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Health clinic gardens as models for social-ecological systems: Floristic composition and potential utilization of plants in the Bojanala Platinum District North-West Province, South Africa

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ABSTRACT

Health clinic gardens (HCGs) are social-ecological systems (SESs) associated with health clinics on government land and are intended to provide fresh vegetables and fruits to patients struggling to keep healthy immune systems. Little is known about their comparability to other garden types with regards to plant distribution and potential utilization, and thus their potential to address some of the challenges limiting ecosystem services (ESs) provision in other garden types. In this study, we report on the floristic composition and presence of utilitarian plant species at 105 HCGs across a district municipality in the North-West Province, South Africa. Different micro-gardens, including vegetable, medicinal, ornamental, natural vegetation, bare soil, orchard, hedge, and lawn micro-gardens, were identified. To understand plant composition, species were classified according to status of origin, invasive characteristics, Raunkiaer's life-forms, growth forms, and potential usefulness. To determine the frequency of species occurrence we enumerated the number of gardens containing the respective species. Six-hundred and thirty-three species from 404 genera and 116 plant families were encountered. *Cynodon dactylon* (L.) Pers. and *Urochloa mosambicensis* (Hack.) Dandy, found in 91 % and 79 % of gardens, respectively, occurred the most. Herbaceous species were the most dominant, with *Schkuhria pinnata* (Lam.) Kuntze ex Thell. and *Conyza bonariensis* (L.) Cronquist occurring the most. Plant species richness was greater in the ornamental (282 species) and natural area (*naga*) (281 species) micro-gardens, while the hedge had the least (8 species). Fifty-five percent of species in the natural vegetation micro-garden were indigenous, compared to 44 % in the ornamental micro-garden. There was greater diversity in fruit-bearing plants, and most medicinal plant species (70 %) are used as a tonic. Health clinic gardens resemble home gardens and are well positioned to enhance ESs provision at the community scale. Future HCGs research should evaluate community usage of the gardens and the extent to which knowledge of useful plants and efficient gardening practices is upscaled to home gardens around HCGs.

1. Introduction

Social-ecological systems (SESs) are complex, open, dynamic systems coupling humans and nature, and humans highly depend on them for ecosystem services (ESs) provision (Berkes et al., 2000). Gardens, as essential types of green infrastructure (GI), are "the most interconnected parts of urban and rural areas" (Cilliers et al., 2012) and influence human health and well-being because of their close connection to humans. Thus, they are regarded as SESs where humans interact with the ecological environment through soil and plant cultivation (Berkes et al., 2000), and are important hubs for multiple ESs provision, including regulating, provisioning, cultural, and supporting ESs (Cubino et al., 2014). The potential for ES provision in gardens depends on garden design, especially the composition and diversity of cultivated or spontaneously growing plants (Cameron, 2023).

Forms of management and ownership, purpose, and thus the potential for ES provision is used to classify gardens according to privately-owned (home and domestic gardens) (Cameron, 2023), and institution or community-owned and managed gardens (community and botanical gardens) (Cilliers et al., 2018). Health clinic gardens (HCGs) are community gardens associated with medical facilities (Milliron et al., 2017), and in South Africa are mainly associated with primary health-care

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facilities (health clinics), developed, and managed by different stakeholders on government-owned land (Gwedla et al., 2022). Health clinics in South Africa were established at the dawn of democracy across the country "to provide free, accessible, equitable and integrated health services to communities" (Cullinan, 2006). Gardens in health clinics were developed to benefit the community through aiding in their nutritional needs (Vorster et al., 2011) by supplying malnourished patients and those struggling to keep healthy immune systems with fresh fruits and vegetables (Cilliers et al., 2018). Health clinic gardens exemplify SESs because they are characterized by the involvement of multiple stakeholders who are an important social resource as they manage both the ecological and social aspects of these gardens and contribute their skills and knowledge for optimum ESs provision (Cilliers et al., 2018; Gwedla et al., 2022). The structure of HCGs resembles the Tswana *tshimo* garden layout, which Molebatsi et al. (2010) describe as "a traditional home-garden structure characterized by a variety of micro-gardens, including *lebala* (bare soil), *naga* (natural vegetation), lawn, vegetable garden, medicinal garden, ornamental garden, hedge, and an orchard".

Notwithstanding gardens' vast provision of a host of ESs (Shackleton et al., 2021) and in line with ESs provision for improved quality of life, different types of gardens grow plants with varying utilitarian properties, including food and medicines. Other ESs include gardens' contribution to biodiversity conservation, and as sites for sustainable natural resource management (Naigaga et al., 2022). Health clinic gardens can also be sites for foraging among surrounding communities as they may contain wild and spontaneous vegetation. As a result of poverty, there is growing reliance on the harvesting of provisioning ESs in urban areas of the Global South (GS) (Shackleton et al., 2021), which subsequently increases the demand for tangible plant and tree products. In these contexts, home and community gardens are the most accessible and economic nutritional sources (Gopal and Nagendra, 2014). However, optimum ES provision in home gardens in the GS is marred by several challenges that limit households' optimal use of the gardens. These challenges include the lack of available land and space for gardening (Thornton, 2008), compromised security leading to crop theft (Pham et al., 2023), and negligence of the importance of gardens as regards to food production since social grants are deemed to be sufficient (Thornton, 2008). Inefficient gardening practices that may compromise the quality and quantity of yield (Reuther and Dewar, 2006), knowledge gaps regarding nutrient status of vegetables, especially African Leafy Vegetables (ALVs) (Kruger et al., 2012), and gardens being sources of localized plant invasions through invasive exotic species cultivation (McLean et al., 2018) also hinder optimum ESs provision. Health clinic gardens can mitigate many of these challenges through the involvement of several stakeholders (Gwedla et al., 2022) who may co-produce different knowledge types, and "provide technologies, devise strategies, concepts, and ideas" to improve the prospects of ES delivery (Cilliers et al., 2018).

