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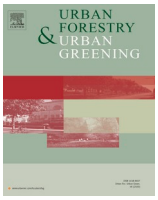

Moving green infrastructure planning from theory to practice in sub-Saharan African cities requires collaborative operationalization

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ABSTRACT

Researchers increasingly consider the systematic integration of green infrastructure (GI) concepts in urban planning as an essential approach to tackle significant current and future challenges. Cities in sub-Saharan Africa (SSA) face rapid urbanization, unregulated land-use practices, and poor enforcement of policies. These cities struggle to address the depletion and degradation of existing GI that increases their vulnerability to climatic hazards that threaten ecosystem integrity, and compromise human health. This paper draws on a review of policy documents, semi-structured interviews with metro officials, and cross-sector focus group discussions to explore ways to operationalize GI spatial planning and design on the ground. Through a case study of the City of Tshwane Metropolitan Municipality, South Africa, which takes a public-private co-development approach, we investigate the uptake of GI planning principles, the challenges, and local proposals for GI applications. In conjunction with the literature, we discuss the alternatives at hand. The local policy documents reflected many planning principles anchored in the Global North literature. Together with public and private partners, we co-developed four locally informed GI objectives: environmental protection, safety, joint ownership, and collaborative governance. We co-identified local planning principles and three strategies for operationalizing GI planning, including working with conventional planning, greater flexibility and creativity, and cross-sectoral collaboration. The findings suggest that collaborative strategies that allow greater access and the active, diverse use of GI could provide much-required cross-sectoral care and management. The real challenge is the establishment of such participatory partnerships as mechanisms to consolidate diverse priorities and co-develop technical and financial alternatives.

1. Introduction

1.1. Green infrastructure uptake and applications

The challenges for Global South cities in the face of rapid urbanization, climate change risks, and a lack of access to essential services are well documented (Dodman et al., 2017; Du Toit et al., 2018). Numerous studies have emphasized the decline and neglect of green space or green infrastructure (GI) that could play a mitigatory role in the risks that cities are fronting (Titz and Chiotha, 2019; Zuniga-Teran et al., 2020). The UN-Habitat's New Urban Agenda (UN-Habitat, 2016) calls for "safe, inclusive, accessible, green, and quality public spaces," which are explicitly lacking in many Global South cities (Guneralp et al., 2018; Dobbs et al., 2019). Several cities are faced with unregulated land-use practices and inadequate spatial planning policies to regulate GI implementation in public and private development (Zakka et al., 2017; Takyi et al., 2022). GI planning principles, such as connectivity, multi-functionality, and social inclusion, have been developed in the Global North literature (Pauleit et al., 2017; Monteiro et al., 2020). In contrast, although many Global South studies emphasize the broader implications of this work for urban spatial planning and design, studies that propose specific GI planning principles for the Global South context are lacking, despite distinct forms of urbanization. Moreover, the spatial applications to transform these theories into more effective GI projects on the ground do not seem to gain similar traction in Global South countries. However, the need for Global North "green" planning concepts and

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validity of their applications in the Global South context must also be interrogated, as elaborated below.

Though GI has its roots in 19th- and 20th-century planning, it has been more recently defined as "an interconnected network of green spaces that conserves natural ecosystem values and functions and provides associated benefits to human populations" (Benedict and McMahon, 2001:5). Since, the concept of GI has been extended from being described as a list of different typologies of vegetated areas in the city (e.g. parks, gardens, remnant vegetation, street trees), to articulating the "*purposeful planning, design and management* of an integrated network of natural and semi-natural green spaces to deliver a wide range of ecosystem services" (European Commission, 2013) (our emphasis). Critics of the GI concept have highlighted its disparate definitions (Sussams et al., 2015), while supporters point out that such "fuzzy concepts" can be refined and adapted to different contexts (Hansen et al., 2021). The gradual change in emphasis in the definitions and coverage noted above reminds us that urban spatial planning and management, as a mainly public sector endeavor (Wilkinson et al., (2013)), drive to a large extent the manifestation of GI on the ground through the approval of public and private developments. In this venture lies competing priorities of effectively mitigating future climate risks, while ensuring the equitable delivery of benefits critical to the sustainability of fast-growing cities. Green infrastructure advantages include flood mitigation (Zuniga-Teran et al., 2020), urban cooling (Ngulani and Shackleton, 2020), improving air and water quality (Keeler et al., 2019), protecting biodiversity (MacKinnon et al., 2019), improving mental health and wellbeing (Engemann et al., 2019), the provisioning of resources and economic opportunities (Lindley et al., 2018), and mitigating systemic injustices (Venter et al., 2020) critical to the Global South context. These examples illustrate that GI, as a concept, and its applications have been adapted to different and dynamic contexts in which each country and location has its trajectory of impacts and priorities.

In pursuit of sustainable urban development, the GI concept has become mainstream in Europe, North America, and Australia in recent decades. Some scalar and disciplinary variations in its applications range from a broader ecological planning approach to a narrow engineering application (Mell, 2017). With essential evaluations increasing in the literature (Sussams et al., 2015; Mell, 2017), there remains a consensus on GI planning principles in an urban context, supported by various publications (Hansen and Pauleit, 2014; Pauleit et al., 2017; Monteiro et al., 2020). Such principles are generally accepted tenets that cover, for instance, gray-green integration, multifunctionality, connectivity, and social inclusion that support specific objectives to overcome

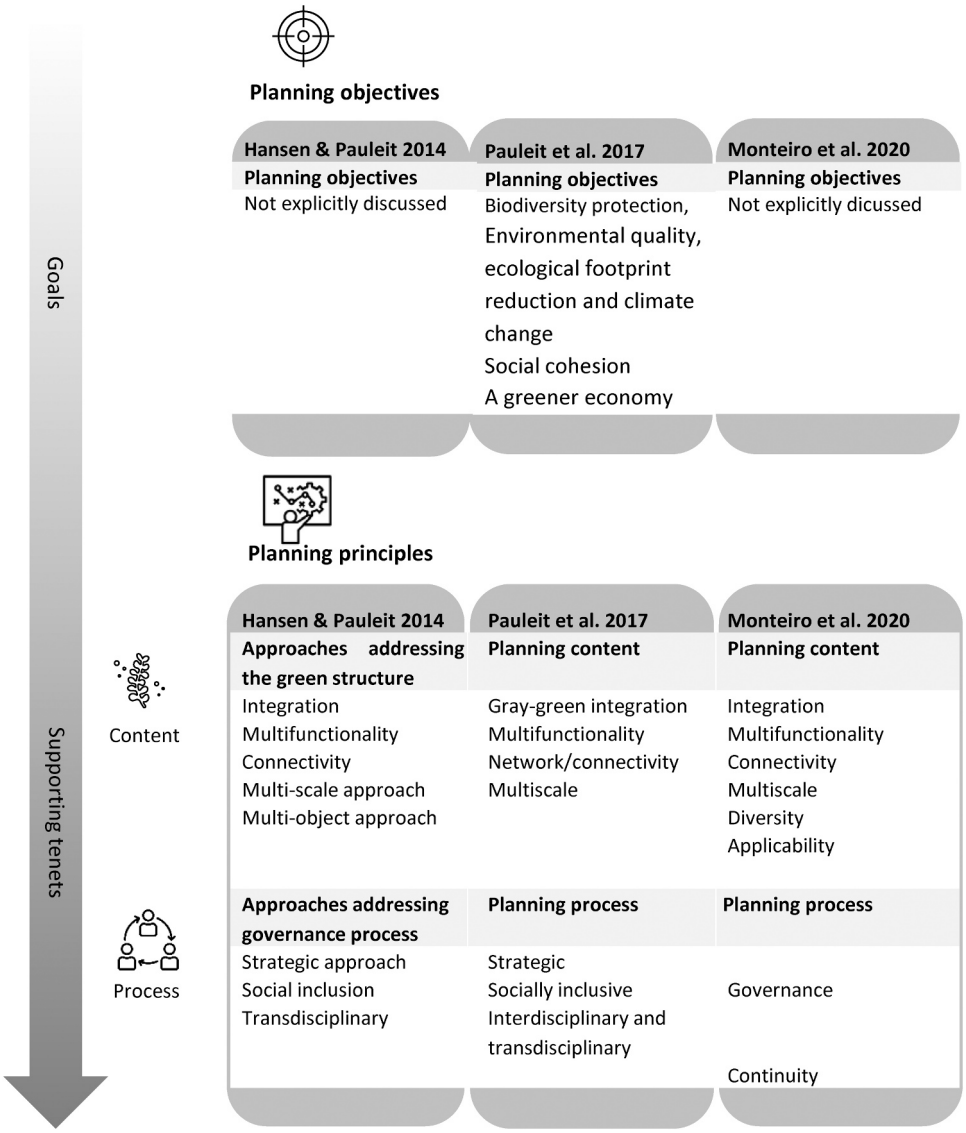

Fig. 1. Urban GI planning principles and objectives.

current urban challenges such as biodiversity protection, ecological footprint reduction and climate change adaptation, social cohesion and a greener economy (Pauleit et al., 2017). Fig. 1 illustrates some of the leading urban GI planning principles discussed in the literature in the last decade (as referred to in the column headings), with similar concepts (at times differently worded) aligned across rows. Though casually mentioned by other authors, only Pauleit et al. (2017) have distinguished pertinent GI objectives.

