Global Ecology and Conservation 33 (2022) e01972

Contents lists available at ScienceDirect

Global Ecology and Conservation

journal homepage: www.elsevier.com/locate/gecco

The prevalence, composition and distribution of forageable plant species in different urban spaces in two medium-sized towns in South Africa

Hesekia Garekae[a,*], Charlie M. Shackleton[a], Gaolathe Tsheboeng[b]

[a] *Department of Environmental Science, Rhodes University, Makhanda 6140, South Africa*
[b] *Department of Biological Sciences, University of Botswana, Private Bag UB0074, Gaborone, Botswana*

ARTICLE INFO

Keywords:
Diversity
Indigenous species
Livelihoods
Plant communities
Provisioning services
Urban foraging

ABSTRACT

Globally, the importance of urban vegetation in the quality and maintenance of life in urban areas is increasingly recognized. As the basis of urban green infrastructure, urban vegetation provides a diversity of ecosystem services, including provisioning services. However, there is limited understanding of the potential of urban vegetation as a supply of forageable resources within urban landscapes. This study examined the prevalence and distribution of forageable plant species across different spaces in the towns of Potchefstroom and Thabazimbi, South Africa. A multi-stage sampling technique was employed for selecting study sites, with a total of 136 plots sampled. In total, 88 plant species (foraged and forageable) were encountered across the sample plots, with almost three-quarters (70%) being indigenous to South Africa. Most of the species had multiple uses, with medicine, food and firewood being the most common uses, in order of frequency. Species cover and richness significantly differed across the urban spaces, being markedly higher in protected areas as compared to other spaces. Moreover, five plant communities were identified, resembling various species uses. Overall, the findings show that the fragmented urban spaces are endowed with a diversity of forageable plant species, with many valuable to particular sectors of urban society, such as foragers. Moreover, the notable number of forageable plant species encountered across the different spaces demonstrates the potential of urban green infrastructure as a supply of provisioning and cultural ecosystem services. This provides the basis for the selection of a diversity of species in urban greening programs for enhancing liveability and overall well-being in urban areas.

1. Introduction

Globally, the importance of urban vegetation in the quality and maintenance of life is increasingly recognized (Larondelle and Strohbach, 2016; Hurley and Emery, 2018; Caliskan and Aktağ, 2019). As the basis of urban green infrastructure, urban vegetation provides diverse ecosystem services such as provisioning, regulating, supporting and cultural services (TEEB, 2011; Haase et al., 2014) and thus nature's benefits to people. Provisioning services include tangible benefits derived from ecosystems such as food, raw materials, fresh water and medicinal resources (Haase et al., 2014; McLain et al., 2014; Shackleton et al., 2015; Russo et al., 2017), while regulating services maintain the ecosystem functions such as air quality, flood control and carbon sequestration (Nolon, 2016; Masoudi

---

[*] Correspondence to: African Climate & Development Initiative, University of Cape Town, Rondebosch 7701, South Africa.
E-mail address: garekae@yahoo.com (H. Garekae).

https://doi.org/10.1016/j.gecco.2021.e01972
Received 5 April 2021; Received in revised form 1 November 2021; Accepted 12 December 2021
Available online 15 December 2021

and Tan, 2019). Cultural services are intangible, psychological, spiritual and cognitive benefits enjoyed through human-biodiversity interactions such as tourism, recreation, aesthetic inspiration, spiritual, mental and physical health well-being (Nazir et al., 2014; De Lacy and Shackleton, 2017a). Supporting services are existential to other ecosystem services through providing conducive environments for plants, animals and microorganisms to survive, diversify and adapt to changing dynamics (Haase et al., 2014). These ecosystem services play a vital role in enhancing urban liveability and promoting sustainable cities (Russo et al., 2017; Caliskan and Aktağ, 2019). Moreover, urban vegetation is essential in establishing and strengthening social ties within neighborhoods (Gopal and Nagendra, 2014), a phenomenon critical for community resilience and adaptation to many urbanization challenges. Over and above, urban vegetation is often the only avenue for human-biodiversity interaction in urban areas (Jaganmohan et al., 2012).

Although there is abundant literature on urban vegetation and ecosystem services, a greater proportion of the literature has largely concentrated on non-consumptive benefits such as recreation and regulating functions (Shackleton, 2012; Poe et al., 2013; Russo et al., 2017; Hurley and Emery, 2018). In contrast, the prospect of urban vegetation as a source of consumptive benefits has received limited attention, particularly from urban planners and developers (Larondelle and Strohbach, 2016; Hurley and Emery, 2018; Sardeshpande and Shackleton, 2020c). This might result in underestimating the potential contribution of urban vegetation to livelihoods and human well-being (Kaoma and Shackleton, 2014a) and therefore misaligned policies and interventions. Nonetheless, emerging studies demonstrate that urban vegetation is multifunctional in providing a suite of ecosystem goods and services to both the human and physical environment (Haase et al., 2014; Russo et al., 2017). For example, urban vegetation is a source of forageable resources worldwide (Shackleton et al., 2017). Many urban residents forage various plant resources from a mosaic of urban green spaces for their subsistence, income and well-being needs. This is documented in North America (Poe et al., 2013; McLain et al., 2014; Synk et al., 2017); Germany (Palliwoda et al., 2017; Landor-Yamagata et al., 2018) and sub-Saharan Africa (Kaoma and Shackleton, 2014a; Mollee et al., 2017; Garekae and Shackleton, 2020a). These studies conclude that urban foraging is a ubiquitous practice, transcending different socio-demographic attributes and contexts. Moreover, several plant taxa have multiple uses. In Berlin (Germany), a total of 125 distinct plant taxa were foraged (Landor-Yamagata et al., 2018). In the USA, about 486 and 170 plant taxa were foraged in the cities of Seattle and Baltimore, respectively (Poe et al., 2013; Synk et al., 2017), and approximately 48 in Kampala (Uganda) (Mollee et al., 2017).

Although the above studies demonstrate the potential of urban vegetation as a supply of forageable resources, there is still limited

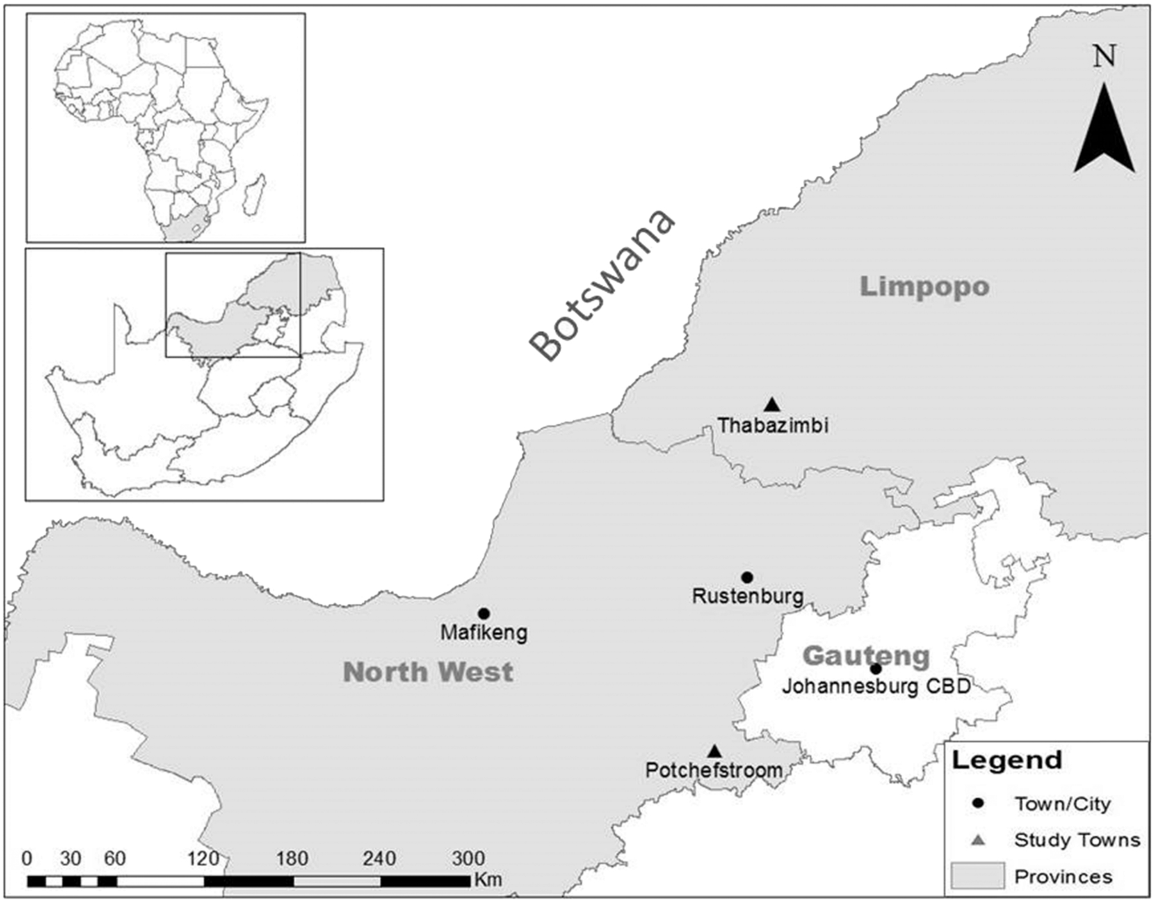

Fig. 1. Location of the study towns.

research quantifying what proportion of the entire species pool found in urban landscapes is forageable (Hurley and Emery, 2018). There has been examination of urban vegetation compositional patterns across different land-use types, such as sacred sites (De Lacy and Shackleton, 2017b; Jaganmohan et al., 2018; Caliskan and Aktağ, 2019), homesteads (Jaganmohan et al., 2012; Kaoma and Shackleton, 2014b), parks (Nagendra and Gopal, 2011; Talal and Santelmann, 2019), streets (Nagendra and Gopal, 2010; Gwedla and Shackleton, 2017c) and urban commons (Jha et al., 2019). These studies have quantified the composition, distribution, abundance and structure of urban vegetation in these urban landscapes. Although this information is important in informing planning, conservation and sustainability of urban vegetation; it overlooks the multifunctionality and diversity of urban ecosystems. Thus, there is a need to also quantify the composition of forageable plant resources within the total flora across different urban spaces. This will provide insights on the spaces most endowed with valuable resources. Furthermore, this can inform management and conservation of provisioning hotspots within the urban landscapes. Hence, the aim of this study to examine the prevalence and distribution of forageable plant species across different spaces in the towns of Potchefstroom and Thabazimbi, South Africa.

