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RESEARCH ARTICLE

Transdisciplinary approaches assessing unmanaged urban green spaces reveal benefits for biodiversity and people

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Abstract

Rapid urbanization is projected for African cities at the cost of urban green space, which could jeopardize biodiversity and human benefits. Studies focusing specifically on human–green space relationships in the Global South are lacking, and the validity of extrapolating results from studies in the Global North remains questionable and cannot provide local context-specific design solutions. This study combines methods and perspectives from ecology and human geography with landscape design to better understand the benefits for biodiversity and people derived from unmanaged green spaces in the City of Tshwane, South Africa. Based on empirical data from two unmanaged green space areas in disadvantaged communities, we identify benefits for biodiversity and people and define guidelines for inclusive trans-disciplinary interventions. We combine information from a vegetation survey, a community survey of 200 respondents and a rapid assessment of multifunctional benefit provision to formulate in holistic landscape design proposals. We show that the sites have biodiversity value and provide habitat for > 169 different plant species, including protected species, and smaller wildlife. Residents use the spaces for utility, passive and active leisure, and > 76% of residents benefit from the use of these spaces. However, the integrity and provision of benefits from green spaces are threatened by pollution, safety concerns, biological invasions, and land conversion. Context-specific designs could be developed by merging methods across disciplines and involving local stakeholders to integrate the multifunctionality of socioecological benefits into landscape interventions. Collaboration across ecology, human geography and landscape design generates multifunctional perspectives of unmanaged green spaces that consider benefits for biodiversity and disadvantaged communities.

Keywords Environment · Community · Landscape design · Well-being · Environmental justice · Urban ecology

1 Introduction

Cities are home to an increasing number of people attracted by the promise of a better life with access to job opportunities, food, health care, and education (Adli et al. 2017, p. 183; Dye 2008). However, dense, gray and polluted cities are also centers of inequality and environmental health hazards (McMichael 2000, p. 119) (Johnson 2001; Power 2001). In the future, the largest cities are projected to be in developing countries, with the African continent experiencing the fastest urban land cover conversion rate, with urban area increases of 590% compared to the year 2000 (Angel et al. 2011, p. 58; Seto et al. 2012, p. 16083). For South Africa, several studies have shown that urban densification has caused a loss of green space and urban vegetation which is becoming increasingly fragmented and unequally distributed threatening the health of ecosystems and communities (Jagarnath et al. 2019, p. 92; Magidi & Ahmed 2019, p. 344; Munyati & Drummond 2020).

To improve quality of life and respond to global development challenges, sustainable city planning approaches are needed. Protecting, managing and restoring urban green spaces can be a cost-efficient approach to sustainable urban development with multifunctional benefits for both

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biodiversity and communities (MacKinnon et al. 2019, p. 365), as multifunctionality here, compared to ecosystem services, is broadly considered as functions from urban green spaces providing benefits for ecosystems and people (Ahern et al. 2014, p. 255; Hansen et al. 2019, p. 100; Van Zyl et al. 2021a, b, p. 2). Adequately planning for multifunctional urban green spaces requires an uptake of multifunctionality as a principle in planning, management and design perspectives (C. A. Breed et al. 2023, pp. 9–10; Hansen et al. 2019, p. 100). To catalyze this uptake interdisciplinary collaboration around green space planning is required to ensure the integration of complementary expertise and worldviews (Hansen et al. 2019, p. 107). However, integrated approaches to green space planning transcending sector silos are rare in the Global South, and poor governance and planning, lack of inclusion of local socio-cultural and ecological perspectives are specifically highlighted as barriers to implementation in Sub-Saharan Africa (S. Cilliers et al. 2014, p. 264; Pauleit et al. 2021, pp. 107–143; van Zyl et al. 2021a, b, p. 130). These challenges are explored by this study.

1.1 Urban green space from a Global South perspective

On the African continent specifically, fast-growing cities suffer from unequal provision of infrastructure and services, including green spaces, rooted in colonial planning separating rather than connecting and benefitting people (Dodman et al. 2017, p. 9; C. M. Shackleton and Gwedla 2021, p. 7; Venter et al. 2020, p. 6). With this legacy in mind, it is important to understand the role and combined benefits for people and biodiversity provided by urban green spaces—especially for marginalized communities. Inter- and transdisciplinary research could provide insights into complex socio-ecological systems and bring forth transformative change (Roux et al. 2017, pp. 719–722; Tobi and Kampen 2018, p. 1222). However, rootedness in vastly different academic institutions may hinder collaboration between researchers speaking different "languages" and using different methodological approaches (Fry 2001, p. 162; Kelly et al. 2019, pp. 152–153).

There are major (albeit generalized) differences between the Global North and Global South regarding urban development and living conditions. Differences in growth rates, governance, poverty, pollution, and planning histories (Dodman et al. 2017) influence green space distribution, as shown by a South African study where green space distribution was found to be highly unequal, with more green space in predominantly "white" neighborhoods (Venter et al. 2020, p. 7). Perception of benefits, interactions with nature and ability to benefit from nature are likewise locally determined as, e.g., cultural background shape self-identity and a sense of belonging (C. A. Breed 2022, p. 3; Cocks et al. 2016, p. 828; Ngulani & Shackleton 2019, pp. 101–102). Quantification of locally perceived benefits from urban green spaces in an South African context could inform much needed evidence-based decision making (E. Cilliers 2019, p. 13). While distribution and access to green spaces is mostly studied in terms of physical distance (ibid. Willemse 2013, p. 151), only a few studies include more sociopolitical perspectives of access, e.g., access to services, knowledge or markets (Bahta et al. 2018, p. 102; Paganini and Lemke 2020, p. 1010), which sheds light on people's actual *ability to benefit* (cf. Ribot & Peluso 2009, p. 154). Hence, human–green space relationships are context-specific and should be assessed relative to local environmental and cultural settings, and studies are needed to untangle the complex relationship between green space, people and socioeconomic factors beyond the Global North (Ives et al. 2017, pp. 109–110).

1.2 Green space multifunctionality requires holistic approaches

Green spaces can be classified as formal–managed possibly with restricted access; or informal–unmanaged without formal recognition or management (Lurdes et al. 2021, p. 2; Rupprecht and Byrne 2014, p. 597). Whereas formal urban green spaces are often designed to provide a single or few specific benefits, multifunctionality through biodiversity conservation, environmental protection and access for people are often overlooked (C. A. Breed 2022, pp. 16–17; C. A. Breed et al. 2015, p. 12) or unattained due to colonial legacies or apartheid planning in the case of South Africa (Baruah et al. 2021, p. 44; Landman 2020, Chapter 2; Moodley 2019, p. 308). For many disadvantaged communities, unmanaged green spaces are the only kind accessible (Lurdes et al. 2021, p. 14; Takyi et al. 2022, pp. 329–330), and they may provide habitats and dispersal corridors for biodiversity by connecting to larger habitat patches outside cities (Aronson et al. 2014, p. 6; Ives et al. 2016, pp. 123–124; Mbiba et al. 2021, p. 8). However, it remains unclear what benefits they provide for people and biodiversity and how transdisciplinary collaboration can be applied jointly to asses and design interventions at the landscape scale.

Green spaces are situated within the larger context of urban development, pollution and invasive species threatening ecological integrity and the provision of benefits for people (Carbutt et al. 2011, p. 19; Karani & Jewasikiewitz 2006, p. 165; Wessels et al. 2021, pp. 6–7). These complex social and environmental issues need trans-and interdisciplinary collaboration and trans-sector participation to find holistic solutions utilizing strengths from both quantitative and qualitative approaches (Kelle 2006; Klein 2014, pp. 15–16). Urban planners play a key role in the planning of urban green spaces but are dependent on on-the-ground knowledge for locally relevant and holistic decision making and implementation (C. A. Breed et al. 2023, pp. 6–7; E. Cilliers 2019, pp. 6–9; Tyrväinen et al. 2007, pp. 15–16).

We argue that a more nuanced knowledge on human–green space relationships should be used to develop context-specific and inclusive (inter- and transdisciplinary) approaches to landscape design and (co-) management to preserve and diversify unmanaged urban green spaces toward multifunctionality for people and biodiversity.

We propose a trans- and interdisciplinary approach to investigating socio-ecological aspects of the human–green space relationship in deprived unmanaged green space study areas within a Global South urban context. The aim is to combine methods from ecology, human geography, and landscape architecture to assess the potential multifunctional benefits from unmanaged green spaces, exploring whether local communities can coexist with biodiversity by asking the following research questions:

(1) What characteristics are present in unmanaged green spaces?
(2) Which benefits do people identify from unmanaged green spaces?
(3) To what degree does biodiversity and community benefits overlap in unmanaged green spaces?