Numerous studies have explored plant distribution, diversity, and utilization in various types of urban and rural gardens in Africa and across the globe. For example, Clarke and Jenerette (2015) recorded 707 managed plant species in 14 community gardens of Los Angeles County, California, and noted the tendency for ornamental plant richness to increase with neighborhood income, compared to edible and medicinal plant richness which increased with the size of garden plots. In another instance, Mekonen et al. (2015) enumerated 113 plant species from 46 families in 42 home gardens around Sebeta-Awas District, Oromia Region, Ethiopia, reporting that 24 species were used as food plants, 13 species as sources of medicine, nine species as household tools, and eight species as live fence.

Previous research on gardens in South Africa has outlined the ESs they provide. Gwedla et al. (2024) recently explored the value of ESs at HCGs in a South African context, highlighting their potential to produce a variety of provisioning, regulating, supporting, and cultural Ess; and concluded that HCGs resemble other types of gardens like home and domestic gardens whose rich biodiversity positions them as ideal ecosystems to benefit both animals and the most vulnerable members of society. Other studies focus on gardens as spaces for food security (Baiyegunhi and Makwangudze, 2013), and the cultivation of medicinal plants (Maroyi and Mosina (2014). Detailed studies on the distribution and potential uses of plant species in gardens include Nemudzudzanyi et al. (2010) who examined various use categories of garden plants and observed the existence of a specific home garden layout containing useful species in home gardens around Kwa-Zulu Natal, South Africa. The floristic composition of domestic gardens, together with the contribution of domestic gardens to plant diversity in urban ecosystems in the Tlokwe City Council Local Municipality, South Africa, was also assessed (Lubbe et al., 2011). Molebatsi et al. (2010) investigated the different use categories of garden plants in the Tswana *tshimo* and found over 500 useful plant species from 105 plant families. Currently, such scholarly research is limited for HCGs in South Africa, and no extensive examples of such research on medical facilities in other parts of the world have been found.

Considering the accessibility of HCGs to communities and especially the most vulnerable, it is especially crucial to understand the plant composition of the gardens, and potential usefulness of such plants to demonstrate the full potential of these gardens which, when realized, are significant and well worth promoting the establishment of HCGs in other parts of the world alongside championing their use locally. The availability of a variety of stakeholders with varying knowledge and skills involved in these gardens (Gwedla et al., 2022) makes them auspicious spaces for knowledge upscaling and may engender processes of social and expansive learning about the significance of harnessing easily accessible vegetation options to supplement livelihoods and enhance general well-being, especially in periods of vulnerability. The HCGs model is prevalent in South Africa, and the high visibility and accessibility of health clinics to poor urban and rural communities positions them as sustainable gardens and strong cases for useful models for countries in the Global South to assimilate. Therefore, this study seeks to position HCGs as alternative models to gardening in rural, peri-urban, and urban areas where other types of gardens may fail to provide ESs for well-being in households and communities. This is done by determining the floristic composition and presence of utilitarian plant species at selected HCGs and how this compares to home and domestic gardens. This was guided by three research questions, namely:

1. What is the plant species composition of HCGs?
2. What are the potential uses of plant species found in HCGs?
3. How do the plant species composition and usefulness differ between municipalities and settlements?

2. Methods

2.1. Study area

One hundred and five HCGs in various clinics situated in small to large rural villages and small towns across the Bojanala Platinum District, North-West Province, South Africa. The province borders Botswana (Fig. 1) and covers 104,882 km^2 of land area (STATS SA, 2018). Most of the provincial population live in rural areas, hence its classification as a rural province (North-West Department of Rural et al., 2014). The Bojanala Platinum District Municipality is 18,333 km^2 large and is comprised of Kgetlengrivier, Madibeng, Moretele, Moses Kotane, and Rustenburg local municipalities. These municipalities are also known as sub-districts with varying numbers of HCGs (Kotane=42; Moretele=22; Madibeng=21; Rustenburg=17; and Kgetlengrivier=3).

The Bojanala Platinum District is in the Central Bushveld area of the Savanna Biome which includes 22 vegetation units (Mucina and Rutherford, 2006). This area is between 1000 and 1500 m above sea level, experiences high summer rainfall, and the winters are dry and frosty (North-West Department of Rural et al., 2014). The district receives