Originating in the Global North, the GI concept is increasingly adopted in other global contexts (Lindley et al., 2018; Pauleit et al., 2021). Despite some deficiencies in practical implementation strategies (Monteiro et al., 2020), examples of GI applications in various cities are growing. The European Union funded GREEN SURGE (2013–2017) project demonstrated that many European cities have adopted some strategic green space planning (Pauleit et al., 2019). An example is "The Barcelona Green Infrastructure and Biodiversity Plan" (Ajuntamento de Barcelona, 2020), which structures long-term actions to achieve GI that can offer advantages to its residents. In the USA, some major cities started to explore the potential of advancing GI in land management and climate resilience through an engineering approach, for example, "A Stronger, More Resilient New York" (City of New York, 2022). A few Global South studies of GI applications include a review of the planning documents of three cities in Ethiopia that found the use of three GI planning principles in policy documents that were not applied or implemented (Girma et al., 2019). The recent comparison of Washbourne (2022) of planning documents in London and Birmingham in the UK, and Cape Town, Durban and Johannesburg in South Africa found that all the cities studied showed evidence of integrating elements of GI planning into their urban environmental decision-making. One example of such integration is the Environmental Strategy for Cape Town which has developed best practice guidelines for GI networks, trees, and watercourses (City of Cape Town, 2022). From these selected cases, the need to turn GI objectives and principles into strategies for operationalization on the ground becomes clear. To what extent this has been happening in sub-Saharan Africa, will be considered in the next section.

1.2. Green infrastructure in sub-Saharan Africa

Takyi et al. (2022) (our emphasis) highlight the disparity between GI and green space in sub-Saharan Africa (SSA), defining green space as "strategically planned or *unplanned*, public or private, managed or *unmanaged* natural or semi-natural vegetation that delivers *varied* ecosystem services." Although private gardens (Cilliers et al., 2018) and unmanaged spaces could have important functions, this definition, in conjunction with other studies below, suggests that, in several SSA cities, not all green spaces are regulated or considered in "purposeful planning". By this, we do not suggest that no informal GI exists in the Global North (see Rupprecht et al., (2015)). Researchers, however, report that the adaptation and integration of different GI typologies strategically into planning practices and policy has not been occurring in SSA (Zakka et al., 2017; Girma et al., 2019; Takyi et al., 2022) to the same extent as in the countries noted above in the Global North. This tendency coincides with limited research on GI, with the exceptions of countries such as Ethiopia, South Africa and Ghana (Titz and Chiotha, 2019), and the lack of attention to the concept in many other developing regions. The lack of GI application could be ascribed to the contextual mismatch between local planning and current dynamic socioecological, climatic and political conditions. As the contextual challenges and considerations differ dramatically, knowledge, instruments and tools developed in the Global North require local interpretation and development in Global South cities (Pauleit et al., 2017; Dobbs et al., 2019). GI planning applications must reflect the local understanding of practitioners, and existing institutional structures (Sussams et al., 2015; Pauleit et al., 2019).

Although urbanization in SSA cannot be generalized, some commonalities include the legacy of colonialism, rapid unplanned and unregulated growth, weak urban planning institutions, and high levels of informality (Halloran and Magid, 2013; Guneralp et al., 2018). Cilliers et al. (2014) further remind us that SSA urban landscapes are rich in biodiversity and characterized by cultural diversity, but steep socio-economic gradients. Du Toit et al. (2018) have summarized the various challenges to the sustainable delivery of ecosystem services through GI in SSA. We briefly review these challenges below, with a focus on GI spatial planning and management, in the light of recent research in the region.

Mainly led by governments' planning and environmental management divisions (Wilkinson et al., 2013), GI in SSA cities suffers loss and depletion due to problematic governance regimes and planning systems. Research shows the unfavorable impact of historical and colonial legacies on GI distributions (Titz and Chiotha, 2019; Shackleton and Gwedla, 2021). In the colonial and post-colonial eras, GI was systematically but spatially inconsistently implemented in the planning and governance of cities (Titz and Chiotha, 2019). After democracy, limited revenue bases and institutional failures, due to historical hasty and partial decentralization, have resulted in weak legal frameworks and a lack of political capacity and will, compromising the effective and adequate implementation of planning strategies and by-laws and sustaining social exclusion and inequalities (Smit, 2018). Weak planning of GI is exacerbated by a general lack of awareness of its full benefits (Takyi et al., 2022). Several studies illustrate persistent urban planning challenges from a current management perspective (Matamanda et al., 2019; Cobbinah and Nyame, 2021). This includes studies by Zakka et al. (2017) and Takyi et al. (2022), who emphasize the lack of enforcement of conventional GI policies and plans.

The pressure from rapid urbanization and poverty has increasingly raised social justice concerns in planning (Roy et al., 2018); conversely, others report encroachment and conversion of natural green areas such as wetlands, farmlands, and earmarked open spaces in urban areas to residential and other uses (Zakka et al., 2017). Research increasingly illustrates that spatial inequality and specific access to resources and green areas influence citizens' and policymakers' perceived importance and need for urban green space (Dipeolu et al., 2021). Guenat et al. (2020) recommend ways to change perceptions by communicating a context-specific evidence-base, which emphasizes the full economic benefits of green spaces.

Green infrastructure research in SSA is building such an evidence base for the local values and uses of GI. This evidence includes examples of ecological studies with a faunal (Mbiba et al., 2021) and climate focus (Ngulani and Shackleton, 2020), while social studies consider foraging (Garekae and Shackleton, 2020), the benefits and values of trees (Shackleton et al., 2015), and human preferences in existing green space structure or typologies (Gashu et al., 2020; Dipeolu et al., 2021). However, current implementation policies and strategies for GI concentrate primarily on green growth, integrated energy, climate adaptation, or climate resilience plans (Pauleit et al., 2021), with the above aspects of ecological network integration and socioeconomic and health benefits of GI generally neglected. Pauleit et al. (2021) further emphasize that, due to future risks, the most important and more immediate goals for GI in Africa include temperature regulation, food provision and security, and for cultural reasons aesthetic appeal and recreational facilities; while job creation, is rarely acknowledged as a benefit of GI. King and Shackleton (2020) report how the maintenance of urban GI provides work opportunities for skilled and unskilled workers in the public and private sectors. The authors argue that providing and maintaining urban GI is an investment in environmental sustainability, liveability, economic welfare, and poverty alleviation in the Global South (King and Shackleton, 2020). Titz and Chiotha (2019) further illustrate the potential of GI to increase the sustainability of livelihoods. They found that research on urban agriculture is a dominant feature of GI in SSA due to its provisioning and potential socioeconomic benefit, but is challenged by its lack of legitimacy, formality, and institutionalization (Halloran and Magid, 2013).

Research is increasing on specific stakeholders, such as planning professionals (Van Zyl et al., 2021; Breed, 2022), who are generally in short supply in SSA governments (Pauleit et al., 2021). Cilliers et al. (2014) have argued for transdisciplinary approaches, integrating both non-academic and academic role players. To this extent, Guenat et al. (2020) and Barraclough et al. (2022) did social network analyses of stakeholders involved in urban GI planning. Barraclough et al. (2022) show the disconnect between stakeholders and government networks, and a lack of cultural services in natural resource management agendas. In line with this, Guenat et al. (2020) recommend governance structures that support collaboration, coordination and co-development of green spaces. This is supported by Halloran and Magid (2013), who advocate co-ownership among stakeholders. Ogu (2000) similarly advocates a bottom-up participatory stakeholder partnership as a strategy capable of enlisting the financial, material resources and expertise of the whole urban community towards improved urban GI. Breaking away from a cross-sectoral approach, Lamson-Hall, et al. (2019) focus on planning operationalization through alternative "simple plans" led by residents, which they argue can increase access and implementation with minimal public investment and limited support from consultants and local government.

The SSA literature discussed above shows few studies that have asked how GI goals could be operationalized in spatial planning and whether the specific GI principles developed in the Global North apply to these local contexts. The challenges and initiatives discussed above served as an evidence-based background for our case study to draft local GI planning principles through co-creation.

1.3. Study objectives

Studies by Takyi et al. (2022) and Zakka et al. (2017) emphasize the need to strengthen and enforce land-use plans, regulations, and clear-cut policies to guide GI in SSA. Based on such findings, numerous authors suggest that current GI planning practices need to be challenged (Titz and Chiotha, 2019; Guenat et al., 2020; Dipeolu et al., 2021). Our study aims to build on these former studies with a focus on the uptake of GI, but with a specific intention to shed light on context-specific proposals and actionable principles toward operationalizing land-use plans and regulations for spatial planning and design that could manifest in GI on the ground.

We use the City of Tshwane (Tshwane) in South Africa as a case study for GI spatial planning and implementation. A peripheral country in geopolitics, South Africa represents several social, spatial and environmental challenges in its urban environment representative of Global South cities. This includes urban sprawl, deteriorating infrastructure, rising poverty levels, inequality, growing informal settlements (Landman, 2019), environmental risks (Cock, 2007), and a lack of access to GI and ecosystem services (Du Toit et al., 2018). The administrative capital, Tshwane, is less progressive in GI applications than more frequently studied sister cities such as Durban and Cape Town, and demonstrates most of the typical challenges experienced in other SSA cities. Therefore, the findings of this study could have great upscaling potential. The following questions guided the study to inquire into the process from GI planning to operationalization:

Which GI planning principles currently manifest locally in planning and design? What are the challenges and opportunities faced by metro officials in GI planning? What are strategies identified from a public-private collaboration perspective and the underlying causes that must be addressed to improve local GI planning and operationalization on the ground?

In the Global South literature, numerous challenges in GI management are disclosed, but little emphasis is placed on actionable guidelines for improving GI planning. This study aims to address this shortcoming.

