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Priorities and barriers for urban ecosystem service provision: A comparison of stakeholder perspectives from three cities

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Urban Green Infrastructure (UGI) can provide many needed ecosystem services (ES) to help address challenges like biodiversity loss and climate change while contributing to the health and wellbeing of urban inhabitants. In order to optimize UGI for a given city, a first step is to assess the local ES needs and the potential barriers to ES provision. However, it is not known how consistent these needs and barriers are among cities in different settings. To help address this knowledge gap, the aim of this study was to assess ES priorities and existing barriers to ES provision for three cities varying in socioeconomic, cultural and climatic setting: Addis Ababa (Ethiopia), Cincinnati (USA) and Malmö (Sweden). In case studies of each of the three cities, we carried out workshops with key stakeholders and collected their assessments of both current provision of ES from UGI and future priorities. The workshops were followed by expert stakeholder interviews aimed at highlighting existing barriers to ES provision. In spite of the different urban contexts, expressed ES priorities were similar among the cities, with the highest cross-cutting priorities being climate change adaptation, stormwater runoff management and water quality, mental and physical health, biodiversity, and provision of local food. Stakeholder-expressed barriers to ES provision were also broadly similar among cities, falling into three main categories: structural pressures, gaps in governance, and lack of ecological awareness and vision. Our results suggest that certain key ES priorities and barriers may apply broadly to cities regardless of climatic or socio-cultural context. These generic needs can help direct the focus of future studies, and imply a clear benefit to international, even cross-continental study and knowledge-exchange among practitioners and researchers working with UGI.

KEYWORDS

urban planning and management, Urban Green Infrastructure (UGI), Cascade Model of ecosystem services, Nature-based Solution (NbS), Global South, Sustainable Development Goals (SDG)

Introduction

Cities today face multiple challenges to sustainable development, including aspects of socio-economic equality and cohesion, health and wellbeing of the urban population, climate change mitigation and adaptation, and biodiversity loss (e.g., Kabisch et al., 2016; Almenar et al., 2021). As part of the effort to address those challenges, Nature-based Solutions (NbS) and Urban Green Infrastructure (UGI) are finding a place within urban planning and management as important components in transition to a more sustainable society (e.g., Davies et al., 2015; Albert et al., 2019; Hobbie and Grimm, 2020). NbS are "Solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience" (EC: European Commission, Directorate-General for Research and Innovation, 2021), and thus can help to recoup some of the functions that would have been provided by natural ecosystems, in locations that have undergone urban development. Examples of NbS include the preservation of a natural woodland, the creation of a constructed wetland, the construction of a vegetated roof, or the planting and maintenance of street trees (e.g., Eggermont et al., 2015). 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" (Box 1) (EU, 2013).

Whether thinking about specific NbS actions or a more broad UGI network strategy, the idea behind the implementation of these concepts in urban planning and management is to support sustainable development and address societal challenges by providing needed ecosystem services (ES) (MEA, 2005). Documented ES from urban NbS include for example recreational opportunities (e.g., Tyrväinen et al., 2005), provision of food and raw material (e.g., du Toit et al., 2018), cooling, wind control and air pollution removal (e.g., Tyrväinen et al., 2005), habitat for biodiversity (Canedoli et al., 2018) and improved psychological and physical wellbeing (e.g., van den Bosch and Sang, 2017). In contrast to many engineered "gray" solutions to urban challenges like pipes and reservoirs, NbS are often well-equipped to support multiple ES at once especially when integrated in a network of urban green infrastructure (Pauleit et al., 2017). This multifunctionality is an important consideration in the context of making planning decisions, but also provides a challenge due to the interrelatedness of different benefits, and the resulting tradeoffs associated with different UGI strategies (Randrup and Jansson, 2020).

While UGI/NbS are now recognized as useful tools for providing ES to help address global challenges, e.g., as expressed in the UN Sustainable Development Goals (SDG), (Wood et al., 2018; Anderson et al., 2019; Maes et al., 2019), there is also evidence of their potential being underutilized. Rall et al. (2015) study of green space planners and managers in New York and Berlin for example shows a good understanding and awareness of ES, but little operational uptake. Effective implementation of UGI for ES requires consideration of social, economic and political structures as well as the biophysical functioning of the vegetation (van der Jagt et al., 2019; Almenar et al., 2021), thus barriers to ES can occur in any of these domains (Figure 1). Specifically, the way that people perceive, value and use nature is culturally determined (e.g., Hägerhäll et al., 2018), requiring an understanding of underlying social structures and value systems (e.g., Vasquez et al., 2016). In addition, the desired biophysical function from a given NbS cannot be assumed, as functions like carbon sequestration, shading, and air quality improvement are all dependent on plant species selection and healthy growth over time (e.g., Haase et al., 2014). Finally,

BOX 1
Definitions of ecosystem services (ES) and urban ES as used in this study.

Ecosystem Services (ES): have been broadly defined as "the benefits people derive from ecosystems" (MEA, 2005), and are commonly divided into four main categories or types of service:

- **Cultural ES:** Non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences.
- **Provisioning ES:** products obtained from ecosystems, for example food and fiber, fuel, fresh water, natural medicines, and ornamental resources.
- **Regulating ES:** benefits obtained from the regulation of ecosystem processes, for example air quality maintenance, climate regulation, water regulation, erosion control.
- **Supporting ES:** services that are necessary for the production of all other ecosystem services, for example soil formation, nutrient cycling, water cycling, provision of habitat.

Urban Ecosystem Services: Rather than having a distinct analytical definition, urban ecosystem services has emerged as an eclectic framework from various studies finding relevance of locally generated ES in urban areas (see for example Bolund and Hunhammar, 1999; Gómez-Baggethun et al., 2013; Andersson et al., 2014; Haase et al., 2014). Studies of urban ES have for example included: regulating services such as temperature, pollution and noise reduction and stormwater management; cultural services contributing to recreation, aesthetic value and sense of place; supporting services such as creation of habitats; and also provisioning services often in the form of urban farming and gardening (Gómez-Baggethun et al., 2013; Haase et al., 2014). Certain approaches to providing urban ES are well-established and hold long traditions (e.g., establishing parks, planting street trees), while others are relatively new responses to contemporary challenges such as installing rain gardens and green roofs to help with climate change adaptation (Kabisch et al., 2016). In this study, we apply the concept broadly to ecosystem services *in* (relative to *of*) the city (Gómez-Baggethun et al., 2013) to capture the widest range of urban ES already described in the academic literature that can be meaningfully integrated into planning practices in diverse cities.

the local political and governmental structures will determine which types of NbS are prioritized, and whether the long-term management is attuned to user needs and preferences (Jansson et al., 2019; Randrup and Jansson, 2020). Several recent studies have underlined a variety of governance challenges to working with ES and UGI in municipal practice (Qiao et al., 2018; Lähde and Di Marino, 2019; Hagemann et al., 2020). However, the complex relationships between environmental, ecological, socio-cultural and governance dynamics relevant to UGI are complex (Dobson et al., 2021), and still poorly understood (Pauleit et al., 2019).

The climatic, geographic, sociocultural, economic and governance contexts are all important in determining a given city's optimal UGI strategy for meeting needed ES, as well as the barriers to implementation. While many urban challenges are common across a wide range of contexts, other challenges are associated with specific social and biophysical contextual factors (Almenar et al., 2021). Thus, a one-size-fits-all approach to planning and managing UGI for ES is unlikely to work for a broad range of cities, unless the local context is thoroughly acknowledged and incorporated into the process. Additionally, because the factors influencing urban ES provision encompass so many disciplines, transdisciplinary engagement of researchers and practitioners is crucial for local uptake of ES and UGI/NbS approaches (Beery et al., 2016; Herslund et al., 2018; Wamsler et al., 2020). This can be accomplished by applying both quantitative and qualitative methods in collaboration with local practitioners to create a rich knowledge base (Herslund et al., 2018; Pauleit et al., 2019). Such studies have so far been conducted primarily in relatively similar socio-economic and climatic contexts (e.g., Lähde and Di Marino, 2019) though notably Pauleit et al. (2019) carried out a study of UGI encompassing several cities in Europe spanning from the UK to Scandinavia to the Mediterranean. There is a need for studies that cut across different urban contexts, including a range of climatic and socioeconomic settings, and including the Global South, which is in general underrepresented in ES studies (Almenar et al., 2021).