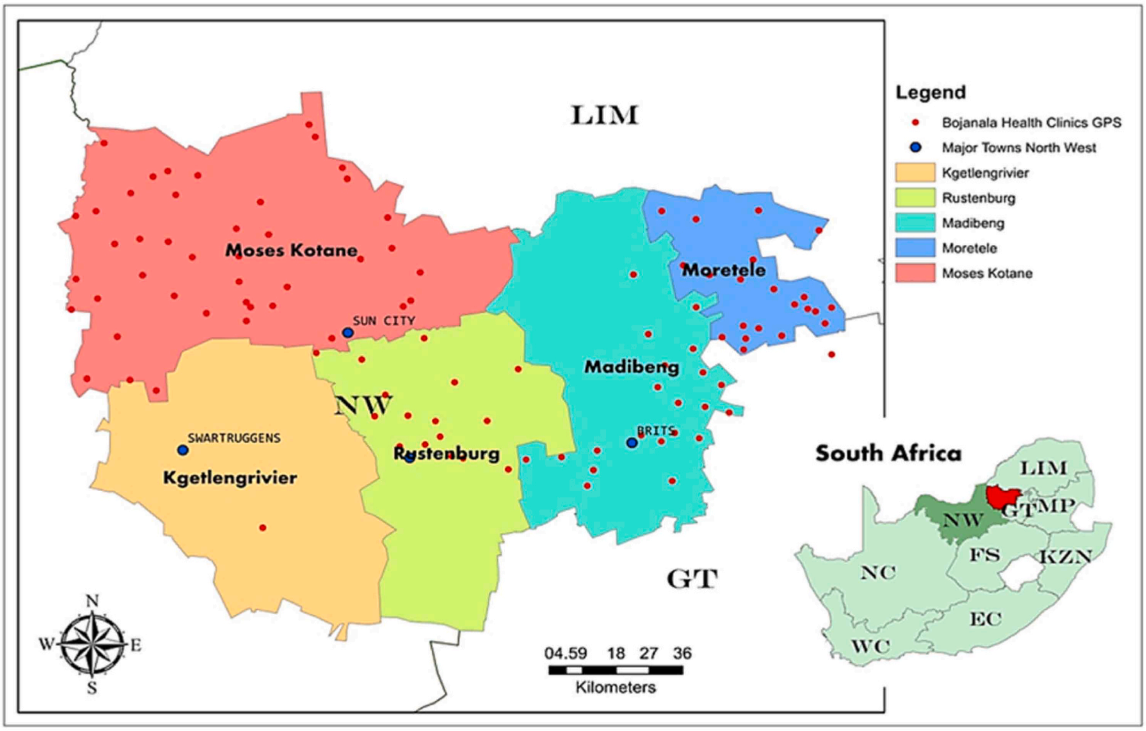

Fig. 1. Sampled HCGs across local municipalities in Bojanala Platinum District Municipality, North-West Province, South Africa (Adapted from Cornelius, 2016; Gwedla et al., 2022).

between 550 and 650 mm of rain per annum, which sometimes reaches 700 mm in the east (North-West Department of Rural et al., 2014). There are approximately 501,696 households in the district (STATS SA, 2018), more than 50 % of the population are living in poverty, and primary healthcare is provided in 121 healthcare facilities (Massyn et al., 2020).

2.2. Data collection

Sampling occurred during the summer and spring seasons of 2015. The provincial Department of Health and Primary Health Care managers of the various sub-districts granted access to health clinics and respective gardens (Gwedla et al., 2022). Micro-gardens were identified and delineated in each HCG (Molebatsi et al., 2010). The size of HCGs and each micro-garden within them were determined using the traditional steps method by the same individual across all clinics. Plant species composition, floristic and physiognomic diversity in HCGs and associated micro-gardens were determined and compared with data from similar studies in domestic and home gardens in the sample province (Molebatsi et al., 2010; Lubbe et al., 2011) for verification. Common names were used in the initial plant identification, and photographs and samples collected for more accurate identification up to species level using expert knowledge at the [blinded for peer-review].

Using field guides, the PlantzAfrica South African national Biodiversity Institute SANBI (2016) database, and previous studies, identified plant species were classified according to status of origin (exotic-naturalized, exotic-cultivated, indigenous and native species), invasive characteristics, Raunkiaers' life-forms (phanerophytes, chamaephytes, hemicryptophytes, therophytes, geophytes and hydrophytes), and growth forms (herbs, herb: graminoids, herb: succulents; shrubs, shrub: succulents; trees, tree: succulents, climbers and parasites). Following suggestions by Kehlenbeck and Maass (2004), Van Wyk and Gericke (2000), Van Wyk et al. (1997) and previous studies in the North-West province, identified species were assigned to different use categories such as food, medicine, ornamental, shade, hedge, and their sub-categories, which were subsequently used to determine the potential usefulness of species. The potential toxicity of the identified species was classified according to Van Wyk et al. (2002) and informal conversations with present stakeholders in the HCGs.

Declared invasive species were identified and categorized based on South Africa's National List of Invasive Species, according to C1a (combat and eradicate species, trade or planting strictly prohibited), C1b (control or remove and destroy species, any form or trade or planting strictly prohibited), C2 (invasive or potentially invasive species where a permit is required perform a restricted activity), and C3 (may remain in prescribed areas or provinces, i.e. *Jacaranda* spp. in urban areas but further planting, propagation or trade prohibited) (National Environmental Management Biodiversity Act NEMBA, 2004).

Some of the food plants found in home and domestic gardens include leafy vegetables and ALVs. In the context of this study, leafy vegetables are plant species where the leafy parts, including young succulent stems, flowers, and young fruit, are consumed as vegetables (Towns and Shackleton, 2018), while ALVs are the traditional leafy vegetables included in the culinary repertoire of contemporary African communities (van Jaarsveld et al., 2014) through custom, habit, and tradition (Towns and Shackleton, 2018).

2.3. Data analysis

Preliminary data analyses yielding descriptive statistics such as mean HCG size were conducted on Microsoft Excel 2016, and subsequently on SPSS 29.0. The frequency of occurrence of each species was determined by enumerating the number of gardens containing the respective species. Species richness was calculated by summing up the number of species encountered in each HCG, and ultimately HCGs in the broader municipality. After checking for normality, regression was used to analyze the relationship between continuous variables such as HCG size and species richness, while differences in species richness between HGCs in different settlement types and local municipalities were analyzed via ANOVA tests.