2. Method

2.1. Study area

The province of Gauteng, the economic hub of South Africa, is densely populated, with rich biodiversity pressured by development and rapid urbanization (Pfab et al., 2017). As with many African urban landscapes, those in Tshwane are characterized by biotic and cultural diversity and steep socioeconomic gradients (Cilliers et al., 2014). Tshwane covers a large area of 6345 km^2 and has a population of 3,31 million people (City of Tshwane, 2020), with considerable local density variation for geographic and political-historic reasons.

The impact and spatial effects of an unequally oppressive and segregating governing system are still evident in the spatial fabric of South African cities (Landman, 2019; Shackleton and Gwedla, 2021). During the colonial and apartheid regimes, cities and public spaces were designed to specifically exclude and divide communities (Patel, 2005). Since democracy, SA has consciously attempted to address these injustices. Previously marginalized areas were upgraded to include public amenities, parks and recreational spaces (Stoffberg et al., 2012). Despite these efforts, green spaces remain unequally distributed in terms of race and income (Venter et al., 2020).

Spatial planning in South Africa is anchored in four principles: 1) spatial justice, 2) spatial sustainability, 3) efficiency, and 4) spatial resilience (Republic-of-South-Africa, 2013). Tshwane has a three-tier spatial planning system, comprising spatial development frameworks (SDFs), open space frameworks (OSFs) and open space plans (OSPs). The SDF is enforceable by national legislation (Republic-of-South-Africa, 2013), and provides an overall vision for the spatial development of the city for three to five years. The OSF gives more details and guidance to waterways, protected areas and open space nodes, including the protection and upgrading of green spaces, but its implementation is not nationally enforced. The OSPs further elaborate on details of specific precincts, their present state and future uses. They are, however, often absent or outdated and not enforced either.

2.2. Data collection and analysis

This study adopted a multi-method approach that provided triangulation through the complementarity in the range of insights and perspectives, and in method development (Creswell, 2003). The study obtained research ethics clearance from the university ethics committee and the Tshwane Knowledge Management unit. An initial desktop analysis of academic literature and policy documents was complemented by semi-structured interviews with public-sector officials involved in the spatial planning of urban GI. These interviewees were subsequently invited to attend a co-creation workshop together with private practitioners (planners, engineers, landscape architects) and urban developers who all work in the local context. The methodology emphasizes the importance of local potential in co-development processes but has limitations in terms of the lack of community participation and the presentation of a once off co-creation workshop. The data compiled from the above sources are briefly discussed below.

2.2.1. Desktop review

The desktop review comprised national, provincial, and municipal policy documents relevant to GI spatial planning and design to identify shared principles. Scoping interviews were held with public officials and private consultants involved in spatial planning in Tshwane. In addition, searches were conducted on local municipalities and national institutions involved in environmental and spatial planning, and research. From this, a list of documents was compiled and tested with the interviewees for their relevance (see supplementary material, Table a).

An initial list of ten GI planning principles was compiled from the scientific literature (see Fig. 1). A three-pronged review process was then followed for the spatial policy documents. Firstly, the research

considered the planning principles present in the policy documents and discussed in interviews, identifying 15 principles (see supplementary material, Table b), it then considered whether these principles aligned with those from the literature. The principles found in the scientific literature (10), interviews and policy documents (15) were then cross-checked for overlaps and differences, producing 18 discrete principles.

2.2.2. Interviews

A snowball sampling method was followed, starting at the Environmental Planning Department and assimilating officials from other departments in the metro that influence GI planning decisions. To gain a more holistic perspective, two private-sector landscape architects who specifically work with the metro were interviewed on the municipal process around GI. Fifteen interviews of approximately one hour each

Table 1
Alignment of policy document spatial planning principles (left column) and proposed GI planning principles (top row) assimilated from academic literature, policy documents and stakeholders.

Spatial planning principles from policy documents	Proposed GI planning principles for the CoT																	
	Planning Principles											Process Principles						
	Accessibility & use	Adaptability & flexibility	*Connectivity	Conserve, restore & protect	*Contextually appropriate	*Diversity/ heterogeneity	*Green-grey integration	*Multifunctionality	*Multi-scale approach	Quality & inclusive	Safety	Green socio-economic opportunities	Collaborative governance	Cross-sectoral partnerships	*Co-ownership, continuity &	*Inter- & transdisciplinary approach	*Participation, equity & inclusivity	*Strategically planned
Environmental justice	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Environmental sustainability	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Spatial resilience		X	X	X	X	X	X	X	X				X	X	X	X	X	X
Spatial quality	X			X	X			X	X	X	X		X	X	X	X	X	X
Spatial efficiency		X	X		X	X	X	X	X			X	X	X	X	X	X	X
Equitable access to resources	X		X	X	X	X	X	X	X		X	X	X	X	X	X	X	X
Equitable & effective participation		X	X	X	X	X		X		X	X	X	X	X	X	X	X	X
Environmental integration and linkage				X	X	X			X	X	X		X	X	X	X	X	X
Protect the environment		X	X	X	X	X	X						X	X	X	X	X	X
Flexibility					X	X	X	X			X		X	X	X	X	X	X
Anticipatory planning	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Transparent & inclusive decision-making	X	X	X	X	X			X				X	X	X	X	X	X	X
Empowering communities		X		X	X	X		X	X		X	X	X	X	X	X	X	X
Co-operative governance			X	X	X		X	X	X		X	X	X	X	X	X	X	X
Safety and security	X	X	X	X	X			X		X	X	X	X	X	X	X	X	X

*proposed principles that concur with those in Fig. 1

were conducted between February and May 2022 (see supplementary material for questionnaire). All interviews were held in person, recorded with permission, and transcribed. The interview transcripts were content-coded in MS Excel, and thematically analyzed (Mayring, 2014) to identify opportunities and challenges regarding the implementation of GI.

At the time of the interviews, the officials had been employed by the metro between 8 and 39 years (see Table c for details of respondent profiles). The interviewees represented the following departments and units: City Sustainability, Economic Development and Spatial Planning, Environment and Agriculture Management, Community and Social Development Services, Human Settlements, and Roads and Transport.

2.2.3. Co-creation workshop

One four-hour co-creation workshop was held in July 2022 to facilitate the co-development of GI planning principles for Tshwane. An online pre-workshop questionnaire was sent to the participants before the workshop to inquire about local GI priorities. At the workshop, the authors presented the GI planning challenges and opportunities revealed by the interviews, as well as a draft list of the GI principles extracted from the literature, interviews and document review.

Of the 40 people invited, 23 participated in the workshop – six private practitioners, two developers, two independent researchers and 13 public-sector officials. The participants were divided into three focus groups, each containing representatives from different departments and practices. To gain insight into the perceived local GI priorities, each group was given a set of hard copies of draft GI planning principles, and were asked to rank them in order of importance for Tshwane. The 12 draft GI principles were: connectivity, multi-functionality, contextually appropriate, adaptability/ flexibility, green-gray integration, diversity, multi-scale approach, accessibility, legibility, quality, safety and security, and conserve and protect.

Note that we did not distinguish between GI principles and objectives, and the selected principles were focused on the planning content. The groups could add or omit principles and were given 40 min to debate their rankings before presenting the outcome, which was then further discussed and interrogated. Lastly, participants were asked – as a combined group – to consider what they believed to be the metro's key objective for the inclusion of GI at different scales.

The three focus groups and combined discussions were recorded and transcribed. The content was then coded using Atlas TI version 9 software. The thematic analysis (Mayring, 2014) focused on the underlying causes for concern, proposed priorities and proposals for GI planning and operationalization.

3. Results

3.1. Overview of GI planning principles

The two sets of GI planning and process principles are presented in a matrix in Table 1. From the policy document analysis and interviews, 15 planning principles that covered aspects of planning and process were identified (see Table 1, left column). A total of 25 policy documents were reviewed, of which 14 contained spatial planning principles. The SDFs supported fewer principles than the OSFs and OSPs, while the interviews and focus groups supported all proposed 18 principles (see supplementary material, Table b).

In Table 1, the 15 spatial planning principles from the policy document and interview analysis were aligned with those identified in the academic literature to produce 18 proposed GI planning principles , for example, "environmental integration and linkage" from policy was aligned with "connectivity" from the literature. The 18 proposed GI planning principles were grouped under either planning or process, based on Pauleit et al. (2017) (see Table 1 matrix, top row). The focus of the workshop was on GI planning, but through the interviews and focus group discussions it was clear that GI operation across stages needs support from GI process principles. In addition, we found that some GI objectives, distinguished from principles by Pauleit et al. (2017) such as "biodiversity protection", were included as principles from the policy documents and were retained as such. We formulated descriptions for the 18 proposed GI planning principles (see supplementary material, Table d), based on the policy documents, interviews and academic literature reviewed.

3.2. Local GI challenges and opportunities

Besides informing the local GI planning principles above, the interviews were also analyzed for challenges, opportunities and the underlying reasons influencing current GI operationalization priorities, which are presented in this section.

3.2.1. Challenges: resources, joint vision, priorities, compliance

An overarching challenge mentioned by interviewees in the metro is the scarcity of resources, especially in terms of GI. This includes implementation, management, and maintenance (Metro official 7). An interviewee expressed: *"… development keeps on being approved, but no money gets invested into park infrastructure…"* (Metro official 5).

Although knowledge, skills and technical support are often lacking inside the metro, there are further issues such as general work ethic and a lack of social and political priority, will and buy-in for GI (Metro officials 6 and 7). Green Infrastructure implementation and maintenance *"are perceived as expensive and a luxury by all spheres of government that are budget-strapped."* (Metro official 4). At the same time, GI is not raised as a priority, partly because: *"Communities do not relate to spaces if they are not engaged and included in the planning and design process"* (Metro official 3).