A fundamental question which has not yet been answered, is "How consistent are the perceived needs for urban ES, and how consistent are the challenges to implementing and using UGI to provide those ES across different climate and sociocultural and economic settings?" This knowledge gap can be addressed by examining the experiences of expert stakeholders in cities in different regions and socio-cultural contexts, looking for commonalities and differences. Recognizing this gap, the aim of the current study is to explore the current perceived status, stakeholder priorities, and barriers for urban ES provision in three case study cities on three different continents, under different climatic and socioeconomic settings: Addis Ababa (Ethiopia), Cincinnati (USA), and Malmö (Sweden). A mixed methods approach was taken, focusing on input from a diverse group of stakeholders in each city with expertise in planning, managing, and implementing UGI/NbS. Three research questions guided our explorative study:

RQ1: What are the similarities and differences in expert-stakeholder perceptions of ES supply from UGI among three cities in different climate and sociocultural and economic settings?

RQ2: How do stakeholder-identified priority and need for ES from UGI show similarities and differences among three cities in different climate and sociocultural and economic settings?

RQ3: What are the main barriers identified to provision of needed ecosystem services in each of the three cities, and in which domain (biophysical-functional, social-cultural, or governance-management) do the barriers lie?

Our *a priori* expectation was that the perceived current provision and future priorities for ES would vary, but that the identified barriers would be largely the same among cities. The expectation of among-city differences in perceived current ES supply and stakeholder priorities is based on the known differences in climatic, cultural and socioeconomic contexts for the three cities. The expectation of among-city consistency in barriers to ES provision is based on previous reviews of governance challenges to implementation of urban ES from UGI, which found that governance challenges tended to be quite similar across a broad range of cities, both for stormwater management ES and for urban forests and associated ES (Qiao et al., 2018; Ordóñez et al., 2019).

Methods

Case study cities

We applied a case study approach involving three distinctly different cities: Addis Ababa, Ethiopia, Cincinnati, USA and Malmö, Sweden. We chose the cities in order to represent a broad range of climate and sociocultural settings, and for the known existence of reliable research and municipal partners within each region. The cities differ greatly, shaped by their unique combination of climate and biophysical settings as well as socio-cultural, political and economic history and current conditions (Table 1). However, for each city there has been extensive collaboration with high profile international or national projects on UGI (Woodruff and BenDor, 2016; Herslund et al., 2018; Pauleit et al., 2019). These three cities could be considered "explanatory cases" (de Vaus, 2001) for contemporary efforts to optimize UGI to meet societal challenges. We do not assume the three cities are generally representative for

TABLE 1 Key UGI characteristics for the three case study cities.

	Addis Ababa	Cincinnati	Malmö
Population (2019)	4 M (estimate)	305,000	335,000
Area (km^2)	520 km²	206 km²	156 km²
Climate	Subtropical highland Precip: 1,100 mm/yr, with rainy season and dry season Mean Annual Temp: 16°C	Humid subtropical, continental Precip: 1,000 mm/yr, fairly even throughout year Mean Annual Temp: 12°C	Mild temperate/coastal Precip: 600 mm/yr, fairly even throughout year Mean Annual Temp: 9°C
Land Use/Land Cover	ca. 40% residential, 24% agriculture, 10% other vegetation, 10% business, transport and manufacturing, 5% bare land	40% residential, 15% parks and recreation, 12% public svcs./transportation, 16% Commercial or institutional, 6% Industrial, 6% vacant land, 0.3% agriculture	44% built up area, 30% arable land, 20% other uses (includes harbor, railroad-yard, etc.)
Total public green area	2 km^2 public parks	31 km² (15%) including only parks and recreation, or 42 km² (21%) if include vacant land[b]	24 km^2 (includes public land plus private land accessible through the Right of Public Access)[c]
Public green space area per capita	0.7 m^2 per person[a]	102 m^2 per person	81 m^2 per person
Proportion of city inhabitants within a 10 min walk (500 m) of a public park	Not known	82%[d]	100%[c]
General information and UGI focus	Fast-growing capital city of Ethiopia; large-scale river-rehabilitation projects with focus on flood protection, biodiversity, and recreation	Post-industrial riverside city; key UGI strategies around increasing tree canopy-cover and stormwater management project to reduce CSOs	Post-industrial harbor-city; city leads several UGI-projects on climate change adaptation, biodiversity, and stormwater management

Data sources: [a]AACPPO (2017); [b]Cincinnati City Planning Commission (2012); [c]SCB (2020); [d]Trust for Public Lands (2020).

how cities deal with, define or refer to UGI, but through a comparison across these cities on three different continents, we have aimed at finding commonalities with regards to urban challenges, and with regards to pathways for how UGI may address those challenges and contribute needed ES.

City #1: Addis Ababa

Addis Ababa, the capital of Ethiopia, has a population of ∼4 million and is one of the fastest growing cities in sub-Saharan Africa (UN-Habitat, 2008). The city is developing large urban extensions and is restructuring and rebuilding existing developed areas, while informal settlements also continue to grow. The city grows at the fringe, thus causing loss of farmland, and at the same time densifies. Moreover, informal settlements have developed along river corridors, which are prone to flooding, and on hillsides. UGI-related goals for Addis Ababa include increasing the (currently low) cover of accessible green space, restoration of river corridors, enhancing food security *via* urban farming, and improving the quality and functionality of all non-built up areas (Wubneh, 2013). Many of these goals have been laid out explicitly in the city's recent master plan (AACPPO, 2017), though the implementation often falls short of the idealized planning vision due to practical reasons like pressure from developers and other economic/political forces (Herslund et al., 2018). There are currently three public institutions responsible for managing UGI in Addis Ababa. These are (i) Environment and Green Development Commission which is a regulatory body, (ii) River Basins and Green Area Development and Administration Agency which is an operational body and (iii) Farmers and Urban Agriculture Commission, an operational body responsible for providing extension service to urban farmers involved in urban agriculture.

To date there have been a handful of research studies of UGI in the city. Woldegerima et al. (2017) highlighted the potential role of different forests for the provisioning of ES such as carbon sequestration and soil protection. In a study of urban forest planning it was recognized that urban forests provided important functions, but that they are also lacking definite borders and thus in need of re-demarcation (Fetene and Worku, 2013). Within the city, parks act as important temperature regulating resources locally (Feyisa et al., 2014; Teferi and Abraha, 2017). At the same time, the city is undergoing rapid changes, highlighting the need for action to connect and safeguard UGI in order to sustain its heat reducing capacities and other key ES (Teferi and Abraha, 2017; Woldegerima et al., 2017). Several studies have also dealt with the role of UGI in stormwater management (e.g., Herslund et al., 2018; McFarland et al., 2019).

City #2: Cincinnati, USA

Cincinnati is a Midwestern US city with an urban population of ca. 300,000 inhabitants. The city has a well-established urban park and street tree network, and is one of the top-ranked cities in the U.S. for park accessibility with 82% of residents living within a 10-min walk of a park (Trust for Public Lands, 2020). As a post-industrial city, Cincinnati lost population following WWII, dropping from >500,000 in 1960 to the current level by about 1990, and has recently begun to rebound in population (U.S. Census Bureau, 2020). Substantial areas remain underdeveloped with 7% of the city's area classified as "vacant land"; at the same time, the urban core is experiencing renewed growth accompanied by a re-greening of the city's riverfronts, converting formerly industrial areas to public parks and other community spaces. Pressing environmental and social issues include poor air quality, water pollution primarily from Combined Sewer Overflows (CSOs), and a large income and health inequality, with high infant mortality and low life expectancy particularly among the poor and Black communities (Cincinnati City Planning Commission, 2012). The city's Metropolitan Sewer District (MSD) is currently under a consent decree from the US Environmental Protection Agency to reduce CSOs by 85% - at an estimated cost of >$3,000,000,000. Thus, a primary focus in implementing new UGI has been on reducing stormwater runoff, although co-benefits including economic and ecological benefits are cited in project plans (MSD, 2020). As part of this effort, a wide range of NbS have been implemented including daylighting streams and restoring riparian zones, retention/detention basins, bioswales, rain gardens, rain barrels, previous pavers, and green roofs (www.projectgroundwork.org). The governance and management of UGI in Cincinnati is complex, involving a large number of different societal actors and stakeholders including regional and national government agencies, NGOs, local communities, universities and private landowners as well as more than 30 local municipalities (Shifflett et al., 2019).

There are a growing number of peer-reviewed studies led by researchers from the U.S. EPA office in Cincinnati, focusing largely on the biophysical capacity and economic viability of UGI to reduce stormwater runoff in the city. For instance, the capacity of rain gardens and rain barrels to reduce stormwater runoff and improve local stream ecosystem health has been tested (Shuster and Rhea, 2013; Roy et al., 2014), and a recent hydrologic modeling study pointed to the combined use of UGI and gray infrastructure to address CSO problems (Fu et al., 2019). A life cycle assessment of the implementation of different UGI elements in Cincinnati revealed that residential rain gardens could be a cost-effective approach (Vineyard et al., 2015), while another study compared street tree coverage and associated stormwater runoff benefits among different communities within the city (Berland and Hopton, 2014).