3. Results

3.1. Families, genera, and species in HCGs

The total cover area of HCGs, excluding the buildings, ranged from 631.5 m^2 to 110,444 m^2, with an average of 5740.3±1247.4 m^2 per garden. The largest HCGs (7583.2±3096.0 m^2) were found in Madibeng Local Municipality, while those in Rustenburg Local Municipality were smaller (3757.5±1450.1 m^2). One hundred and sixteen plant families, 404 genera, and 631 species were recorded across all HCGs (Appendix 1 A). Asteraceae Bercht. & J.Presl, Poaceae Barnhart, and Fabaceae Juss. were the three most frequently recorded families, while the top 20 encountered genera (Appendix 1B) accounted for 16 % of all recorded species. Among the recorded genera, *Vachellia* Wight & Arn and *Senegalia* Raf. (12 species), *Eragrostis* Wolf (12 species) and *Euphorbia* L. (11 species) were the most frequently occurring species. The *Vachellia* and *Senegalia* genera, and *Eragrostis* consisted mostly of indigenous species, while most species representing the *Euphorbia* L. and *Solanum* L. genera were exotic.

Species richness was 40±1.6 plant species per HCG and was highest (40±3.0) in Rustenburg Local Municipality HGCs, while HCGs in the Moretele Local Municipality had the lowest species richness (31±3.3). Garden size was a significant predictor of species richness in several HCGs (r^2=0.48; p<0.05). The most common species encountered in more than 50 % of HCGs across the district were *Cynodon dactylon* (L.) Pers. (91 %) and *Urochloa mosambicensis* (Hack.) Dandy (79 %), *Vachellia tortilis* (Forssk.) Gallaso & Banfi (60 %), and *Schkuhria pinnata* (Lam.) Kuntze ex Thell. (58 %) (Appendix 2). *S. pinnata* is exotic but naturalized, while the rest are native to the North-West Province. Herbaceous plant species (301) were dominant, followed by trees (137) and shrubs (71). *S. pinnata* and *Conyza bonariensis* (L.) Cronquist were the most frequently occurring herbaceous plant species found in 61 and 45 HCGs, respectively. Common tree species included *V. tortilis* and *Prunus persica* (L.) Batsch. which were found in 63 and 48 HCGs, respectively, and the most common shrub species found was *Dichrostachys cinerea* (L.) Wight & Arn. subsp. *africana* Brenan & Brummitt var. *pubescens* Brenan & Brummitt (30 HCGs). Health clinic gardens in small towns had a higher species richness (49±4.4) than those in large rural settlements (46±2.7) and those in small rural settlements (41±2.1) (H=82.4; p>0.05).

Phanerophytes (195 species, including *V. tortilis*, *P. persica*, and *D. cinerea*) was the most abundant life-form. Therophytes (156 species including *S. pinnata* and *C. bonariensis*), were also dominant. Chamaephytes (122 species), hemicryptophytes (103), and geophytes (63 species) were also found, and only one hydrophyte, *Typha capensis* (Rohrb.) N.E.Br., was recorded across all HCGs. Phanerophytes and Therophytes were both found in 90 % of HCGs.

Plants indigenous to South Africa accounted for 51.8 % of all encountered species (Appendix 1B), and 72 % of these are native to the North-West Province. Most (90 %) of these species are non-succulent, and 28 % are classified as important for medicinal purposes. There was no significant variation in the species richness (x^2=155.9; p>0.05) and combinations of species assemblages in HCGs between the different local municipalities. There was, however, significant variation in the number of species found between the various micro-gardens within HCGs across local municipalities (p<0.05). The *naga* micro-garden had a higher species richness than other micro-gardens (Fig. 2), and native species were dominant across all micro-gardens. The *naga* micro-garden had the most (55 %) native species and highest number of different growth-forms dominated by herbs (48 %), while the ornamental micro-garden had the least (21 %) native species. On the other hand, the medicinal micro-garden had four growth forms (herb, herb: graminoid, herb: succulent, shrub), while the hedge micro-gardens had three (herb, shrub, climber). Most encountered trees and shrubs (67 %) were found in the *naga* micro-garden.

Among the exotic species encountered, 14 have been declared as invasive (Table 1). Frequently encountered invasive species include *Morus alba* L. var. *alba* (39 HCGs), *Malvastrum coromandelianum* (L.) Garcke (38 HCGs) and *Melia azedarach* L. (38 HCGs). Nine of these species have been naturalized and are categorized as C1b invaders (Table 1), but many of the species have edible, medicinal or ornamental use potential (Table 1).

3.2. Potential utilization of plants in HCGs

Most encountered species (187) can be used for ornamental purposes, compared to 146 that can be used for medicinal purposes, and 95 for food (Fig. 3). Dye for wool or leather, wood, thatch grass, fibre for string or weaving, perfume, and tooth brushing were other potential uses for up to 16 of the encountered species (Fig. 3). There are some overlaps in the potential use of certain species such as *Ziziphus mucronata* Willd subsp. *mucronate* which can be used as both a medicinal treatment

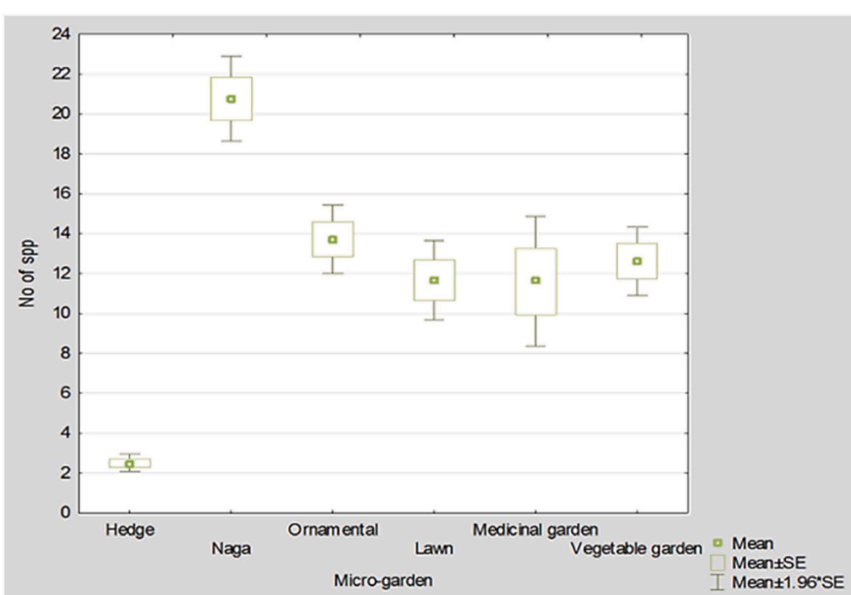

Fig. 2. Differences in the number of species in each micro-garden within HCGs (Source: Authors).

