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Exploring the value of ecosystem services at health clinic gardens in a South African context

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Abstract
Ecosystem services (ESs) valuation is important for advancing biodiversity objectives and investing in green infrastructure (GI) establishment. Little is known about the potential of health clinic gardens (HCGs) to provide ESs and their potential values. This study sought to determine the plant and bird species composition and potential value of ESs provided by 32 HCGs in two South African district municipalities. HCG sizes range from 513.0m^2 to 13531.0m^2 and each had at least one micro-garden. Among the 312 plant species observed across all HCGs, 60% were exotic. The small HCGs had 31 ± 3.6 different plant species per garden, compared to the medium-sized (32 ± 3.7) and large ones (49 ± 5.2). Provisioning ESs from the observed species were prominent with 17.4 ± 1.16 species potentially used for general well-being, 13.66 ± 1.08 as potential food plants, and 11.91 ± 0.93 potentially raw materials. Trees in HCGs were estimated to sequester up to 163481.87 kg of carbon from trees covering an area of up to 9620.80m^2. Approximately 1390.70 ± 427.50m^2 of HCG space had the potential to provide a habitat for plants and birds, and 11 bird species were observed across all HCGs. Sixty-three bird nests encountered in 18 HCGs are believed to belong to the *Passer domesticus*. HCGs resemble other types of gardens like home and domestic gardens, and their rich plant biodiversity positions them as ideal ecosystems to benefit even the most vulnerable members of society. They provide an opportune platform for knowledge upscaling in the cultivation and use of plant species as a supplement of primary healthcare and food security issues in the summer months to the rural, urban, and peri-urban poor in the Global South.

Keywords Bird species · Carbon sequestration · Ecosystem services · Habitat provision · Health clinic gardens · Micro-gardens · Plant species · Provisioning ecosystem services

Introduction

Assessing ecosystem service (ES) values is a key action for the advancement of biodiversity objectives like better protecting ecosystems and the services they provide through green infrastructure (GI) establishment (Maes et al. 2016). While it is crucial to understand people's subjective evaluations of ESs for better communication, maintenance, and ES benefits enhancement (Larson et al. 2019), such evaluations can be distorted by people's perceptions, preferences, and demands for ESs (Plieninger et al. 2013). Thus, actual (real) ESs values may be crucial motivating factors for GI establishments and expansion, maintenance, and stakeholder engagement in environmental stewardship action to protect GI (Langemeyer et al. 2018).

The value of ecosystems can be divided into three types: ecological, economic, and socio-cultural value (De Groot et al. 2002). The ecological value of a system is determined by the integrity of the regulation and habitat functions of the ecosystem and by ecosystem parameters including complexity, diversity, and rarity (De Groot et al. 2002). The tracing of the social and political trajectories of local practices and decision-making are the core to better understand the changing value of ESs, and Sutherland et al. (2016) suggest the concept of ecological economics to understand the economic value of Ess, which focuses on creating markets

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for ESs and payments for ecosystem services (PESs) programmes to value the environment. Human perceptions are crucial in determining the socio-cultural value of an ecosystem, and social reasons facilitate the identification of crucial environmental functions (De Groot et al. 2002).

Gardens are essential types of GI that are important hubs for multiple ESs provision (Cubino et al. 2014). In South Africa, health clinic gardens (HCGs) are community gardens developed and managed by a variety of stakeholders for the community on government-owned land (Cilliers et al. 2018; Gwedla et al. 2022). They were first developed after 1994 around health clinics to contribute towards the nutritional needs of the surrounding community through the provision of fresh fruits and vegetables to malnourished patients (Voster et al., 2011). HCGs in the North-West province structurally resemble the Tswana *tshimo* garden layout (Cilliers et al. 2018), which refers to "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, shade trees and an orchard" (Molebatsi et al. 2010).

