation	Round 1	Round 2
Academia	24	15

Civil engineering	9	3	Local level government	4	0
Environmental sciences	12	10	National level government	5	3
Landscape architecture	2	0	NGO/ INGO or similar	19	10
Urban planning	14	6	Private practice	20	11
Other	11	6	Other	2	2
Total	74	41	**Total**	74	41

Table 1. Participation in the Delphy Survey

One hundred thirty-three experts were invited to participate, 82 accepted, and eight answers were excluded after applying the selection criteria or because of incompleteness (n=74) (56% response rate). In the first round, experts were asked to identify the most pressing environmental challenges in Amman and to rate them in terms of their significance, impact and urgency. Participants were then asked to suggest possible interventions across the city, neighbourhood and building scales that could be applied to address them. The data collection occurred from 31 August to 20 September 2021.

The second round explored the experts' awareness of the terms ecosystem services, green infrastructure and nature-based solutions and aimed at consolidating their views on the most applicable NBS in Amman. The two main environmental challenges identified in round one were water management (encompassing water quantity and quality) and the urban heat island effect. A list of 24 NBS considered effective against these challenges was created from the participants' suggestions in round one and the literature review. In round two, participants were asked how aware they were of these NBS and to rate the applicability of these solutions to Amman. For each NBS, they were asked to identify the main barriers for their implementation. In addition, the survey allowed experts to suggest other suitable green solutions to address these challenges. 41 experts out of 74 completed round 2 (n=41) (55.4% response rate).

Gender distribution was consistent across the two rounds, with only a slightly higher percentage of males in round 1 and females in round 2. Most participants resided in Jordan and had professional experience ranging from 6 to 15 years. The majority were academics working in architecture for over five years. 15% of participants indicated other affiliation, the most significant proportion of them have experience in the energy field, and few participants worked in agriculture.

Subsequently, five semi-structured interviews (n=5) were conducted with key experts participating in both surveys to triangulate the data. Methodological triangulation was employed to deepen the understanding and evaluation of the data (Carter et al., 2014). Interviewees were selected to ensure gender balance (i.e. three males and two females), that they came from different areas of expertise (i.e., urban planning, civil engineering, environmental sciences), occupy diverse positions within the working sectors (i.e. academia, governmental and non-governmental sectors), and have not less than five years of experience. Their experience ranged from six to 25 years. The interviews were recorded between 30 January and 27 February 2022 using the Zoom platform. Their average duration was 35 minutes. During the interviews, experts were asked to comment on the Delphi Survey's preliminary findings. For example, they were asked to reflect upon the selection of NBS by the local experts and to elaborate on the identified barriers to implementing them in Amman and how to mainstream such solutions in the city. Interviews were conducted in Arabic, transcribed following the simple transcription method (Dresing et al., 2015), and translated into English.

For each step of the Delphi Survey and the interviews, three rounds of coding were undertaken in *QDA Minor Lite* software to identify concepts and themes, with no predetermined codebook used. Multiple coders carried out the coding in different periods to avoid errors, overlapping codes and to overcome biases. Differences in coding were discussed, and an agreement was reached to define the final coding

structures. This process was followed to enhance consistency in the process and the reliability of findings (Seale & Silverman, 1997).

4. Results and Discussion

4.1 Amman, GI and NBS

The literature review showed that studies in Jordan concentrate on water stress and management (Albalawneh et al., 2015; Becker et al., 2014; Vanham et al., 2021) and the social values of ecosystem services and local knowledge (Orenstein & Groner, 2014; Peck & Khirfan, 2021; Sagie et al., 2013), with a smaller number of studies in forestry (Al-Assaf et al., 2014; Majdalawi et al., 2016) and ecosystem services in rural areas (Schaldach et al., 2013). Notwithstanding the lack of localised GI and NBS research in Jordan, suggestions for their consideration in urban and regional planning have emerged tentatively. For instance, Peck and Khirfan (2021) highlighted how path dependency is a decisive factor in the debates over preferences for hard-engineered solutions for water management but still recommended that the Greater Amman Municipality should integrate nature-based solutions in future decision-making. Similarly, Awad (2022) advances the case for NBS mainstreaming by providing a list of suitable solutions for the Jordanian context.