Table 1
Invasive exotic species encountered in HCGs and their status of invasiveness (Source: Authors).

Plant Species	Origin	Status of invasiveness	Potential use
Morus alba L. var. *alba*	Central, Eastern, Northern China	Exotic: naturalized C3	Food
Malvastrum coromandelianum (L.) Garcke	North America	Exotic: naturalized C1b	Medicinal
Melia azedarach L.	India, Sri-Lanka	Exotic: naturalized C3	Medicinal
Tecoma stans (L.) Juss. ex Kunth	Mexico, Southern USA	Exotic: naturalized C1b	Hedge
Jacaranda mimosifolia D. Don	Bolivia, Argentina	Exotic: naturalized C1b	Shade; Ornamental
Catharanthus roseus (L.) G.Don.	Madagascar	Exotic: naturalized C1b	Medicinal
Duranta erecta L.	Florida, South America	Exotic: naturalized C3	Ornamental
Argemone ochroleuca Sweet	Mexico	Exotic: naturalized C1b	Medicinal
Datura stramonium L.	North America	Exotic: naturalized C1b	Medicinal
Casuarina cunninghamiana Miq.	Eastern Australia	Exotic: naturalized C2	Shade; Windbreak
Mirabilis jalapa L.	Central America	Exotic: naturalized C1b	Ornamental
Verbena bonariensis Rendle	South America	Exotic: naturalized C1b	Ornamental
Coreopsis lanceolata L.	North America	Exotic: cultivated C1a	Ornamental
Nerium oleander L.	Europe	Exotic: naturalized C1b	Medicinal

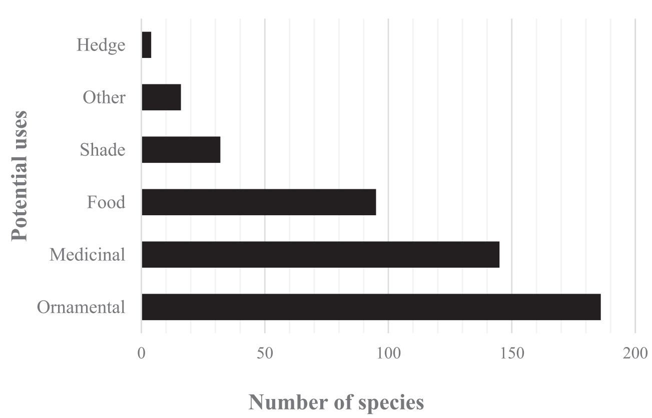

Fig. 3. A grouping of potential uses of species recorded in HCGs (Source: Authors).

and as food, depending on which part of the plant is used. There were no significant differences in the potential uses of species between the different local municipalities (p>0.05), and food, medicinal, and ornamental uses were the dominant potential uses of plant species across all municipalities.

Fig. 4 illustrates the distribution of potential uses among species identified as useful medicinal and food sources. Among the medicinally useful species, 70 % are used as tonic, while only one species is potentially useful as soap or cosmetics (Fig. 4a). Food types identified from edible species include ALVs, leafy vegetables, edible fruit, fruit trees, vegetables, grain, tubers or rhizomes, spice or herbs, and roots used for coffee or as yeast (Fig. 4b). Most species identified as potential food sources are fruit, while only one of each can be used as spices and herbs, respectively (Fig. 4b).

Agapanthus sp. were the most frequently occurring medicinal plant species (Appendix 3). Some *Agapanthus* sp. are commonly used as traditional medicine for antenatal purposes or to induce labour. *M. azedarach* occurred in 38 HCGs and although it is poisonous to humans when heavily ingested, its ethnomedicinal uses include providing relief from rheumatic pain, treating bacterial skin diseases in children, and gonorrhea. Four of the top 10 most frequently occurring medicinal plant species are considered toxic when ingested in high volumes, while one, *Tulbaghia simmleri* P.Beauv., is endemic to South Africa.

Plant species with edible fruit occurred in the greatest variety, followed by leafy vegetable and ALV species (Appendix 3). The most frequently occurring edible plant species was *U. mosambicensis*, an indigenous grass that can be used as grain (Appendix 3). *P. persica* was the most abundant fruit species, while 41 HCGs had *Boerhavia erecta* L., a leafy vegetable that can also be used for medicinal purposes. In some instances, these species were found growing together (Fig. 5) while in others they were each found growing individually. Although plants with potential uses in the categories of ornamental, food, and medicinal uses were dominant across all municipalities, their distribution varied between different clinics, but no significant differences were established in this variation (p>0.05).

4. Discussion

4.1. Plant composition and diversity in HCGs

Previous studies on gardens in Sub-Saharan Africa have outlined the use and ESs provided by various types of gardens including domestic and home gardens (Molebatsi et al., 2010), HCGs (Cilliers et al., 2018; Gwedla et al., 2022; Gwedla et al., 2024) - which are positioned as SESs (Cilliers et al., 2018), and sacred sites (De Lacy and Shackleton, 2017). Ecosystem services delivery in gardens depends on species diversity and composition (Lubbe et al., 2011). In this study, we augment insights into ESs by specifying the potential usefulness of species in HCGs and shed light into the currently under-studied SES of HCGs by illuminating their usefulness in relation to other types of gardens.