Extensive scholarly research has been conducted on the value of ESs provided by various types of gardens (Ge et al. 2022). However, little is known about the structure, composition, ESs value, and efficacy of community gardens associated with hospitals and healthcare centres (George and Ethridge 2023), specifically HCGs in South Africa. Therefore, the aim of this study was to explore the actual presence and ecological, socio-cultural, and economic value of ESs provided by vegetation in urban and peri-urban HCGs, thereby making a case for the establishment and maintenance of these garden systems beyond food provision. Ecosystem disservices (EDS) in the HCGs, such as allergies, accidents, and infrastructure damage caused by branches and roots are acknowledged (Muller, 2019) but not included in this paper.

Methods

Study areas

This study was part of a larger study on HCGs and community engagement conducted in the Dr Kenneth Kaunda District Municipality in the North-West province, and the Frances Baard District Municipality in the Northern Cape province of South Africa (Fig. 1). Data were collected in 32 HCGs situated in urban and peri-urban areas of the two districts (Fig. 1). The Dr Kenneth Kaunda District is situated in the grassland biome, with small patches of savanna biome throughout the district, while the Frances Baard District is in the savanna biome (Mucina and Rutherford 2006). Both districts experience summer rainfall (Mucina and Rutherford 2006).

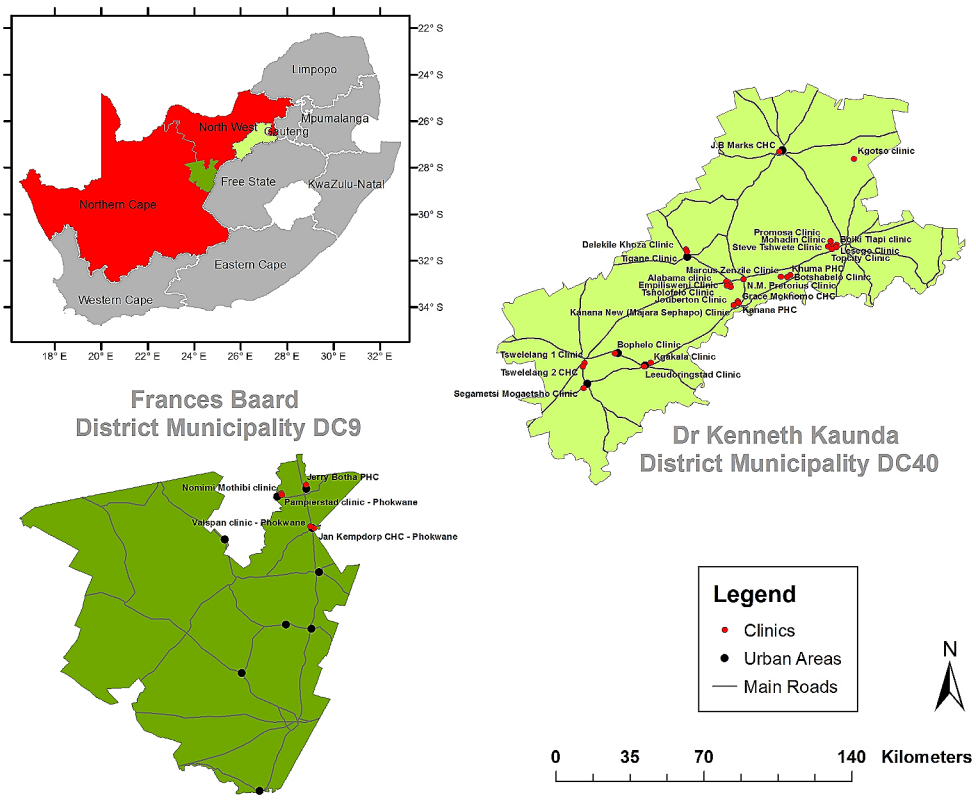


Fig. 1 The locations of HCGs sampled in the two districts of the North-West and Northern Cape provinces in South Africa (Muller, 2019)