4.2 The Most Pressing Environmental Challenges in Amman

In round 1 of the survey, a free-text response was available to participants to define the three most pressing environmental challenges in Amman. The foremost challenge identified was water quantity. In a subsequent ranking question, participants were asked to independently rank six environmental challenges previously determined based on the literature review. Water quantity also ranked first in this question. Participants were allowed to add other challenges freely, and a few were mentioned, such as lack of urban planning, conflicting land use, transportation and resource management. Finally, the environmental challenges were tested using a 5-point Likert scale regarding their impact on the city and level of urgency, and the result showed that water quantity was the most urgent and impactful challenge. Water quality was also of significant concern for most participants. We clustered it with water quantity in the higher water management category. For this study, this term includes (i) flood and drought protection, (ii) the water-food-energy nexus, and (iii) water purification. While waste management was ranked second overall, evidence-based research on the applicability of green infrastructure and nature-based solutions to this challenge is scarce in urban planning (European Commission, 2020). Most of the indications for this category in the survey were related to wastewater rather than solid waste. As such, given that this article aims to explore the conceptualisations of GI and NBS in Jordan and to identify how they could become effective urban planning strategies in this context, and that wastewater was comprised in the first challenge, urban warming was identified as the second most relevant environmental challenge. This challenge has been operationalised in the concept of the urban heat island effect (UHI), the phenomenon that urban areas are generally warmer than non-urban areas surrounding them. With global warming, water management (ARUP, 2011; Johannessen & Mostert, 2020) and the moderation of urban temperatures (Arnfield, 2003; Stewart & Oke, 2012) are crucial challenges cities face worldwide.

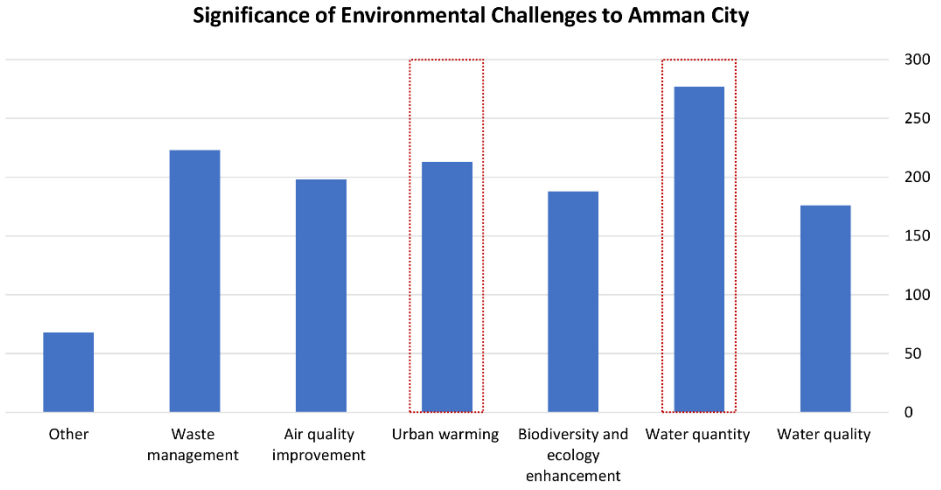

Figure 1. The most significant environmental challenges in Amman

Interviewed experts justified the selection of water management and the urban heat island effect as the top environmental challenges for several reasons. Firstly, the need for climate change adaptation and to address the UN Sustainable Development Goals were crucial factors. This is in line with the severity of predictions for the region. Seckler et al. (1999) estimated that the Middle East is risking a state of absolute water scarcity by 2025. Recent research confirmed that the region will face an enhanced water deficit, a 25% decrease in annual precipitation and an increase in mean annual temperature up to 4.5ºC (Sowers et al., 2011; Suppan et al., 2008). As such, there is an urgent need to sustainably manage water and tackle increasing urban temperatures. Moreover, the growth of population and the influx of refugees were explicitly identified as determinants heightening the criticality of water management (Hadadin et al., 2010). Second, the tangibility of certain environmental challenges was also recognised by interviewees as a factor making them more evident (e.g. water quantity) and, thus, more recognisable by local communities than other environmental challenges (e.g. air pollution). Similarly, literature has shown people's positive values of locally-based climate change adaptation interventions of direct perceived impact on their lives (Alfie-Cohen & Garcia-Becerra, 2022; Evans et al., 2014). Third, the role of relevant authorities was brought up throughout in that they have the power to either augment or diminish environmental challenges in the city according to their responsibilities and performance. Fourth, it was emphasised that urban challenges are interconnected (e.g. lack of water and urban warming). The city's dense urban fabric and lack of greenery contribute to these problems. One of the interviewees also identified the topography and the existing valley system as features that hinder flows across the city, including natural air ventilation and water influx, exacerbating the urban heat island effect and water management challenges. Indeed, the definition and preservation of ventilation corridors in cities has become one of the main adaptation strategies in metropolitan plans (Ren et al., 2018; Wong et al., 2010), such as in Milan (Citta Metropolitana di Milano, 2022) and Freiburg (Lemes de Oliveira, 2017). Finally, a systemic approach to tackling Amman's environmental challenges conjointly was considered a necessary step to address their complexity and urgency.