Key results indicate that HCGs are more than just spaces for food provision but are characteristic of both Tswana *tshimo* (Molebatsi et al., 2010) and colonial garden design elements that portray a combination of formal and informal garden designs (Davoren et al., 2016). They resemble home (Nemudzudzanyi et al., 2010), domestic (Bigirimana et al., 2012; Mosina et al., 2015), and community gardens (Pearsall et al., 2017), as evidenced by their plant species richness, and the potential uses of these plants for ornamental, food, and medicinal purposes. This makes HCGs prime sites for biodiversity conservation, and thus crucial vehicles towards attaining the African Union's (AU) Agenda 2063 Goal 7 of "achieving environmentally sustainable and climate-resilient economies and communities through biodiversity conservation and the sustainable use of natural resources" (African Union Commission AUC, 2013).

4.2. Growth forms, life forms, and status of origin

The maintenance of multiple layered systems of trees, climbers, grasses, and herbs in home and domestic gardens (Clarke et al., 2014), and managed land-use systems is prevalent in rural and urban areas. This emphasizes the importance of having biodiverse ecosystems which in turn contributes to the resilience of those garden ecosystems. This study mirrored this assertion, as evidenced by the variety of plants of various life-forms and growth forms encountered across all HCGs. This study indicates that herbaceous plant species are the most dominant growth forms in HCGs, followed by trees and shrubs, and correspondingly have an abundance of phanerophytes and therophytes. According to Avolio et al. (2020), these characteristics are some of the most favourable in people's preferences of plant traits for plants to grow in gardens, including ornamental characteristics which correspond with phanerophytes, and drought tolerance which corresponds with

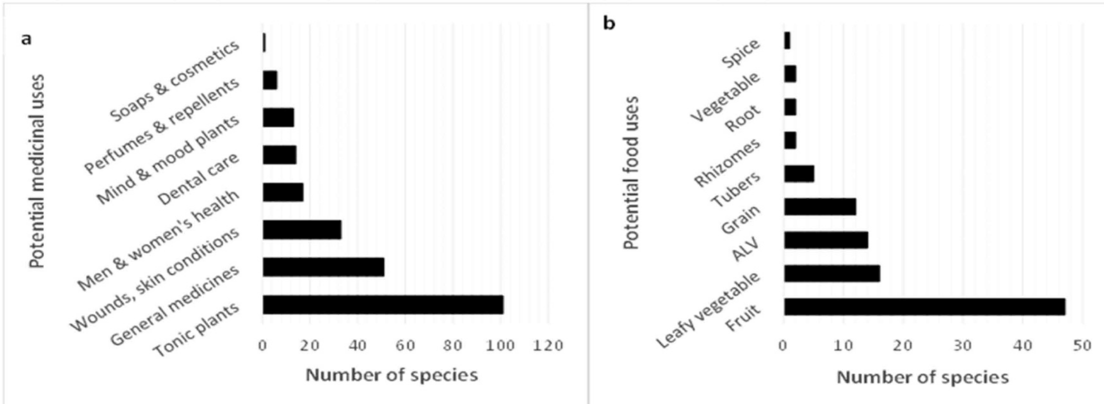

Fig. 4. Established potential uses of species found in HCGs as medicinal (a) and food (b) species (Source: Authors).

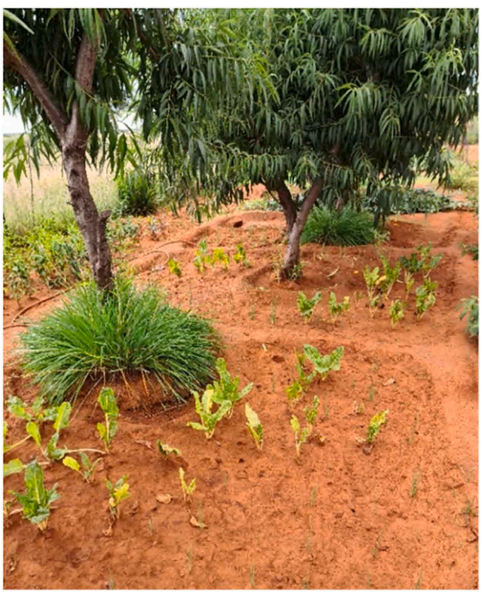

Fig. 5. Some of the most frequently occurring edible (*P. persica*; *Spinacia oleracea*) and medicinally useful plants (*Tulbaghia simmleri*) encountered cultivated together in an HCG (Source: Authors).

therophytes. The dominance of herbs, trees, and shrubs in HCGs supports Mohamed et al. (2014) findings that trees (53 %), shrubs (21 %), and perennial herbs (8 %) were the most abundant growth forms in the Aswan Botanical Garden in Egypt.

The composition and diversity of garden floras established in this study can also be attributed to a variety of stakeholders who are actively involved in HCGs (Cilliers et al., 2018; Gwedla et al., 2022) and belong to various ethnic groups, whose indigenous cultures may become westernized as reflected by the floristic composition of their gardens (Davoren et al., 2016). Cubino et al. (2014) concluded that certain cultural variables, such as the language of a particular region, influence plant diversity in gardens. Since traditionally useful native species usually regenerate naturally in some areas, Tswana households generally keep a natural area (*naga* micro-garden) which typically contains native species for household purposes such as food, medicine, and forage (Molebatsi et al., 2010). The *naga* micro-gardens in the HCGs also reflected the importance of some of these species as food and medicinal sources, and this may account for the larger proportion of plant species indigenous to South Africa compared to exotic ones reported in this study. Gopal et al. (2018) noted similar patterns in selected sacred sites in an Indian megacity, reporting that the species pool was dominated by native plants which accounted for 69 % of all species. This is contrary to other studies which found that exotic plant species usually account for the largest proportion of plant species found in various types of gardens, including home and domestic gardens (Sierra-Guerrero and Amarillo-Suárez, 2017). The amalgamation of various micro-gardens in this study, which typically serve different purposes, can account for the overall abundance of indigenous and native plants compared to exotic ones.