A unified vision, shared by the different spheres of government for GI, and collaboration between the functional departments in the metro and with external parties, is lacking. There are conflicting policies, regulations and processes around GI, which result in poor compliance, both in the metro and by the metro (Metro officials 3 and 7). For example, the metro's Department of Human Settlements is challenged to comply with the provisioning of open space and recreational facilities, as the housing need in the metro is massive (Metro official 3).

The conflicting interpretation of policies and by-laws internally causes frustration for officials, professionals and developers (Metro official 13). Another shared frustration was that payments, made by developers in terms of legislation, disappear into a communal metro coffer, and cannot be allocated to GI improvement in the city (Metro officials 1, 2, 5, and 15).

The inefficient policies are aggravated by competing interests, individuals operating for their own interest, and departments for their mandate: *"Developers are only concerned about their development and not about the implications of the development on the whole ecosystem"* (Metro official 3). Besides challenges such as failed bureaucracy and inefficiency, there is a further lack of compliance with regulations by the public, and an inability by the metro to enforce this, which is exacerbated by little post-construction monitoring.

Unmanaged land is seen as *"government land"*, owned by no-one (Metro official 12). Therefore, homeless people settle in environmentally sensitive areas such as riparian zones and wetlands as they know the metro is obliged by law to move them to safety, and provide them with housing (Metro officials 3, 6, 8–13). In this way, informal living and informal recycling often occupy unmanaged GI areas, while practices of misuse downgrade the qualities of existing GI. Consequently, GI is perceived as neglected, unsafe, crime hot-spots due to poor or no maintenance, and is therefore not valued. This increases illegal practices such as dumping (Metro officials 3, 4, 7, and 11).

Interviewees felt that greater root causes must be addressed: *"… first solving the socioeconomic problems, and then environmental solutions will follow"* (Metro official 11).

3.2.2. Opportunities: collaborative governance, vision, partnerships, active citizenship

Interviewees identified the possibility of institutional and political buy-in through cooperative governance inside the metro as an important opportunity. This entails the need for a unified vision for GI for the metro and collaboration between all departments (Metro officials 2–4, 7, and 14). Good internal communication and working relationships between core value-chain departments are essential. Still, they are also lacking at the national and provincial level, with a tendency to work across purposes and disregard the root causes of problems. Developers should be encouraged to appoint specialists, such as landscape architects, and consult with the metro at the beginning of project applications. More qualified personnel are needed internally to support departments within the metro, like Human Settlements (Metro official 5). To operationalize GI in the metro, an interviewee suggested that GI planning guidelines and best practice sketches should be incorporated into spatial development frameworks and policies, complemented by the development of GI by-laws (Metro official 5).

Social and political buy-in is critical, and can be obtained through greater awareness, knowledge and skills development in GI: *"creating awareness of the value of biodiversity, and that we have to protect it"* (Metro official 12). Some interviewees felt strongly that the local communities must be informed and educated on GI, but engaged through the appropriate metro structures. Involving the community from the start of a project, especially in the design stage, can lead them to care for and identify with the space: "*The community needs to take ownership"* (Metro official 7).

The metro must build cross-sectoral partnerships, internally, and with the private sector and the community: "*The social part is the spin-off and it's very important"* [along with the] *"ecological services that this GI gives to the residents"* (Metro official 9). Potential partnerships were identified that could improve the implementation and long-term success of GI in the city. Furthermore, active citizenship could be encouraged through community organizations, consolidated through the "Friends" group by-law, "… *who alert the metro when non-compliant land development applications may slip through the system"* (Metro official 2). The involvement of partnerships could assist with the funding and affordability of GI. Many interviewees believed economic incentives such as *subsidies and green tax rebates* are all that will motivate citizens to implement and maintain GI *"… for individual homes and businesses …"* (Metro officials 3, as well as 8–10, and 15).

3.3. Local GI planning principles and objectives

The co-creation workshop was held to initiate the co-development of a joint vision for the provision of GI at a metro-wide level. We focus the findings here on articulating priority principles and related objectives for effective GI planning by targeting the greater underlying concerns that influenced the rankings and proposed solutions.

The three focus groups were provided with 12 GI planning principles (see 3.2.3), focused on the planning content. The interconnectedness of the principles was repeatedly emphasized, but the most articulated principles were to conserve and protect, multifunctionality, green-gray integration, a multiscale approach, safety and security, and connectivity, in that order.

The ranking discussions articulated the underlying causes that frustrate GI operationalization. This largely has to do with processes. From the analyses of the group discussions, four local GI planning principles were formulated and four related GI objectives, which are presented below.

3.3.1. Environmental protection: protect the environment by using it

In the joint discussion, several people felt the main priority of the metro was to conserve and protect GI*: "I mean ultimately […] it is to protect the environment"* (Practitioner 2, landscape architect). However, the perceived conundrum here was that: *"sustainability can't come with conservation"* […] *"our biggest problem is that we've conserved and protected and put it in glass boxes and no one values those glass boxes at the moment"* (Metro official 20).

What intensifies this absence of value of GI is the current lack of access to green spaces for people due to privatization: "*most of these places are […] on private developments and not accessible to the general public…*" (Practitioner 6, town planner). Therefore, the priority ranking of the GI principles was driven by co-benefits and use to increase value *"because if it is not going to be used, it is not going to be maintained, it makes everything else irrelevant"* (Developer 2).

3.3.2. Co-ownership: create GI access for co-ownership

One group argued for the dual importance of the connectivity and accessibility of GI. Despite the importance of financial considerations and legislation, this group's main concern was access to open space and questions of ownership. As expressed by two interviewees: *"Conserve and protect comes automatically if people take ownership of their open space network"* (Developer 1).

"Doesn't help you say connectivity and then you have a lot of blocked areas [fenced off]. You need to…[address] the accessibility part" (Practitioner1, landscape architect).

3.3.3. Safety: usable, (multi) functional and flexible GI for safety

One group emphasized small-scale green-gray integration, since this group's most important priority was safety and quality: … "*if people don't feel safe, […] it doesn't get used, it doesn't get maintained […] what is important is that the space is far more functional"* (Developer 2).

For another group access and ownership could provide sustainability and resilience, embodied by the principle of multifunctionality – for this group, it encompassed diversity and adaptability that allows for "redundancy". As described by a practitioner (Practitioner 1, landscape architect): *"a network that can grow organically and change with time and be flexible,"* or as articulated by these officials: "*You find with sustainability its useable, within a functional space*" (Metro official 20). With these principles in place, the group members argued that other important considerations are within reach.

3.3.4. Collaborative governance: GI (multiscale) functional integration with collaborative governance

One group searched for a strategy to address "integration". This term spoke to GI integration: *"… focus local and start branching it out from there"* (Practitioner 2, landscape architect), but also to integrate different role players and departments: *"… getting everybody on board and buying into …"* (Practitioner 2, landscape architect).

Another group felt the principles were interconnected, but spoke to different things at different scales. At a large scale: *"…we* [must] *show what must be connected"* (Practitioner4, landscape architect). On a smaller geographic scale, the focus was on multifunctionality, green-gray integration, with an aim to integrate departments: *"… if we say multifunctionality* [it means] *more departments that will be involved and more access to funding [..] that will also enhance GI and linking it"* (Metro official 15).

3.4. Strategies to improve GI planning

Since the focus group discussions were on the GI planning content principles, the process principles were not as explicitly ranked or discussed**.** Therefore, we co-developed the following three strategies for improved GI planning, considering both the focus group discussions and the interviews.

3.4.1. Improve conventional planning measures for GI

One main argument was to improve the measures of conventional planning for GI. In order to: *"bring green infrastructure to the same level as all the other infrastructure"* you must plan and cost it "*for all other infrastructure there is a formal agreement"* (Metro official 15). Otherwise,

"spaces will be fragmented […] the only open space eventually is the road (Practitioner6, town planner).

The need for different entry points in GI planning in terms of time and scale was emphasized: *"…we can work on it at a metro level, regional level and at a day-to-day application stage"* (Metro official 20).

3.4.2. Flexibility and creative alternatives in context

Despite the general agreement on the need for planning, there was an emphasis on non-generic, context-specific solutions that are encumbered through detailed guidelines and legislation. "*Because open space means different things in different areas. And if we have detail, and detailed guidelines that adaptability and that context specific-ness disappears*" (Practitioner 6, town planner).

Several people also spoke about creative alternatives to existing policies and the need to: *"do things differently in the city"* (Practitioner1, landscape architect) to mobilize change and avoid risks: *"the legislation is not our biggest obstacle. It's changing the minds of the policymakers so that there can be […] creativity …*[and] *alternative solutions to GI"* (Developer 1).

However, this should not override practicality and working with existing GI assets and benefits (Practitioner 4, landscape architect).

3.4.3. Incentivize cross-sectoral partnerships

From the opportunities presented in the interviews, the need for collaborative governance that could involve cross-sectoral partnerships, with specific emphasis on community and expert engagement in processes, was proposed. A shared vision, awareness and education could enable operationalization through cross-departmental, community, and specialist involvement; while partnerships could create greater affordability, care, and co-ownership, but more incentives for collaboration are required.