4.3 Selection of NBS Based on the Level of Awareness and Applicability in Amman

In the first round of the survey, participants were also asked to suggest solutions for the selected environmental challenges across scales, as summarised in Table 2. The question text did not include the term 'nature-based solutions' so as not to influence the responses. Although some NBS were cited, most recommendations do not fit within its definition. Similarly to results in Peck and Khirfan (2021), this fact may suggest path dependence at play, the expert's familiarity with grey approaches and a lack of awareness of other NBS.

Table 2. Expert's proposed solutions for water management and reduction of urban temperatures per scale

Scale	Solutions Cited by Survey Participants
1. Building	- Insulating walls and roofs - Green roofs - Installing double-glazed windows and shading devices - Avoiding paving the surrounding areas - Solar energy for winter heating - Smart heating and cooling systems - Net-zero energy buildings - Eliminating cold bridges - Applying and controlling the needed U-values - Landscaping around buildings - Rainwater harvesting - Installing water-saving devices and applications - Buildings designed in a way that do not require much energy or water - Grey water re-use/ grey water system
2. Neighbourhood	- Increasing the number of green spaces - Neighbourhood parks - Green squares - Selecting native or adapted plants for gardens and parks - 15-minute city concept - Renewable energy at the level of the neighbourhood - The re-use of treated wastewater for greening and landscaping purposes instead of using fresh water - Flash flood management - Water retention basins
3. City	- Urban parks - Avoid land take toward major stream flows - Detect water losses in the networks - Implementing wastewater treatment plants - Installing grey water nets - WWTP for irrigation - Providing safe, affordable, timely, and non-polluting (electric) public transport. - Improving the transportation network - Planting large trees in areas with high urban temperatures t - Implementing waste-to-energy plants - Renewable energy for transportation.

In round 2 of the survey, definitions of ecosystem services (European Commission), green infrastructure (European Commission, 2013) and nature-based solutions (European Commission, 2015) were presented, and participants were asked about their awareness of them and to rate the relevance of these concepts to the Jordanian context. All respondents reported awareness of the concept of ecosystem services, which was considered relevant to half of the participants (moderate 32% and irrelevant 18%). The awareness of GI was of 97%, and 55% of respondents rated it as relevant (moderate 18% and irrelevant 27%). The definition of NBS in turn was known to 87.5% of respondents, with only 47% considering it relevant to the Jordanian context (39% moderate and 14% irrelevant). Arguably the low rate of relevance assigned to these concepts might be due to (1) background of most participants (majority from architecture and not environmental sciences), (2) scepticism due to water scarcity for the implementation of GI and NBS, and (3) NBS being a relatively new term, with respondents showing a general lack of awareness of typologies and potentialities, as corroborated by the absence of scientific publications on the topic and as supported by interviewees' comments.

Subsequently, we listed 24 appropriate NBS to tackle the selected environmental challenges from round one recommendations and a literature review. For each solution, a photograph and brief description were provided to define common ground and avoid misinterpretations. The awareness level varied

significantly across participants regarding the suggested 24 NBS. All local experts were aware of urban trees, green squares, urban parks and green roofs, while the lowest level of awareness was regarding green wedges (58%) and controlled flood plains (60%), as shown in Figure 2.