2. Methods

2.1. Study area

The study was conducted in two medium-sized towns in South Africa, Potchefstroom and Thabazimbi (Fig. 1). These towns are situated in North West and Limpopo provinces, respectively. Potchefstroom (26° 42’ 35" S; 27° 5′ 49" E) lies at 1350 m above the sea level, occupying an estimated area of 55 km^2 (Tlokwe City Council, 2012). The population of Potchefstroom is 250,000 people (Tlokwe City Council, 2012) made up of Black Africans (75%), Whites (17%), Coloureds (5%) and Indians/Asian (0.6%) (JB Marks Local Municipality, 2020). Over three-quarters (80%) of the residents live in formal dwellings. However, North West province generally is battling deteriorating socio-economic living conditions, particularly poverty, unemployment and inadequate access to services and food. Almost half of the households reported incomes of less than R1000.00 (US$70) per month. Nearly two-thirds (64%) of the people are considered poor (STATS SA, 2017). The unemployment rate is 21.6%. Moreover, 25% of the households in the province reported

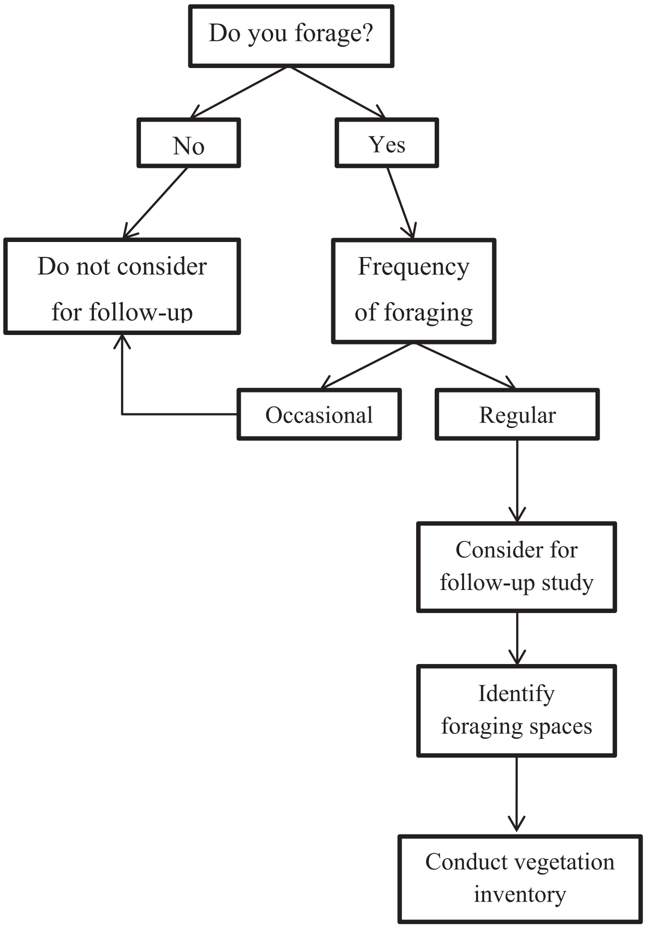

Fig. 2. Sampling procedure.

inadequate access to food, well above the national prevalence rate of 16% (STATS SA, 2019). Potchefstroom's economy is derived from mining, manufacturing and agriculture (Tlokwe City Council, 2012). The climatic conditions of the town are evenly defined, with wet summers and cold, dry winters which are often accompanied by frost. Mean annual rainfall averages 600 mm, normally between October and May. The maximum and minimum daily temperatures are 30° C and 0° C, respectively. Potchefstroom is situated in the grassland biome consisting of mixed grassland vegetation types, namely Rand Highland Grassland, Carletonville Grassland and Andesite Mountain Bushveld (Mucina and Rutherford, 2006).

Thabazimbi (24° 35' 30" S; 27° 24' 42" E) lies at the foot of the Ysterberg Mountains, elevated at 1042 m above sea level. Thabazimbi is home to approximately 28,847 people of different racial backgrounds (STATS SA, 2011), with Black Africans (82.3%) in the majority, along with Whites (16.9%), Coloureds (0.4%) and Indians/Asians (0.2%) (Thabazimbi Local Municipality, 2016). The majority (75%) lives in formal dwellings. Most of the households are middle-class, with their monthly household incomes ranging between R3000 and R6400 (US$200–420). Nevertheless, poverty is widespread in the province, with 70% of the people considered poor (STATS SA, 2017). Similarly, unemployment is also on the rise (21%). The town's economy comprises mostly mining, agriculture and tourism (Thabazimbi Local Municipality, 2016). Thabazimbi is semi-arid and characterised by highly variable rainfall, averaging 450 mm per year, concentrated between October to April. The mean maximum temperature reaches the highs of 36° C while minimum temperature is – 4° C (Thabazimbi Local Municipality, 2016). Thabazimbi falls in the savanna biome at the confluence of three vegetation types: Dwaalboom Thornveld, Western Sandy Bushveld and Waterberg Mountain Bushveld (Mucina and Rutherford, 2006).

2.2. Data collection

This study is part of an ongoing research project at the two towns. A multi-stage sampling technique was employed in selecting sites for vegetation sampling (Fig. 2). Firstly, we conducted a household survey with 374 randomly selected households. The household survey elicited data on, among others, forager's profile, prevalence and patterns of foraging practice, and frequented foraging spaces (see Garekae and Shackleton, 2020a). During the survey, we identified regular foragers to be revisited for follow-up studies. Regular forager refers to a respondent who forages on a regular basis. Secondly, we asked the regular foragers to volunteer their time and lead the researcher to the various spaces they visit for foraging. The subsequent spaces visited consisted of public and institutional green spaces, remnant vegetation, gardens, private spaces, informal spaces, and interstitial spaces. The identified spaces are grouped into five broad types: cemeteries, domestic gardens, protected areas, riparian areas and vacant spaces. This categorization was used to organize the diverse spaces into fewer but manageable groups and also denote the most common spaces visited for foraging. In this study a cemetery refers to a piece of land designated for burying human remains; domestic gardens refers to a space within a private homestead which is normally reserved for cultivating plants, while riparian areas are pieces of land situated alongside water bodies, such as along rivers, streams and lakes. A vacant space denotes a piece of public or private land that has no building or infrastructure on it, it is largely unmanaged and access is not controlled. This land can be situated within and at the edges of towns. We adopted the IUCN definition of protected areas, which refers to "… a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long term conservation of nature with associated ecosystem services and cultural values" (IUCN, 2008: 8). However, these zones are not exhaustive and foraging occurs in wide range of spaces, depending on foragers' decisions. Moreover, some spaces are multifunctional and hence there might be some overlaps in the five space types.

The unit of analysis is the green spaces situated within the five types, where foraging normally takes place. Since the total number of the actual foraging spaces was unknown, a purposive sampling technique was deemed suitable in selecting the sample sites. With the assistance of regular foragers, we purposively sampled 28 sites spanning across the five types. With the exception of domestic gardens, between 2 and 10 plots of 20 × 10 m size are sampled at each foraging site. At each sample site, the sample plots were dispersed to cover a reasonable proportion of the site. However, the number of sample plots across the sample sites varied (Table 1). This was mostly influenced by the total size of the sample site. Within each plot, we demarcated five 2 × 2 m quadrats for characterizing the herbaceous layer, one at each corner and one in middle of the plot. A total of 136 plots were purposively sampled. Since most of the homestead plots are small in area and the stipulated plot sizes couldn't fit therein, we resorted to recording all trees within the homestead regardless of the area occupied.

Within each plot, all the plant species are listed. The cover of woody plants and the herbaceous layer is visually estimated following Mueller-Dombois and Ellenberg (1974). Unknown species were collected, pressed and deposited to the following herbariums for identification: Selmar Schonland Herbarium (Rhodes University), AP Goossens Herbarium (North-West University) and Larry Leach Herbarium (University of Limpopo).

2.3. Data analysis

The data were captured in Microsoft Excel 2010. Two statistical packages are used to analyze data, dependent on the type of analysis. 'R′ version 3.5.1 is used to perform descriptive analysis while PC-ORD 6 for multivariate analysis. Descriptive statistics were

Table 1
Total number of plots sampled per space type.

Cemeteries	Domestic gardens	Protected area	Riparian area	Vacant spaces
25	7	20	39	45

Table 2
Species attributes and variation of indicator values across different spaces.