Like home and domestic gardens in other parts of the world (Mayer et al., 2017) and South Africa (Davoren et al., 2016), ornamental species in HCGs are also mostly exotic. Comparable with other countries with long colonial histories, thousands of exotic plants were introduced into South Africa, and many of them have become naturalized and some even invasive (McLean et al., 2018). The relative abundance of native to exotic plant species tends to decrease with increased urbanization (McLean et al., 2018). The aesthetic value of plants often influences the introduction of cultivated exotic plants, which usually constitute a large proportion of garden flora in urban areas (Swan et al., 2021). This resonates with the results of this study where most plant species found in the HCGs are exotic and are used for ornamental purposes, among other uses. Additionally, the large numbers of exotic species recorded could also indicate their usefulness as food plants.

4.3. Potential utilization of plants in HCGs

Satisfying the needs and requirements of garden owners and beneficiaries of gardens is an important aspect of any form of gardening (Cubino et al., 2014). The presence or absence of useful plants in gardens, and the capacity in which they are used, depends on the intended use of the garden. For example, botanical gardens may have more ornamental plants than domestic gardens, while domestic gardens could have a larger representation of food plants than botanical gardens. The results of this study in relation to species useful for ornamental, medicinal, and food purposes in HCGs are consistent with other garden types, as reported by Regassa (2016) who found that out of the total useful plants encountered in 120 home gardens across Hawassa city, Ethiopia, 47 % were used for ornamental purposes, 30 % as food plants, and 16 % for medicinal purposes.

4.3.1. Ornamental plants in HCGs

Ornamental plants comprised the highest proportion of useful plants in HCGs. Although this is contrary to the intended function of these gardens and may be interpreted as unexpected, this pattern has been observed in home and domestic gardens (Mosina et al., 2015; Regassa, 2016), community gardens (Clarke and Jenerette, 2015), and botanical gardens (Guo et al., 2016) of both urban and rural settings. In keeping with the dual nature of HCGs resembling both Tswana *tshimo* and colonial gardens, it is plausible that European influences on the

Batswana culture that have encouraged ornamental plants cultivation and use in home gardens for aesthetical purposes may have influenced ornamental plants diversity in HCGs too (Davoren et al., 2016).

Plants with ornamental utility provide valuable cultural ES such as recreational potential, aesthetics, environmental education, social empowerment such as increased self-esteem, social interaction and strengthening of community ties (Cilliers et al., 2018). Gwedla et al. (2022) found that stakeholders of HCGs in various small to medium-sized cities in South Africa perceived cultural ESs as some of the most important ESs provided by HCGs. Therefore, the prevalence of ornamental plants in HCGs suggests that these gardens have a far more significant utilization potential for species present, and this potential, which can have multiple benefits to stakeholders and end-users, is not fully realized.

4.3.2. Medicinal plants in HCGs

The abundance of medicinal plants in HCGs emphasizes the health advantages associated with green spaces (Bressane et al., 2024). Given the usefulness of medicinal plants to communities in peri-urban and rural communities (Murata, 2021), it is not surprising that plants with potential medicinal uses constitute a substantial proportion of species found in HCGs. In fact, these patterns of abundance are plausible for the North-West province because Savanna ecosystems are biodiversity-rich, and approximately 71 % of their vegetation is a source of medicinal products (Mbinile et al., 2020). Much of the North-West province land area is in the Savanna biome, specifically the Bojanala Platinum District (Mucina and Rutherford, 2006). Evidently, there is a high demand for medicinal plants in most parts of South Africa, and it is estimated that 27 million citizens will self-medicate with traditional medicine at some stage in their lives (Nwafor et al., 2021). According to Rasethe et al. (2022), plants are usually preferred in the preparation of medicine than animal products, and both lay people and traditional health practitioners actively plant species for medicinal use in their gardens. Notable species such as *M. azedarach*, an exotic invasive species found in 38 HCGs, has been lauded for its usefulness as an antiseptic and antiviral treatment for diseases like Malaria and diabetes (Khan et al., 2018).

4.3.3. Food plants in HCGs

There are approximately 821 million undernourished people globally, a statistic that paints a clear picture on the intensity of food insecurity in areas, particularly the GS, that are currently vulnerable to hunger and undernutrition (Omotayo and Aremu, 2020). It has thus become increasingly important for society to consider incorporating indigenous plant species to their diet as these are almost always easily accessible and easier to grow. Leafy vegetables accounted for the bulk of the most frequently occurring edible plant species encountered in HCGs. These are prime sources of food to many rural communities across Sub-Saharan Africa, and ALVs' nutrient content is generally higher than alternative cultivated species and will likely be useful in alleviating the nutrition deficiency in communities (Van Jaarsveld et al., 2014). Given the intended role of HCGs in providing nutritional fruits and vegetables to people who visit the clinics, it is concerning that very few of the indigenous plant species encountered are edible. More so because traditional leafy vegetables, for example, have the potential to increase the levels of iron and vitamin A in the diets of people living in poor countries (Van Jaarsveld et al., 2014). The scarcity of indigenous plants in HCGs can be attributed to the movement away from traditional diets (Kruger et al., 2012) which sees extremely low consumption of traditional vegetables because people are unfamiliar with the crops and they are rarely available in nature and on markets (Molebatsi et al., 2010).