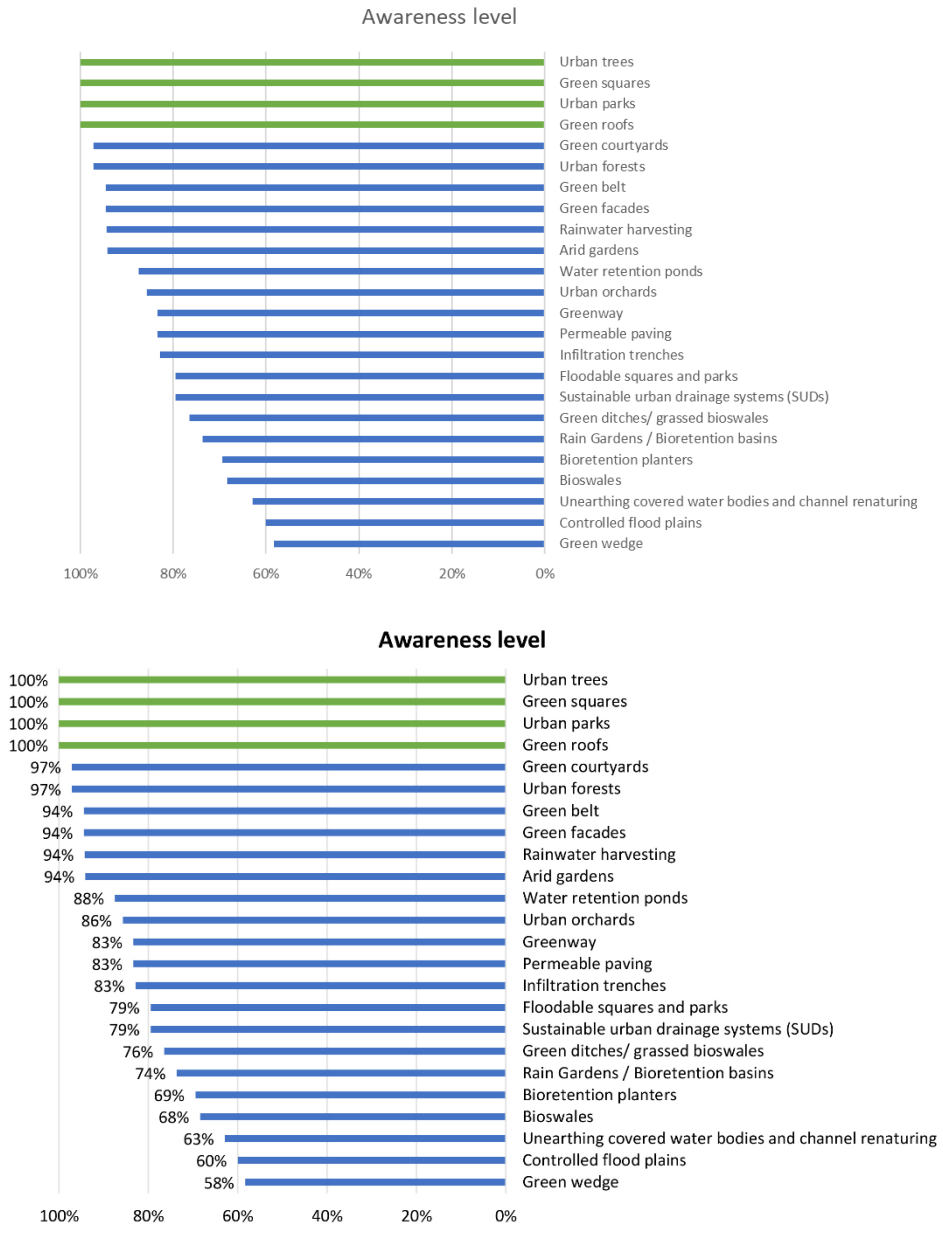

Figure 2. Awareness level of nature-based solutions

Subsequently, using a 5-point Likert scale, participants were asked to address each solution's applicability to Amman. Rainwater harvesting and trees were perceived by local experts as the most applicable nature-based solutions to address water management challenges. In contrast, controlled flood

plains and green wedges were considered the least suitable, as seen in

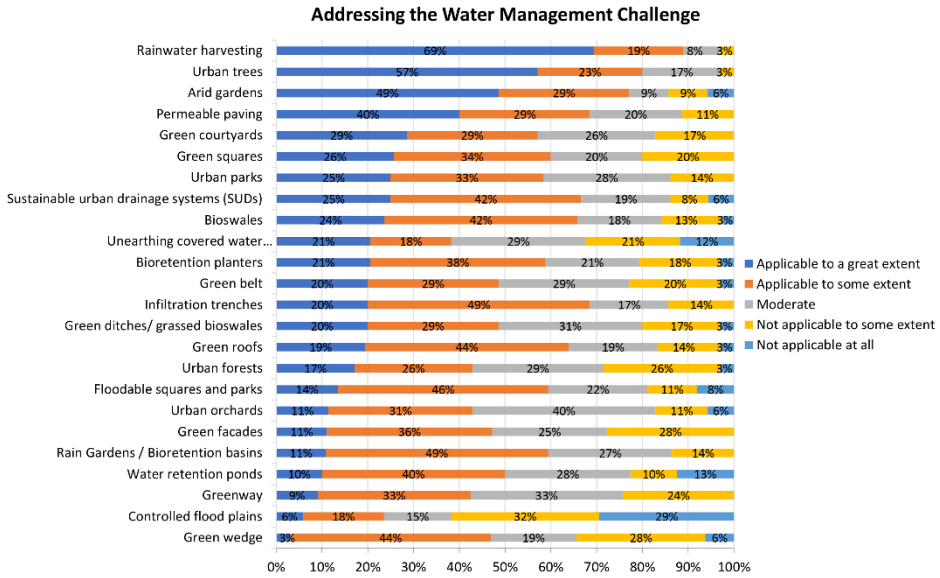

Figure 3. Trees and rainwater harvesting were also considered the most relevant NBS to tackle the urban heat island effect, while controlled floodplains and infiltration trenches were the least (Figure 4).