				Spaces				
Species	Growth form	Family	Status	Cemetery	Domestic Gardens	Riparian areas	Protected area	Vacant spaces
Vachellia karoo	Shrub	Fabaceae	I	100.0	17.5	48.7	95.1	64.8
Senegalia caffra (Thunb.) P.J.H. Hurter & Mabb	Shrub	Fabaceae	I	17.5	–	16.6	98.0	21.0
Grewia flavescens Juss	Shrub	Malvaceae	I	66.7	25.0	18.5	38.3	29.6
Amaranthus hybridus L	Herb	Amaranthaceae	E	8.8	100	77.2	–	21.7
Aloe greatheadii Schönland	Herb	Asphodelaceae	I	33.3	25.0	7.4	58.4	30.4
Dichrostachys cinerea (L.) Wight & Arn	Shrub	Fabaceae	I	20.0	33.3	29.6	–	68.2
Asparagus laricinus Burch	Shrub	Asparagaceae	I	66.7	–	3.7	46.3	21.7
Ziziphus mucronata Willd	Tree	Rhamnaceae	I	60.0	–	25.9	6.7	6.7
Peltophorum africanum Sond	Tree	Fabaceae	I	40.0	–	18.5	–	16.5
Combretum imberbe Wawra	Tree	Combretaceae	I	60.0	–	22.2	–	–
Celtis africana Burm.f	Tree	Cannabaceae	I	20.0	–	–	13.3	26.1
Sida dregei Burtt Davy	Herb	Malvaceae	I	66.7	–	7.4	–	–
Triumfetta rhomboidea Jacq	Herb	Malvaceae	I	30.0	–	18.5	–	4.5
Vachellia tortilis (Forssk.) Gallaso & Banfi	Shrub	Fabaceae	I	60.0	–	11.1	–	–
Searsia lancea (L.F.) F.A.Barkley	Tree	Anacardiaceae	I	50.0	–	11.1	–	–
Olea europaea L	Shrub	Oleaceae	I	30.0	–	–	–	–
Vangueria infausta Burch	Shrub	Rubiaceae	I	–	26.7	–	20.0	9.6
Ipomea purpurea (L.) Roth	Herb	Convolvulaceae	E	–	33.0	8.5	–	8.7
Senegalia burkei (Benth.) Kyal. & Boatwr	Tree	Fabaceae	I	–	25.0	25.9	–	–
Sclerocarya birrea (A.Rich.) Hochst	Tree	Anacardiaceae	I	–	33.3	–	–	14.3
Capsicum frutescens L	Herb	Solanaceae	E	–	75.0	–	–	–
Prunus persica (L.)Batsch	Tree	Rosaceae	E	–	43.2	–	–	–
Cleome gynandra L	Herb	Capparaceae	I	–	59.9	–	–	–
Cucurbita maxima Duchesne. ex Lam	Herb	Cucurbitaceae	E	–	50.0	–	–	–
Spinacia oleracea L	Herb	Amaranthaceae	E	–	50.0	–	–	–
Solanum lycopersicum L	Herb	Solanaceae	E	–	50.0	–	–	–
Prunus armeniaca L	Tree	Rosaceae	E	–	50.0	–	–	–
Mangifera indica L	Shrub	Anacardiaceae	E	–	29.9	–	–	–
Vigna unguicaculata L	Herb	Fabaceae	E	–	25.0	–	–	–
Citrullus lanatus (Thunb.) Matsum. & Nakai	Herb	Cucurbitaceae	E	–	33.3	–	–	–
Brassica oleracea L	Herb	Brassicaceae	E	–	25.0	–	–	–
Citrus limon L.) Burm	Tree	Rutaceae	E	–	25.0	–	–	–
Pyrus communis (F)	Tree	Rosaceae	E	–	25.0	–	–	–
Searsia leptodictya (Diels) T.S.Yi, A. J.Mill. & J.Wen	Tree	Anacardiaceae	I	–	–	3.7	53.3	8.7
Ehretia rigida (Thunb.) Druce	Shrub	Boraginaceae	I	–	–	7.4	33.0	–
Pentarrhinum insipidum E.Mey.	Herb	Apocynaceae	I	–	–	–	40.0	–
Ziziphus zeyheriana Sond	Shrub	Rhamnaceae	I	–	–	3.7	25.1	8.7
Opuntia humifusa (Raf.) Raf.)	Shrub	Cactaceae	E	–	–	3.7	26.7	13.0
Elephantorrhiza elephantina (Burch.) Skeels	Herb	Fabaceae	I	–	–	–	33.3	–
Gnidia capitata L.F.	Herb	Thymelaeaceae	I	–	–	–	13.3	–
Pappea capensis Eckl. & Zeyh.	Shrub	Sapindaceae	I	–	–	–	13.3	–
Cassine aethiopica (Thunb.) Loes	Shrub	Celastraceae	I	–	–	–	13.3	–
Euclea crispa	Shrub	Ebenaceae	I	–	–	–	13.3	–
Grewia occidentalis L	Shrub	Malvaceae	I	–	–	–	6.7	–
Combretum apiculatum Sond	Tree	Combretaceae	I	–	–	7.4	–	–
Tribulus terrestris L	Herb	Zygophyllaceae	E	–	–	50.0	–	17.4
Datura stramonium L	Herb	Solanaceae	E	–	–	71.7	–	4.3
Flueggea virosa (Roxb.ex Willd.) Voigt	Shrub	Phyllanthaceae	I	–	–	18.5	–	21.2
Chenopodium album L	Herb	Amaranthaceae	E	–	–	11.4	–	8.7
Bidens pilosa L	Herb	Asteraceae	E	–	–	17.5	–	–
Grewia retinervis Burret	Shrub	Malvaceae	I	–	–	7.4	–	22.7
Solanum gigante Jacq	Shrub	Solanaceae	I	–	–	14.8	–	4.3
Combretum zeyheri Sond	Tree	Combretaceae	I	–	–	3.7	–	8.4
Euclea undulata Thunb	Shrub	Ebenaceae	I	–	–	14.8	–	4.5
Grewia bicolor Juss	Shrub	Malvaceae	I	–	–	7.4	–	13.6
Senecio inornatus DC	Herb	Asteraceae	I	–	–	19.8	–	–
Ceratotheca triloba (Bernh.) Hook.f.	Herb	Pedaliaceae	I	–	–	25.0	–	–
Achyranthes aspera Linn	Herb	Amaranthaceae	E	–	–	7.4	–	–

(*continued on next page*)

Table 2 (*continued*)

Species	Growth form	Family	Status	Spaces				
				Cemetery	Domestic Gardens	Riparian areas	Protected area	Vacant spaces
Bauhinia variegate L	Shrub	Fabaceae	E	–	–	7.4	–	–
Combretum molle R.Br. ex G.Don	Tree	Combretaceae	I	–	–	7.4	–	–
Bidens bipinnata L	Herb	Asteraceae	E	–	–	7.4	–	–
Vachellia erioloba	Shrub	Fabaceae	I	–	–	3.7	–	–
Ximenia americana L	Shrub	Olacaceae	I	–	–	–	–	50.0
Searsia pyroides (Burch.) Moffett	Shrub	Anacardiaceae	I	–	–	–	–	43.5
Strychnos spinosa Lam	Shrub	Loganiaceae	I	–	–	–	–	13.6
Commelina africana L	Herb	Commelinaceae	I	–	–	–	–	21.7
Dombeya rotundifolia Hochst	Tree	Malvaceae	I	–	–	–	–	17.4
Pterocarpus rotundifolius (Sond.) Druce	Tree	Fabaceae	I	–	–	–	–	5.9
Tagetes minuta L	Herb	Asteraceae	E	–	–	–	–	13.0
Melia azedarach L	Tree	Meliaceae	E	–	–	–	–	13.0
Emex australis Steinh	Herb	Polygonaceae	I	–	–	–	–	8.7
Eucalyptus camaldulensis Dehnh	Tree	Myrtaceae	E	–	–	–	–	8.7
Calpurnia aurea (Aiton) Benth	Shrub	Fabaceae	I	–	–	–	–	9.1
Euclea natalensis A.DC	Shrub	Ebenaceae	I	–	–	–	–	9.1
Ficus lutea Vahl	Tree	Moraceae	I	–	–	–	–	2.3
Trichilia emetica Vahl	Tree	Meliaceae	I	–	–	–	–	4.5
Pellaea calomelanos (Sw.) Link	Herb	Pteridaceae	I	–	–	–	–	4.3
Grewia villosa Willd	Shrub	Tiliaceae	I	–	–	–	–	4.5
Boscia oleoides Burch. ex DC	Tree	Brassicaceae	I	–	–	–	–	4.3
Ehretia amoena Klotzsch	Shrub	Boraginaceae	I	–	–	–	–	4.5
Zanthoxylum capense (Thunb.) Harv	Shrub	Rutaceae	I	–	–	–	–	4.3
Boscia albitrunca	Tree	Capparaceae	I	–	–	–	–	4.5
Morus alba L	Shrub	Moraceae	E	–	–	–	–	4.3
Pseudolachnostylis maprouneifolia Pax	Tree	Phyllanthaceae	I	–	–	–	–	4.5
Clerodendrum glabrum E.Mey	Tree	Lamiaceae	I	–	–	–	–	4.5

Note: ‘I′ denotes indigenous species and ‘E′ exotic species.

used to summarize the data about species cover, distribution, and composition. Kruskal-Wallis test was used to compare variations in species cover, richness and diversity across the five spaces. Species diversity was determined using species richness (S) and Shannon-Wiener index of diversity (H). Species richness was calculated as the total number of different plant species (woody and herbaceous) represented within foraging spaces. On the other hand, species diversity takes into account the richness and the relative abundance of each species within a given community. The Shannon-Wiener index of diversity is the most widely used index for analyzing species diversity, expressed as follows:

$$H^{'} = -\sum_{i=1}^{S} p_{i\ln p_i} \tag{1}$$

Where H' = Shannon index, S = species richness, $p_{i\,=}$ proportional relative abundance of the i^{th} species.

Agglomerative Hierarchical Cluster analysis (flexible β linkage, $\beta = -0.25$, Sorensen distance, data relativized by maximum) was used to classify different species encountered in this study (McCune and Grace, 2000). Bray-Curtis ordination (Sorensen distance, data relativized by maximum) was used to infer plant communities’ distribution across spaces. This was done using the variance-regression method (Beals, 1984). In each community, an indicator value (IV), which is the sum of relative frequency and relative abundance, was calculated for each species (Dufrêne and Legendre, 1997). This was followed by a Monte Carlo test to determine the significance of IV for each species (Dufrêne and Legendre, 1997). Multi-response permutation procedures (MRPP) were used to statistically compare plant species composition between the different plant communities (McCune and Grace, 2000). We solicited information about the species uses through foragers interviews as well as from key botanical textbooks for the area (Venter and Venter, 2002; van Wyk and Gericke, 2000; van Wyk et al., 2009).