City #3: Malmö, Sweden

Malmö is the third largest city in Sweden, with ∼335,000 inhabitants. In 2019, one-third of Malmö's residents had been born outside of Sweden, representing at least 182 different nationalities (Malmö Stad, 2018). Malmö has an industrial background with a focus on heavy industry until the mid-1970s, followed by an economic downturn and decrease in population. Malmö's transition into a post-industrial city has been developing since the mid 1990's but the city still faces ecological, economic and social challenges. Cities in southwestern Sweden have low green space cover as compared to Sweden as a whole (Statistics Sweden, 2019) and Malmö has experienced a gradual decrease in amount of green space per inhabitant over the last 20 years, which might be related to both increased population and continued brownfield and infill development (Malmö Stad, 2021). Malmö has been heavily impacted by recent extreme rain events where substantial surface flooding has hit in particular low lying areas and areas along now-culverted rivers. In general, Malmö has several challenges in relation to urban green infrastructure development as it ranks the lowest in Sweden and in the lower part overall on the ISGlobal ranking of European cities (Pereira Barboza et al., 2021). To this end, the City of Malmö has led several projects to develop urban green space for climate adaptation as well as urban biodiversity and socioeconomic development. In particular, Augustenborg and the western harbor areas have developed as international flagship projects for UGI over the past 20 years, with background information and baseline studies available on environmental performance (Haghighatafshar et al., 2018; Sörensen and Emilsson, 2019).

Malmö has also been included as a case city in multiple research studies focusing on challenges in governance aspects related to UGI including studies broadly covering ES (Wamsler et al., 2014; Schubert et al., 2018) and others focused specifically on stormwater management (Qiao et al., 2019; Wihlborg et al., 2019). The role of UGI for health and recreation has also been demonstrated in several Malmö-based studies, with themes including promoting physical activity (Qvistrom, 2016; Grabalov, 2018), green school yards (Jansson et al., 2018), urban agriculture's role for social cohesion (e.g., Vierikko et al., 2016) and developing health related indicators (Van den Bosch et al., 2016). While both the concepts of ecosystem services and sustainable stormwater management are familiar within the city government, there remain governance related challenges to their wider implementation (Wamsler and Pauleit, 2016; Schubert et al., 2018; Qiao et al., 2019). The governance and management of UGI in Malmö is primarily a concern of the city authorities, but a large amount of urban green spaces are also under the ownership and related management of private and semi-private housing companies.

Overview of approach

For each city, we explored the perception of different city stakeholders and subject experts regarding the current state and future suggested priorities for ES provision by UGI. The information we gather thus focuses on the expert assessment of the UGI situation in their respective cities, and thus differs from a more conventional/quantitative assessment of ES supply and demand which might use e.g., GIS modeling. Expert opinion methodology has been used in several studies within ES research, providing a first step toward actionable understanding in the face of complex, urgent challenges—especially where empirical data is lacking and/or spotty. Expert opinion is not a guarantee of truth but provides a way to move forward in complex situations, offers a base for validation, and informs deeper research (Elliott et al., 2020). We have taken both practical and methodological inspiration from Rall et al. (2015), Herslund et al. (2018), and Lähde and Di Marino (2019), all of whom emphasized the need for mixed methods to generate accurate and contextualized analysis of UGI, and for engaging diverse stakeholders. In each of the three cities we carried out a half-day stakeholder workshop (Chambers, 2002) with representatives from key expert stakeholder-groups from academia and practice. At the workshops, we conducted an individual-based questionnaire regarding current ES provision, as well as a group-based Q-sorting analysis (Barry and Proops, 1999) of ES priorities and challenges with the selected participants. We also selected three experts in each city for individual semi-structured interviews (Kvale and Brinkmann, 2009), and finally, for each city we conducted group interviews (Creswell and Creswell, 2018) with 3–4 local experts, aiming at locating barriers to the optimization of specific common UGI elements (city parks and street trees), using the Cascade Model for ecosystem services (TEEB, 2010) as an organizing framework (Figure 1). More details on the methods follow below.

Selection of workshop participants

The aims of the workshops were to (1) establish collaboration with key local expert stakeholders; (2) better understand the current situation and existing challenges to provisioning of ES from UGI; (3) elicit individual and collective visions for future development of UGI in each city. Participants included researchers and stakeholders from the city administration and other public organizations involved in researching, planning and managing urban green spaces and green infrastructure, as well as relevant stakeholders from outside public administration, including private consulting companies and NGO's (Supplementary Table S1).

Questionnaire for current ES provision

During the workshop, each participant was asked to complete a questionnaire regarding the current provision of ES from green spaces/green infrastructure in the focal city. The questionnaire (Supplementary Table S2) consisted of a list of 36 ES (Table 2) compiled by browsing various manuals and frameworks for working with ES (MEA, 2005; EU, 2013; Naturvårdsverket, 2018). We aimed for the list of ES to be exhaustive rather than aligning with any particular framing of ES, and no particular spatial scale was specified. For each service the participants were given an option to rate the current provisioning of each ES from the city's UGI on a scale from 1 to 5, where 1 indicated "not provided for at all" and 5 indicated "very well provided for", and also included an option to rate it "not relevant". The questionnaire also had space to specify additional services not captured by the list and to rate these, as well as a blank space for additional comments. The questionnaire response rate was 81% (17 of 21 workshop participants) in Addis Ababa, 80% (24 of 30) in Cincinnati, and 100% (11 of 11) in Malmö. The average assessment value was calculated for each ES for each city, as the mean value given by all respondents for the given ES. The actual number of respondents thus varied from 11 to 24 depending on city, which should be adequate to get a trustworthy estimate of expert opinion for each given city (e.g., Elliott et al., 2020). Due to the non-random selection of participants and unequal sample sizes among the different cities, a direct statistical comparison among the results for different cities was not made, but results were visualized for comparison.

Q-sorting method for future ES priorities

A Q-sorting exercise (e.g., Barry and Proops, 1999) was the central interactive part of the workshops, with participants working in small groups (4–6 people each) to generate consensus priorities for future provisioning of ES from UGI. Participants were not given a specific timeframe for the future, other than having a long-term perspective, which may be considered to be 25 years or more (van Notten et al., 2003). Group members

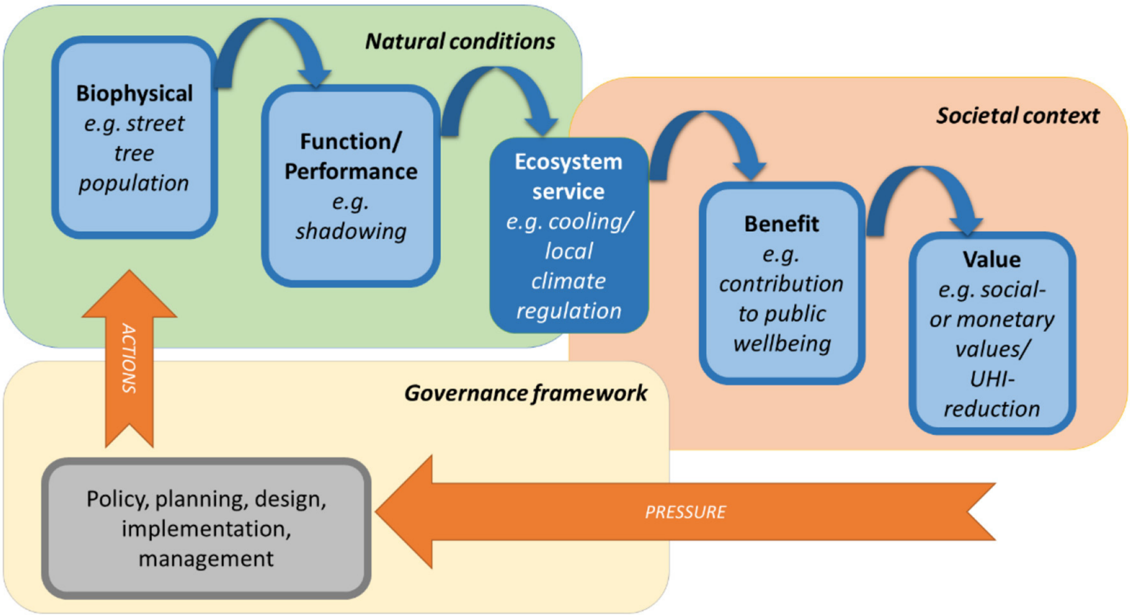

FIGURE 1
Cascade Model of ecosystem services. The performance of Urban Green Infrastructure (UGI) to support functions and deliver services and benefits to the gain of the society are dependent on a multifaceted context (TEEB, 2010; Potschin-Young et al., 2018), with interrelationships between the physical realm (natural conditions), social values and norms, and governance and management structures.

were assigned by the organizers in order to include a variety of backgrounds and stakeholder roles within each group, and to avoid multiple representatives from the same stakeholder organization in the same group. To guide group discussion, we used Q-boards (Supplementary Figure S1) with 36 slots shaped in a pyramid and corresponding cards naming the same 36 ES as in the questionnaire (Table 2; Supplementary Table S2). Participants were instructed to negotiate and agree within their group on ranking the ES on a scale of importance from 1 to 7 (1 = least important, 7 = most important) with a varying number of slots by category including only two slots in the "most important" category (Supplementary Figure S1). The aim of this exercise was to establish a negotiated consensus for rankings within each of the smaller groups, followed by an open discussion with all of the groups, primarily focusing on the rationale for choosing the two most important key priorities.