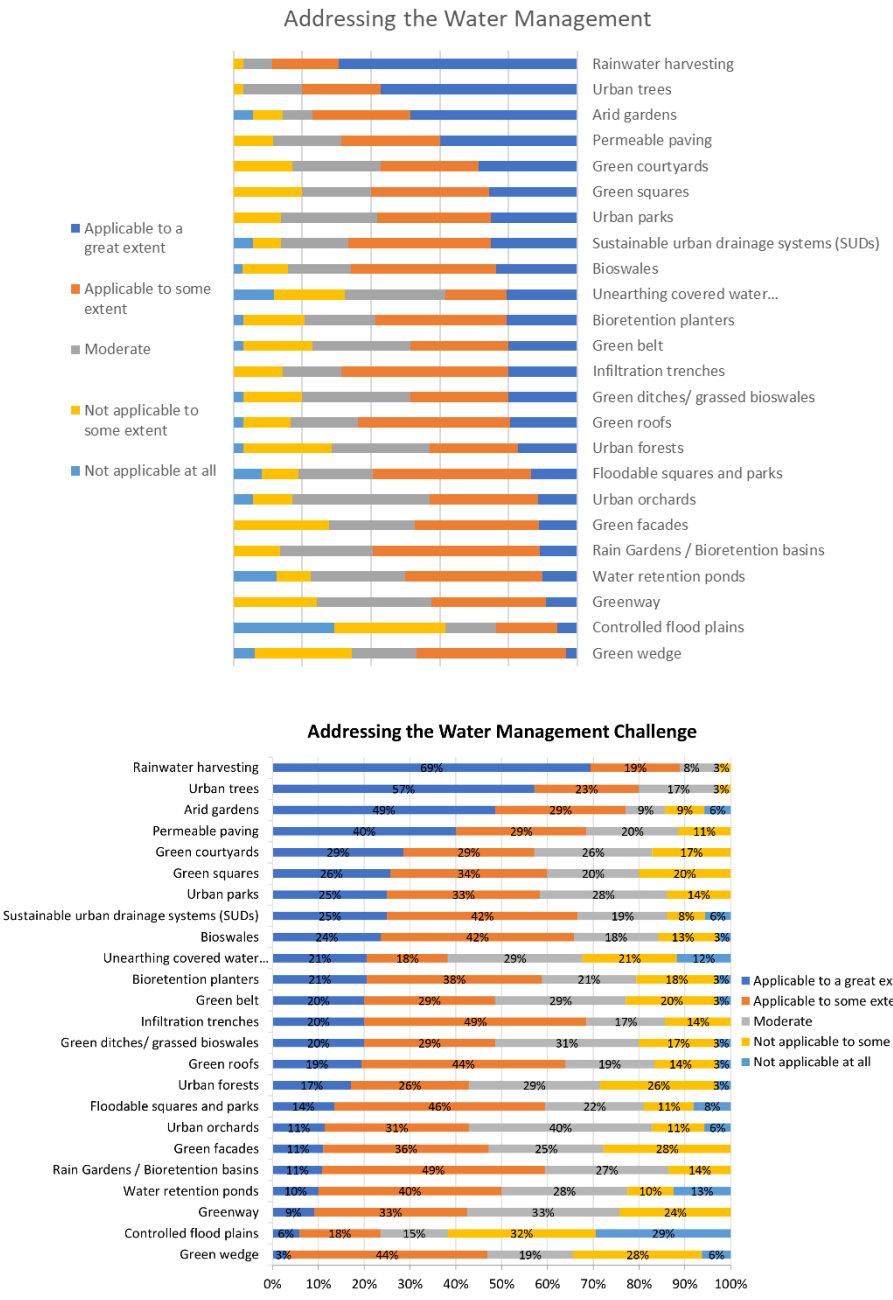

Figure 3. Applicability of NBS to water management in Amman

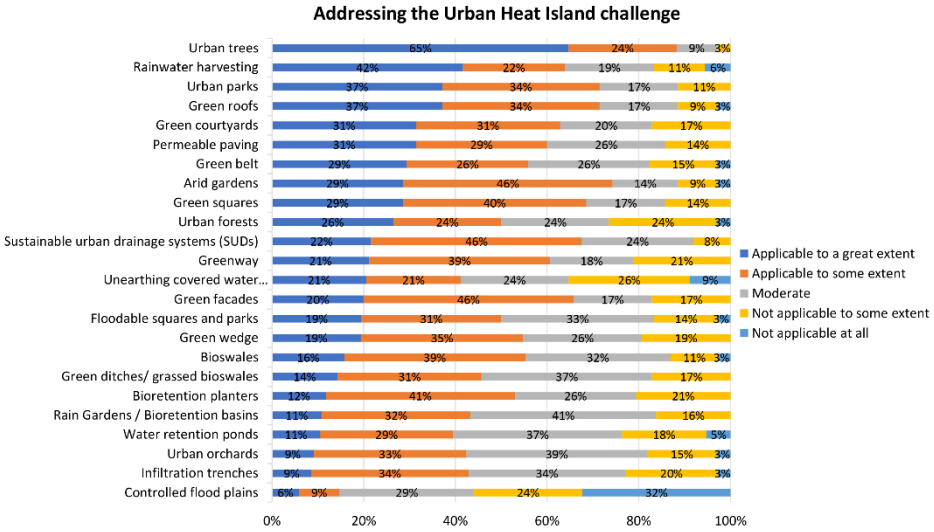

Figure 4. Applicability of NBS to tackling the urban heat island effect in Amman

Interviewed experts shed light on why local experts were more aware of certain NBS and perceived them as more applicable in Amman than others. Most stated that there is a lack of local technical knowledge and awareness regarding the full scope of NBS, with the more unfamiliar and 'foreign' solutions being neglected by participants. The limited implementation of NBS in Jordan was believed to hamper the awareness of the wide range of NBS. Several interviewees even admitted that they were unaware of many NBS presented in the survey:

> *"To me, it's very logical for it [rainwater harvesting] to be the first solution. The rest of the list is not well-known for people, I guess. That's why they didn't choose many others"* (Interviewee D).

> *"Clearly, there is a lack of information in this area. I, myself, as a specialist, didn't know many of these solutions"* (Interviewee A).

As such, participants tended to rely on their experience and technical knowledge in identifying solutions and their applicability. Interviewees picked on the fact that many participants were from an architectural background, which may have increased the awareness levels of micro-scale solutions compared to meso and macro ones. The desirable imaginary of a future 'green' city, as seen in international discourses and more recently in local visions, was thought to prompt participants to focus their selection of NBS dominated by green features.

Moreover, interviewees stressed the necessity of evidence-based knowledge of ecosystem services to select NBS. Interviewees noted that it is only through appropriate studies that the local community could determine the ecosystem services derived from each NBS and its applicability to the local context. As such, there is an interplay between the need to improve literacy and enhance awareness levels of the scope of the array of existing NBS (Kabisch et al., 2016; Raymond et al., 2017) and working with communities to develop locally-tailored solutions (Arlati et al., 2021). Building on local knowledge is crucial to breaking path dependence (Davies & Lafortezza, 2019) and progressing