2 Study sites

2.1 Study site description

This study focused on two unmanaged urban green spaces between settlements within the City of Tshwane, South Africa, in Atteridgeville and Mabopane (Fig. 1). The City of Tshwane metropolitan area has nearly three million inhabitants and a low average population density of only 464 people/km^2 (Statistics South Africa 2011). The city struggles with localized overpopulation, urban sprawl, rising poverty levels, and growing informal settlements (Landman 2020; Sutcliffe and Bannister 2018). Under the oppressive apartheid planning regime, the city was spatially segregated, with racially marginalized communities living in high-density township settlements at the urban periphery with limited provision of and access to services (Landman and Ntombela 2006; Sutcliffe and Bannister 2018) which is still evident today.

Two study sites were chosen jointly with public project partners from the City of Tshwane, who identified the two municipal areas as needing attention and intervention due to challenging infrastructural, green space and socioeconomic conditions. More specifically, sites were chosen based on a criteria of potentially providing both biodiversity and human benefit, and in need of interventions from the municipality's perspective. A list of 10 potential sites was shortlisted and the two study sites were selected because—they had people living in and around them (residential neighborhoods), were on a river system and contained wetlands (biodiversity value), were unmanaged and quite large (100 ha plus—biodiversity value), were in areas that needed green space development (social need for green space). Recent recreational projects planned by the City for these two areas had come to an unexpected halt due to lack of funding and land ownership issues.

The researchers were cognisant of the historical legacy of large expanses of unmanaged municipal green space, that were historically used to segregate communities of different races or isolate (buffer off) black township areas. Often the unmanaged spaces that are still undeveloped in these historically marginalized areas, are still there because they are in floodplains (which is a national phenomenon, see Breed and Mehrtens (2022) indicating a similar scenario in eThekwini). With an interest in working in marginalized communities, the two areas selected were historically and

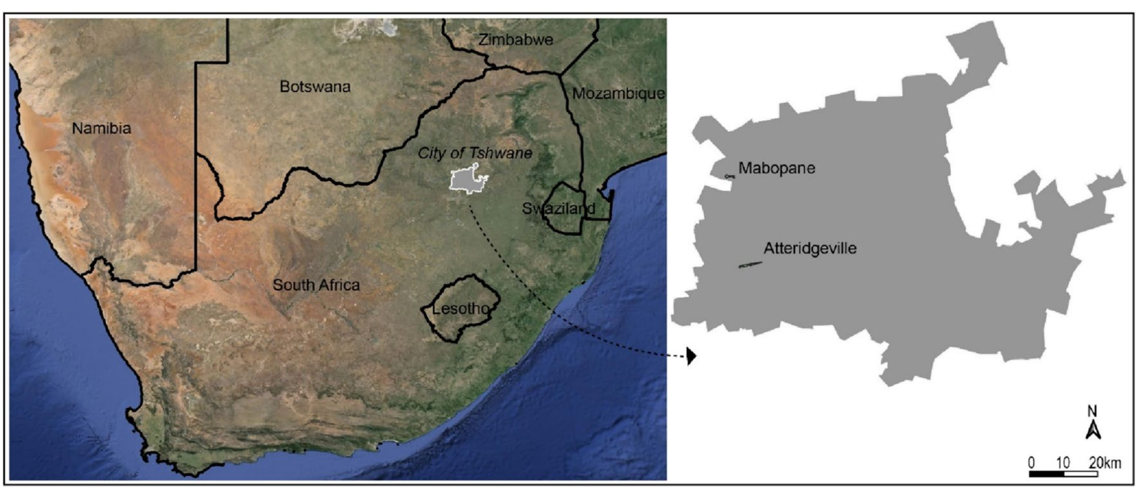


Fig. 1 The study sites were located in City of Tshwane in the Northern part of South Africa

remain currently—green buffers that separate communities—a legacy of apartheid planning. The two green spaces are also the biggest green spaces at the landscape scale. The neighborhoods of Mabopane and Atteridgeville have few small parks, while there are resorts (municipal and privately owned) in both areas, entry is charged and not all residents would be able to afford this.

Both Mabopane and Atteridgeville are former marginalized black-only residential areas and were therefore developed as residential areas only. Retail and commercial insertions occurred post-1994, and even today many commercial activities happen informally with vending stalls along open spaces and main routes or in converted residences on main streets. Formal shopping centers and informal commercial activities, attract vehicle and pedestrian movement in and around the study areas. Both unmanaged green space presents shortcuts, although through the river, to aid pedestrians from walking long distances on formal vehicle routes to get to trading areas.

Atteridgeville is a township area that is historically underserviced by gray and green infrastructure and experiencing rapid inward migration and uncontrolled urbanization. Atteridgeville has a population of approximately 64,425 and a density of 6,500/km^2 (Statistics South Africa 2011). The green space study area is located between two dense residential areas, Lotus gardens and Atteridgeville, which were historically spatially segregated by infrastructure and vacant land because they housed differently raced communities. Two highways and a train track buffers the green space and isolates the Northern neighborhood, Lotus Gardens, (historically Indian neighborhood) from Atteridgeville (historically black neighborhood). The only area where pedestrians can cross the green space and the river is an engineered pedestrian crossing of the highway and river, which is mainly for people from Lotus Gardens to reach the government hospital of Kalafong on foot. This same crossing is used to reach the train station in Atteridgeville that connects to the inner city, and nearby schools and shopping centers across neighborhoods. The green space has little registered use and mostly of informal character including illegal dumping of building material, informal housing and recycling activities, crossing to and from the hospital and train station and some urban agriculture. Formal development into private, high-density housing has started and is planned to continue. The green space is predominantly grassland vegetation and covers 228 ha. It contains a variety of land uses, including recreational and unregulated businesses. The *Skinnerspruit* River runs through the site and is partially channelized with several stormwater outlets discharging into the unchannelized valley bottom wetlands. Current challenges include river degradation, development encroachment, illegal dumping, lack of maintenance, and safety issues.

Mabopane was historically a black-only residential settlement. It is a peri-urban area containing a mix of dispersed land uses, including recreational and green spaces. Mabopane has a population of approximately 110,972 and a density of 2,600/km^2 (Statistics South Africa 2011). The green space is located within a relatively homogenous community and contains an old stadium and a community sports center located at the midwestern end of the green space. In Mabopane there are attractions and destinations on opposite sides of the river aligned unmanaged green space such as shopping center, many schools, and a clinic. Compared to Atteridgeville, the green space in Mabopane have more activities and more formal development including a running stadium used by the community for training, a municipal "sport center" with halls and ablutions, a petrol station, an illegal resort with swimming pools, informal soccer field, vending stall for medicinal plants, food stalls, urban agriculture, urban gardening, vending of gates and security doors, vending and mending of clothing and a car wash area. People from the community are actively preventing informal settlements in the green space. The dominant vegetation is savannah, with intermittent grassland patches and covers 100 ha. A tributary of the Sand River flows through the site and is channelized and canalized at the western and eastern ends where stormwater is led from the residential areas into the green space. Current challenges include open space encroachment, flooding risks, natural wetland deterioration, sewer leaks, safety risks, and dumping of solid waste.

This study was part of a bigger research project and an overview of the involved researchers and stakeholders and the methods have been described by Breed et al. (2023). Additional background information and continuous updates on research activities are available on the project webpage: https://consusresearch.weebly.com/

3 Research methods

3.1 Combining methods

To understand the biophysical and social dimensions of benefit provision from our study sites and translate the results into proposed landscape design initiatives, we used a mixed methods approach combining quantitative and qualitative methods. The biological status of the sites was assessed using a vegetation survey and the social benefits, as perceived by the local community, were assessed using an interview-based survey. A rapid site assessment was used to map and quantify the multifunctional benefits of the site from a landscape design perspective. Below we describe each method in greater detail.

3.2 Vegetation survey

A private consultancy firm was commissioned to assist with a vegetation survey of each study site. The vegetation of both areas was surveyed during January and February 2022, the optimal period for vegetation studies in the summer rainfall area of South Africa. The Braun-Blanquet approach was applied to describe and map the vegetation, and aerial-based remote-sensing platforms (drones) were used to determine vegetation cover. Braun-Blanquet plots (200 m^2) were placed according to a stratified random design based on soil and landscape information and physiognomic differences observed on large-scale aerial photographs and satellite imagery. A total of 24 (Mabopane) and 22 (Atteridgeville) plots were surveyed recording all plant species and classifying them into the following growth form categories: grasses, forbs and woody species (shrubs and trees). Ground cover (trees, shrubs, herbs, open water, rock), and the average height of trees, shrubs and herbs was also recorded. The species plots were used to classify delimited plant communities on ordination analysis with the TWINSPAN algorithm. Canonical correspondence analysis (CCA) based on abiotic factors (altitude from GPS and 5 m digital terrain model, slope (%) from survey and 5 m digital terrain model, wetness Index from 5 m DTM, % clay (A-horizon) from survey, soil depth (mm) from survey, cover bare rock (%) from survey) was used to identify the most important environmental factors for each plant community. Based on this information, the past and present land use from historical aerial images, plant species diversity, and vegetation sensitivity were combined to understand the sites' biodiversity value and characteristics. A full description of the vegetation survey is available online (Appendix A and Appendix B).