Provisioning-priority-urgency analysis

For each city, the average values for perceived current ES provisioning (using the data gathered from the individual questionnaires) and the future priorities (from the Q-sorting group exercise) were reported for each ES, after rescaling the data from each of these two exercises to express them on the same scale (from 0 to 4). A third category called apparent urgency was also calculated for each ES, defined as the difference between perceived current provision and future priority after rescaling. High values for urgency indicate ES for which future priority is high while current provision is low. Negative values for urgency indicate ES for which current provision outstrips the future priority. Values near neutral for urgency indicate that the assessment of current provision and future priority were similar—note that this can happen either with two high values (high priority for future but also high current ES provision) or two low values, or anything in between. Thus, the analysis of apparent urgency is only meaningful in conjunction with analysis of the ES provision and priorities, and is most useful for identifying the most urgent high priority ES. In our analysis we highlight ES which have an apparent urgency value of >0.4, which corresponds to a value >10% of the total potential range of values.

Interviews

We conducted four expert interviews in each of the three cities: three individual, semi-structured interviews and one group interview with 3–4 participants where a semi-structured discussion was facilitated with a picture of the Cascade Model of ES (TEEB, 2010) as reference-point. These interviews served to develop a more full understanding of the context and rationales behind the responses to the questionnaire and Q-sorting exercise. The interviewees were selected among the workshop participants and in dialogue with the main stakeholder collaborators in each city. We aimed to represent

TABLE 2 List of the 36 urban ES explicitly considered in our study.

Cultural services	Regulating services
• Spaces for socializing • Relaxation • Physical recreation • Mental and physical health • Aesthetic value • Awareness and understanding of nature • Spiritual experience and religious values • Sense of place • Arena for group activities • Route for active travel • Tourism	• Air quality regulation • Water quality regulation • Reduction of noise • Storm water management • Flood control • Wastewater treatment • Local climate regulation • Pollination • Carbon sequestration • Adaptation to climate change • Pest and disease control
Provisioning services	**Supporting services**
• Food • Freshwater for household use • Freshwater for irrigation • Raw materials for building • Fuels for household use • Biomass for energy production • Medicinal resources • Fodder for animals • Ornamental resources	• Biodiversity • Habitats for species • Erosion prevention • Soil quality and fertility • Nutrient cycling

The list is compiled of locally generated ES described as relevant in studies of urban areas, obtained by browsing various manuals and frameworks for working with ES (MEA, 2005; EU, 2013; Naturvårdsverket, 2018). The distinctions between services and categories are not considered hard boundaries, but rather serve as a pedagogical organizing framework that can facilitate discussion and collaboration.

expertise from different organizations, and the respondents included municipal planners and managers, academics, and representatives from local and regional special interest groups (Supplementary Table S3). All interviewees received both oral and written information about the study and had the chance to ask questions before deciding on participation. All interviewees provided written consent for voluntary participation in the study.

The individual interviews followed a semi-structured approach, using a thematic and dynamic question guide (Kvale and Brinkmann, 2009) shown in Supplementary Table S4. Each interview took about 45–60 min and was conducted by members of the research team in the days following the workshop. All interviews were recorded and verbatim transcribed. Following transcription, interviews were analyzed independently by two members of the research team. The analysis was primarily exploratory, to develop in-depth understandings of the interviewees NbS, UGI and ES perceptions. Initially, the analysis focused on three main aspects: (1) Concrete examples of NbS explicitly connected to ES provision, (2) Rationales for the current UGI situation/strategies and potential future developments, (3) Challenges to the current UGI situation/strategies and potential future developments. In the analysis, emphasis is placed on key themes that occurred in at least two of the three interviews for each city.

The group interview was undertaken with a group of 3–4 local expert participants in the days following the initial workshop. Participants were different from the individual interviewees, to help broaden the perspective and allow for new insights. The interviews followed a semi-structured approach organized around the Cascade Model for ES (Figure 1) as a framework. Two NbS were placed in focus, in two consecutive discussion sessions of about 60 min each: street trees and mid-sized city parks, both of which are ubiquitous and important NbS as parts of the overall UGI in each of the three cities and most others worldwide. Participants were asked to envision the specific NbS in their city, then start by listing and describing the ES provided, and gradually proceeding to discuss other aspects related to ES provisioning. During those interviews, when biophysical aspects of NbS were discussed, the micro-scale was often in focus—for instance, the ways in which traits like crown shape of different specific tree species affected their ability to provide shade. The results of these interviews were summarized both as Cascade model diagrams illustrating the identified factors and barriers, and as a list of challenges to ES provision, organized by domain (biophysical, societal, or governance-related).

Results

As a foundation for analysis, we first present similarities and differences across the three cities in the current UGI and ES situation as perceived by local expert stakeholders. In the second section we summarize the stakeholder-expressed ES priorities and apparent ES urgency. The final section of results contains a mapping of challenges to optimizing UGI to meet the identified ES needs in the three cities.

Current status of UGI and perceived ES provision

Expert assessment of current ES provision

Local expert stakeholders perceived all four ES categories (cultural, provisioning, regulating and supporting ES) as being more or less equally provided at a low-intermediate level in Addis Ababa, while in both Cincinnati and Malmö, cultural ES were seen as being more well-provided than either regulating or supporting ES, while provisioning ES were seen as only minimally provided (Figure 2A).

In general, these patterns were reflected in the responses for individual ES (Figure 3), with for instance Cincinnati scoring