the mainstreaming of NBS (Puskás et al., 2021). Introducing NBS into the educational system was considered a significant step toward it (Schweitzer & Gionfra, 2018). The abandonment of historic NBS practices, particularly rainwater harvesting, was also identified as a primary reason behind the absence of this practice from the participants' selection of the top NBS in terms of awareness level, despite their widespread implementation in vernacular practices in the region. These findings are aligned with the literature on the sociocultural valuation of ES in Jordan. For instance, Sagie et al. (2013) showed how the diverse

social values assigned to arid geographies must be better understood for more comprehensive management and provision of ES and Peck and Khirfan (2021) argued that local ecological knowledge deriving from both local experts and laypeople must be the basis upon which to build robust ES-based strategies.

4.4 Barriers for Implementing NBS in Amman

Finally, local experts were asked to identify the barriers for implementing NBS in Amman (Figure 5). They can be grouped into three main categories: (1) urban planning, design and governance; (2) biophysical and climatic conditions; and (3) awareness, knowledge and local capacity, as further elaborated in Table 3.

Table 3. Interlinked barriers for implementing NBS in Amman

Main NBS barriers	Sub-barriers
1. Urban Planning, design and governance	- Urban morphology (e.g. space availability, narrow streets & sidewalks, vacant lands and infrastructure) - Lack of financial frameworks - Planning policy & governance (e.g. planning laws, regulations, land ownership and lack of public participation) - Project design (e.g. consideration of ecosystem "disservices", existing building structures and retrofitting) - Construction and maintenance (i.e.the sustainability of these solutions in the long run)
2. Biophysical and climatic conditions	- Climate change - Semi-arid environment (e.g. water scarcity, low rainfall, high evaporation and soil type) - Topography
3. Awareness, knowledge and local capacity	- Technical capacity/knowledge (e.g. planning, design, and proper plant selection) - Evidence-based knowledge (e.g. research and implemented cases) - Cost-effectiveness - Community awareness (e.g. perception of benefits) - People behaviours (e.g. vandalism).