3.3 Multifunctionality at sites

Field work was conducted from October 4–15, 2021, to assess and map green space benefits at the two study sites. The data were collected as rapid assessments covering the categories of access, attractiveness, biodiversity, human health and climate benefits. Landscape architects and planners routinely use walking methods and rapid site assessments to qualitatively scope areas to guide their responses and proposals (Kanstrup et al. 2014; Powell 2010). The aim of our mapping was to develop and apply a method for making transect walks more rigorous and quantitative, yet still quick and effective. We developed questions to survey indicators of each category by adapting the Natural Environment Scoring Tool (NEST, Gidlow et al. 2018) and the Green Quality assessment from Greenspace Scotland (Greenspace Scotland 2008) to the local context. The fieldwork was conducted in two steps for each study site. First, researchers walked along transects that ran perpendicular to the surrounding street and that were spaced out at ~ 200-m intervals, and they evaluated the benefits at each transect based on 43 questions. Second, a general evaluation based on 48 questions about benefits was evaluated for the entirety of each site. Questions were co-developed through an inter- and transdisciplinary process between the authors, private and public project partners. The public partners consisted of representatives from the Department of Environmental Management City of Tshwane and Department of Planning, Aarhus Municipality, Denmark. The private partners MdK Architects and Urban Designers, Civil Concepts and Habitat Landscape Architects from South Africa and NIRAS, Denmark. The protocol was presented at a workshop with the partners during September 9 and 10, 2021. Data were collected using the free platform Epicollect (Aanensen et al. 2009). The full field work manual is available in Appendix C, and all collected data are available in Appendix D.

3.4 Community survey

A survey was conducted in October 2021 and March 2022 among 200 residents living near each site. The overall aim was to gain knowledge on how people use their green space, the benefits and risks they see, the values they hold, their involvement in decisions and activities, and their hopes and ideas for change. The survey questions were a combination of closed-ended, open-ended, multiple choice questions and a ranking exercise using graphic icons (Appendix E). Four enumerators familiar with several of the local languages collected the survey responses from willing passers-by through purposeful sampling, seeking representation in terms of gender and age, as well as geographical spread (sampling was divided into five residential zones for each site, and 20 responses were collected in each zone). Data were collected using Epicollect and processed through MS Excel.

3.5 Statistics and data handling

Benefit index values were calculated for each benefit category across all individual transects and jointly for each study site. The index values were calculated by recoding all questions from the transect and site surveys to numeric values between 0 and 1 and calculating the mean across all questions falling within a category.

The community survey explored resident use, activities and benefits from the green spaces (focusing on physical and social access mechanisms). First, descriptive statistics of socioeconomic indicators were calculated for all respondents and aggregated by each study site. Next, exploratory plotting was used to elucidate patterns of use, physical access, activities, and perceived benefits and barriers from the study sites.

Residents' preferences for different vegetation types and fauna were compared to vegetation cover and the presence of livestock and wildlife from the transect data for analytical inference as an indicator of the current overlap between the needs and conditions of the green spaces. All data analyses were performed using the free software R (R Core Team 2022) and Inkscape (Inkscape 2020).

3.6 Ethics statement

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Committee for Research Ethics and Integrity, Faculty of Engineering, Built Environment and Information Technology at the University of Pretoria (reference number EBIT/45/2021, approved April 18, 2021); and the Director of Knowledge Management, City of Tshwane (approved June 17, 2021). All participants were informed about the purpose of the study and possible means of dissemination of the results. Participation was voluntary, with consent and all participants remained anonymous. The study including field work was conducted under the memorandum of understanding (MOU) between University of Pretoria and City of Tshwane, as a joint research activity.

4 Results

4.1 Biodiversity value of green spaces

In Atteridgeville, we found 169 plant species representing 47 plant families and 124 genera (Appendix B). Of the 169 plant species, 103 were forbs (61%), 40 were graminoids (grasses and sedges, 24%) and 26 were woody (trees and shrubs, 15%). In Mabopane, we found 184 plant species representing 52 plant families and 148 genera (Appendix B). Of the 184 plant species, 84 were forbs (46%), 41 were graminoids (grasses and sedges, 22%), and 59 were woody species (trees and shrubs, 32%). For both sites, the species recorded in the plots were representative of the plant species present within the study area based on an asymptotic species-area curve. No threatened Red Data-listed species were recorded, but six regionally protected plant species were recorded in Mabopane and five in Atteridgeville (Appendix F). Fifteen and 16 invasive plant species, 16 and nine plants with medicinal properties, and 28 and 11 plant species beneficial to butterflies and birds were recorded in Mabopane and Atteridgeville, respectively.

Based on the historical images from 1969, large parts of the study sites have been used for cultivation and forestry, indicating that most of the vegetation is secondary and only a few patches could potentially be remnant primary vegetation. Human-influenced areas covered 27% of Mabopane and 17% of Atteridgeville, indicating that 73 and 83% of the sites, respectively, are in relatively natural conditions. For both sites, the lowest vegetation sensitivity occurred in the most human-influenced areas, where most of the natural vegetation was replaced by hard surfaces, and the wetland areas around the rivers which had a low number of plant species, were heavily polluted and were infested with invasive species (Fig. 2). The most sensitive vegetation communities were in the dry, terrestrial areas due to the high number of native plant species.

4.2 Characteristics of green spaces

The two study sites differed in both the amount and qualitative characteristics of green space. Atteridgeville generally scored lower than Mabopane across benefit realms (Table 1).

The overall multifunctionality score was 0.64 for Mabopane and 0.25 for Atteridgeville on a scale of 0–1, showing potential for improvement. Specifically, Atteridgeville scored lower than Mabopane on physical access, health and community indicators, and both scored 0 for attractiveness. Atteridgeville scored slightly higher on biodiversity. The higher access score for Mabopane was mainly due to roads having low amounts of traffic and the presence of parking facilities (Appendix D). Higher health scores were due to Mabopane's formal and informal sport facilities and facilities for children's play and socializing, and higher community scores were due to being more physically accessible to the community and contributing to a sense of local identity (Appendix D). Both sites scored "to some degree" on having the right amount of space and quality for biodiversity, but Atteridgeville scored slightly higher than Mabopane, as measured by the combined biodiversity indicator. This was mainly due to higher scores for water features and scenic views.

Maps of the transects showed that specific areas of the green spaces scored high or low across all indicators of benefits (e.g., Mabopane around the stadium and Atteridgeville at its extremities; Fig. 3). Other areas scored high or low on specific indicators (e.g., the northeastern parts of Mabopane scored low on attractiveness but high on health, and the middle southeastern parts of Atteridgeville scored high on biodiversity and low on attractiveness). Consequently, some areas already provide multiple benefits, whereas other areas provide only low levels of benefits.