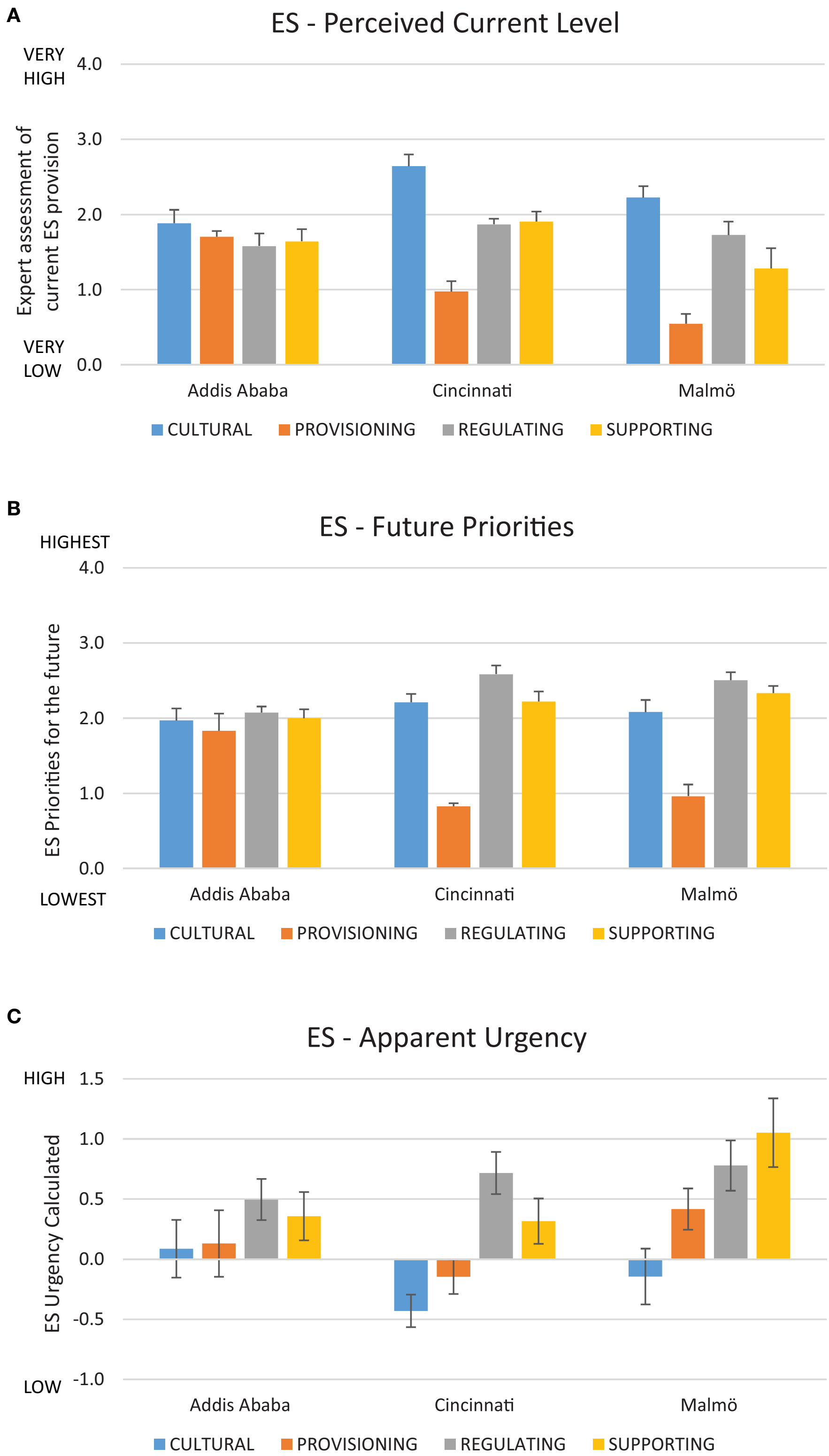

FIGURE 2
Expert stakeholder assessments of ecosystem services (ES) provided by urban green infrastructure in the three study cities, grouped by ES category. **(A)** Current ES provision; **(B)** highest priorities for the future; **(C)** Calculation of apparent urgency as the normalized difference between ES priority and current perceived provision. Values given are the average expert stakeholder rating for ES in the given category, with error bars indicating the standard error of the mean. High positive values correspond to high perceived provision, priority, or urgency, respectively.

particularly high on the cultural ES "physical recreation," "relaxation," and "socializing informally." There were also some clear among-city differences, for instance spiritual experience and religious values are seen as well-provided by UGI in Addis Ababa but not in the other two cities; while green spaces are seen as providing arenas for group activities only in Cincinnati and Malmö, but not Addis Ababa. Individual regulating ES were generally assessed at similar intermediate-low levels for all three cities, though Malmö was seen as somewhat more successful providing storm water management than the other two cities. In contrast, the assessment of the current availability of provisioning services varied widely among cities, with Addis > Cincinnati > Malmö. In Addis Ababa, provision by the urban landscape and associated vegetation of raw materials for building, fuels for household use, and food were noted as particularly prevalent (Figure 3).

UGI elements emphasized

NbS/UGI emphasis from individual expert stakeholder interviews varied from city to city, though with some common to all, particularly street trees, city parks, and river corridors/blue spaces (Table 3). For Addis Ababa a primary focus was on developing neighborhood parks, while Cincinnati stakeholders emphasized integrating existing parks as part of a larger-scale watershed management strategy. In Malmö, common examples included green corridors along roads and paths connecting parks from city center to periphery. Interviewees from Malmö also emphasized the relevance of green roofs and walls, as well as the city's blue spaces such as coast, canals, ponds, and streams. Urban agriculture was additionally highlighted by the interviewees from Addis Ababa.

Ecosystem services emphasized

There was variation in ES emphasis among the cities (Table 3), but also common threads and a clear recognition of the multifunctionality of individual NbS, particularly for street trees and city parks. Examples from street trees in Addis Ababa included local climate regulation with emphasis on shade and heat regulation, but also to create a sense of place. In Malmö and Cincinnati local climate regulation and walking/cycling possibilities provided by street trees and green corridors were primarily emphasized. In Malmö, emphasis was also placed on recreational and aesthetic elements, while in Cincinnati, emphasis was placed on integrating street trees with bioswales, in order to better manage the city's stormwater and flooding issues. For city parks, across the three cities, cultural ES (socializing and group activities, relaxation, physical recreation, mental and physical health, aesthetic value, and sense of place) and regulating ES (regulation of air quality, noise, stormwater runoff, local climate, and habitat provision) were primarily emphasized.

Stakeholder priorities and perceived urgency for specific ES

Priorities for future ES

For Addis Ababa, each of the four different ES categories were prioritized by stakeholders about equally for the future (Figure 2B). However, the top individual ES priorities (Figure 3) centered on provision of food and clean water for both household-use and irrigation. Simultaneously, the stakeholders saw issues with food security and the importance of urban agriculture for feeding the current population of Addis Ababa as an essential service provided by UGI. Biodiversity and "awareness and understanding of nature" were also prioritized.

For Malmö and Cincinnati, regulating and supporting ES were given by far the highest priority for the future, then cultural ES, and lastly provisioning ES (Figure 2B). For Cincinnati, "Stormwater management" emerged as a clear top priority, with "adaptation to climate change," "mental and physical health," and "flood control" also very highly ranked (Figure 3). The strong focus on UGI for stormwater management pervaded the discussions of for example street trees, river corridors, and governance-regimes and incentives, while a broader perspective including more potential ES also emerged. For Malmö, "Adaptation to climate change" emerged as the most commonly selected priority, with stakeholders noting that this ES could encompass a range of other services, and thus be a good strategic pick to garner multiple ES. Also prioritized in Malmö were "mental and physical health," "biodiversity," "habitats for species," and "stormwater management" (Figure 3).

Apparent urgency for specific ES

For each city, apparent urgency was estimated for each individual ES by taking the normalized difference between future priority and perceived current provision. We highlight those ES with particularly high urgency values, which we interpret as having high perceived potential to help address pressing urban challenges through further expansion/development of UGI (Figure 3; See Supplementary Table S2 for numerical values). The results were also summarized by ES category (Figure 2C).

For all three cities, a majority of regulating and supporting ES were identified as having a high degree of urgency (Figure 3). Although most provisioning ES were seen as adequate currently for all three cities, a particularly strong urgency was identified for the provision of freshwater for irrigation, freshwater for household use, and food in Addis Ababa. The same three ES had high perceived urgency in Malmö as well, with provision of food highlighted for Cincinnati as well. Finally, awareness and understanding of nature and mental and physical health emerged as important cultural ES with high apparent urgency for all three cities (Figure 3).

FIGURE 3
Expert stakeholder assessments of current provision and future priority for 36 ecosystem services (ES) from UGI in Addis Ababa, Ethiopia (ADD), Cincinnati, USA (CIN) and Malmö Sweden (MAL); plus a calculation of apparent urgency as the normalized difference between provision and priority. Apparent urgency highlights those ES for whom future priority is higher than perceived current provision, with a difference >10% of the potential range.

TABLE 3 UGI/NbS elements and the associated ES that were most commonly emphasized during the expert stakeholder interviews.

City	Key UGI examples cited	Key ecosystem services cited
Addis Ababa	Street trees	**Local climate regulation, shade provision, aesthetic value, air quality regulation,** sense of place, pedestrian mobility, roadside microbusiness, reduced UHI, SWM, flood control
	Neighborhood parks	**Recreation, mental and physical health, aesthetics, social gatherings, air quality, local climate regulation,** relaxation, spiritual experience and religious values, group activities, noise reduction, flood control, C sequestration, biodiversity, habitat
	River corridors	storm water management (SWM), flood control, wetland reestablishment, groundwater storage, fresh-water provision, pollution control
	Urban agriculture	Food provision/security
Cincinnati	Street trees	**Local climate regulation, reduction in UHI, shade, SWM, traffic calming, C sequestration, habitat for pollinators and other biota**, pleasant route for active travel (walking and bicycling), aesthetic, improved air quality, improved water quality, noise reduction, erosion prevention, (crime reduction), (improved public health), (property value increase), sense of place
	City parks	**Recreation, mental and physical health, socializing informally, air quality regulation, water quality regulation, SWM, local climate regulation,** erosion-prevention, watershed management, inspiration, aesthetics, sense of place, awareness and understanding of nature, group activities, noise reduction, C sequestration, biodiversity, habitat, soil quality and fertility
	River corridors	SWM, biodiversity, nature education, clean water, aesthetics, recreation, flood control
Malmö	Green corridors/street trees	**Local climate regulation, cultural values, aesthetic value, sense of place, water quality regulation, biological diversity,** recreation, social gatherings, physical activity, SWM, air quality regulation, noise reduction, habitat
	City parks	**Socializing informally, relaxation, physical recreation, aesthetic value, group activities, SWM, pollination,** mental and physical health, sense of place, food provision, noise reduction, flood control, local climate regulation, habitat
	Blue elements	Recreation, health, aesthetics, interconnectedness, biodiversity
	Green-roofs and walls	SWM, aesthetics, biological diversity, climate adaptation, reduced UHI

ES in boldface were cited in multiple contexts (e.g., both in individual interviews and in the group interviews centered around the Cascade model exercise on ES from street trees and city parks).