4. Discussion

The literature review on SSA shows that researchers are building up an evidence base for ecological and social studies related to GI for the region. Several studies elaborate on GI urban planning process challenges, with social actor and network studies gaining traction. Two

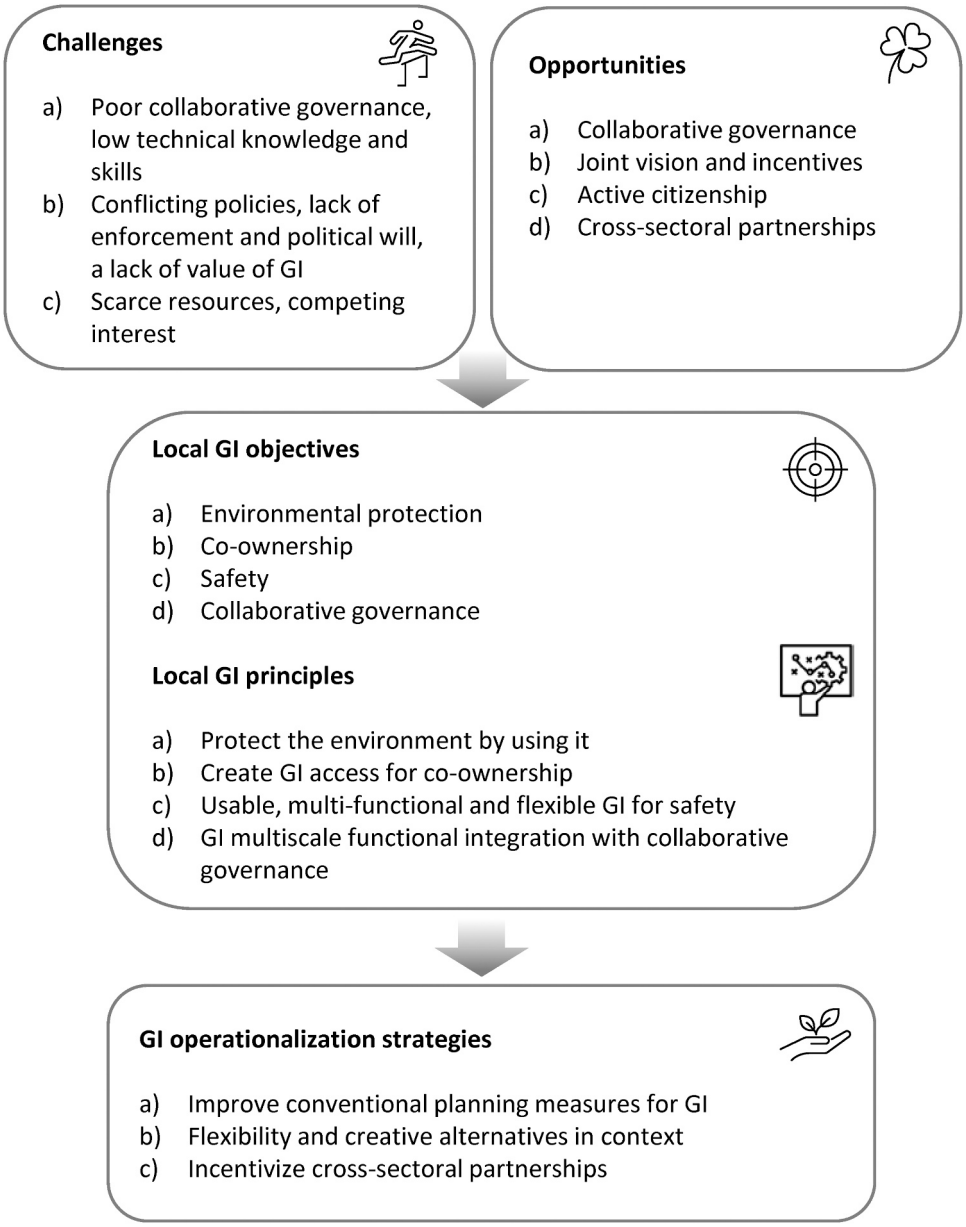

Fig. 2. Proposed GI operationalization for Tshwane.

studies considered GI planning principles' presence in policy documents in SSA and found some evidence of their applications in South Africa (Washbourne, 2022), but not in Ethiopia (Girma et al., 2019). Our findings indicate that many of the Global North principles for GI planning and process are applied in local policy documents and are known concepts in the private and public sectors in Tshwane. At the metro level, the SDFs documents showed a poor presence of GI planning principles, while the OSF and OSPs (not legally enforceable) reflected the most. We consolidated 18 GI planning principles (Table 1, top row) that retain all ten Global North principles (Fig. 1). Fig. 2 summarizes the empirical findings, purposefully indicating the interrelatedness of the local challenges and opportunities with the proposed regional GI operationalization strategy. The local priority objectives for GI planning operationalization differ from those in the Global North literature. Where Global North objectives currently hinge on biodiversity protection, ecological footprint reduction, and climate change adaptation, social cohesion, and a greener economy (Pauleit et al., 2017), in Tshwane some of these ambitions were retained, but with a local emphasis, namely environmental protection, co-ownership, safety, and collaborative governance.

Based on these priority objectives, three strategies were identified (section 4.2) that could help operationalize GI in the contexts that are discussed below. Still, before doing so, we discuss the GI planning objectives and the related local principles (4.1).

4.1. Proposed GI planning objectives and principles

Four GI objectives were identified that underpin four proposed GI planning principles (see Fig. 2). Due to their interconnected ambitions, the principles overlap in addressing the current identified GI challenges.

Two objectives, protecting the environment and human safety, were among the most discussed priorities during the workshop. They are both considered planning principles in the policy documents (see Table 1, left column). To "conserve and protect" and "safety and security" do however not feature as GI planning principles in the Global North literature, but rather as objectives or outcomes. The Global North literature rationale suggests that the principles of green-gray integration, multifunctionality, connectivity, and social inclusion, when applied, are seen to contribute directly to "biodiversity protection" and "securing the needs and demands of vulnerable and less vocal groups" (Pauleit et al., 2017:18–19), but little is stated on safety. The above two objectives were not seen as implicit in local GI planning outcomes and were therefore included in the proposed local GI planning principles (see Fig. 2).

4.1.1. Protect the environment by using it

We argue that the root causes of safety and environmental protection concerns in Tshwane rest on questions of equity and related access to (and use of) GI benefits. Researchers report safety concerns in green spaces in South Africa, e.g. (de Vries, 2019; Breed, 2022), including protected areas (Graham, 2015). Safety related to green and protected areas has a strong historical legacy embedded in current perceptions. In South Africa, for many decades, national parks and protected areas did not permit entry by most of the population based on race (Spierenburg and Wels, 2006). Strict urban spatial and environmental conservation policies often depended on fencing and patrolling areas (Pekor et al., 2019). Dipeolu et al. (2021) illustrate how citizens' and policymakers' perceived importance and need for urban green space are based mainly on spatial inequality and specific access to resources and green areas. In addition, levels of awareness and opportunities for social activities have been shown to influence GI perception (Gashu et al., 2020). In South Africa, there is still a evident need for access considerations to be broadened to explicitly embrace both spatial and sociopolitical barriers that shape people's abilities to benefit from GI (Paganini and Lemke, 2020). Unless equity and ownership concerns are sufficiently addressed, safety and protection will remain important priorities for GI planning.

4.1.2. Create GI access for co-ownership

Another proposed GI planning principle hinges on co-ownership and accessibility – a principle seen as implicit in the Global North literature (Monteiro et al., 2020). The threat of "using spaces or losing them" versus keeping them "in a glass box" was a strong point of discussion during the focus groups. In Tshwane and cities in SSA, urban dwellers often compete with other urban needs and development priorities for space, or get involved in conflicts with other land uses (Cocks et al., 2016; Smit, 2018). In SSA, the heterogeneity of public, institutional and private landowners, and differences in access and disposal rights raise social and environmental justice issues concerning GI (Titz and Chiotha, 2019). Echoing this, the Tshwane stakeholders argued for "access and ownership" of GI for all residents. Green infrastructure that does not meet the requirements of the different stakeholders of urban society can intensify social inequalities and inherent disparities rather than promote social cohesion (Titz and Chiotha, 2019). Titz and Chiotha (2019) advocate that using, appropriating, and accessing GI can promote equity, ownership, and a sense of belonging among urban dwellers. This access to and use of GI enables urban inhabitants to become active, and produce and manage space for themselves (Titz and Chiotha, 2019). Urban dwellers have affinities and deep-rooted relations with urban nature (Cocks et al., 2016), which must be reflected in GI design to connect urban residents with nature (Mnisi et al., 2021; Breed, 2022).

4.1.3. Usable, multifunctional and flexible GI for safety

Increasing the functional use of GI could be an essential economic and equity measure. The desire for GI multifunctionality, emphasized in the Tshwane focus groups, is a reaction to the reported "low value" of GI in the metro. To compete with gray infrastructure, GI in SSA needs an instrumental utility function and monetary value (Breed, 2022), echoed by the focus groups. In line with this, Titz and Chiotha (2019) suggest that GI concepts in SSA have primarily evolved around nostalgic visions of the African village, portraying GI as highly valued provisioning agriculture. However, this vision has become obsolete since urban agriculture does not fit the political notions of "modern" African cities (Titz and Chiotha, 2019). Green infrastructure functionality has latent potential for expansion beyond a beautification measure in SSA (Lindley et al., 2018).

Despite the ability of the principles of multifunctionality and multiscale approaches to significantly augment GI value, they show operationalization complications. In the UK, Sussams et al. (2015) observe that the multifunctional character of GI creates problems with departmental organizational structures, remits and responsibilities, with greater competition for resources and funding. The lack of coordination in GI governing was raised in interviews in Tshwane. The current departmental division of the Tshwane management problematically separates departments that impact the implementation of GI in the metro. The high heterogeneity of landowners makes the involvement of many stakeholders in planning and implementation necessary (Smit, 2018), with a general lack of collaboration in decision making reported in Tshwane.