4.3 Community characteristics

The residents interviewed had a similar distribution across socio-economic and cultural groups, except that more students in Atteridgeville and more women in Mabopane were interviewed (Table 2). The majority had completed high school education, earned between R5.000 and R10.000/month, identified as Christians and had an urban upbringing. A similar number of garden owners and users of their

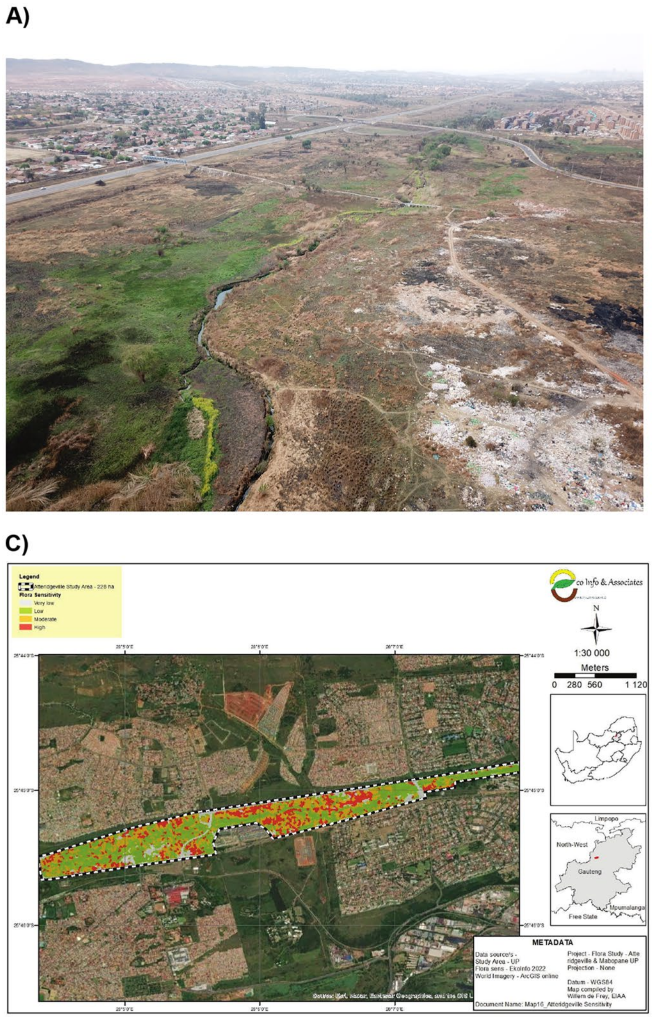


Fig. 2 Condition of study sites and vegetation sensitivity. Drone photographs were used to get an overview of the condition of each study site and capture the potential and challenges of these unmanaged green spaces. Vegetation diversity was mapped using the Braun-Blanquet method, and vegetation communities was classified based on landscape information and physiognomic differences. The current sensitivity of each plant community was estimated from plant species composition and anthropogenic impacts derived from historical aerial images. Sensitivity was ranked from very low to high. **A** The river flowing through Atteridgeville is unchannelized but threatened by pollution from illegal dumping of waste (white patches), **B** physical access to the green space in Mabopane is high due to the close proximity to the local community and presence of minor, slow moving roads, **C** vegetation sensitivity map of Atteridgeville, **D** vegetation sensitivity map of Mabopane. Photographs by (blinded for peer review)

respective green spaces were interviewed at each study site. Less than half of the participants were willing to state their income, but almost all participants answered all the other questions.

4.4 Benefits to people

Most residents went to the green spaces daily, got there by foot and spent < 10 min of transportation time (Fig. 4). They either passed through or spent > 2 h in the green space and generally visited alone.

Only 6% of residents perceived mental and physical health as a direct benefit from the spaces but contact with nature was ranked as the single highest perceived benefit, followed by clean air and providing transit routes (Fig. 5). Time with friends and relatives, time alone and mental health were ranked the lowest. Benefits related to "Health" were experienced by 19.2% of respondents as well as benefits related to "Utility" (18,9%) and "Identity" (38.5%, Fig. 5). More people in Atteridgeville than in Mabopane reported benefits from the green space primarily driven by benefits related to "identity". In particular, the benefits "Peace and silence", "Contact with nature" and "Open space—less crowding"

Table 1 Multifunctionality assessment of study sites

	Mabopane	Atteridgeville
Typology	Semi-natural/natural	Semi-natural/natural
AMOUNT of open space suitable for recreation (informal games, play and walking)	A lot	None
AMOUNT of open space suitable for biodiversity (native, undisturbed vegetation and water features)	To some degree	To some degree
AMOUNT of open space suitable for climate change adaptation and mitigation (alleviating storm water and heat)	To some degree	To some degree
QUALITY of open space suitable for recreation (informal games, play and walking)	Good	None
QUALITY of open space suitable for biodiversity (native, undisturbed vegetation and water features)	To some degree	To some degree
QUALITY of open space suitable for climate change adaptation and mitigation (alleviating storm water and heat)	To some degree	To some degree
Indicators of benefits		
Access	0.64	0.25
Attractiveness	0.00	0.00
Biodiversity	0.22	0.24
Health	0.47	0.14
Community	1.00	0.40
Climate	0.75	0.25
Total index value	0.64	0.25

The typology, amount and quantity of space were evaluated as a total by walking on perpendicular transect lines across each site every 200 m (see Fig. 2 for maps of transect lines)

Individual index values were calculated by recoding all questions on the site survey to numeric values between 0 and 1 and calculating the mean across all questions for each indicator

were important (Appendix H). In general, reported activities and benefits were relatively similar across the two sites.

4.5 Social access as a prerequisite for benefitting

When survey respondents were asked what shapes people's ability to benefit from the green space, several aspects were raised. Knowledge about animals and plants, social relations/network, physical distance, and the ability to avoid crime were some of the most frequent answers, indicating that several barriers rooted in sociopolitical structures and processes must be overcome to experience the benefits listed above. Similarly while 83.8% of respondents expressed a willingness to participate in community-driven activities (e.g., facility maintenance, community patrols, gardening, or youth education), many felt held back by time and resource constraints, concerns for their safety, and lack of organization and opportunities for involvement (Pasgaard et al. 2023, pp. 5–6). In particular, residents expressed an association between dense vegetation and danger to personal safety.

4.6 Biodiversity and community benefits

Considering people's preferences for their green space relative to the conditions of the sites provides an indication of the current benefit overlap between benefits for communities and biodiversity. "Access to nature" was ranked relatively low in importance by respondents for well-being. Instead, "secure employment" and "safety from crime" ranked highest for both sites (Fig. 6). Access to nature was ranked higher by Mabopane residents, and "secure employment" and "safety from crime" was ranked highest by residents of both sites (Appendix G).

Open vegetation and ornamental plants had high preference among residents, and closed vegetation and wildlife had low preference (Fig. 7). From the transects, we found that both sites had a mixture of vegetation classes, with 1/3–1/4 of transects having > 25% tree and shrub cover (Fig. 7). Ornamental plants were rarely present and were poorly maintained. Smaller wildlife, such as birds, reptiles and mammals, were present at both sites. These findings indicate both overlaps and discrepancies between community preference and the vegetation and wildlife at the sites.

5 Discussion

Our study shows that unmanaged urban green spaces in South Africa provide multifunctional benefits for people and biodiversity despite disturbance, pollution, and lack of amenities. Parts of the study sites were transformed by human activities and use, but the majority of the areas retained natural vegetation and contained protected plant species and wildlife. People from the surrounding communities used green spaces for different activities, such as active and passive leisure, and perceived a variety of benefits related to health, identity and utility. Broadening the access perspective to include barriers and constraints on people's ability to benefit and be involved in activities in green spaces, the findings show that benefits were socially determined by factors such as knowledge, relations, and safety.