Challenges to UGI planning and management for ES provision

Challenge mapping by domain and theme

Based on the expert interviews, challenges to UGI optimization were identified in all three domains (biophysical, social, governance) in each of the cities (Table 4), and were most often related to gaps in governance, structural pressures and lack of ecological vison and awareness.

Gaps in governance

Gaps in governance included both lack of implementation of existing plans, lack of collaboration to ensure that plans and strategies were understood and correctly implemented, lack of coordination between departments with different areas of responsibilities, and jurisdictional and geographical boundaries that made systematic efforts for UGI development harder. The need to work across these boundaries both within and among municipal, private, and civil society actors appeared as a major challenge for all cities involved (Table 4). For example in Cincinnati a local NGO-leader described the difficulty of restoring polluted river corridors: "there are 37 different political entities just in this watershed", and a representative from the local Sewer department added: "the water doesn't know these political boundaries". In Addis Ababa, the gap related more strongly to the lack of implementation and enforcement of plans and even basic zoning requirements (I.1): "We build on flood-plains, we build on fertile agricultural land – the plan says one thing but the reality on the ground looks very different".

Structural pressures

Barriers to UGI success were also pronounced in terms of structural pressures such as densification and diverging needs and interests for infrastructure development (Table 4). Lack of equitable accessibility to green spaces was also noted in all three cities. Especially in Addis Ababa and Malmö, the need for housing often trumped the plans for UGI development resulting in a lack of available space for UGI. For instance, a Malmö stakeholder declared (G.3): "In Malmö there's a political decision to build 'Dense and Green' but it seems like it comes at the

TABLE 4 List of challenges/barriers to successful ES provision by city parks and street trees, as emphasized by expert stakeholders in group interviews in each of three cities.

City	Biophysical domain	Societal domain	Governance and Management domain
Addis Ababa	• Currently very low coverage of public park space, i.e., only about 1 m^2per person. • Palette of street trees used is limited, many species used are non-native and may be invasive, many do not provide shade effectively • Too few street trees, and high street tree mortality rate.	• Lack of ownership and public awareness, tragedy of the commons leads to de-valuing of the resource. • Low use of the formal public parks, relative to informal outdoor spaces. • Lack of accessibility for many people, mainly due to distance or entry fees. • Perception that parks are unsafe, and that parks have little value. • No clear mechanism for communication to the decision-makers of values/needs of the people, and those avenues that do exist are often ineffective	• Low priority/lack of funding for relevant municipal agencies in the city government. • Shortage of landscape architect expertise at the city government for designing city parks, shortage of expertise among managers and maintenance staff. • Lack of government enforcement of existing policies to protect green spaces • Lack of standards, monitoring and follow-up to assure tree survival and function. • Decisions take place at city and subcity level, while the Woreda (local) level is responsible for the small city parks. • Parks devalued relative to alternate uses of urban land for development.
Cincinnati	• Physical threats to the park infrastructure from overuse • Invasive pests (in part facilitated by climate change) pose a threat to many of the park trees and street tree species.	• Parks are not equitably distributed among communities, and street tree cover varies by neighborhood. • Many people perceive parks as being inaccessible to them (perceived as dangerous, too hot during the summer, etc.) even if they are physically accessible. • Park activities not always communicated *well* to the public • Disincentives to walking: lack of sidewalks, summer heat, schools don't encourage students to walk. • Value of street trees often not recognized, some residents resist street tree planting.	• Lack of appreciation of the connection between urban green spaces/street trees and neighborhood economic development. • UGI given low priority in the local government, resulting in substantial budget cuts for the past 10 years. • Maintenance costs are high and often not covered in plans, so budget is insufficient • Complex mix of partner stakeholders managing the parks, duplication of efforts, gaps and inefficiencies. • Privatization and lack of transparency in park management may not serve some communities well, especially underprivileged local communities.
Malmö	• Fundamental lack of adequate space with the right conditions for growing healthy trees. • Green spaces, particularly new ones, are small and fragmented. • All green spaces are constructed, the city lacks truly wild preserves or remnant forests. • Difficult environmental conditions including road salts, poorly draining soils vulnerable to floods, and occasional droughts exacerbated by climate change. • Plant palette is limited by difficult environmental conditions and includes few native trees.	• Parks are not equally accessible to all, since large parks are distant from many urban dwellers • In some parks there isn't enough space for large groups to visit comfortably.	• Relevant city offices have different but sometimes overlapping missions and may be at odds with one another. • Historically street trees have been seen as a one-time investment with little thought to long-term development/maintenance (though this is improving). • Street tree and city park maintenance are carried out by private contractors which can result in a lack of continuity. • The city does not have access to privately owned lands, including many lands around the perimeter of the city which could be a valuable location for peri-urban trees. • When private properties are developed, typically all trees are removed before starting construction.

Barriers are organized by domain as indicated in the Cascade model framework (Figure 1).

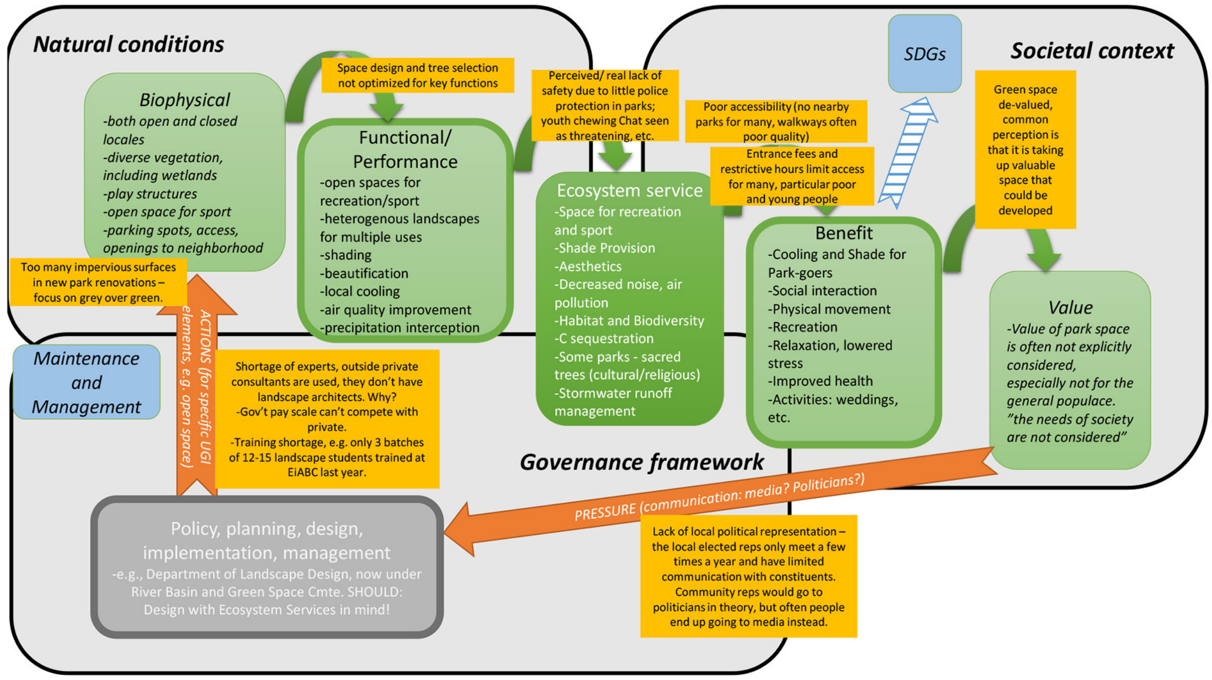

FIGURE 4
Example of challenge mapping using the Cascade Model framework—here showing the results of a group interview with Addis Ababa expert stakeholders on the topic of ES provision by city parks in that city. Green boxes show the different aspects of ES provision within the three main domains (biophysical/natural, societal, and governance). Yellow boxes illustrate specific challenges noted, and are located by where they present a "barrier" to the ability of the cascade to proceed to successful ES provision for optimized societal benefits.

expense of public parks". In Addis Ababa this pressure has resulted in both formal development and informal settlements replacing existing green spaces, both in the urban center and periphery. Lack of funding and low government prioritization of UGI were also noted as common structural barriers, with e.g., Cincinnati stakeholders reflecting that UGI is not high on the political agenda (Table 4).