3. Results

3.1. Plant species, uses, and spatial distribution in different spaces

3.1.1. Floristic composition and spatial distribution

A total of 88 plant species (foraged and forageable) belonging to 39 families were recorded across the five different spaces in the two study towns (Table 2). The most common occurring families were Fabaceae (14%), Malvaceae (8%), and Anacardiaceae (6%). Seventy percent of the species were indigenous while 30% were exotic. Most of the exotic species were found in domestic gardens (43%) and vacant spaces (35%). Species were divided into five groups, based on their presence in the different spaces (Table 2):

i) Group A: Species found in all the five spaces. For instance, *Vachellia karoo*, *Grewia flavescens* and *Aloe greatheadii*.
ii) Group B: Species found irregularly across spaces, such as *Senegalia caffra, Asparagus laricinus* and *Ziziphus mucronata*.
iii) Group C: Species found in domestic gardens only. Examples include *Capsicum frutescens*, *Prunus persica* and *Cleome gynandra*.
iv) Group D: Species found in the protected areas only. These include *Pentarrhinum insipidum*, *Elephantorrhiza elephantina* and *Gnidia capitata*.
v) Group E: Those that were found in vacant spaces only such as *Ximenia americana, Searsia pyroides* and *Strychnos spinosa*.

3.1.2. Plant uses

Of the 88 species, 44% of them were reported as foraged by the foragers while 55% had at least one documented use for food, medicine, energy or other purposes. The species have prospects of complementing livelihoods in urban areas and could be essential in fulfilling basic household needs such as food, energy, health, and other purposes. Most of the individual species had multiple uses (i.e. fuelwood, food, medicinal and other uses), with one or more distinct plant parts (e.g. leaves, fruits, and branches) collected for various uses. Therefore, the sum of distinct uses and parts collected was greater than the total number of plant species encountered in the study. Following, approximately 144 distinct plant uses were identified, mostly dominated by food, medicine, energy and others such as crafting and carving; with fruits, leaves, branches, bark and roots being the principal plant parts. Most tree species provided more than one use, with one and two uses being modal (Fig. 3). In contrast, shrubs were mostly dominated by three uses while herbaceous being one use. The most common species use was for medicine, followed by food and firewood (Fig. 4). However, a considerable proportion of species also provided other uses such as crafting, carving and construction materials. Trees were mostly a source of food or a combination of firewood, medicine and other uses, while herbaceous provided either food and/or medicine.

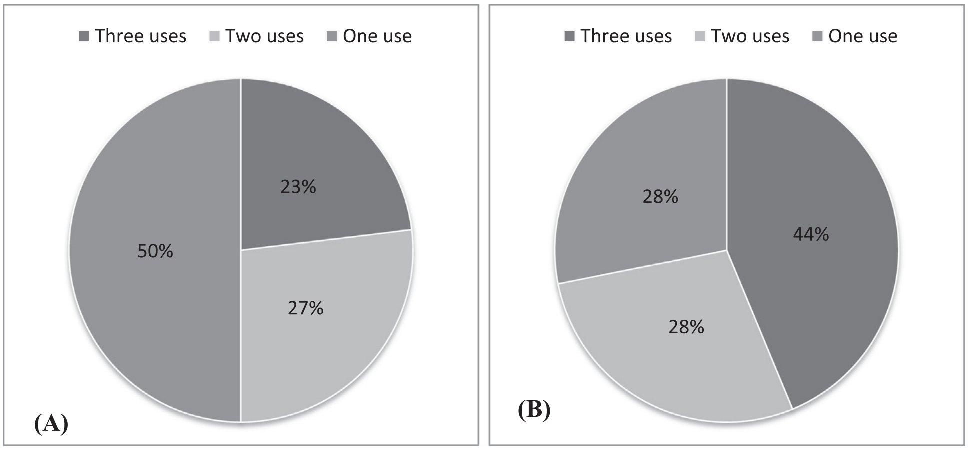

Fig. 3. Number of uses for individual species of trees (n = 26) (A) and shrubs (no=32) (B).

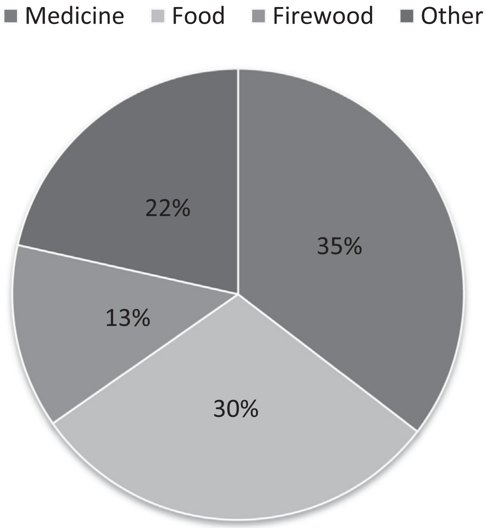

Fig. 4. Proportion of plant species uses (n = 144).

3.2. Diversity of forageable species

3.2.1. Diversity across the spaces

Species cover and richness differed with space type (Fig. 5). The findings revealed a significant difference in species cover ($\chi^2_{4,\,136} = 24.14$, $p = 0.001$) and richness ($\chi^2_{4,\,136} = 12.87$, $p = 0.012$) across the spaces. Protected areas had significantly higher species cover and richness compared to other spaces. In contrast, species diversity did not differ significantly across the space types ($\chi^2_{4,\,136} = 8.85$, $p = 0.065$) (Fig. 5).

3.2.2. Diversity in different growth forms

Species diversity also varied across different life forms (Fig. 6). Species richness was high for shrubs as compared to the other two life forms. Herbaceous layer contained high species cover, which was significantly different from the other life forms ($F_{2,\,137} = 32.93$, $p = 0.001$).

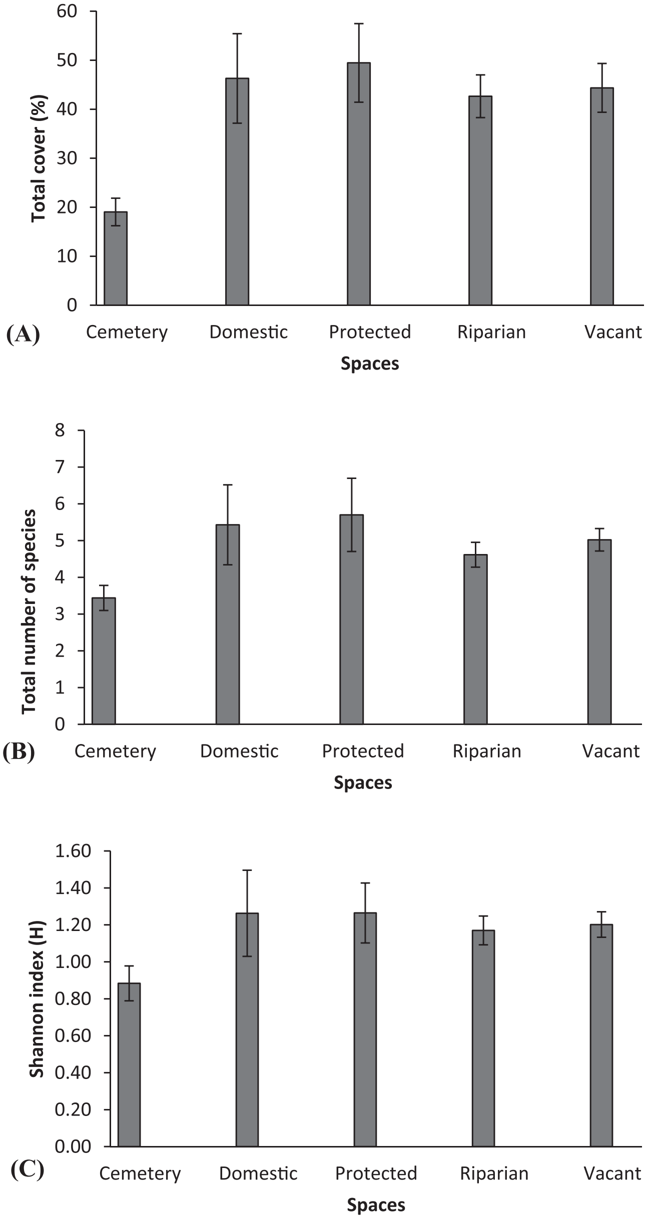

Fig. 5. Species cover (A), richness (B) and diversity (C) across the different spaces.

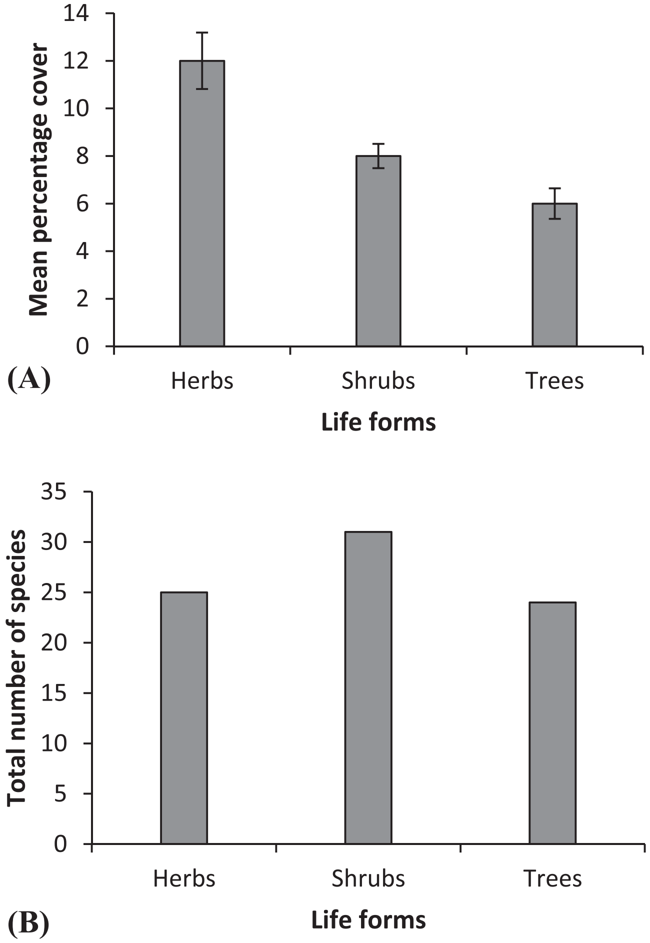

Fig. 6. Species cover (A) and richness (B) between different life forms.