5.1 Mapping multifunctional benefits

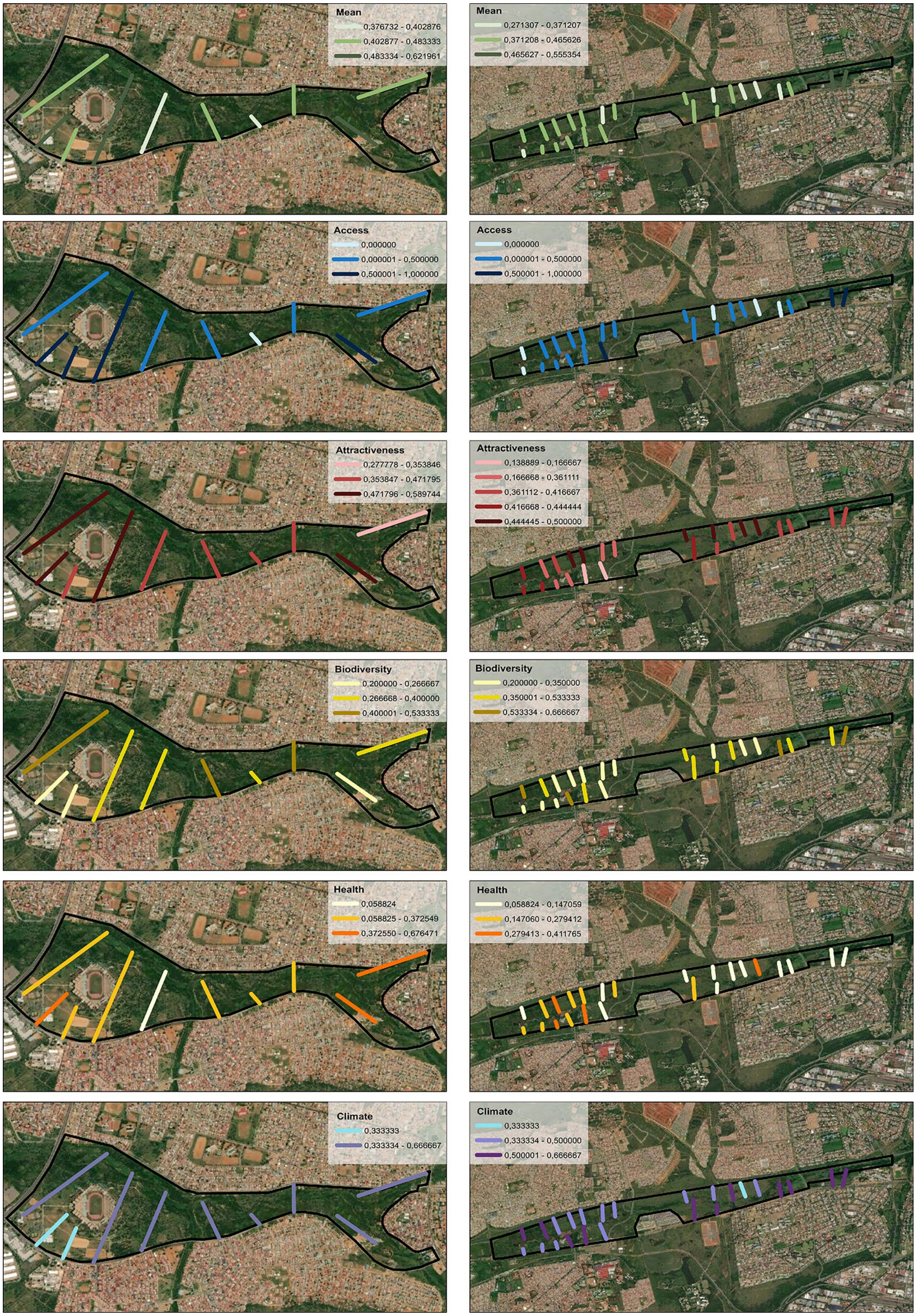
The sites were characterized by a variety of land use, with most of the space being covered by natural vegetation and some areas being used for mainly recreation, sports or economic activities, but the sites generally had limited formal physical access, few amenities and low-to-medium benefit provision. The overall multifunctionality score showed that both sites have the potential to improve and increase their benefit provision, as the maximum indicator score was only achieved for the community category in Mabopane. Most benefit indicators were less than half of the maximum possible score, signaling strong potential for improvement by targeting benefit provision and restoring local biodiversity.

Most of the sites contained native vegetation and protected plant species, illustrating that unmanaged green spaces also provide benefits for biodiversity. Attractiveness was generally low, and littering and illegal dumping were prominent at both sites consistent with an estimated 29% of domestic waste not being collected as a municipal service (Rodseth et al. 2020, p. 5). Exposure to waste not only lowers the attractiveness of green space, but has also been linked to harmful effects on the health and wellbeing of communities (Tomita et al. 2020, pp. e230–e231) and compromises biodiversity through localized extinction (Schell et al. 2020, p. 8). Invasive species were also recorded and pose additional threats by outcompeting or harming native species and can lead to extinction by interacting with habitat loss and climate change (Brook et al. 2008, p. 459). Urban green space can be valuable habitat for birds (Mbiba et al. 2021, p. 104,094; McPherson et al. 2019, p. 184) and mammals (Ofori et al. 2018, pp. 479–480) in Sub-Saharan Africa, and our study shows that even unprotected, unmanaged urban green spaces can contain protected plant species and wildlife. Providing a variety of habitats, patches of connected vegetation and naturalized, clean water features are key ecological features to consider in biodiversity-inclusive landscape design, and management should target rehabilitation actions such as cleaning up waste and combatting invasive species to increase and protect diversity (Beck 2013, Chapter 4; C. A. Breed 2020; Rottle & Yocom 2010, pp. 12–17) and improve the quality of human–green space experiences. The vegetation sensitivity of terrestrial parts of the sites shows the importance of protecting drylands, as greenbelts through cities, as well as rivers.

5.2 Activities and benefits identified and accessed by local communities

Respondents identified varied activities and derived benefits from their green spaces. Green spaces were used by most residents in some way, even if only for transit. In a context where most people are poor and living in peripheral locations in a city, non-motorized transport is an important mode of movement (Behrens 2004, p. 334) and can provide additional health benefits, especially in and/or around green spaces (van den Bosch and Ode Sang 2017, p. 378). Walking in safe and attractive green spaces provides physical, mental and social health benefits (C. J. Gidlow et al. 2012, pp. 347–349; Sugiyama et al. 2008, p. 3) and can help alleviate everyday life stress (Bratman et al. 2015, pp. 8568–8669). However, in the developing world, conditions such as those associated with South Africa's urban poor, green spaces are often perceived as unsafe or even dangerous (Graham 2015, p. 28). Fear expressed by residents in our study aligns with a study undertaken in Cape Town linking poverty to threats of physical violence to humans and threats to biodiversity (Graham 2015, pp. 27–28) and emphasizing a need to address the sense of safety as a pathway to accessing the benefits of nature. Our study reveals how local perceptions and conditions call for a nuanced interpretation of the observed and recorded benefits, especially in light of the social and political factors shaping individual people's access as understood as a person's ability to benefit (Ribot and Peluso 2009, p. 154). Notably, this ability is not equal across ethnicity, income level, gender, or political connection (Ernstson 2013, p. 14; McKay and Tantoh 2021, pp. 2185–2186; Paganini and Lemke 2020, pp. 1002–1003).

The most common activity was active leisure, with passive leisure ranking third—both were frequently mentioned as important pathways connecting green spaces and health (Lachowycz and Jones 2013, pp. 65–67; Reyes-Riveros et al. 2021, pp. 2, 7). Benefits relating to identity and health were more frequently perceived as benefits from the green spaces. This contrasted with the utility benefits identified in other South African studies (C. M. Shackleton et al. 2017, p. 1884; S. Shackleton et al. 2015, pp. 79–82) but coincides with long-term studies and in-depth interviews by (Cocks et al. 2016, pp. 828–834) from the Eastern Cape. Their findings show benefits for well-being and identity formation that bind people to a shared heritage. These findings support our


Mean
0,376732 - 0,402876
0,402877 - 0,483333
0,483334 - 0,621961
Mean
0,271307 - 0,371207
0,371208 - 0,465626
0,465627 - 0,555354
Access
0,000000
0,000001 - 0,500000
0,500001 - 1,000000
Access
0,000000
0,000001 - 0,500000
0,500001 - 1,000000
Attractiveness
0,277778 - 0,353846
0,353847 - 0,471795
0,471796 - 0,589744
Attractiveness
0,138889 - 0,166667
0,166668 - 0,361111
0,361112 - 0,416667
0,416668 - 0,444444
0,444445 - 0,500000
Biodiversity
0,200000 - 0,266667
0,266668 - 0,400000
0,400001 - 0,533333
Biodiversity
0,200000 - 0,350000
0,350001 - 0,533333
0,533334 - 0,666667
Health
0,058824
0,058825 - 0,372549
0,372550 - 0,676471
Health
0,058824 - 0,147059
0,147060 - 0,279412
0,279413 - 0,411765
Climate
0,333333
0,333334 - 0,666667
Climate
0,333333
0,333334 - 0,500000
0,500001 - 0,666667

◂**Fig. 3** Distribution of health, ecological and climatic benefits of study sites. The lines show the position of each transect (walked on foot), and the color indicates the score of a given benefit indicator—light colors indicating a low score and dark colors indicating a high score. Index values were calculated by recoding all questions on the transect survey to numeric values between 0 and 1 and calculating the mean across all questions for each indicator and transect line

findings since the most frequently perceived benefit by people was contact with nature.

Few studies have explored the variety of relationships with nature that exist in the African context, but evidence points to deep identity-related and spiritual connections with nature in urban areas (Ngulani and Shackleton 2019, pp. 99–101), specifically in relation to native species (C. A. Breed 2022, p. 11; Cocks et al. 2016, p. 822). Our study thus provides support for a beneficial human–green space relationship in a Global South context, emphasizing how improving urban green spaces may be key to achieving healthy, sustainable urban living. South African cities are generally greener than most Global North cities (C. M. Shackleton et al. 2018, p. 278), but the distribution and access to green space are highly unequal (McConnachie and Shackleton 2010, p. 247; C. M. Shackleton and Gwedla 2021, p. 3; Venter et al. 2020, p. 6). Considering the various sociopolitical aspects shaping residents' benefits from and involvement in their green spaces, urban planners and ecologists alike face many interrelated challenges complicating the creation of green, equitable cities—challenges that should be taken up jointly across disciplines, sectors, and stakeholders given their historical, ecological, social and political complexities (see, e.g., Cilliers et al. 2014, pp. 264–265; Cockburn et al. 2016, pp. 28–29).