Lack of ecological vision and awareness

While several of the stakeholders had visions for interconnected UGI planning and development, many noted a lack of overarching vision and awareness within their organizations (Table 4). Cincinnati stakeholders decried the conceptual narrowness, explaining that NbS to most members in their organization primarily referred to technical solutions to stormwater management, at the expense of a broader vision for UGI development. The lack of awareness among key stakeholder organizations presented a challenge in both Cincinnati and Addis Ababa, and was accompanied by (or perhaps reflective of) a relatively low priority and funding appropriated for UGI in the city budgets. For these two cities, stakeholders also noted a lack of ownership and public awareness among the general public about the value of green spaces such as street trees and public parks (Table 4). The trajectory in Addis Ababa was emphasized as a spiraling loss of green areas both private and public, while important cultural practices and appreciation for green areas were also declining. In general, problems with ecological vision and awareness seemed to be less acute in Malmö which has already seen integration of ES frameworks in city planning, but even in Malmö, the lack of long-term political UGI related visions was underlined by expert stakeholders. For each of the cities, the need for an overarching guiding UGI vision frequently seemed to succumb to short-term solutions, and UGI developments mostly on a project scale, rather than as a vision of UGI as an integrated part of the wider long-term urban development.

Conceptual framework—Expanded cascade model

During the group interviews focused on urban parks and street trees, many challenges to UGI optimization were highlighted by the expert stakeholders (Table 4), and these challenges could be depicted as barriers between the different parts of the ES cascade model (e.g., Figure 4). For instance, in Addis Ababa many of the existing parks are closed to the general public except during limited hours, and require entrance fees. This introduces inequity and prevents certain groups of people from realizing the benefits of the parks, even though the green spaces may be physically providing the desired functions (space for recreation and sport, shading, cooling, beautification, etc.). This challenge can best be depicted as a barrier between the "Ecosystem service" and "Benefit" boxes in the Cascade Model diagram (Figure 4).

Discussion

Similarities and differences in perceived ES supply from UGI

The among-city differences in perceived current ES provision can largely be explained by differences in city context (Table 1), and differences in the current green space development within each city. For example, stakeholders in Addis Ababa particularly highlighted the importance of provisioning ES. This is a sensible result since many residents of Addis Ababa depend on local sources for food, clean water and fuel, while the other two cities import nearly all their food and fuel, and have technological treatment of their water sources. The importance of UGI for provisioning services in African cities are something also found in several other studies (e.g., Debolini et al., 2015; du Toit et al., 2018). On the flip side, the higher assessment of cultural ES from UGI in Cincinnati and Malmö can be explained by the high coverage of public park space in those two cities (>90 m^2 per person, >80% of inhabitants within a 10 min walk of a public park), in contrast to Addis Ababa which only contains about 1 m^2 per person of public park space.

Stakeholder priorities and apparent urgency for ES

The ability of UGI to provide *regulating ES* was deemed of central importance for the future of all three cities. This corroborates many existing studies in which regulating ES are receiving high attention within urban planning (e.g., Cortinovis and Geneletti, 2018; Sang et al., 2021) amid popularity of NbS and ecosystem-based adaptations to address the associated challenges (e.g., Brink et al., 2016; Geneletti and Zardo, 2016; Seddon et al., 2020). At the same time, our study made clear the importance of different cultural, provisioning and supporting ES in all three cities. These have been less commonly highlighted in previous studies of urban ES. Notably, in this study the analysis centered on assessments done by a group of expert stakeholders with considerable experience and familiarity with the local context, something that among others Luederitz et al. (2015) has called for. This may explain the contrast between results of our study and past studies many of which rely on quantitative modeling approaches, often in relation to different Environmental Quality Standards (e.g., Baró et al., 2015; Parsa et al., 2019) and hence tend to focus primarily on regulating ES (e.g., Luederitz et al., 2015).

Current provision of *cultural ES* was seen as adequate for all three cities, except for "mental and physical health" and "awareness and understanding of nature", which were seen as being underprovided for all three cities and thus having high apparent urgency (Figure 3). However, it has been argued that the realization of cultural ES is specific to the individual (Kumar and Kumar, 2008) and hence the approach used here is unable to provide the full nuance of the situation. Studies have also highlighted the importance of spatial patterns in the provision of cultural ES (Rall et al., 2017) emphasizing that while the overall ES delivery might be sufficient, the availability of individual cultural ES will vary spatially within each city.

Provisioning ES were seen as adequate for the most part, except for the provision of food and freshwater for household use and irrigation in Addis Ababa which were seen as underprovided. Provision of food was a particularly high priority in Addis Ababa, but interestingly was seen as a relatively important priority with high apparent urgency for all three cities, reflecting a widespread motivation for growing/supplying more local food. There is a strong potential role for urban agriculture, particularly in the Global South as a means to safe-guard and ensure food availability for a growing urban population (du Toit et al., 2018; Nogeire-McRae et al., 2018). Interestingly, in spite of the high priority/urgency given to food provision in all cities in our study, urban domestic/community gardens were not consistently emphasized as discrete NbS for Malmö and Cincinnati interviewees. This may be because the majority of the expert stakeholders in our study were focused primarily on public spaces rather than private spaces in their work on UGI.

In terms of *supporting ES,* the need for biodiversity was highlighted for all three cities, and habitat provision for Malmö and Addis Ababa. These two supporting ES were also identified as the most relevant urban supporting ES by Charoenkit and Piyathamrongchai (2019). Biodiversity is recognized as important for human health, and loss of biodiversity could have devastating effects on both human's habitus, food supply and hence overall survival (MEA, 2005). For both Addis Ababa and Cincinnati the role of UGI for providing erosion prevention was seen as important reflecting the risk of landslides in both cities, which is absent for the flat city of Malmö—a clear example of the importance of geographic/geologic context.

In summary, in spite of the divergent assessment of current ES status, stakeholders among the three cities had broadly similar priorities for future ES, when ES are considered by category. Specifically, all three cities ranked regulating ES highest for future prioritization, and provisioning ES lowest; though, the differences among ES category priorities were most pronounced in Cincinnati and Malmö (Figure 2B).

The individual ES which were ranked as having high *apparent urgency* for all three cities may indicate shared goals that are seen as critical to meeting fundamental urban challenges, and thus may be relevant to a wide range of cities in different contexts. Specifically, the common high urgency ES were: (i) climate change adaptation (encompassing a number of regulating ecosystem services like flood control and local climate regulation); (ii) storm water management and water quality regulation; (iii) mental and physical health and wellbeing, which is in turn supported by a number of other ES like air and water quality regulation, space for recreation, and awareness and understanding of nature; (iv) support for biodiversity and habitat; and (v) provision of food. Notably, each of these priorities shows a clear connection to at least one of the UN's Sustainable Development Goals (Wood et al., 2018; Maes et al., 2019), perhaps indicating that this set of priorities can be expected to apply broadly to cities regardless of climatic or socio-cultural context. The similarity in ES prioritization, and even more so in apparent urgency, is an interesting result considering the widely differing contexts of the three cities, which represent three different continents, an order of magnitude difference in population, different climates and cultures, and different socioeconomic conditions.

Main barriers identified to provision of priority ES

The main barriers identified to successful provision of ES fell into three broad categories: (1) Gaps in governance, (2) Structural pressures, and (3) Lack of ecological vision and awareness. The observed **gaps in governance** echoed those found to be most common in recent reviews focusing on governance of urban stormwater management (Qiao et al., 2018) and urban forestry (Ordóñez et al., 2019). Qiao et al. (2018) for instance found that unclear leadership and responsibilities, lack of funding, space and knowledge, and lack of stakeholder participation were among the most common barriers to successful implementation of sustainable stormwater management. Likewise, Ordóñez et al. (2019) described that municipal urban forest managers found lack of resources including funding as the most frequently barrier to program performance or urban forest success. Other commonly found challenges were: lack of coordination between stakeholders, lack of coordination between municipal units, lack of community education, lack of management plan/policy/strategy, and lack of a pro-active management culture (Ordóñez et al., 2019). These challenges are similar to the barriers expressed by expert stakeholders in our study.

Structural pressures including physical constraints (space availability) are a common barrier to successful UGI implementation (Pauleit et al., 2019), as are pressures related to economy, i.e., lack of funding (e.g., Ordóñez et al., 2019). In Addis Ababa for instance, there was a lack of enforcement of existing regulations regarding development, at the same time as exceptionally rapid development, including large numbers of high-rise residential buildings as well as informal settlements, all of which place pressure on a rapidly diminishing stock of available land. Herslund et al. (2018) noted about this situation that new buildings can be produced at such a high pace that they can render structural plans outdated before they are even implemented. In Cincinnati, legal and fiscal pressure to reduce combined sewer overflows led to stormwater runoff management taking an overwhelming precedence in implementation of new NbS. While in Malmö, a growing population and policies emphasizing densification over sprawl, increased pressure on existing spaces to provide a wide array of ES in limited area. Thus, structural pressures present substantial challenges for each city, manifested differently depending on context.