Data collection and analysis

Data were collected during the spring and summer seasons in each health clinic identified to have at least one micro-garden. Micro-gardens refer to different pockets of vegetation and bare ground intended for specific uses such as food cultivation and ornamental plants propagation within a larger garden space (Molebatsi et al. 2010; Nemudzudzanyi et al. 2010). Gardens were subjectively categorized into small, medium-sized, and large based on the sum areas of the HCGs. Table 1 outlines the objectives and brief methods employed in conducting this study. Various quantifiable provisioning, regulating, supporting and cultural Ess as described in the MEA (2005) (Table 1) were subjectively selected for the study (Muller, 2019). Data analyses were conducted on IBM-SPSS 29.0.

Results

Provisioning ESs from the observed species were prominent and 17.4 ± 1.16 species had the potential to contribute to general well-being ($F = 4.5$; $p = 0.019$); 13.66 ± 1.08 were potential food plants ($F = 3.4$; $p = 0.048$), and 11.91 ± 0.93 had the potential to be used as raw materials ($F = 4.3$; $p = 0.024$) (Table 2). Trees covering an area of up to 9620.80m^2 in HCGs were estimated to sequester up to 163481.87 kg of carbon (Table 2). No significant relationship was established between the size of HCGs and total tree cover per garden ($r^2 = 0.26$; $p = 0.15$) or potential carbon sequestration ($r^2 = 0.34$; $p = 0.06$).

Cynodon dactylon was found in 23 HCGs and has the potential to improve general well-being and the ecological value of the HCGs. On the other hand, *Portulaca oleracea* and *Prunus persica* were the most frequently occurring potential food plants each found in 20 HCGs (Appendix 2). One hundred and sixteen plant species were identified to

Table 1 Methods employed in data collection. (Generated by the authors)

Objective	Variables of Focus	Data Collection Instruments and Analysis
Determine the plant species distribution in HCGs	Composition and abundance of plant species	Vegetation surveys: Plant identification across HCG; Expert knowledge at [Concealed for Review] Herbarium. Species abundance: sum of species encountered in each HCG. ANOVA tests and their non-parametric equivalents used to determine differences in means of plant species abundance.
Estimate the value of provisioning ES	Number of potential food plant species Number of potential raw materials plant species Number of plant species for general well-being	Vegetation surveys: Plant identification across HCG Expert knowledge; Field guides (Van Wyk and Gericke 2018). Frequency of occurrence: number of HCGs in which species were encountered. ANOVA tests and their non-parametric equivalents used to determine differences in means of plant species with different potential uses.
Estimate the value of regulating ES	Amount of carbon stored	Stem circumference/tree at 1.3 m height: DBH = CBH/π CHB: Stem circumference at breast height π: PI() r:DBH/2 $Y = a\,(\pi r2)\,\beta$ Regression analysis to determine the relationship between the size of HCGs and potential carbon sequestration.
	Value of carbon stored	$P_3 = K \times P_2$;K: atomic ratio of CO_2 (44) to C (12), P_3: carbon price of sequestrated carbon per tonne, P_2: proposed carbon price of (R120/tonne of CO_2-e)
	Total tree cover (m^2) (Local climate regulation)	Crown coverage where tips of longest branches were measured in two directions in a 90° angle. Regression analysis to determine the relationship between the size of HCGs and total tree cover per garden.
Estimate the value of supporting ES	Total garden size	Sum of micro-garden sizes
	Number of micro-gardens	Identification and enumeration of all present micro-gardens from Molebatsi et al. (2010).
	Habitat size	Number of micro-gardens and their sizes (m^2) Sum of size of present micro-gardens
	Proportion of habitable garden space	Observation and enumeration of present bird species
	Number of bird species	Chi-square tests to determine association between size of HCGs and potential to provide bird habitat based on number of observed bird species
	Number of plant species	Enumeration of encountered plant species
Estimate the value of cultural ES	Number of plant species with spiritual or cultural use	Informal conversations with present stakeholder in HCG; literature studies and field guides (Van Wyk and Gericke 2018).
	Number of plant species for ornamental purposes	Plant species observation of placement in HCG, literature studies (PlantzAfrica 2022).