4.1.4. GI multiscale functional integration with collaborative governance

Collaborative governance can improve decision making. Tshwane stakeholders need a transdisciplinary and collaborative approach (Cilliers et al., 2014), leaning on integrating knowledge and experience from different stakeholders, reflexive learning and joint ownership, to reconcile values and preferences (Ogu, 2000; Roy et al., 2018). This objective is a paradox, as this is mainly missing from conversations at the co-development workshop and in cities in SSA. Since the 1970 s, the World Bank has encouraged the "private sector" – communities, institutions, private professionals and non-governmental organizations – to assume major participatory roles in urban development (Ogu, 2000). Such collaborative cross-sectoral decision making allows for inlcuding people with different skills, expertise and training in urban planning and development (Ogu, 2000).

4.2. Proposed GI operationalization strategies

Due to the challenges that remain imbedded in the objectives and principles (highlighted above), we propose three operationalization strategies for GI in Tshwane.

4.2.1. Improve conventional planning measures for GI

One of the focus groups' main discussion points was how to sharpen conventional planning practices to increase GI allocation in developments in Tshwane. Several studies call for developing and enforcing GI instruments or legislation in SSA (Zakka et al., 2017; Guenat et al., 2020; Takyi et al., 2022), which are currently lacking. Contrary to this, Scholz et al. (2015) mark how many former British colonies adhere to a static and complex top-down master planning paradigm unsuitable for guiding SSA's rapid and informal urban development processes.

There is a general belief that a more "level playing field" could be created for GI by nullifying individual interests and political and societal influences through more prescriptive policies, as Sussams et al. (2015) reported. This top-down solution seems particularly enticing when researchers report challenges in GI allocation such as a lack of accountability, law enforcement and absence of political will in SSA (Guenat et al., 2020). However, as raised by the Tshwane focus groups, if prescriptive planning principles and master plans are blindly applied, one risks targeting only the direct drivers of GI. With a contextualized, dynamic approach, one can identify deeper causes leading to challenges, such as a lack of awareness of GI benefits, and then develop suitable strategies to target these challenges. Underlying causes, including governance challenges, are largely missing from the South African scientific literature related to GI, but were very much emphasized in the results we found. The management challenges faced by Tshwane indicate that current planning strategies are not delivering GI on the ground, which is a similar frustration to other cities in SSA mentioned above.

The co-development workshop included local potentials, circumstances and problems,advocated by Mngumi (2020), as the basis for stakeholders to start developing their own GI principles (see Fig. 2) and jointly create a vision and sense of co-ownership of GI in Tshwane. These principles need further elaboration by stakeholders such as residents and community structures, as advised byTitz and Chiotha (2019). The follow-through requires that the co-development process continues, anchored and embedded in the metro (Wolfram et al., 2019).

4.2.2. Flexibility and creative alternatives in context

The GI concept calls for sectors to cooperate in "a discursive policy environment" (Sussams et al., 2015). Legislation and regulations are often conceived to reduce risks, but could become restrictive to innovation and creative solutions based on specific communities and conditions. The private-sector consultants and developers specifically emphasized that place-based strategies and responses are required rather than a one-size-fits-all approach, which Angelstam et al. (2017) recommended. If the identified policies in Tshwane are more flexible, they can favor GI implementation and continuity through partnerships, direct project funding and improved cost estimations.

Long-term sustainability requires policies that could allow for community initiatives for infrastructure development and ensure some cost-recovery efficiency in infrastructure management (Ogu, 2000). Ogu (2000) argues that involving local stakeholders in planning, design and construction could lead to the provision of levels of service that meet their requirements, and which they can afford and maintain. A shift in the above policies towards participatory planning would also take informality, land rights, and social exclusion into account, and allow for the inclusion of previously unused grassroots capacities to complement the role of public administration (Titz and Chiotha, 2019).

In the above, Tshwane stakeholders agreed with Lamson-Hall et al. (2019) that a governance structure that fosters integration, adaptability, and the involvement of non-state stakeholders would deliver more positive outcomes than governmental "command-and-control" mechanisms. However, polycentric-governance involves other challenges, such as legitimacy and accountability (Bäckstrand et al., 2018). Another way to have greater legislative flexibility is through improved collaborative governance in combination with local leadership (Bianchi et al., 2021).

4.2.3. Incentivize cross-sectoral partnerships

Though highly recommended by Cilliers et al. (2014), the lack of cross-sectoral (transdisciplinary) collaboration is not only reported in the interviews, but also in the scientific literature (Cobbinah and Nyame, 2021; Barraclough et al., 2022). In SSA, the collective mobilization of resources, including financial, material and labour, and other categories of support, is required to face the enormous environmental improvement challenge in low-income cities (Halla, 1994). Cross-sectoral collaboration could develop joint strategies that include options for technical support, and leverage capital, but it needs to allow for capacity building and conflict resolution (Ogu, 2000).

Acknowledging the importance of active community participation, interviewees also emphasized the need for multidisciplinary specialist input so that GI benefits are prioritized for greater wellbeing. Reconciliation of conflicting and competing interests includes identifying, clarifying, and prioritizing environmental issues between community and specialist opinions (Ogu, 2000; Titz and Chiotha, 2019). Guenat et al. (2020) warn that collaborative governance needs to acknowledge that many people perceive green spaces as vacant or unused land that would be better put to other uses. In addition, specialist and practitioner knowledge, is perceived to come from outsiders and therefore disregarded by government departments (Guenat et al., 2020).

Interviewees recommended economic incentives for participation. However, research shows that both intrinsic and extrinsic motivations are needed for long-term change and uptake (Pretty, 2003). MacKinnon and Derickson (2012) suggest the alternative concept of "resourceful communities" that can create benefits for their area. In this respect, Roy et al. (2018) advocate an inclusive and creative form of urban planning building on the inherent local knowledge and innovative power of communities. Titz and Chiotha (2019) argue that, for such collaborative operationalization to happen in SSA, the right to appropriation and participation must first be addressed. The Integrated Development Plan process in South Africa allows for some public involvement in high-level development planning, the process faces many challenges for "genuine" participation, including practicalities such as time delays and no participative follow through toward implementation stages (Everatt et al., 2010). Effective participation transcends the contribution of ideas and consensus molding, and involves issues like empowerment and the instilment of a sense of care and ownership (Halla, 1994; Everatt et al., 2010).

5. Conclusions

We found that Tshwane metro applies the Global North concept of GI, and most of the prominent GI planning principles in open space frameworks and plans, but less in spatial development frameworks. Our research confirms several local challenges on GI in SSA, such as scarce resources, competing interest, a lack of value of GI, poor cooperative governance, conflicting policies, lack of enforcement and political will, and low technical knowledge and skills. Opportunities lie in collaborative governance, promoting active citizenship, cross-sectoral partnerships, and a joint vision. Historical and contextual issues result in an emphasis on environmental protection, multifunctionality, multiscale approaches, and safety in relation to GI. Based on stakeholder discussions, we co-developed four local GI planning principles for Tshwane that speak to the local challenges and opportunities experienced in GI operationalization. These are to protect the environment by using it, creating GI spatial and social access for co-ownership, multifunctional and flexible GI for safety, and integrating GI with collaborative governance. To our knowledge, these are the first locally developed GI

principles in an SSA context, which considerably differ from GI principles derived in the Global North. We propose three strategies for GI planning operationalization, which include working with conventional planning, greater flexibility and creativity, and cross-sectoral partnerships.

Our methodology emphasizes the importance of local potential (or resourcefulness), circumstances and problems in co-development processes. Similarly, inclusion and co-ownership are essential to reconcile conflicting and competing interests, and to clarify and prioritize environmental issues. We argue, along with several other authors, that cross-sectoral partnerships are essential to finding robust joint strategies, options for technical support, and leveraging capital for GI in SSA. We hypothesize that a combined grassroots and (top-down) management approach is required to realize these ambitions. The recommended cross-sectoral involvement could be the catalyst that triggers public demand and, consequently, political buy-in. We recommend more specific case studies that can provide insight on how partnerships are formed, operationalized and anchored around GI planning in the region.

CRediT authorship contribution statement

Christina, A. Breed: Conceptualization, Visualization, Investigation, Data curation, Project administration, Funding acquisition, Formal analysis, Methodology, Supervision, Validation, Writing - original draft, Writing - review & editing. **Tania Du Plessis:** Data curation, Visualization, Project administration, Formal analysis, Writing - original draft. **Kristine Engemann:** Visualization, Project administration, Funding acquisition, Writing - review & editing. **Stephan Pauleit:** Writing - review & editing. **Maya Pasgaard:** Project administration, Funding acquisition, Writing - review & editing.

Declaration of Competing Interest

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

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ufug.2023.128085.

References

Ajuntamento de Barcelona, 2020. Barcelona Green Infrastructure and Biodiversity Plan 2020. Retrieved December 8th, 2022 from ⟨https://ajuntament.barcelona.cat/ecologiaurbana/sites/default/files/Barcelona%20green%20infrastructure%20and%20biodiversity%20plan%202020.pdf⟩.

Angelstam, P., Barnes, G., Elbakidze, M., Marais, C., Marsh, A., Polonsky, S., Richardson, D. M., Rivers, N., Shackleton, R. T. and Stafford, W. 2017. Collaborative learning to unlock investments for functional ecological infrastructure: Bridging barriers in social-ecological systems in South Africa. Ecosystem Services, 27291-304.https://doi.org/10.1016/j.ecoser.2017.04.012.

Bäckstrand, K., Zelli, F., Schleifer, P., 2018. Legitimacy and accountability in polycentric climate governance. In: Jordan, A., Huitema, D., van Asselt, H., Forster, J. (Eds.), Governing Climate Change: Polycentricity in Action? Cambridge University Press, Cambridge.