5.3 Overlap between green space characteristics and people's preferences

Residents expressed preferences for open vegetation. Based on the vegetation survey, these sites contain a mixture of shrubland and grassland vegetation types. Consequently, people's desired vegetation type matches the natural state of these green spaces or reflects their relational affinity to the regional vegetation, as claimed by Cocks et al. (2016, p. 822) and Breed (2022, p. 8). However, parts of our study sites are ecologically deteriorated by pollution and illegal dumping of solid waste and are at risk of being overgrown with shrubs and trees. Overgrown savanna systems indicates an unbalanced ecosystem that lacks ecological dynamics such as fire and grazing (Boon et al. 2016, p. 5). Parts of the sites are impacted by past agricultural practices, and the native species are threatened by the presence of invasive alien species. Together, these threats compromise the provision of high-quality green space benefits that both fulfill community desires and aid local biodiversity. Thus, engaging local communities in managing such sites for biodiversity could create synergistic effects and increase the value of green spaces (Felappi et al. 2020, pp. 9–10; van Zyl et al. 2021a, b, pp. 124–125). Secure employment was ranked as the most important factor for mental well-being, and local co-management and informal green entrepreneurship could potentially create essential work opportunities and equally improve the biological condition and communities' benefit provision.

Residents expressed preferences for ornamental plant species, but some ornamentals, such as morning glory found at the site, are invasive alien species that, by law, should be removed (National Environmental Management of Biodiversity Act (NEMBA), 10 of 2004). Residents also feared wildlife, and human−wildlife conflict is a risk that must be mitigated even in urban areas (Soulsbury and White 2015). In addition, safety from crime was ranked high as a prerequisite for well-being. Although tree height and basal cover demonstrably show weak relationships with crime (Escobedo et al. 2018, p. 588), other studies note that dense vegetation reduces the actual and perceived safety and ability to benefit from green spaces in the Global South (Junior & Santos, 2017, pp. 15–16) consistent with our finding of residents' preference for open vegetation. Individual factors such as gender and age influence fear of crime in urban green spaces (Sreetheran and van den Bosch, 2014, p. 3), which shows that we need to improve our understanding of local community needs. These points illustrate the potential for conflict between people and biodiversity benefits, but also show that they may be alleviated through co-management and co-design that specifically targets local nature appreciation through environmental education and creating safe spaces around ecologically sensitive areas.

5.4 From mapping to design interventions

Mapping the spatial distribution of benefit indicators shows how targeted management and design interventions could improve multifunctionality, e.g., by improving climate, safety or biodiversity benefits around the sports stadium in Mabopane, which already scored high for health benefits and physical access. Likewise, interventions targeting health benefits (e.g., sports facilities) in low-scoring Atteridgeville could be placed along the southeastern disturbed edge, which has low biodiversity value and is close to the community. The maps also show a tradeoff between physical access and the condition of the green space; for example, the relatively inaccessible parts of Atteridgeville's northeastern edge, which are along a highway, scored high on attractiveness due to the absence of littering and vandalism.

In the Global South, green spaces have a poor track record of being "protected" through fencing (Pekor et al. 2019) as fences have negative associations which can lead

Table 2 Characteristics of the study population

	Total	Atteridgeville	Mabopane
Respondents (*n*)	200	100	100
Sex	(*n* = 200)	(*n* = 100)	(*n* = 100)
Female	53,5% (107)	51% (51)	56% (56)
Male	46,5% (93)	49% (49)	44% (44)
Age	(*n* = 200)	(*n* = 100)	(*n* = 100)
Mean age (SD)	32.5 (12.8)	31.4 (12.6)	33.5 (12.9)
Education	(*n* = 191)	(*n* = 97)	(*n* = 94)
completed some schooling	13,6% (26)	12,4% (129	14,9% (14)
completed matric	37,7% (72)	32,0% (31)	43,6% (41)
completed diploma or degree	30,9% (59)	30,9% (30)	30,9% (29)
studying undergraduate currently	16,2% (31)	21,6% (21)	10,6% (10)
completed postgraduate degree	1,6% (3)	3,1% (3)	0,0% (0)
Income	(*n* = 74)	(*n* = 42)	(*n* = 32)
Below R5000/month	39,2% (29)	35,7% (15)	43,8% (14)
R5 000-R10 000/month	36,5% (27)	42,9% (18)	28,1% (9)
R10 000-R20 000/month	17,6% (13)	14,3% (6)	21,9% (7)
R20 000-R30 000/month	6,8% (5)	7,1% (3)	6,3% (2)
Faith	(*n* = 193)	(*n* = 96)	(*n* = 97)
African traditional	2,1% (4)	4,2% (4)	0,0% (0)
Christian	60,1% (116)	61,5% (59)	58,8% (57)
Interdenomination	1,0% (2)	1,0% (1)	1,0% (1)
Non-religious	40,4% (78)	37,5% (36)	43,3% (42)
Upbringing	(*n* = 200)	(*n* = 100)	(*n* = 100)
Urban	56,5% (113)	44% (44)	69% (69)
Rural	8% (16)	10% (10)	6% (6)
Unclear	35,5% (71)	46% (46)	25% (25)
Garden owners	(*n* = 200)	(*n* = 100)	(*n* = 100)
Yes	53,5% (107)	47% (47)	46% (46)
No	53,5% (93)	53% (53)	54% (54)
Users of green space	(*n* = 200)	(*n* = 100)	(*n* = 100)
Yes	89% (178)	87% (87)	91% (91)
No	11% (22)	13% (13)	9% (9)

N shows the number of answers for each variable used to describe the study population, and (%) shows the percentage

Columns show the value across all answers and for each study site separately

to vandalism while also causing secluded areas and safety concerns. In South Africa, fenced conservation areas remain controversial with local communities because fences compromise access (Spierenburg and Wels 2016, p. 302) and can be detrimental to wildlife migration (Løvschal et al. 2017, p. 4; Pekor et al. 2019, p. 73). High scores on physical access and attractiveness are seen on the southern side of the stadium in Mabopane, illustrating that access and community use do not necessarily lead to littering or vandalism. The need for changes in policy to involve local communities in the management of protected areas has been emphasized, especially due to the historic legacy of racial exclusion from conservation areas (Hoole and Berkes 2010, p. 313; Spierenburg and Wels 2016, p. 306; Twyman et al. 2001, pp. 11–12); therefore, we argue that co-management, and not fences, should be extended to urban green spaces.

5.5 Holistic interventions for improving multifunctionality

Using an inter- and transdisciplinary approach, we found that unmanaged green spaces provide multifunctional benefits for biodiversity and people, and we have shown that there is also potential to increase the provision of benefits through strategic planning and holistic landscape design. There are potential trade-offs between managing the sites for biodiversity and community needs, as native species may be threatened by greater use and installation of amenities, but co-management and appropriate levels of usage can lead to more benefits for both biodiversity and people (Mauerhofer et al. 2018, p. 60; Schultz et al. 2011, pp. 664–665). These trade-offs must be transparently weighed and discussed to reach sensible outcomes for long-term, sustainable benefits (O'Farrell et al. 2019, p. 5). Left unmanaged, the spaces risk further environmental degradation and being perceived as overgrown, crime-filled wastelands without community ownership. Finally, in response to housing needs, these spaces are at risk of being lost to encroachment of high-density residential formal development and uncontrolled informal settlements.

To achieve multifunctional socioecological benefits, planning and landscape interventions should be jointly planned across public entities together with community stakeholders to adequately address needs and implement strategic, context-specific practices and designs (Benedict and McMahon 2002, p. 17; C. Breed and Mehrtens 2022, p. 16; Jabeen et al. 2021, p. 72; Kondo et al. 2015, pp. 806–807). Following ongoing collaboration with City of Tshwane city planners, we provide the following examples of concrete initiatives to bridge socioecological perspectives and landscape design for biodiversity and people in green space planning (Fig. 8):

(a) Conserve existing natural habitats to prevent habitat loss and ensure green space provision and climate change benefits, such as mitigation of flooding and the urban heat island effect
(b) Limit habitat fragmentation by establishing green/blue corridors for plant and animal dispersal in combination with non-motorized transport routes where people can move while appreciating contact with nature
(c) Clean dumping areas and chemical pollution and discourage littering and dumping of waste by encouraging