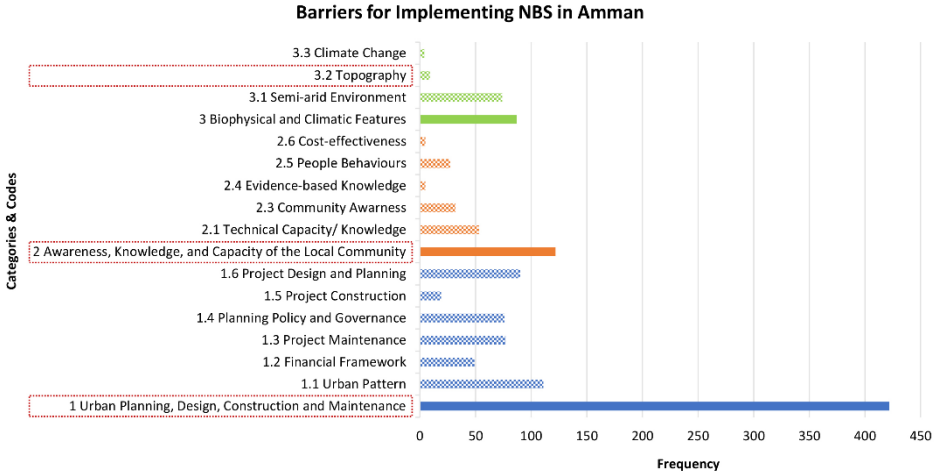

Figure 5. Barriers for implementing NBS in Amman

Interviewees emphasised that the most significant barrier refers to the lack of enforcement of planning policies to control land take. For example, one interviewee stated that *"as practitioners, who have implemented NBS and worked on city planning, the most significant challenges we face are the random urban patterns and the random planning growth"* (Interviewee C). Land take for urbanisation heightens the environmental challenges the city is already facing and compromises the implementation of NBS such as parks, green belts and green wedges. Lack of space availability suggests that opportunities for NBS implementation are larger in retrofitting the existing building stock, infrastructure and public space. Additionally, short-term actions tend to be more acted upon than longer-term ones, such as climate change (Nesshöver et al., 2017), and prioritised in terms of financial frameworks. One of the interviewees referred to this phenomenon as *'the paradox of horizon'*, stating "*I see that climate change didn't take much weight in the list. I think maybe because of the paradox of horizon. People tend to consider challenges in the short term, like maintenance and design, while challenges on the long term are less prioritised, which cause real issues for planning"* (Interviewee B).

The biophysical conditions were referred to as an explicit factor that must be considered and addressed. These include the city's topography and the unavailability of natural resources, mainly water. The latter was identified as a core difficulty that defies the very conception and development of a 'green' strategy in Amman, as can be seen in statements such as "*Greening Amman is a great concept. However, do we have enough water to do this?"* (Interviewee C). As water scarcity becomes a greater problem worldwide, questions regarding how 'green' green infrastructure and nature-based solutions ought to be arise. For example, Coutts et al. (2012) showed that the combination of excessive heat driven by urban development, low water availability and climate change impacts may lead to new forms of climate-sensitive interventions in cities.

Lack of awareness of NBS compromises the break away from standard grey infrastructure approaches, reinforcing path dependence and a business-as-usual scenario: *"The main issue is that there is no willingness to manage [NBS] properly. Our decision-makers are not aware or educated about these solutions"* (Interviewee A). Perceived ecosystem disservices were also identified as barriers for NBS implementation, with, for instance, water retention ponds in urban areas being seen as potentially leading to the proliferation of mosquitos. Kronenberg (2015) showed that lack of awareness of urban green infrastructure is a significant problem internationally. As Kabisch et al. (2016) highlighted, lack of information coupled with risk aversion by local policymakers and planners lead to roadblocks to the uptake of NBS in cities.

It is important to emphasise that many of the identified challenges for NBS implementation are not unique to the context of Amman. In a literature review of the fundamental barriers to realising the potential of NBS, Nelson et al. (2020) include such issues as the lack of political will and sufficient commitment to NBS implementation, knowledge gaps concerning NBS effectiveness, implementation and design, the disconnection between short-term actions and long-term goals and path dependence. Similarly, Dorst et al. (2022) identify urban NBS barriers based on a comparative study of multiple countries (UK, Sweden, Spain, the Netherlands, Hungary, and Germany), showing that these tend to fall in issues related to urban planning, policy development and governance, competition for space, knowledge and awareness, citizen engagement and lack of resources.

Furthermore, some participants stressed the importance of participatory planning and communal dynamics in implementing and maintaining NBS in Amman. In the first survey, one participant suggested that pilot projects that engage people and involve them in implementing NBS could be effective to convince people with the "green changes" at the levels of buildings, neighbourhoods, and cities. Another participant in the second survey highlighted the role of participatory planning and local knowledge about community's skills and nature-based when addressing environmental challenges.

4.5 Recommendations for Advancing GI and NBS in Amman

Experts have proposed several recommendations to overcome the barriers to implementing NBS in Amman across previously identified main domains. First, urban planning must embed nature-based approaches across its various phases and in a systemic manner. This requires the training of local experts and planning officers. Best practice and evidence-based research on NBS must be further disseminated and the applicability of solutions considered locally. These recommendations are in line with the literature on principles for mainstreaming NBS. For instance, Kabisch et al. (2022) argue for the need for a systemic approach, that attention must be placed on communication and learning, and that NBS ought to be inclusive and context-based. In addition, our results show that integrating knowledge and skills from various disciplines and departments and coordination across levels of governance are crucial to breaking path dependence. Albert et al. (2021) equally claim that evidence base, transdisciplinarity and integration across scales and levels are crucial and that targeting local challenges through practical means can support future mainstreaming. Experts also pointed to the need to develop financing mechanisms in tandem with the prompt testing of pilots prioritising water management and the reduction of urban temperatures.