Barraclough, A.D., Cusens, J., Måren, I.E., 2022. Mapping stakeholder networks for the co-production of multiple ecosystem services: a novel mixed-methods approach. Ecosyst. Serv. 56101461 https://doi.org/10.1016/j.ecoser.2022.101461.

Benedict, M.A., McMahon, E.T., 2001. Green Infrastructure: Smart Conservation for the 21st Century. Sprawl Watch Clearinghouse, Washington, D.C. (Available). ⟨http://www.sprawlwatch.org/greeninfrastructure.pdf⟩

Bianchi, C., Nasi, G., Rivenbark, W.C., 2021. Implementing collaborative governance: models, experiences, and challenges. Public Manag. Rev. 23 (11), 1581–1589. https://doi.org/10.1080/14719037.2021.1878777.

Breed, C.A., 2022. Value negotiation and professional self-regulation – environmental concern in the design of the built environment. Urban For. Urban Green. 74127626 https://doi.org/10.1016/j.ufug.2022.127626.

Cilliers, S., du Toit, M., Cilliers, J., Drewes, E., Retief, F., 2014. Sustainable urban landscapes: South African perspectives on transdisciplinary possibilities. Landsc. Urban Plan. 125260–125270. https://doi.org/10.1016/j.landurbplan.2014.02.009.

Cilliers, S.S., Siebert, S.J., Du Toit, M.J., Barthel, S., Mishra, S., Cornelius, S.F., Davoren, E., 2018. Garden ecosystem services of Sub-Saharan Africa and the role of health clinic gardens as social-ecological systems. Landsc. Urban Plan. 180, 294–307. https://doi.org/10.1016/j.landurbplan.2017.01.011.

City of Cape Town, 2022. Green Infrastructure Programme. Retrieved December, 2nd, 2022 from ⟨https://www.capetown.gov.za/departments-city-initiatives/environmental-resource-management/green-infrastructure-programme⟩.

City of New York, 2022. A Stronger, More Resilient New York. Retrieved December 17th, 2022 from ⟨http://s-media.nyc⟩. gov/agencies/sirr/SIRR_singles_Hi_res.pdf.

City of Tshwane, 2020. City of Tshwane Integrated Development Plan: Revision for 2020/21. Retrieved December 17th, 2022 from ⟨https://www.cogta.gov.za/cgta_2016/wp-content/uploads/2020/11/City-of-Tshwane-Approved-2020–2021-IDP-and-SDBIP-City-of-Tshwane-30–06-2020.pdf⟩.

Cobbinah, P.B., Nyame, V., 2021. A city on the edge: the political ecology of urban green space. Environ. Urban. https://doi.org/10.1177/09562478211019836.

Cock, J., 2007. The war against ourselves, nature, power and justice. Wits University Press, Johannesburg.

Cocks, M., Alexander, J., Mogano, L., Vetter, S., 2016. Ways of belonging: Meanings of "Nature" among Xhosa-speaking township residents In South Africa. J. Ethnobiol. 36 (4), 820–841, 22.

Creswell, J.W., 2003. Research design: Qualitative, quantitative, and mixed methods approaches, second ed. Sage Publications, Thousand Oaks.

de Vries, L., 2019. A 'paradox of the commons'? The planning and everyday management of Green Point Park. Urban Forum 30 (3), 325–339. https://doi.org/10.1007/s12132-019-09362-8.

Dipeolu, A.A., Ibem, E.O., Fadamiro, J.A., 2021. Determinants of residents' preferences for Urban Green infrastructure in Nigeria: evidence from Lagos Metropolis. Urban For. Urban Green. 57 https://doi.org/10.1016/j.ufug.2020.126931.

Dobbs, C., Escobedo, F.J., Clerici, N., de la Barrera, F., Eleuterio, A.A., MacGregor-Fors, I., Reyes-Paecke, S., Vásquez, A., Zea Camaño, J.D., Hernández, H.J., 2019. Urban ecosystem services in Latin America: mismatch between global concepts and regional realities? Urban Ecosyst. 22 (1), 173–187. https://doi.org/10.1007/s11252-018-0805-3.

Dodman, D., Leck, H., Rusca, M., Colenbrander, S., 2017. African urbanisation and urbanism: implications for risk accumulation and reduction. Int. J. Disaster Risk Reduct. 267-15. https://doi.org/10.1016/j.ijdrr.2017.06.029.

Du Toit, M.J., Cilliers, S.S., Dallimer, M., Goddard, M., Guenat, S., Cornelius, S.F., 2018. Urban green infrastructure and ecosystem services in sub-Saharan Africa. Landsc. Urban Plan. 180249–180261. https://doi.org/10.1016/j.landurbplan.2018.06.001.

Engemann, K., Pedersen, C.B., Arge, L., Tsirogiannis, C., Mortensen, P.B., Svenning, J.-C., 2019. Residential green space in childhood is associated with lower risk of psychiatric disorders from adolescence into adulthood. Proc. Natl. Acad. Sci. 116 (11), 5188–5193. https://doi.org/10.1073/pnas.1807504116.

European Commission, 2013. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Green Infrastructure (GI) – Enhancing Europe's Natural Capital. COM (2013) 249 final.

Everatt, D., Marais, H., Dube, N., 2010. Participation … for what Purpose? Analysing the Depth and Quality of Public Participation in the Integrated Development Planning Process in Gauteng. Politikon 37 (2–3), 223–249. https://doi.org/10.1080/02589346.2010.522333.

Garekae, H., Shackleton, C.M., 2020. Urban foraging of wild plants in two medium-sized South African towns: people, perceptions and practices. Urban For. Urban Green. 49126581 https://doi.org/10.1016/j.ufug.2020.126581.

Gashu, K., Gebre-Egziabher, T., Wubneh, M., 2020. Local communities' perceptions and use of urban green infrastructure in two Ethiopian cities: Bahir Dar and Hawassa. J. Environ. Plan. Manag. 63 (2), 287–316. https://doi.org/10.1080/09640568.2019.1578643.

Girma, Y., Terefe, H., Pauleit, S., 2019. Urban green spaces use and management in rapidly urbanizing countries: the case of emerging towns of Oromia special zone surrounding Finfinne, Ethiopia. Urban For. Urban Green. 43126357 https://doi.org/10.1016/j.ufug.2019.05.019.

Graham, M., 2015. Everyday human (in)securities in protected urban nature – collaborative conservation at Macassar/Wolfgat dunes nature reserves, Cape Town, South Africa. Geoforum 6425–6436. https://doi.org/10.1016/j.geoforum.2015.05.016.

Guenat, S., Dougill, A.J., Dallimer, M., 2020. Social network analysis reveals a lack of support for greenspace conservation. Landsc. Urban Plan. 204 https://doi.org/10.1016/j.landurbplan.2020.103928.

Guneralp, B., Lwasa, S., Masundire, H., Parnell, S., Seto, K.C., 2018. Urbanization in Africa: challenges and opportunities for conservation. Environ. Res. Lett. 13 (1) https://doi.org/10.1088/1748-9326/aa94fe.

Halla, F., 1994. A coordinating and participatory approach to managing cities: the case of the Sustainable Dar es Salaam Project in Tanzania. Habitat Int. 18 (3), 19–31.

Halloran, A., Magid, J., 2013. Planning the unplanned: incorporating agriculture as an urban land use into the Dar es Salaam master plan and beyond. Environ. Urban. 25 (2), 541–558. https://doi.org/10.1177/0956247813500903.

Hansen, R., Pauleit, S., 2014. From multifunctionality to multiple ecosystem services? A conceptual framework for multifunctionality in green infrastructure planning for urban areas. AMBIO - A J. Hum. Environ. 43 (4), 516–529. https://doi.org/10.1007/s13280-014-0510-2.

Hansen, R., van Lierop, M., Rolf, W., Gantar, D., Šuklje Erjavec, I., Rall, E.L., Pauleit, S., 2021. Using green infrastructure to stimulate discourse with and for planning practice: experiences with fuzzy concepts from a pan-European, a national and a local perspective. Socio-Ecol. Pract. Res. 3 (3), 257–280. https://doi.org/10.1007/s42532-021-00087-2.

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

King, A., Shackleton, C.M., 2020. Maintenance of public and private urban green infrastructure provides significant employment in Eastern Cape towns, South Africa. Urban For. Urban Green. 54, 126740 https://doi.org/10.1016/j.ufug.2020.126740.

Lamson-Hall, P., Angel, S., DeGroot, D., Martin, R., Tafesse, T., 2019. A new plan for African cities: the Ethiopia Urban Expansion Initiative. Urban Stud. 56 (6), 1234–1249. https://doi.org/10.1177/0042098018757601.

Landman, K., 2019. Evolving public space in South Africa: towards regenerative space in the post-apartheid city. Routledge, New York.

Lindley, S., Pauleit, S., Yeshitela, K., Cilliers, S., Shackleton, C., 2018. Rethinking urban green infrastructure and ecosystem services from the perspective of sub-Saharan African cities. Landsc. Urban Plan. 180328–180338. https://doi.org/10.1016/j.landurbplan.2018.08.016.

MacKinnon, D., Derickson, K.D., 2012. From resilience to resourcefulness. Prog. Hum. Geogr. 37253–37270.

MacKinnon, K., van Ham, C., Reilly, K., Hopkins, J., 2019. Nature-based solutions and protected areas to improve urban biodiversity and health. In: Marselle, M.R., Stadler, J., Korn, H., Irvine, K.N., Bonn, A. (Eds.), Biodiversity and Health in the Face of Climate Change. Springer International Publishing, Cham.