Our finding that **lack of ecological vision and awareness** was a barrier to successful UGI implementation, aligns with the findings from other recent studies across different regions of the globe. Pauleit et al. (2019) for instance noted that common barriers to successful UGI uptake in European cities include low attentiveness to UGI within planning systems, lack of discourses and champions supporting UGI, and path dependency (inertia, lack of awareness and knowledge) within relevant institutions. A study focused on Finnish cities also found that rigid planning practices present obstacles to the development of UGI including (Lähde and Di Marino, 2019). In a study focused on Namibia, Wijesinghe and Thorn (2021) argued that integration of urban green infrastructure into local government mandates, spatial planning and targeted action plans are limited, and further inhibited by scarce empirical research on urban green infrastructure governance in Africa. For Addis Ababa specifically, Herslund et al. (2018) reported that urban green space plans lack guidelines and actual projects on how to incorporate ecosystem services and strengthen green infrastructure in urban farmland and residential areas. And in South Africa, van Zyl et al. (2021) reported that low to moderate knowledge and awareness regarding ecological aspects such as ecosystem services, green infrastructure, and multi-functionality are argued to be main factors preventing integration of ecological considerations in urban planning practice. Similarly, in a global review, Qiao et al. (2018) found that a reliance on an established engineering culture and resistance to change were among the most commonly cited barriers to successful implementation of sustainable stormwater management.

Common rationales for UGI

We would argue that in the context of these challenges the three cities have come to develop common rationales for UGI which have also led to a prioritization of specific groups of ES. Specifically, stakeholders expressed rationales which emphasized three themes: (1) the need for multifunctional UGI, (2) A problem-solving focus in deciding which UGI elements to prioritize, and (3) the importance of interconnectedness.

The structural pressures that many cities are experiencing has led to attempts to maximize the efficiency of UGI, and thus rely on **compact multifunctional UGI** to deliver and accommodate more services in increasingly smaller spaces. This aligns with results from Sang et al. (2021) who found that Swedish municipal planners saw the potential for multifunctional UGI combining regulating, supporting and cultural ES. This was particularly the case where specific problems needed to be solved, resulting in negotiation on a project-by-project basis. With a **problem-solving approach** tending to focus on regulating ES in order to deal with imminent challenges within each cities, this could lead to a de-prioritization of supporting ES within the multifunctional approach (Lee and Lautenbach, 2016), and these types of tradeoffs were rarely considered by Swedish stakeholders, compared to potential synergies (Sang et al., 2021).

Stakeholders frequently expressed the importance of **interconnectedness**. Based on context we interpret this as a general aspiration with two distinct meanings. First, administrative/collaborative connectivity within and among institutions was a common theme, which if implemented could help address gaps in governance, as well as helping to improve ecological awareness and vision among decision-makers. Second, stakeholders frequently mentioned physical connectivity in the form of networks or corridors of UGI, which are particularly needed for supporting ES like biodiversity and habitat provision. However, practically there are a number of barriers that exist to successful connectivity. These barriers include the noted gaps in governance creating silos within and among urban decision-making organizations which make collaborative long-term planning difficult. Connectivity in the physical urban landscape is also challenged by structural pressures limiting the amount of available (and affordable) space which can be dedicated to UGI. Thus, although interconnectedness was often brought up in discussion by municipal stakeholders, it was frequently in the context of aspiration for the future rather than a description of the current reality.

Tools and lessons to carry forward

One key outcome of the project was a test of transdisciplinary methods for assessing ES priorities from UGI, and challenges to ES provision. The provisioning-priority-urgency analysis provided a quantitative method to summarize the expert assessment of current and future ES, with the calculation of "apparent urgency" indicating ES that may demand particular attention in a given city. This approach could be used to identify possibilities and obstacles to implementing UGI to meet diverse urban challenges. In a similar vein, Wood et al. (2018) has provided a mapping tool for connecting ES to human wellbeing. These complementary tools could help clarify where strategic interventions will need to be made to optimize provision of priority ES from UGI.

We also found the Cascade model of ES provision to be a useful framework for identifying city-specific resources and barriers around ES provision. The Cascade model is a flexible framework and can take on many different formats depending on context (Potschin-Young et al., 2018). Our "enriched" Cascade model (cf. Buchel and Frantzeskaki, 2015) emphasized the aspects that were perceived by expert stakeholders to be most important to consider, including the possibility to add new relationships and categories in the model as needed. The most significant enrichment of our Cascade Modeling approach is to explicitly include barriers to ES provision as blockages between different categories within the model (e.g., Figure 3).

Perhaps most importantly in terms of local impact, the workshops provided a forum to discuss key challenges for UGI in a transdisciplinary setting, and invited collaboration. Many of the identified challenges included governance gaps and lack of communication among different key actors. By facilitating and coordinating discussions among a diverse group of local and regional stakeholders, the research process itself helped buffer some of the governance gaps. In particular, the Q-sorting exercise with small groups encouraged invested discussions, negotiations and prioritizations among diverse stakeholders. Many stakeholders also expressed a keen interest in learning about the other partner cities in the study, and since at least one representatives from each city was present at each of the workshops, there was ample opportunity for cross-pollination of ideas. This co-creation approach has been used to good effect in this and other studies of UGI and ES (e.g., Pauleit et al., 2019) to help increase collaboration and communication among different stakeholder groups.

The approach taken in this study to present stakeholders with a whole range of urban ecosystem services, was helpful in inducing participants to consider tradeoffs and potential dis-services as well as synergies and benefits involved in specific UGI strategies. There is a limit to the number of different ES that can be provided in a given space. Taking into account the whole suite of potential ES will help in defining strategic objectives, and explicitly identifying demand and beneficiaries could increase awareness of the values at stake, helping to ensure long-term commitment and strengthening planning arguments in the face of conflicting interests (Cortinovis and Geneletti, 2018). Similarly, attention should be paid to the quality of services provided, not just the presence/absence or quantity (if measurable) of the ES in question. This approach needs to be taken from a spatial perspective as well with spatial modeling to look at synergies and tradeoffs.

Summary and conclusions

This study examined the insight of local expert stakeholders on current urban ES conditions and future priorities across three distinct cultural and climate contexts, and revealed key challenges to optimizing UGI for ES provision. The assessment of current provision of ES differed among the three cities, particularly for provisioning services. However, stakeholder-expressed priorities for the future were broadly similar among the three cities, with all three expressing the highest priorities for Regulating and Supporting ES. Our analysis suggested a high level of urgency for a common set of ES including climate change adaptation, stormwater runoff management and water quality, mental and physical health, support for biodiversity and habitat, and provision of local food. Each of these ES have a clear connection to at least one of the UN's Sustainable Development Goals, and may indicate common goals that are seen as critical to meeting fundamental urban challenges, thus having relevance for a wide range of cities in different contexts. This is something that could be tested in a more robust way with a global sampling of cities, including more cities in the Global South which to date have been under-represented in studies of urban green infrastructure (Almenar et al., 2021). Barriers to successful implementation of NbS were also broadly similar among cities, and most fell under three categories: gaps in governance, structural pressures, and lack of ecological knowledge and vision. The most commonly cited barriers were related to governance and management, including lack of political will, funding priorities, and lack of communication and coordination among municipal agencies and to the public.

Further, we found that in spite of the differing socio-economic and climatic contexts, common rationales for UGI have been developed among expert stakeholders who are involved in planning and managing UGI. In all cities we identified a vision for building a stronger UGI through more ecologically interconnected cities by the use of waterways and/or green corridors. NbS such as street trees, green and blue corridors were considered important for mitigating environmental problems (e.g., pollution, flood control and heat islands), and thus needed for improved living conditions. This problem-solving focus was in many cases seen as a key driver for building interests and investments in UGI. With increasing urbanization and densification this has led to an increasing focus on developing user-oriented, multifunctional green spaces.

For any given city or neighborhood, the best UGI strategies will undoubtedly depend on climate, geography, governance, socio-cultural and economic context. It is not realistic to expect one-size-fits-all solutions to work effectively. In spite of this, our study indicated that a number of UGI/NbS-related priorities and challenges can be expected to apply broadly to cities regardless of climatic or socio-cultural context, and may represent generic challenges to cities around the world. In this vein, there is a need for international, and even cross-continent exchange of knowledge and experience among practitioners as well as researchers. Similar studies, including a wider range of cities representing an even wider range of socio-ecological settings should be conducted in the future to test this assertion, as well as guide future UGI planning and management for improved ES provisioning globally.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author/s.

Author contributions

IB wrote the first draft of the paper with the help of ÅOS and FAH, led the writing effort, and carried out the challenge-mapping analysis with the Cascade Model. IB and FAH carried out the group interviews. AMP and FAH carried out the analysis of the individual interviews. All authors contributed substantially to the conceptual framework, study design and implementation. All authors contributed to writing the final article and approved the submitted version.

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Conflict of interest

Author DG was employed by Davey Resource Group, Inc.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frsc.2022.838971/full#supplementary-material

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