3.3. *Community composition of forageable species*

The Agglomerative Hierarchical Cluster analysis (AHC) identified five plant communities comprising of species found in different spaces. These are *Vachellia karroo-Asparagus laricinus* (VK-AL), *Senegalia caffra-Aloe greatheadii* (SC-AG)*, Amaranthus hybridus-Datura stramonium* (AH-DS), *Combretum apiculatum-Strychnos spinosa* (CA-SS) and *Vachellia tortilis-Ziziphus mucronata* (VT-ZM) (Table 3). The plant species for these communities were found in all spaces except for CA-SS community which was only found in vacant spaces. These communities differed in terms of species richness and diversity, which were relatively high in SC-AG cluster (Appendix 1).

The VK-AL community was composed of 11 species, with *Vachellia karroo* and *Asparagus laricinus* being dominant. There was also presence of *Bidens bipinnata*, *Melia azedarach*, and *Eucalyptus camaldulensis*, albeit with low IVs (Table 3). This community was mostly endowed with key species supplying a range of provisioning ecosystems services such as food (*Grewia flava*, *Bidens bipinnata*) and medicine (e.g. *Asparagus laricinus*, *Commelina africana*). About 32% of the species were found in vacant spaces and riparian areas while cemeteries and protected areas respectively accounted to 24% and 11%.

The SC-AG cluster was characterised by the presence of species such as *Senegalia caffra*, *Aloe greatheadii*, *Searsia leptodictya*, and *Elephantorrhiza elephantina*. This cluster consisted of 17 species with mixed uses, seven of which were for food, four for fuelwood, and six for medicine. *Aloe greatheadii* and *Elephantorrhiza elephantina* are the most sought after species for treating common ailments and diseases in the study towns and elsewhere. The plots harbouring the species in this cluster were only found in three spaces, 65% of them in protected areas, 22% from vacant spaces and 13% from riparian areas. Moreover, this cluster contained some species which were unique and very dissimilar from those in other clusters.

The AH-DS community consisted of 12 species encountered in all but one space type. Over half (54%) of the plots with the presence of the species were situated in riparian areas, 19% in cemeteries, 12% in vacant spaces and 8% in domestic gardens. Species from this community were exclusively used for food and medicine. Species such as *Amaranthus hybridus*, *Chenopodium album*, *Cleome gynandra*, and *Bidens pilosa* are principal source of food, the leaves of which are cooked as relish and commonly served with maize porridge, a staple meal in the study area.

The CA-SS is a distinct cluster consisting of 13 species all encountered in one space type - vacant spaces. The species includes the

Table 3
Plant communities in different space types.

Vachellia karroo-Asparagus laricinus		
Species	**IV**	**P value**
Vachellia karroo	79.8	0.0002
Asparagus laricinus	26.3	0.0010
Grewia flava	20.3	0.0312
Sida dregei	19.0	0.0046
Celtis africana	9.9	0.0938
Tagetes minuta	7.9	0.0704
Commelina africana	6.3	0.1746
Bidens bipinnata	5.3	0.3031
Emex australis	5.3	0.3313
Melia azedarach	4.9	0.3359
Eucalyptus camaldulensis	2.4	0.9288
Senegalia caffra-Aloe greatheadii		
Senegalia caffra	65.9	0.0002
Aloe greatheadii	58.9	0.0002
Searsia leptodictya	33.1	0.0002
Elephantorrhiza elephantina	21.7	0.0006
Ehretia rigida	18.2	0.0060
Dombeya rotundifolia	17.4	0.0026
Opuntia humifusa	11.5	0.0416
Pappea capensis	8.7	0.0372
Euclea crispa	8.7	0.0370
Gnidia capitata	8.7	0.0400
Searsia pyroides	8.0	0.2020
Pentarrhinum insipidum	7.7	0.2382
Ziziphus zeyheriana	5.9	0.3207
Boscia oleoides	4.3	0.2575
Zanthoxylum capense	4.3	0.2575
Ledebouria marginata	4.3	0.2685
Grewia occidentalis	4.3	0.2755
Amaranthus hybridus-Datura stramonium		
Amaranthus hybridus	74.5	0.0002
Datura stramonium	43.5	0.0002
Tribulus terrestris	31.8	0.0002
Chenopodium album	28.1	0.0006
Senecio inornatus	15.4	0.0056
Ipomea purpurea	10.8	0.0636
Ceratotheca triloba	7.3	0.1102
Cleome gynandra	6.9	0.1260
Bidens pilosa	4.7	0.4977
Citrullus lanatus	3.8	0.4587
Morus alba	3.8	0.4635
Mangifera indica	3.5	0.5391
Combretum apiculatum-Strychnos spinosa		
Combretum apiculatum	93.6	0.0002
Strychnos spinosa	30.5	0.0002
Dichrostachys cinerea	24.6	0.0038
Vangueria infausta	15.7	0.0180
Euclea natalensis	15.4	0.0094
Ximenia americana	12.7	0.0380
Sclerocarya birrea	9.4	0.0778
Pseudolachnostylis maprouneifolia	7.7	0.0968
Clerodendrum glabrum	7.7	0.0964
Boscia albitrunca	7.7	0.0984
Trichilia emetica	7.7	0.0990
Grewia villosa	7.7	0.1040
Calpurnia aurea	4.0	0.3587
Vachellia tortilis-Ziziphus mucronata		
Vachellia tortilis	25.7	0.0006
Ziziphus mucronata	20.8	0.0072
Combretum imberbe	19.5	0.0056
Peltophorum africanum	19.0	0.0124
Flueggea virosa	16.9	0.0126
Triumfetta rhomboidea	10.7	0.0552
Senegalia burkei	14.8	0.0180
Grewia retinervis	14.4	0.0146
Solanum gigante	9.0	0.0874
Grewia bicolor	8.7	0.0976

(*continued on next page*)

Table 3 (*continued*)

Vachellia karroo-Asparagus laricinus		
Species	**IV**	**P value**
Capsicum frutescens	8.6	0.0564
Euclea undulata	7.6	0.1316
Achyranthes aspera	5.7	0.1996
Spinicia oleracea	5.7	0.2210
Ficus lutea	5.7	0.2050
Solanum lycopersicum	5.7	0.2050
Cucurbita maxima	5.7	0.2314
Prunus armeniaca	5.7	0.2406
Prunus persica	4.9	0.2893
Combretum zeyheri	3.6	0.6319
Vachellia erioloba	2.9	0.7067
Pellaea calomelanos	2.9	0.7083
Pyrus communis	2.9	0.7095
Citus limon	2.9	0.7247
Ehretia amoena	2.9	0.7289
Vitis vinifera	2.9	0.7247
Brassica oleracea	2.9	0.7313
Vigna unguiculata	2.9	0.7313
Combretum molle	2.1	0.7279
Bauhinia variegata	2.1	0.7283

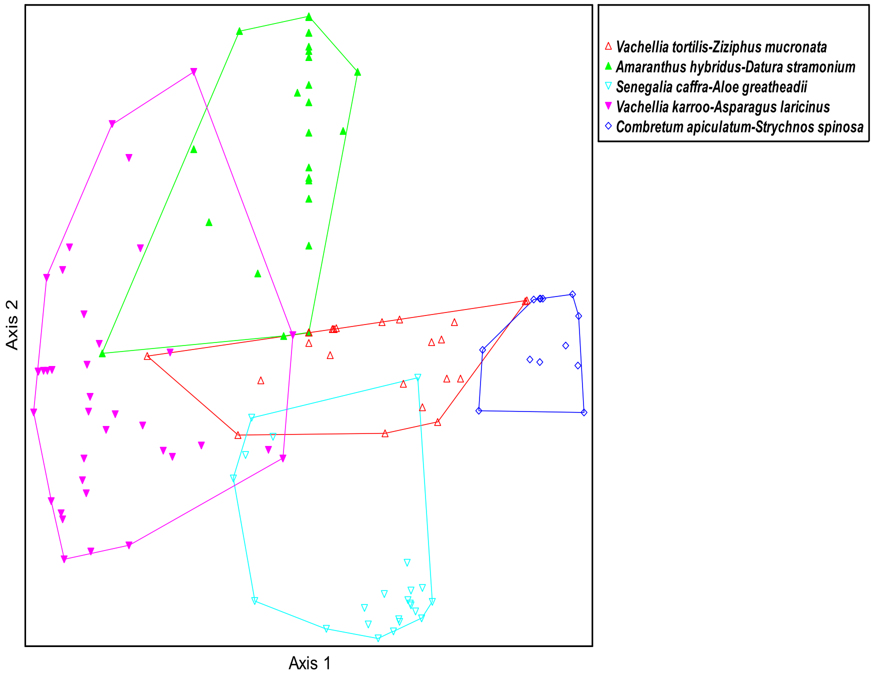

Fig. 7. Bray-Curtis Ordination showing plant species in different communities.

valuable *Sclerocarya birrea* – a multipurpose species which provide among others food (fruits), medicine (bark, fruit nut, leaves), and beverages. Other species in this cluster were *Combretum apiculatum*, *Strychnos spinosa*, and *Dichrostachys cinerea*. This cluster was populated by fruit tree species such as *Strychnos spinosa*, *Vangueria infausta*, and *Sclerocarya birrea*, which are valuable sources of micronutrients essential for human physiology.