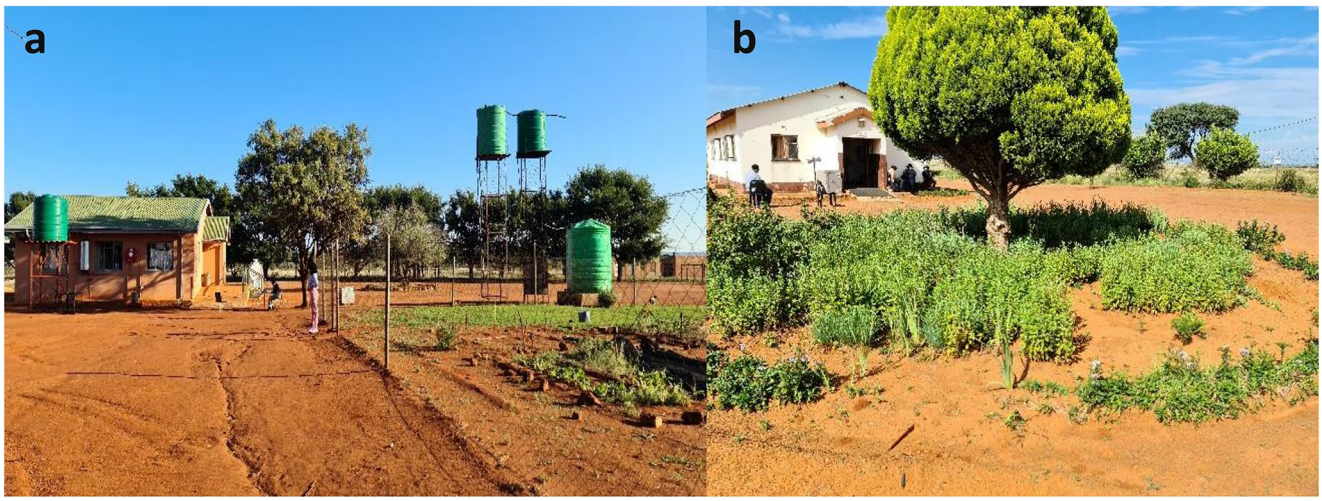


Fig. 2 The sizes of the sampled HCGs ranged from 513.0m^2 to 13531.0m^2 (Table 2). Each had at least one micro-garden, where 82.1% of HCGs had ornamental and vegetable micro-gardens, respectively (Fig. 2). The smallest had 3±0.26 micro-gardens compared to the medium-sized (4±0.29) and large HCGs (4±0.26) (F=2.3, p=0.12). There were 312 plant species observed across all HCGs (Appendix 1), 60% of which were exotic. On average, the small HCGs had 31±3.6 plant species per garden, compared to the medium-sized (32±3.7) and large ones (49±5.2) (F=5.8; p=0.008). Examples of HCG layouts, depicting the presence of at least one micro-garden, including **(a)** the lawn, *lebala*, shade trees, vegetable garden, and **(b)** the ornamental gardens. (Source: Authors)