Second, working across scales with more robust integration of urban and peri-urban policies and projects would strengthen the effectiveness of solutions. Cohen-Shacham et al. (2019) highlight the significance of the landscape scale and how trade-offs should be negotiated within a broad spectrum of participation. Although the possibilities of implementing more extensive green infrastructure interventions in the peri-urban areas are greater, retrofitting the inner-city areas of Amman through NBS must be done for an effective and equitable distribution of ecosystem services. In this context, implementing NBS that considers the initial condition of water scarcity is crucial. The ability to keep water must be a criterion in the applicability of NBS. In addition, plant selection must be appropriate for semi-arid situations. This condition of water scarcity is a fundamental differentiation regarding the international literature and may lead to the development of new approaches and NBS typologies.

Third, there is a need to overcome top-down approaches, reconsider traditional approaches and move towards locally tailored strategies for co-creation, co-management and co-evaluation of NBS. Finally, broadening nature-based thinking across ages was suggested to change the paradigm towards a more balanced relationship with the natural environment. For this purpose, it was recommended that curricula across school levels address such an approach. Likewise, a review of higher education could aim to strengthen the understanding of NBS across different disciplines.

5. Conclusions

This article sought to explore the conceptualisations and applicability of green infrastructure and nature-based solutions for a semi-arid context, the case of Amman, in Jordan, and advance recommendations for the mainstreaming of such solutions to address key environmental challenges. We showed that experts were all aware of the concept of ecosystem services, the vast majority were of green infrastructure, and most were regarding NBS. However, questions over their applicability to Amman emerged. Green infrastructure and nature-based solutions must be locally tailored. Green imaginaries and best practices from international examples must be mediated. The research has shown that the planning, design and governance of GI and NBS must acknowledge the condition of water scarcity and high temperatures from the onset, the lack of open space and high densities of the inner-urban city and the city's topographical condition. Restoring and updating vernacular practices would also contribute to strengthening the historical and sustainability dimensions of resource management. In so doing, new forms of GI and NBS may be developed.

Water management and the urban heat island effect were identified as the most pressing environmental challenges faced. Despite the reservations discussed previously, a range of NBS was considered applicable and effective to deliver ecosystem services that address such challenges in Amman. Barriers to implementing NBS related to planning and governance, the biophysical and climatic conditions and lack of awareness and technical knowledge. A paradigm shift towards a balanced relationship with

nature must be pursued. This involves building nature-based thinking from an early age in the educational system and the continued development and training of planners and local officers. Integrating knowledge and skills across sectors, levels and jurisdictions, and developing a solid participatory framework and financial mechanisms can support this step change. Besides, implementing locally developed pilots targeting the main environmental challenges identified would provide the evidence base and potentially catalyse subsequent initiatives.

Limitations of the study may include the number of participants from architectural backgrounds and their potential predisposition for identifying NBS at the micro-scale, and eventual lack of awareness of other NBS.The evaluation of implemented NBS and their monitoring over time can provide significant empirical data to advance the mainstreaming of such solutions in Amman and similar contexts. Some proposed topics for further investigation include exploring the perceived relevance of GI and NBS beyond expert participants; evaluating the condition of the educational curriculum at different levels in Jordan, comprehending how they may introduce nature-based concepts; how the co-design of NBS may take place in this context; and the relationship between water scarcity and the development of GI strategies and NBS for similar climatic and geographical contexts.

The development and implementation of NBS in a city like Amman implies a deep recognition that localisation must involve the identification and construction of the social values related to nature and the expectations towards NBS, in addition to having the biophysical conditions as the starting point. Such approach may contribute not only to the body of knowledge on full processes of (co-)creation, but also innovate on NBS typologies and outcomes. By completing this research and introducing future avenues of investigation, this article aspires to enhance the conditions for GI and NBS research and practice, support Amman in overcoming its environmental challenges and meet its vision of becoming a resilient and sustainable city.

Disclosure statement

The authors report there are no competing interests to declare.

Funding

[REMOVED]

Ethics

This study has been reviewed by the [REMOVED] Ethics Committee and been given favourable ethical opinion [REMOVED].

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[REMOVED]

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Nour, Abdeljawad ; Imre, Nagy Urban Environmental Challenges and Management Facing Amman Growing City REVIEW OF INTERNATIONAL GEOGRAPHICAL EDUCATION ONLINE 11 : 5 pp. 2991-3010. , 20 p. (2021)