The VT-ZM community comprised of more species (30) than the other four communities. This was the most diverse community in terms of species uses, with various species being multipurpose and useful for fulfilling an array of household needs such as fuel energy, food, medicine and raw materials. Species in this community were found in a total of 36 plots distributed across the five space types. Of these, 34% were from vacant spaces, 29% from cemetery, 26% from riparian while 11% from domestic gardens.

Although all the communities showed some overlap in terms of species composition, CA-SS community was mostly separated from the rest except for VT-ZM (Fig. 7).

All the communities were significantly ($p < 0.05$) different from each other in terms of species composition (Table 4). However,

Table 4

Multi-response permutation procedures pairwise comparisons of plant communities found in different space types.

Plant communities	T	A	*P*
Vachellia tortilis-Ziziphus mucronata vs *Amaranthus hybridus-Datura stramonium*	-25.87	0.11	0.000001
Vachellia tortilis-Ziziphus mucronata vs *Senegalia caffra-Aloe greatheadii*	-26.29	0.14	0.000001
Vachellia tortilis-Ziziphus mucronata vs *Vachellia karroo-Asparagus laricinus*	-32.80	0.12	0.000001
Vachellia tortilis-Ziziphus mucronata vs *Combretum apiculatum-Strychnos spinosa*	-19.85	0.11	0.000001
Amaranthus hybridus-Datura stramonium vs *Senegalia caffra-Aloe greatheadii*	-24.77	0.24	0.000001
Amaranthus hybridus-Datura stramonium vs *Vachellia karroo-Asparagus laricinus*	-28.70	0.18	0.000001
Amaranthus hybridus-Datura stramonium vs *Combretum apiculatum-Strychnos spinosa*	-20.89	0.26	0.000001
Senegalia caffra-Aloe greatheadii vs *Vachellia karroo-Asparagus laricinus*	-31.74	0.23	0.000001
Senegalia caffra-Aloe greatheadii vs *Combretum apiculatum-Strychnos spinosa*	-19.94	0.30	0.000001
Vachellia karroo-Asparagus laricinus vs *Combretum apiculatum-Strychnos spinosa*	-29.02	0.25	0.000001

VT-ZM and CA-SS ($T = 19.85$) were comparatively less separated from each other. The CA-SS cluster was also closely related ($T = 19.94$) to SC-AG in terms of species composition (Table 4).

4. Discussion

4.1. *Spatial distribution of species*

The results demonstrate that fragmented spaces within urban landscapes are endowed with a diversity of plant species, with many valuable to urban people. The notable number of forageable plant species encountered across the different spaces affirms the potential of urban vegetation in supplying provision and cultural benefits to people. Although there are limited comparable studies on the prevalence of forageable species on different urban spaces, the recorded number of species belonging to several families is consistent with observations from other related studies on urban plant diversity from the cities of Istanbul (Turkey) and Bengaluru (India), where mosaics of spaces within the urban landscape host rich biodiversity (Jaganmohan et al., 2018; Caliskan and Aktağ, 2019). Species were classified into five broad groups, based on their occurrence across the spaces. Although there were some overlaps across the spaces, vacant spaces recorded a highest proportion of species unique to that space, followed by domestic gardens and riparian areas.

Seventy percent of the forageable species were indigenous. Indigenous species were mostly concentrated in vacant, riparian and protected areas while domestic gardens were home to many exotic species. Vacant, riparian and protected areas are more likely to harbor indigenous species because there is very minimum human management and limited disturbance which could alter species composition. In these spaces, most of the species are self-propagating, with very minimum human manipulation and stewardship. Moreover, government efforts such as green campaigns may increase the indigenous species stocks in the aforementioned spaces. For example, the national Arbor Week which is a national observance in South Africa for raising awareness and increasing understanding about trees has been widely promoting planting of indigenous tree species across the country (Guthrie and Shackleton, 2006). This effort has potential to increase the presence of indigenous species in public and institutional spaces.

On the other hand, the widespread prevalence of exotic species in domestic gardens could be largely influenced by various factors, including psychological (van den Berg and van Winsum-Westra, 2010; Brambilla et al., 2013) and social-economic factors (Leong et al., 2018; Kuras et al., 2020). Psychological factors pertain to the mental and emotional well-being of a person, which were found to influence species composition in domestic gardens (Tribot et al., 2018; Blanchette et al., 2021). Among others, psychological factors condition species preference and desirability, with those species enhancing scenic beauty and promoting positive aesthetic experience most likely to be preferred as compared to those promoting ecological sustainability (Brambilla et al., 2013; Tribot et al., 2018). However, not all exotic species are detrimental to biodiversity and some provide valuable provisioning ecosystem services (Atyosi et al., 2019). In contrast, socio-economic factors condition species composition and diversity of domestic gardens (Hope et al., 2003).

For example, the affluent people are likely to favor ornamental species and less affluent households more consumptive species (Davoren et al., 2016).

Species relative abundance varied with space type, as evidenced from the individual species indicator values (IV). Cemeteries and domestic gardens recorded many species with IV of 50 and above. The other three spaces recorded fewer species above this threshold. Therefore, the results suggest that species abundance was relatively high in cemeteries and domestic gardens as compared to vacant, riparian and protected areas. This difference could be attributed to range of factors such as harvesting pressure, human management, culture, urban expansion, and environmental conditions (Nero et al., 2017; Talal and Santelmann, 2019; Chimaimba et al., 2020).

4.2. *Forageable plant species*

A total of 88 foraged and forageable species were recorded across the different space types. The species provided multiple uses such as for food, medicine, and energy, with distinct plant parts collected for various uses. Nearly one-quarter (22%) of the plant species provided two or more uses. This finding is similar to the observation made by Hurley and Emery (2018) in New York (USA), where over three-quarters of the known plant species in the city had at least one documented use. Just like in this study, the individual plant species had multiple uses and different parts of the same species were collected for different purposes. In Beijing (China), Wang et al. (2015) observed that over one-third (39%) of the plant species inventoried from some residential areas situated in the inner city had edible or pharmaceutical value. The finding on the proportions of forageable plant species across the different urban spaces demonstrates the potential of urban vegetation as a source of provisioning and cultural ecosystem services. This is despite the limited attention paid to the potential of urban landscapes in the production of provisioning services. Nonetheless, the increasing number of studies conducted in urban areas demonstrates that various urban spaces are endowed with a variety of species with multifunctional uses (Gopal and Nagendra, 2014; Hurley and Emery, 2018).

Medicine, food and firewood were the most common plant uses, in order of frequency. This conforms to the widespread prevalence of foraging in the study towns (Garekae and Shackleton, 2020a). In this study, foraging was conducted on a regular basis and it emerged as an important complementary source of livelihood. The finding on the recurring species uses is consistent with Hurley and Emery (2018) in New York (USA), Gopal and Nagendra (2014) in Bengaluru (India) and Furukawa et al. (2016) in Nairobi (Kenya). Medicine, food and ornamentals occupied the largest proportion of the identified total plant uses in these studies. In regard to Nairobi and Bengaluru, the plant resources were of utmost importance to the urban poor living on the fringes of the city. Traditional medicine is integral to people's health needs and overall well-being. Against this backdrop, traditional medicine emerges as an important alternative for fulfilling health needs to some quarters of the urban society, particularly those without adequate access to allopathic medicine. Therefore, medicinal plants could be a viable and affordable primary health care option for treating minor discomforts and ailments. Approximately 80% of the developing world's population rely on traditional medicine, either as a complement to the institutional health care system or as the only source of health care (Mahomoodally, 2013). In Africa, the use of traditional medicines is widespread and in some countries it is the primary health care option (Mahomoodally, 2013; WHO, 2013), including South Africa (Petersen et al., 2012). From a political ecology perspective, medicinal plants are an integral part of attaining health security and sovereignty (Kassam et al., 2010). Through this lens, people are able to source medicines that suit social, cultural and ecological contexts as well as being affordable and reliable in the long run. This is particularly important in the context of the rapid urbanization worldwide, which increases the costs of providing basic but essential services in urban areas, such as adequate health care system (Bhattacharya, 2002). Therefore, urban vegetation could contribute to fulfilling health needs and in turn promoting health sovereignty.

In regard to plant species used for food and firewood, they are essential in provision of household energy and dietary diversity to some urban residents. In this study, firewood was a complementary source of energy for cooking and heating (Garekae and Shackleton, 2020a). Therefore, firewood still remains an indispensable source of energy for the majority of the households in both rural and urban contexts (Makonese et al., 2017). Wild foods were important in the study towns (Garekae and Shackleton, 2020b). Since time immemorial, humans have subsisted on wild foods as their primary food source (Sachdeva et al., 2018; Garekae et al., 2020). At least one billion people worldwide rely on wild foods for meeting food and dietary needs (Aberoumand, 2009). Although wild foods are not a panacea to attaining food security, they are essential in diversifying monotonous diets, especially for households with financial or physical inadequate access to available food in the market. Therefore, the edible plant species prevalent in different urban spaces in this study, and elsewhere, represent an important complementary food source for some urban dwellers, such as the poor, although not restricted to such. As indicated earlier, poverty is rife in the study towns and is likely to constrain the ability of households to access food despite their availability in the market. Therefore, wild foods have the potential to cushion urban households in the face of adversity. Based on the foregoing, the insights on plant uses demonstrate the role of urban vegetation towards enhancing liveability and in turn promoting sustainable cities. This is crucial in the present study, given the prevailing poor socio-economic conditions.