Table 2 The ESs associated with plant species identified across all HCGs

Ecosystem Services and Ecosystem Services Variables		Type of ES Value	Range/HCG	Mean ± SE
Provisioning	Number of potential food plant species	Ecological; Socio-cultural	2–27	13.66 ± 1.08
	The market value of vegetables and fruit produced (ZAR)	Economic	0.00-1653.81	277.74 ± 101.31
	Number of species with potential to improve general well-being	Socio-cultural	4–31	17.44 ± 1.16
	Number of potential plant species as raw materials	Socio-cultural	3–24	11.91 ± 0.93
Regulating	Amount of carbon stored (kg)	Ecological	0.00-163481.87	11063.79 ± 5148.58
	Value of stored carbon (ZAR)	Economic	0.00-71932.02	4868.07 ± 2265.38
	Total tree cover (m²)	Ecological	0.27- 9620.80	849.75 ± 300.08
Supporting	Size of HCG (m²)	Ecological	513.0-13531.0	2495.40 ± 536.16
	Size of habitat for plants and birds (m²)	Ecological	50.0-10359.0	1390.70 ± 427.50
	Number of micro-gardens present	Ecological	1–5	2.81 ± 0.18
	Proportion of garden potentially a habitat for plants and birds	Ecological	2.85–100	44.05 ± 4.73
	Number of plant species	Ecological	15–70	37.19 ± 2.77
	Number of indigenous plant species	Ecological; Socio-cultural	3–28	12.66 ± 1.19
	Number of exotic plant species	Ecological	9–49	24.53 ± 1.93
	Number of bird species	Ecological	0–11	2.41 ± 0.28
Cultural	Plant species with potential spiritual or cultural value	Socio-cultural	0–2	0.56 ± 0.13
	Plant species with potential ornamental value	Socio-cultural	1–20	10 ± 0.89

have a potential ornamental value, and the most common of these species are outlined in Appendix 3. 65% of all encountered ornamental species were exotic, and 44% of HCGs had at least one plant species with potential cultural value. All encountered species associated with potential spiritual cultural value are indigenous to Southern Africa, for example, several parts of *Celtis africana* and *Dietes.bicolor* species are used for spiritual cleansing and as protective charms across different ethnic groups in South Africa (Table 3).

Approximately 1390.70 ± 427.50m^2 of HCG space had the potential to provide a habitat and food for plants and birds (Table 2). Eleven bird species were observed across all HCGs, and the most common bird species was the house sparrow (*Passer domesticus*) (Table 4). The size of HCGs had no significant bearing on the potential to provide

Table 3 Encountered plant species with potential spiritual or cultural value across all HCGs

Plant species	Frequency of occurrence
Celtis africana	7
Dietes bicolor	4
Helichrysum aureonitens	2
Crinum bulbispermum	1
Hermannia depressa	1
Plumbago auriculata	1
Senegalia caffra	1
Ziziphus mucronata	1

bird habitat based on the number of observed bird species ($\chi^2 = 10.03$; $p = 0.12$) and size of habitat for plants and birds ($\chi^2 = 30.2$; $p = 0.45$). Sixty-three bird nests observed in 18 HCGs are believed to belong to *P. domesticus*, while 59 observed in 12 HGCs are believed to belong to Southern masked weaver (*Ploceus velatus*).

Discussion

Urban ecosystems are highly modified by humans, affecting plant community composition and leading to reductions in various ESs (Hane and Korfmacher 2022). Although highly altered and managed by humans, the HCGs in this study demonstrate the potential for optimal ES provision. Evidence of this is found in the abundance and diversity of plant species and thus the potential for ES provision and enhancement in the gardens. The plant species abundance in HCGs is reminiscent of home, domestic, and other types of community gardens both in South Africa and elsewhere (Clarke et al. 2014; Lubbe et al. 2010; Molebatsi et al. 2010). This also positions HCGs as an ideal ecosystem for biodiversity conservation and restoration. Gardens typically contain an eclectic mix of indigenous and exotic species, although exotic plant species usually account for the largest proportion of plant species (van Heezik et al. 2013). This was evident in HCGs in this study, a pattern McLean et al. (2018) attribute to plant species naturalization and the relative abundance of exotic species with increased urbanization.