4.4. Health clinic gardens for human health and well-being

The AU's Agenda 2063 is set on achieving "a prosperous Africa based on inclusive growth and sustainable development, with the goal to eradicate poverty in one generation and build shared prosperity through social and economic transformation of the continent, where African people have a high standard of living, quality of life, and sound health and well-being" (African Union Commission AUC, 2013). As SESs, HCGs are well placed to contribute to some of these aspirations as they target the most vulnerable members of society. Their visibility and accessibility render them important institutions to contribute to an improved standard of living, better quality of life, and sound health and well-being for African people, as envisioned by the AU's Agenda 2063 (African Union Commission AUC, 2013). The rich biodiversity in HCGs presents a myriad of opportunities to optimize ES provision, and novel approaches to natural resource management championed by a variety of stakeholders with diverse knowledge can make this possible (African Union Commission AUC, 2013). Many utilitarian plants cultivated in gardens play the dual role of stimulating plant diversity as well as contribute to the livelihoods and well-being of those who use the gardens. Expectedly, the species composition in HCGs changes over time and growing season, particularly the composition of cultivated species compared to the naturally generating ones. But some species have versatile functionality and can be consumed in more than one way based on seasonality. For example, some species of *Amaranthus* can be harvested, dried, and preserved for consumption during dry seasons (Rankoana, 2021). There is a wide variety of indigenous fruit trees in Africa that are potential sources of food and nutrition security (Omotayo and Aremu, 2020). However, many of these are barely found in gardens. Out of the 10 indigenous fruit trees regarded as underutilized for their potential contribution to food and nutrition security (Omotayo and Aremu, 2020), only four (*Dovyalis caffra* (Hook.f. & Harv.) Warb., *Mimusops zeyheri* Sond., *Sclerocarya birrea* (A.Rich.) Hochst. subsp. *caffra* (Sond.) Kokwaro, and *Vangueria infausta* Burch. subsp. *infausta* (Appendix 1)) were encountered in HCGs.

4.5. Limitations and future research

This study emphasizes the comparability of HCGs with other types of gardens such as home and domestic gardens. This is limited because the comparison is based on previous studies that assessed the plant composition of various types of gardens in various locations and independent of community gardens. An examination of the plant distribution and composition in domestic gardens in proximity with health clinics can better explain the comparability.

A focus on South Africa and only one district presents an initial and small-scale attempt to understand the potential of HCGs to contribute to human well-being. However, this context is limited because it does not account for the dynamics and needs in other districts, provinces, and countries. While the specific cultural and economic contexts of the North-West province may be prevalent in other parts of South Africa, they may also limit the direct assimilation of the HCGs model in other countries in the Global South that do not share similar contexts. Therefore, an exploration of plant composition and usefulness in HCGs from varying contexts would illuminate their usefulness as intended by the government when they were first established, and an exploration along an urban-rural gradient or neighbourhoods with varying socioeconomic contexts can provide improved insights on this.

The utilization of plants in HCGs reported in this study were based on and supported by literature, and thus regarded as potentially useful. In addressing this limitation, further research should establish the extent to which communities benefit from HCGs through examining the perceptions and experiences of using the plants growing in HCGs by communities in proximity to the gardens, subsequently verify the actual uses of these plants and their contribution to general well-being through observations of use.

5. Conclusion

Gardens host a variety of plant species incorporated from many sources, elevating species richness (Cubino et al., 2014) and utilized for a variety of needs. They are increasingly recognized as beneficial, multifunctional GI that contribute to resilience for human inhabitants and biodiversity alike (Cilliers et al., 2018). This study highlighted the species composition and several potential uses for the species found in HCGs. Health clinic gardens are composed of a diversity of plants that serve different purposes, mainly ornamental, food, and medicinal purposes. Herbaceous plant species were dominant, and the most abundant life-form were phanerophytes. There were more exotic than indigenous and native species, although the margin between them was narrow. Several ALVs were also found, highlighting the potential for improving some nutrient deficiencies experienced in households surrounding the health clinics. Species used as a tonic were the most abundant medicinally useful plants, while fruit-bearing plants for human consumption were the most abundant in the food plants category.

The composition and potential utility of plant species in HCGs found in this study suggest that given the intended role of HCGs, these systems are currently under-utilized. We have indicated that gardens around health clinics which are common throughout South Africa, can be used as alternatives to other types of privately-owned or government-established gardens where challenges to sustainable gardening persist. Furthermore, they are crucial ecosystems that can considerably contribute to the reduction of challenges such as malnutrition, deaths due to HIV/AIDS and TB resulting from nutrient-deficient foods or defaulting on medication because of lack of food, and loss of vegetation and reduced biodiversity (African Union Commission AUC, 2013). Given the purpose of HCGs, findings from this study form a sufficient background for future research that could investigate how traditional and indigenous knowledge on useful indigenous and naturalized species can be illuminated and restored to position health clinics as spaces that encourage their use, champion their supply, and provide a platform for knowledge upscaling to home gardens.

CRediT authorship contribution statement

N. Gwedla: Formal analysis, Validation, Writing – original draft, Writing – review & editing, Data curation. **S.F. Cornelius:** Data curation, Formal analysis, Investigation, Methodology, Writing – original draft. **M.J. Du Toit:** Conceptualization, Investigation, Project administration, Supervision, Validation, Writing – review & editing. **S.S. Cilliers:** Conceptualization, Funding acquisition, Investigation, Project administration, Resources, Software, Supervision, Validation, Writing – review & editing.

Declaration of Competing Interest

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

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ufug.2024.128445.

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