4.3. *Species diversity and community composition*

The diversity of forageable species differed significantly with space type. Species cover and richness of forageable species were slightly higher in the protected areas and domestic gardens as compared to the other three spaces. However, species diversity did not differ with space types. The notable species cover and richness in domestic gardens and protected areas could be influenced by land-use tenure and land management. These spaces are governed under private tenure, which may limit and or restrict access to the resources therein (Garekae and Shackleton, 2021). In regard to protected areas, the area was once fenced off and access and harvesting of resources was controlled. In principle, cutting or harvesting of any plant products within the protected area is prohibited unless sanctioned by the manager. The findings are consistent with Löki et al. (2015) who contend that biodiversity in secluded urban areas has the opportunity to flourish, given the management and conservation interventions and reduced threats from anthropogenic activities. But moving forward, the current study challenges regulations to strike a balance between conservation and sustainable use. In contrast, biodiversity in other areas, such as urban commons and public green spaces is often threatened by urban transformation (Mundoli et al., 2017). This is the case at the study towns, where remnant patches of urban green space are threatened by urban sprawl. Hence, it is necessary for urban planners and developers to identify and zone ecological hotspots endowed with valuable species worth of conservation and at the same time being a source of provisioning and cultural ecosystem services. Although there is lack of comparative literature on the variation of forageable species diversity across different urban spaces, the findings are related to other studies on urban diversity which showed that species diversity differs across urban spaces, being high in secluded spaces such as gardens, institutional spaces and parks (Bourne and Conway, 2014; Nero et al., 2017).

Diversity also differed in different life forms. Species richness was significantly higher for shrubs as compared to the other two life forms. In regard to species cover, it was markedly higher for herbs as compared to shrubs and trees.

The species recorded could be differentiated into five communities. The communities can be generally described based on species distribution and uses. Three clusters were mostly composed of species with multiple uses (i.e. fuelwood, food, medicine, and or other purposes) while two clusters primarily food and medicine. Furthermore, the five clusters were composed of species which were unequally distributed across the different spaces. The plausible explanation on variation of species association within the clusters and across the different spaces could be attributed to natural and anthropogenic factors. Talal and Santelmann (2019) observed that landform attributes (environmental parameters) and management (human intervention) were the primary factors influencing species association across 12 urban parks in Portland (USA). However, these factors are multifaceted and often interactive, thereby demonstrating the complexities of urban ecosystems.

5. Conclusion

This study demonstrates that a range of spaces within the urban landscape provide habitat to a diversity of plant species. The notable number of plant species recorded in this study and elsewhere points to urban green spaces as a key supply of ecosystem goods and services, particularly the provisioning services which are of interest to some segments of the urban community, such as the poor. Therefore, the plant species, especially forageable ones has the potential to complement livelihoods, thereby reducing vulnerability to social shocks and depredation in urban areas. Over half of the identified plant species were indigenous to South Africa. Therefore, indigenous species, particularly edible ones should be prioritized during planting initiatives and urban greening campaigns, thereby increasing the resource stock across the urban landscape. Plant species diversity varied with space types, being significantly higher in protected areas than any other spaces. It is important to formulate holistic but encompassing regulations promoting conservation and management of species hotspots in the urban landscape but at the same time promoting human-biodiversity interactions. This finding calls for the attention of urban space managers and developers. These role-players need to take into consideration the various remnant spaces endowed with valuable species into spatial planning and development.

Funding

This work was funded by the German Federal Ministry of Education and Research (BMBF) (Project ID: 01DG16015). The mobility grant from German Academic Exchange Service (DAAD) is hereby acknowledged (Project ID: 57353580).

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.

Acknowledgments

Special appreciations to the following: Tony Dold (Selmar Schonland Herbarium, Rhodes University), Marlize Muller (AP Goossens Herbarium, North-West University), Dr. Elandrie Davoren (Department of Environmental Science, Rhodes University) and Dr. Bronwyn Egan (Larry Leach Herbarium, University of Limpopo) for their tireless effort in identifying the plant specimens. The constructive comments from the three anonymous reviewers are highly appreciated.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.gecco.2021.e01972.

References

Aberoumand, A., 2009. Nutritional evaluation of edible portulaca oleracia as plant food. Food Anal. Methods 2 (3), 204–207.

Atyosi, Z., Ramarumo, L.J., Maroyi, A., 2019. Alien plants in the Eastern Cape province in South Africa: perceptions of their contributions to livelihoods of local communities. Sustainability 11. https://doi.org/10.3390/su11185043.

Bhattacharya, P.C., 2002. Urbanisation in developing countries. Econ. Polit. Wkly. 37 (41), 4219–4228.

Beals, E.W., 1984. Bray-Curtis ordination: an effective strategy for analysis of multivariate ecological data. Adv. Ecol. Res. 14, 1–55.

Blanchette, A., Trammell, T.L.E., Pataki, D.E., Endter-Wada, J., Avolio, M.L., 2021. Plant biodiversity in residential yards is influenced by people's preferences for variety but limited by their income. Landsc. Urban Plan. 214. https://doi.org/10.1016/j.landurbplan.2021.104149.

Bourne, K.S., Conway, T.M., 2014. The influence of land use type and municipal context on urban tree species diversity. Urban Ecosyst. 17 (1), 329–348.

Brambilla, M., Gustin, M., Celada, C., 2013. Species appeal predicts conservation status. Biol. Conserv. 160, 209–213.

Caliskan, S., Aktağ, A., 2019. The composition of woody plants in the cemeteries of various religious communities in Istanbul-Turkey. Urban For. Urban Green. 43. https://doi.org/10.1016/j.ufug.2019.05.012.

Chimaimba, F.B., Kafumbata, D., Chanyenga, T., Chiotha, S., 2020. Urban tree species composition and diversity in Zomba city, Malawi: Does land use type matter? Urban For. Urban Green. 54. https://doi.org/10.1016/j.ufug.2020.126781.

Davoren, E., Siebert, S., Cilliers, S., du Toit, M.J., 2016. Influence of socioeconomic status on design of Batswana home gardens and associated plant diversity patterns in northern South Africa. Landsc. Ecol. Eng. 12, 129–139.

De Lacy, P., Shackleton, C.M., 2017a. Aesthetic and spiritual ecosystem services provided by urban sacred sites. Sustainability. https://doi.org/10.3390/su9091628.

De Lacy, P., Shackleton, C.M., 2017b. Woody plant species richness, composition and structure in urban sacred sites, Grahamstown, South Africa. Urban Ecosyst. 20 (5), 1169–1179.

Dufrêne, M., Legendre, P., 1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. Ecol. Monogr. 61, 53–73.

Furukawa, T., Kiboi, S.K., Mutiso, P.B.C., Fujiwara, K., 2016. Multiple use patterns of medicinal trees in an urban forest in Nairobi. Kenya Urban For. Urban Green. 18, 34–40.

Garekae, H., Shackleton, C.M., 2021. Knowledge of formal and informal regulations affecting wild plant foraging practices in urban spaces in South Africa. Soc. Nat. Resour. https://doi.org/10.1080/08941920.2021.1977446.

Garekae, H., Shackleton, C.M., 2020a. Urban foraging of wild plants in two medium-sized South African towns: people, perceptions and practices. Urban For. Urban Green. 49 doi.org/10.1016/j.ufug.2020.126581.

Garekae, H., Shackleton, C.M., 2020b. Foraging wild food in urban spaces: the contribution of wild foods to urban dietary diversity in South Africa. Sustainability 12 (2), 678. https://doi.org/10.3390/su12020.

Garekae, H., Lepetu, J., Thakadu, O.T., 2020. Forest resource utilisation and rural livelihoods: insights from Chobe enclave, Botswana. South Afr. Geogr. J. 102 (1), 22–40.

Gopal, D., Nagendra, H., 2014. Vegetation in Bangalore's slums: boosting livelihoods, well-being and social capital. Sustainability 6 (5), 2459–2473.

Guthrie, G., Shackleton, C.M., 2006. Urban–rural contrasts in Arbor Week in South Africa. South Afr. J. Sci. 102, 14–18.

Gwedla, N., Shackleton, C.M., 2017c. Population size and development history determine street tree distribution and composition within and between Eastern Cape towns. South Afr. Urban For. Urban Green. 25, 11–18.

Haase, D., Larondelle, N., Andersson, E., Artmann, M., Borgström, S., Breuste, J., Gomez-Baggethun, E., Gren, A., Hamstead, Z., Hansen, R., Kabisch, N., Kremer, P., Langemeyer, J., Rall, E.L., McPhearson, T., Pauleit, S., Qureshi, S., Schwarz, N., Voigt, A., Wurster, D., Elmqvist, T., 2014. A quantitative review of urban ecosystem service assessments: concepts, models and implementation. AMBIO 43 (4), 413–433.

Hope, D., Gries, C., Zhu, W., Fagan, W.F., Redman, C.L., Grimm, N.B., Nelson, A.L., Martin, C., Kinzig, A., 2003. Socioeconomics drive urban plant diversity. Proc. Natl. Acad. Sci. USA 100 (15), 8788–8792.

Hurley, P.T., Emery, M.R., 2018. Locating provisioning ecosystem services in urban forests: forageable woody species in New York City, USA. Landsc. Urban Plan. 170, 266–275.

IUCN, 2008. Guidelines for Applying Protected Area Management Categories. IUCN, Gland.

Jaganmohan, M., Vailshery, L.S., Gopal, D., Nagendra, H., 2012. Plant diversity and distribution in urban domestic gardens and apartments in Bangalore, India. Urban Ecosyst. 15 (4), 911–925.

Jaganmohan, M., Vailshery, L.S., Mundoli, S., Nagendra, H., 2018. Biodiversity in sacred urban spaces of Bengaluru. India Urban For. Urban Green. 32, 64–70.