An important purpose of HCGs was geared towards food security and assisting ailing patients around the community to meet their nutritional needs through the cultivation of various fruits and vegetables (Voster et al., 2011). However, this study reveals that HCGs are spaces for ESs provision beyond food provision. Provisioning ESs are some of the most widely recognized ESs of gardens (Maroyi 2022) and the results of this study support this assertion. In keeping with this purpose, HCGs in this study had a high number of potential food plants, comparable to domestic gardens in the North-West Province (Molebatsi et al. 2010; Lubbe et al. 2010). Given the rates of undernourishment globally and locally (Omotayo and Aremu 2020), food production is crucial in HCGs, and community gardens may promote access to fresh nutritious foods (Shisanya and Hendricks, 2011), especially from leafy vegetables and grains.

Sutherland et al. (2016) found that the wood for fuel and sticks for building houses, fencing yards, and making brooms, were some of the useful goods derived from the trees and grasslands in selected peri-urban areas in Durban, South Africa. The potential for raw materials harvesting in HCGs was high. This is particularly important in the southern Africa context where poor communities need to have access to alternative means of getting resources such as building materials, fuel, and other crafts such as thatching, weaving, and brooms (van Wyk and Gericke 2018).

While a substantial number of species with the potential to contribute to general well-being were enumerated, no HCG had a delineated medicinal micro-garden, implying an absence of concerted efforts to cultivate such plants around health clinics. This is expected, given the attitudes and perceptions around the use of plants for general well-being in their most natural form in contemporary South Africa which is inclined towards Western biomedicine or removed from the use of "traditional medicine" (Aston-Philander et al. 2011). Notwithstanding, there is a high demand for plants with properties to improve general well-being in

Table 4 The bird species and bird food plant species observed in HCGs

Bird Species	Frequency of occurrence	Bird Food Plant Species	Frequency of occurrence
Passer domesticus	27	*Celtis sinensis*	15
Columba livia	16	*Combretum erythrophyllum*	8
Ploceus velatus	12	*Searsia lancea*	8
Streptopelia senegalensis	9	*Celtis africana*	7
Acridotheres tristis	3	*Searsia pendulina*	7
Euplectes orix	2	*Olea europaea* subsp. *africana*	6
Serinus canicollis	2	*Morus alba/nigra*	5
Tricholaema leucomelas	1	*Melia azedarach*	3
Swallow species	1	*Dovyalis caffra*	3
Turdus olivaceus	1	*Celtis australis*	2
Streptopelia capicola	1	*Ficus carica*	2

most parts of South Africa, with an estimated 27 million citizens expected to self-medicate with such plant species at some stage in their lives (Nwafor et al. 2021). Many species classified as having potential to contribute to general well-being also have a dual use as food plants. This resonates with Chazovachii et al. (2013), medical plants found in selected community gardens in Zimbabwe such as *Allium sativum* and *Allium cepa* may be used to improve digestion and stimulate appetite, alongside their use as flavoring in food. The common grass species, *Cynodon dactylon* also has several potential uses. Due to its rhizomatous nature, it is a good colonizer, arresting soil erosion and is well adapted to disturbances such as trampling and grazing (Cilliers et al. 1998; Du Toit et al. 2021). *C. dactylon* is also widely used in traditional medicine in Africa for different ailments, such as diarrhea and healing of wounds, due to the antimicrobial activities of all its organs (Gebashe et al. 2019).

The impact of urban trees, and thus their potential for carbon sequestration, on climate change is often disregarded because their ESs are not well understood or quantified (Nowak et al. 2013). However, ecosystems and environments with substantial room for trees have the highest potential for carbon sequestration (Kuittinen et al. 2016). The carbon sequestration potential of vegetation in HCGs is comparable to that of other types of UGI like domestic gardens and parks. Ariluoma et al. (2021) estimated that the carbon sequestration and storage potential of urban green areas in residential yards of Kuninkaantammi, Helsinki would be 95 kg CO_2 sequestered per resident and 2.4 kg CO_2/m^2 of floor space over a period of 50 years.