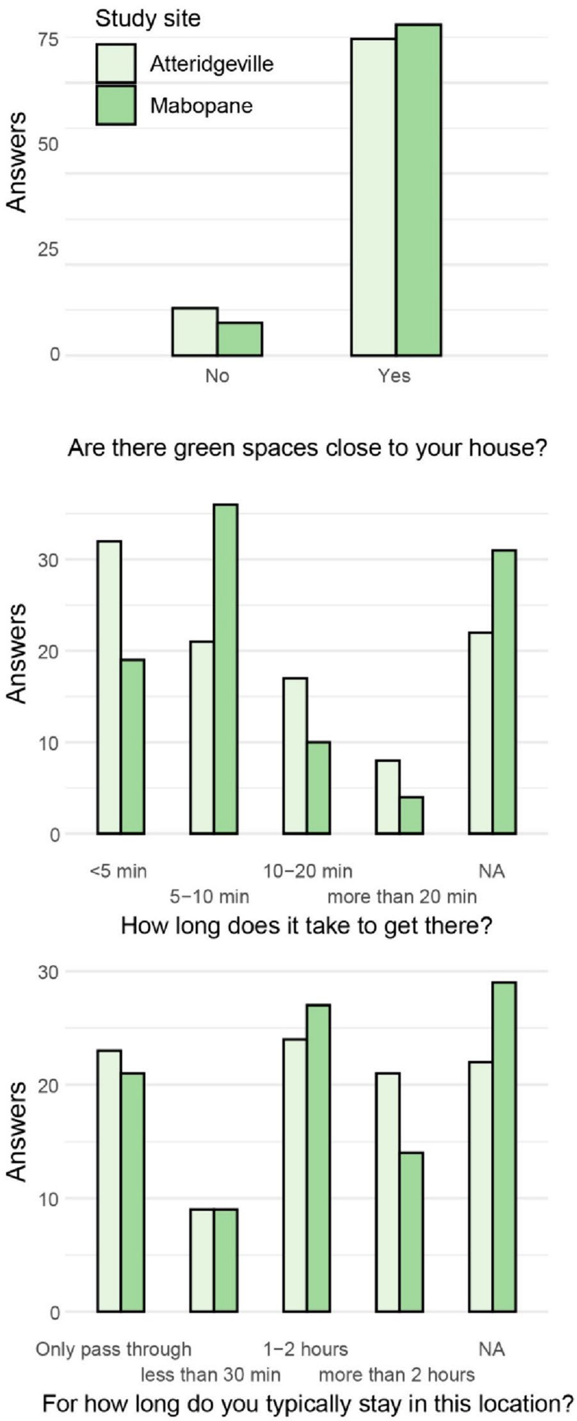


Fig. 4 Use of local unmanaged green space by residents of the community. Bars show the answers from the community survey, and show results from the combined answers across both study sites. The count represents the number of answers to a given question. If visits were prolonged (28% of responses), most residents used the spaces for active (45%, sports, playing, relaxing or socializing) or passive leisure (23%, relaxation/meditation, spiritual use, Fig. 5). A few people used the spaces for economic activities (3.6% for collecting animals and/or plants and/or business/trading/paid work) or spiritual purposes (1.8%)

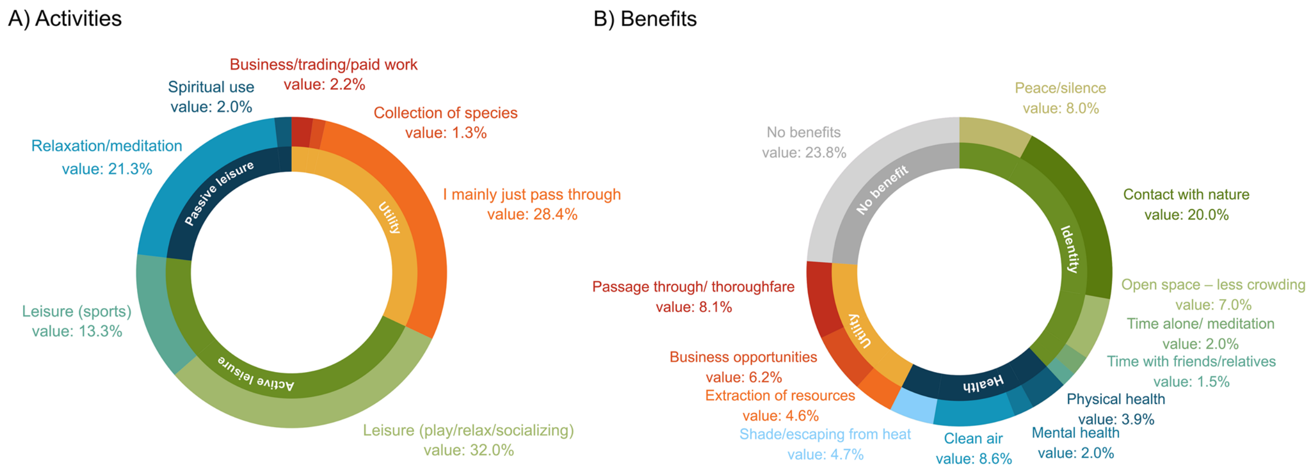


Fig. 5 Activities and benefits gained from unmanaged green space by residents of the community. Activities and benefits are based on answers from the community survey across both study sites ($n = 200$, 100 at each site). Numbers show the total percentage of a given answer. Activities were grouped in categories utility, active leisure and passive leisure, and benefits were grouped in categories identity, health and utility

environmentally safe recycling activities that support economic activities and enhance local ownership

(d) Restore native vegetation by removing alien invasive species, reestablishing native plant species in degraded areas and ensuring a variety of habitats through community actions that create jobs and preserve green spaces for different activities and uses

(e) Reintroduce ecological dynamics such as fire, grazing by livestock or wildlife, river restoration and dispersal and promote high-quality nature-human experiences

(f) Improve physical access through design that targets access, use and safety by improving visual access and surveillance while circumventing ecologically sensitive areas

(g) Reduce barriers that limit social access through, e.g., safety measures, knowledge cocreation campaigns for sustainable use, inclusion in codesign processes, joint management and maintenance activities and supporting local NGOs

h) Balance use and overexploitation through educational activities and community initiatives strengthening social connectivity and nature appreciation through enhanced ownership and care

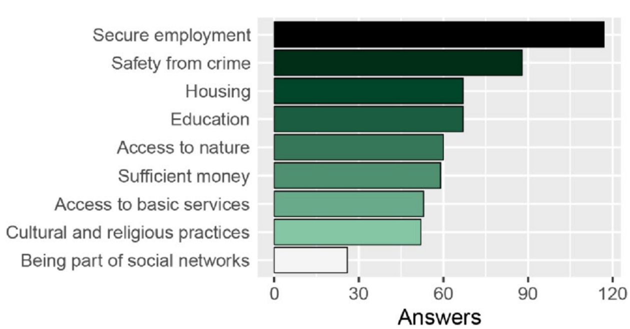


Fig. 6 Rating of the most important factors for well-being by community residents. Residents were asked to rank their top 3 factors for well-being from a list of nine options, and the count shows the number of answers for each factor. Answers indicate the total across the two study sites

5.6 Strengths and limitations

The major strength of this study is the interdisciplinary approach combining an ecological survey, community perceptions and rapid assessment of multifunctionality in South Africa, which provided us with detailed local-scale information about people's uses and preferences for their green space in relation to the actual qualitative state of the green spaces. This combination of ecological, social, and design methodologies and perspectives is, to our knowledge, unique and provide a more rigorous and intentional scoping assessments than traditionally undertaken in design disciplines. The study provides much-needed evidence on the human–green space relationship for low-income urban communities in a Global South context. However, the study also had weaknesses: (1) Only two study sites were analyzed, (2) only 100 people were interviewed at each study site, and representativeness may be low due to people's availability and willingness to participate, (3) the vegetation survey and transects were conducted once and represent a snapshot of the conditions (therefore, they are missing seasonal variation), (4) the multifunctionality transects were done by the researchers and may not accurately reflect benefits for the local residents, and (5) the relationship between green space and benefits was based on self-reported perceptions and should thus not be considered causal. Future studies should