JB Marks Local Municipality, 2020. JB Marks Local Municipality 2017-2022 final integrated plan. Potchefstroom JB Marks Local Munic.

Jha, R.K., Nölke, N., Diwakara, B.N., Tewari, V.P., Kleinn, C., 2019. Differences in tree species diversity along the rural-urban gradient in Bengaluru, India. Urban For. Urban Green. 46. https://doi.org/10.1016/j.ufug.2019.126464.

Kaoma, H., Shackleton, C.M., 2014a. Collection of urban tree products by households in poorer residential areas of three South African towns. Urban For. Urban Green. 13 (2), 244–225.

Kaoma, H., Shackleton, C.M., 2014b. Homestead greening is widespread amongst the urban poor in three medium-sized South African towns. Urban Ecosyst. 17 (4), 1191–1207.

Kassam, K.A., Karamkhudoeva, M., Ruelle, M., Baumflek, M., 2010. Medicinal plant use and health sovereignty: findings from the Tajik and Afghan Pamirs. Hum. Ecol. 38 (6), 817–829.

Kuras, E.R., Warren, P.S., Zinda, J.A., Aronson, M.F.J., Cilliers, S., Goddard, M.A., Nilon, C.H., Winkler, R., 2020. Urban socioeconomic inequality and biodiversity often converge, but not always: a global meta-analysis. Landsc. Urban Plan. 198. https://doi.org/10.1016/j.landurbplan.2020.103799.

Landor-Yamagata, L.J., Kowarik, I., Fischer, K.L., 2018. Urban foraging in Berlin: people, plants and practices within the metropolitan green infrastructure. Sustainability 10 (6). https://doi.org/10.3390/su10061873.

Larondelle, N., Strohbach, M.W., 2016. A murmur in the trees to note: urban legacy effects on fruit trees in Berlin, Germany. Urban For. Urban Green. 17, 11–15.

Leong, M., Dunn, R.R., Trautwein, M.D., 2018. Biodiversity and socioeconomics in the city: a review of the luxury effect. Biol. Lett. 14. https://doi.org/10.1098/rsbl.2018.0082.

Löki, V., Tökölyi, J., Süveges, K., Lovas-Kiss, Á., Hürkan, K., Sramkó, G., Molnár, A., 2015. The orchid flora of Turkish graveyards: a comprehensive field survey. Willdenowia 45 (2), 231–243.

Mahomoodally, M.F., 2013. Traditional medicines in Africa: an appraisal of ten potent African medicinal plants. Evid. -Based Complement. Altern. Med. https://doi.org/10.1155/2013/617459.

Makonese, T., Ifegbesan, A.P., Rampedi, I.T., 2017. Household cooking fuel use patterns and determinants across southern Africa: evidence from the demographic and health survey data. Energy Environ. 29 (1), 29–48.

Masoudi, M., Tan, P.Y., 2019. Multi-year comparison of the effects of spatial pattern of urban green spaces on urban land surface temperature. Landsc. Urban Plan. 184, 44–58.

McCune, B., Grace, J.B., 2000. Analysis of ecological communities. Gleneden Beach. MjM Softw.

McLain, R.J., Hurley, P.T., Emery, M.R., Poe, M.R., 2014. Gathering "wild" food in the city: Rethinking the role of foraging in urban ecosystem planning and management. Local Environ. 19 (2), 220–240.

Mollee, E., Pouliot, M., McDonald, M.A., 2017. Into the urban wild: collection of wild urban plants for food and medicine in Kampala, Uganda. Land Use Policy 63, 67–77.

Mucina, L., Rutherford, M.C., 2006. The Vegetation of South Africa, Lesotho and Swaziland. South African National Biodiversity Institute, Pretoria.

Mueller-Dombois, D., Ellenberg, H., 1974. Aims and Methods of Vegetation Ecology. John Wiley & Sons, New York, NY.

Mundoli, S., Manjunatha, B., Nagendra, H., 2017. Commons that provide: the importance of Bengaluru's wooded groves for urban resilience. Int. J. Urban Sustain. Dev. 9 (2), 184–206.

Nagendra, H., Gopal, D., 2010. Street trees in Bangalore: density, diversity, composition and distribution. Urban For. Urban Green. 9 (2), 129–137.

Nagendra, H., Gopal, D., 2011. Tree diversity, distribution, history and change in urban parks: studies in Bangalore, India. Urban Ecosyst. 14 (2), 211–223.

Nazir, N.N.M., Othman, N., Nawawi, A.H., 2014. Green infrastructure and its roles in enhancing quality of life. Procedia Soc. Behav. Sci. 153, 384–394.

Nero, B.F., Campion, B.B., Agbo, N., Callo-Concha, D., Denich, M., 2017. Tree and trait diversity, species coexistence, and diversity-functional relations of green spaces in Kumasi, Ghana. Procedia Eng. 198, 99–115.

J.R. Nolon Enhancing the urban environment through green infrastructure Environ. Law Report. 46 1 2016.(Retrieved from)⟨https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2724050⟩.

Palliwoda, J., Kowarik, I., von der Lippe, M., 2017. Human-biodiversity interactions in urban parks: the species level matters. Landsc. Urban Plan. 157, 394–406.

Petersen, L.M., Moll, E.J., Collins, R., Hockings, M.T., 2012. Development of a compendium of local, wild-harvested species used in the informal economy trade, Cape Town, South Africa. Ecol. Soc. 17, 2.

Poe, M.R., McLain, R.J., Emery, M.R., Hurley, P.T., 2013. Urban forest justice and the rights to wild foods, medicines, and materials in the City. Hum. Ecol. 41 (3), 409–422.

Russo, A., Escobedo, F.J., Cirella, G.T., Zerbe, S., 2017. Edible green infrastructure: an approach and review of provisioning ecosystem services and disservices in urban environments. Agric. Ecosyst. Environ. 242, 53–66.

Sachdeva, S., Emery, M.R., Hurley, P.T., 2018. Depiction of wild food foraging practices in the media: Impact of the great recession. Soc. Nat. Resour. 31 (8), 977–993.

Sardeshpande, M., Shackleton, C.M., 2020c. Urban foraging: land management policy, perspectives, and potential. PLoS ONE 15 (4). https://doi.org/10.1371/journal.pone.0230693.

Shackleton, C.M., 2012. Is there no urban forestry in the developing world? Sci. Res. Essays 7 (40), 3329–3335.

Shackleton, C.M., Hurley, P.T., Dahlberg, A.C., Emery, M.R., Nagendra, H., 2017. Urban foraging: a ubiquitous human practice overlooked by urban planners, policy, and research. Sustainability 9 (10). https://doi.org/10.3390/su9101884.

Shackleton, S.E., Chinyimba, A., Hebinck, P., Shackleton, C.M., Kaoma, H., 2015. Multiple benefits and values of trees in urban landscapes in two towns in northern South Africa. Landsc. Urban Plan. 136, 76–86.

STATS SA, 2019. Towards measuring the extent of food security in South Africa: an examination of hunger and food adequacy. Stat. South Afr.: Pretoria, South Afr.

STATS SA, 2017. Poverty Tends in South Africa: An Examination of Absolute Poverty Between 2006 and 2015. Statistics South Africa: Pretoria, South Africa.

STATS SA (2011) Statistics by place - Thabazimbi. Retrieved January 12, 2018, from http://www.statssa.gov.za/?page_id=4286&id=13271.

Synk, C.M., Kim, B.F., Davis, C.A., Harding, J., Rogers, V., Hurley, P.T., Emery, M.R., Nachman, K.E., 2017. Gathering Baltimore's bounty: Characterizing behaviors, motivations, and barriers of foragers in an urban ecosystem. Urban For. Urban Green. 28, 97–102.

Talal, M.L., Santelmann, M.V., 2019. Plant community composition and biodiversity patterns in urban parks of Portland, Oregon. Front. Ecol. Evol. 7. https://doi.org/10.3389/fevo.2019.00201.

TEEB (2011) TEEB Manual for cities: Ecosystem services in urban management. Retrieved June 20, 2017, from www.teebweb.org.

Thabazimbi Local Municipality. Integrated Development Plan 2016 Thabazimbi Local Municipality Thabazimbi. http://www.thabazimbi.gov.za/docs/idp/DRAFT_2016_17_IDP_31_MARCH_2016-ilovepdf-compressed.pdf.

Tlokwe City Council Integrated Development Plan of the Tlokwe City Council Third Generation IDP 2012 Tlokwe City Council Potchefstroom.http://mfmamirror.s3.amazonaws.com/Documents/01.Integrated Development Plans/2012-13/02. Local municipalities/NW402 Tlokwe/NW402 Tlokwe - IDP - 2012-13.pdf.

Tribot, A.S., Deter, J., Mouquet, N., 2018. Integrating the aesthetic value of landscapes and biological diversity. Proc. R. Soc. B 285, 20180971. https://doi.org/10.1098/rspb.2018.0971.

van den Berg, A.E., van Winsum-Westra, M., 2010. Manicured, romantic, or wild? The relation between need for structure and preferences for garden styles. Urban For. Urban Green. 9, 179–186.

van Wyk, B.E., Gericke, N., 2000. People's Plants: A Guide to Useful Plants of Southern Africa. Briza Publications, Pretoria.

van Wyk, B.E., van Oudtshoorn, B., Gericke, N., 2009. Medicinal Plants of South Africa. Briza Publications, Pretoria.

Venter, F., Venter, J.A., 2002. Making the Most of Indigenous Trees. Briza Publications, Pretoria.

Wang, H.F., Qureshi, S., Knapp, S., Friedman, C.R., Hubacek, K., 2015. A basic assessment of residential plant diversity and its ecosystem services and disservices in Beijing, China. Appl. Geogr. 64, 121–131. https://doi.org/10.1016/j.apgeog.2015.08.006.

WHO, 2013. WHO Traditional Medicine Strategy: 2014-2023. World Health Organization, Hong Kong.