Matamanda, A.R., Chirisa, I., Mangara, F., Dzvimbo, M.A., 2019. The ecological politics surrounding the downsizing and downgrading of public park: areflection on the history of change of the Harare Gardens in Zimbabwe. Case Stud. Environ. 3 (1) https://doi.org/10.1525/cse.2019.001958.

Mayring, P. 2014. Qualitative Content Analysis Theoretical Foundation.

Mbiba, M., Mazhude, C., Fabricius, C., Fritz, H., Muvengwi, J., 2021. Bird species assemblages differ, while functional richness is maintained across an urban landscape. Landsc. Urban Plan. 212. https://doi.org/10.1016/j.lurbplan.2021.104094.

Mell, I.C., 2017. Green infrastructure: reflections on past, present and future praxis. Landsc. Res. 42 (2), 135–145. https://doi.org/10.1080/01426397.2016.1250875.

Mngumi, L.E., 2020. Ecosystem services potential for climate change resilience in peri-urban areas in Sub-Saharan Africa. Landsc. Ecol. Eng. 16 (2), 187–198. https://doi.org/10.1007/s11355-020-00411-0.

Mnisi, B.E., Geerts, S., Smith, C., Pauw, A., 2021. Nectar gardens on school grounds reconnect plants, birds and people. Biol. Conserv. 257 https://doi.org/10.1016/j.biocon.2021.109087.

Monteiro, R., Ferreira, J.C., Antunes, P., 2020. Green infrastructure planning principles: an integrated literature review. Land 9 (12), 525.

Ngulani, T., Shackleton, C.M., 2020. The degree, extent and value of air temperature amelioration by urban green spaces in Bulawayo, Zimbabwe. South Afr. Geogr. J. 102 (3), 344–355. https://doi.org/10.1080/03736245.2019.1685405.

Ogu, V.I., 2000. Stakeholders' partnership approach to infrastructure provision and management in developing world cities: lessons from the Sustainable Ibadan project. Habitat Int. 24 (4), 517–533. https://doi.org/10.1016/s0197-3975(00)00015-1.

Paganini, N., Lemke, S., 2020. There is food we deserve, and there is food we do not deserve" Food injustice, place and power in urban agriculture in Cape Town and Maputo. Local Environ. 25 (11–12), 1000–1020. https://doi.org/10.1080/13549839.2020.1853081.

Patel, Z., 2005. Understanding environmental change in South African cities: a landscape approach. Transform.: Crit. Perspect. South. Afr. 5724–5740.

Pauleit, S., Vasquéz, A., Maruthaveeran, S., Liu, L., Cilliers, S.S., 2021. Urban green infrastructure in the Global South. In: Shackleton, C.M., Cilliers, S.S., Davoren, E., du Toit, M.J. (Eds.), Urban Ecology in the Global South. Springer International Publishing, Cham.

Pauleit, S., Hansen, R., Rall, E.L., Zölch, T., Andersson, E., Luz, A.C., Szaraz, L., Tosics, I., Vierikko, K., 2017. Urban landscapes and green infrastructure. Oxford University Press.

Pauleit, S., Ambrose-Oji, B., Andersson, E., Anton, B., Buijs, A., Haase, D., Elands, B., Hansen, R., Kowarik, I., Kronenberg, J., Mattijssen, T., Stahl Olafsson, A., Rall, E., van der Jagt, A.P.N., Konijnendijk van den Bosch, C., 2019. Advancing urban green infrastructure in Europe: outcomes and reflections from the GREEN SURGE project. Urban For. Urban Green. 404–416. https://doi.org/10.1016/j.ufug.2018.10.006.

Pekor, A., Miller, J.R.B., Flyman, M.V., Kasiki, S., Kesch, M.K., Miller, S.M., Uiseb, K., van der Merve, V., Lindsey, P.A., 2019. Fencing Africa's protected areas: Costs, benefits, and management issues. Biol. Conserv. 22967–22975. https://doi.org/10.1016/j.biocon.2018.10.030.

Pfab, M.F., Compaan, P.C., Whittington-Jones, C.A., Engelbrecht, I., Dumalisile, L., Mills, L., West, S.D., Muller, P., Masterson, G.P.R., Nevhutalu, L.S., Holness, S.D., Hoare, D.B., 2017. The Gauteng Conservation Plan: planning for biodiversity in a rapidly urbanising province. Bothalia 47 (2). https://doi.org/10.4102/abc.v47i1.2182.

Pretty, J., 2003. Social capital and the collective management of resources. Science 3021912–3021914.

Republic-of-South-Africa 2013. Spatial Planning and Land Use Management (SPLUMA) Act 16 of 2013. Pretoria: Government Printer.

Roy, M., Shemdoe, R., Hulme, D., Mwageni, N., Gough, A., 2018. Climate change and declining levels of green structures: life in informal settlements of Dar es Salaam, Tanzania. Landsc. Urban Plan. 180282–180293. https://doi.org/10.1016/j.landurbplan.2017.11.011.

Rupprecht, C.D.D., Byrne, J.A., Garden, J.G., Hero, J.-M., 2015. Informal urban green space: a trilingual systematic review of its role for biodiversity and trends in the literature. Urban For. Urban Green. 14 (4), 883–908. https://doi.org/10.1016/j.ufug.2015.08.009.

Scholz, W., Robinson, P., Dayaram, T., 2015. Colonial planning concept and post-colonial realities. The influence of British planning culture in Tanzania, South Africa and Ghana. In: Siva, C.N. (Ed.), Urban Planning in Sub-Saharan Africa. Colonial and Post-Colonial Planning Cultures. Routledge, London, UK.

Shackleton, C.M., Gwedla, N., 2021. The legacy effects of colonial and apartheid Imprints on urban greening in South Africa: spaces, species, and suitability. Front. Ecol. Evol. 8 (467) https://doi.org/10.3389/fevo.2020.579813.

Shackleton, S., Chinyimba, A., Hebinck, P., Shackleton, C., Kaoma, H., 2015. Multiple benefits and values of trees in urban landscapes in two towns in northern South Africa. Landsc. Urban Plan. 13676–13686. https://doi.org/10.1016/j.landurbplan.2014.12.004.

Smit, W., 2018. Urban governance in Africa: an overview. Int. Dev. Policy (10), 55–77. https://doi.org/10.4000/poldev.2637.

Spierenburg, M., Wels, H., 2006. Securing space" mapping and fencing in transfrontier conservation in Southern Africa. Space Cult. 9294–9312. https://doi.org/10.1177/1206331206289018.

Stoffberg, G.H., Hindes, C., Müller, L. (Eds.), 2012. South African landscape architecture: A compendium. Unisa Press, Pretoria, South Africa.

Sussams, L.W., Sheate, W.R., Eales, R.P., 2015. Green infrastructure as a climate change adaptation policy intervention: muddying the waters or clearing a path to a more secure future? J. Environ. Manag. 147184–147193. https://doi.org/10.1016/j.jenvman.2014.09.003.

Takyi, E., Mensah, H., Aazore, F.K., Nalumu, D.J., Abu, J., 2022. Understanding the urban planning-green space depletion nexus: insights from the Kwabre East Municipality, Ghana. Urban Forum. https://doi.org/10.1007/s12132-022-09471-x.

Titz, A., Chiotha, S.S., 2019. Pathways for sustainable and inclusive cities in Southern and Eastern Africa through urban green infrastructure? Sustainability 11 (10). https://doi.org/10.3390/su11102729.

UN-Habitat, 2016. The New Urban Agenda. Retrieved December 8th, 2022 from ⟨https://unhabitat.org/the-new-urban-agenda-illustrated⟩.

Van Zyl, B., Lategan, L.G., Cilliers, E.J., Cilliers, S.S., 2021. An exploratory case-study approach to understand multifunctionality in urban green infrastructure planning in a South African context. Front. Sustain. Cities 3. https://doi.org/10.3389/frsc.2021.725539.

Venter, Z.S., Shackleton, C.M., Van Staden, F., Selomane, O., Masterson, V.A., 2020. Green apartheid: Urban green infrastructure remains unequally distributed across income and race geographies in South Africa. Landsc. Urban Plan. 203103889 https://doi.org/10.1016/j.landurbplan.2020.103889.

Washbourne, C.-L., 2022. Environmental policy narratives and urban green infrastructure: reflections from five major cities in South Africa and the UK. Environ. Sci. Policy 12996-106. https://doi.org/10.1016/j.envsci.2021.12.016.

Wilkinson, C., Sendstad, M., Parnell, S., Schewenius, M., 2013. Urban governance of biodiversity and ecosystem services. In: Elmqvist, M.F.T., Marcotullio, P.J., McDonald, R.I., Parnell, S., Schewenius, M., Sendstad, M., Seto, K.C., Wilkinson, C. (Eds.), Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities: A Global Assessment. Springer, Berlin.

Wolfram, M., Borgström, S., Farrelly, M., 2019. Urban transformative capacity: from concept to practice. Ambio 48 (5), 437–448. https://doi.org/10.1007/s13280-019-01169-y.

Zakka, S.D., Permana, A.S., Majid, M.R., Danladi, A., Bako, P.E., 2017. Urban greenery a pathway to environmental sustainability in Sub Saharan Africa: a Case of Northern Nigeria Cities. Int. J. Built Environ. Sustain. 4 (3), 180–189. https://doi.org/10.11113/ijbes.v4.n3.211.

Zuniga-Teran, A.A., Gerlak, A.K., Mayer, B., Evans, T.P., Lansey, K.E., 2020. Urban resilience and green infrastructure systems: towards a multidimensional evaluation. Curr. Opin. Environ. Sustain. 4442–4447. https://doi.org/10.1016/j.cosust.2020.05.001.