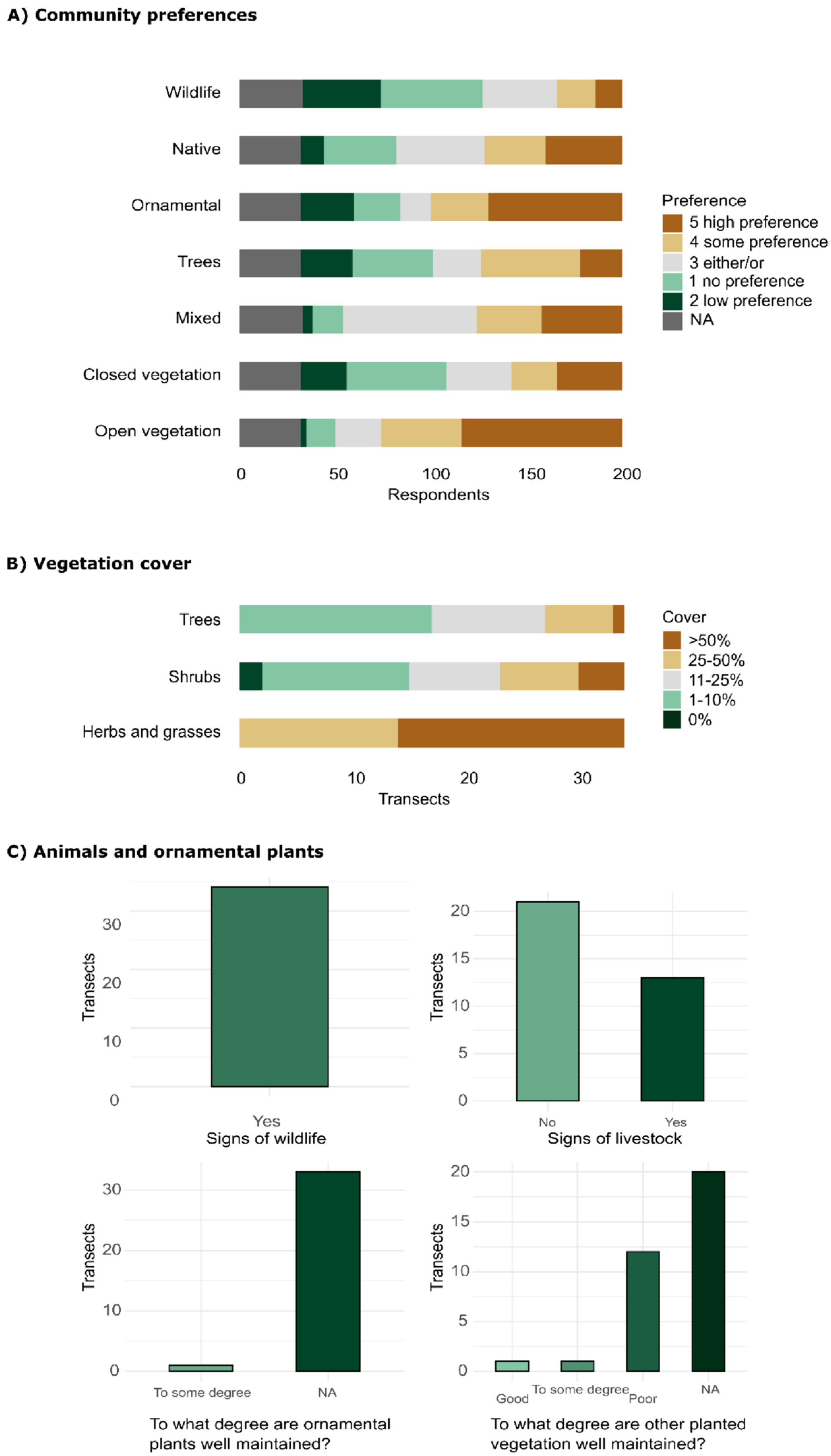


Fig. 7 Community preferences for and vegetation types from transects. **A** Residents' preference for vegetation types and wildlife was derived from the community survey, where residents were asked to rank each vegetation type and wildlife on a scale from 1 (no preference) to 5 (high preference). **B** The actual vegetation type present at study sites was recorded as % cover of each transect line. **C** Signs of livestock and wildlife were recorded as yes/no for each transect and the condition of ornamental and planted vegetation was noted on a scale from poor to good or not present (NA)

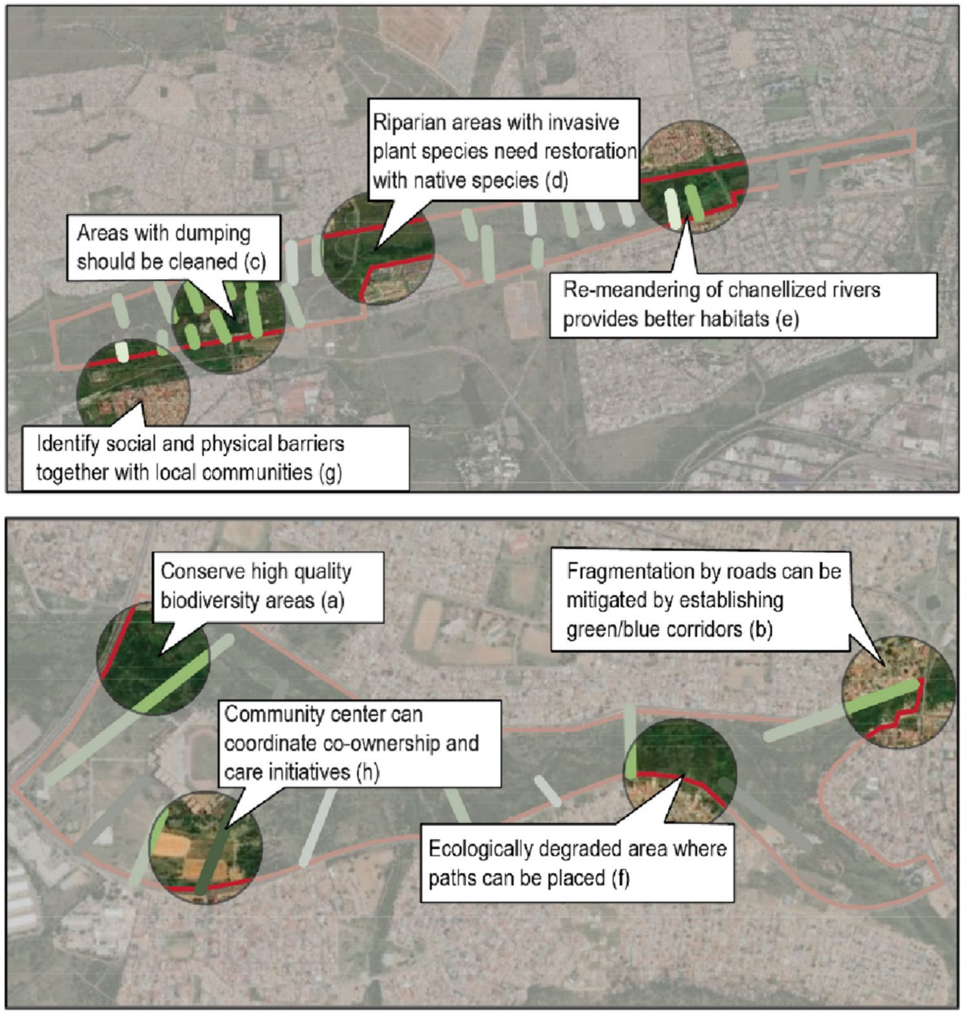


Fig. 8 Applying ecology and landscape initiatives for biodiversity and social benefits to our study sites for improving multifunctionality. Letters in parentheses matches local interventions to ecology and design initiative from the text. Lines show the multifunctionality score (Fig. 3) with light colors indicating a low score and dark colors indicating a high score

investigate stronger transdisciplinary collaborations in and outside academia, quantifying human–green space relationships more strongly through longitudinal studies covering longer time frames and more study sites and creating landscape design with space for ecological dynamics to support biodiversity.

6 Conclusion

In this study, we found that unmanaged urban green spaces provide space for uses and activities linked to the perception of a range of benefits for low-income residents in urban neighborhoods within South Africa's capital. We also found that these spaces have considerable biodiversity value as habitat for protected plants and wildlife. However, the spaces are threatened by urban densification, poor management, safety concerns, and pollution. Benefit provision and access can be enhanced through strategic and inclusive planning and design that builds upon trans- and interdisciplinary collaboration and green space co-management. Inter- and transdisciplinary collaboration requires commitment to the process as it will take more time and effort than disciplinary research, but these investments are outweighed by the resulting holistic and actionable solutions. Establishing trust and strong communication between team members is essential, and having collaboration as an explicit goal from the beginning is recommended. Furthermore, in light of climate change predictions for South Africa, which outline a future with a higher risk of the heat island effect and severe flooding, urban green spaces can be a part of nature-based solutions and increase resilience, making their protection and optimization for multifunctionality an urgent matter. People living in the poorest communities often have less physical and social access to public and private recreational green space, and these unmanaged green spaces should be protected and managed for equitable ability to benefit and for biodiversity protection and restoration. From a Global South perspective, this study provides much needed evidence of an already established positive relationship between green spaces and people, but also provides evidence of a broader range of perceived benefits. The study adds to existing knowledge by outlining a transdisciplinary approach to data collection and illustrating how local context and complex challenges must be considered in holistic green space provision strategies and development plans.

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Declarations

Conflict of 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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