Avian ecological composition and diversity is an important proxy for evaluating the functionality and quality of different types of green spaces (Sandstrom et al., 2006). The bird species richness encountered in HCGs in this study suggests that HCGs are functional ecosystems with the potential for habitat and food provision HCGs thus present considerable opportunity for bird conservation and enhance human experiences with wildlife (Goddard et al. 2017). Moreover, gardens represent potential refugia for native plant and animal communities, including birds which tend to play keystone ecological roles because they form central nodes that hold pollination webs together where many plant species depend on them for pollination (Pauw and Louw 2012). In the HCGs a frequent visitor, *Ploceus velatus*, has documented pollination associations with at least eight plants species (Craig 2014) including *Aloes* (Symes et al. 2008). The most frequently observed bird in the HCGs, *Passer domesticus*, play an important role as natural pest controller due to its omnivorous diet (Narayanappa et al. 2022). A review on the ES provided by birds lists several studies that quantified the contribution of birds as pest-control agents (Whelan et al. 2008). The calming effect of birdsong on humans is also an important cultural ES provided by birds (Ratcliffe et al. 2013). A study in Australia, however, also highlighted the role frugivorous birds play in seed dispersal of alien plants such as *Celtis sinensis* (Stansbury and Vivian-Smith 2003) which commonly occurred in HCGs. The preferential consumption of fruits of alien plants by birds and the resulting unintended seed dispersal of these plants is an important issue that should not be overlooked (Mokotjomela et al. 2013).

The use of vegetation in spirituality and cultural practices is widespread in African culture which contributes to improved general well-being holistically. Two of the plant species encountered in the HCGs with potential uses in this regard are *C. africana* and *D. bicolor*. Zukulu et al. (2012) state that *D. bicolor* is widely used for ritual washing after a death in the family and in the ritual cleansing of cattle a few days after a funeral in the eastern parts of South Africa. *C. africana* stems are believed to have magical properties and are predominantly used to make magical sticks which are driven into the ground to protect against witchcraft in the northern parts of the country (Constant and Tshisikhawe 2018). Rituals, ceremonies, spiritual practices, and other traditions associated with plant use also serve to pass on institutional memory and cultural internalization to support knowledge generation, accumulation, and transmission (Berkes et al. 2000).

It is evident from this study that only a few of the HCGs provide a variety of ESs with high economic, ecological, and socio-cultural values (Muller, 2019). These HCGs could serve as good examples of how the others can be improved, by optimizing the ESs provided by the gardens (Cilliers et al. 2018) through increasing the number and size of the micro-gardens (Molebatsi et al. 2010) and by using plant species which are adapted to specific environmental conditions in the HCG, and following the principles of waterwise gardening (Van Jaarsveld 2013). Several different stakeholders with different perceptions of the "value of nature" are involved in designing, planning and managing the HCG, and that needs to be understood and communicated to the larger community (Cilliers et al. 2018; Gwedla et al. 2022). Great care needs to be taken to increase awareness of the benefits provided by these HCG as complex social-ecological systems (Cilliers et al. 2018) and this study has contributed greatly to our current knowledge on the value of these gardens. By just listing the ESs provided by a specific ecosystem and explain their values, can already increase awareness and recognition in public policy (Costanza et al. 2017) leading to the development of a community-based resource management framework for HCGs for the North-West Province in South Africa, but also for future expansion to other provinces and other African countries (Cilliers et al. 2018).

Conclusion

HCGs in South Africa are important hubs for knowledge upscaling to the larger community and for provision and enhancement of ESs, due to their centrality and accessibility through the primary healthcare system in South Africa. This is made possible by the variety and abundance of plant and bird life present in the gardens, providing ESs beyond the provision of food. The identified ESs included plant species for potential improvement of general health and well-being, food, and raw material, carbon sequestration, habitat provisioning, and the availability of species which can potentially be used for spiritual and ritualistic purposes.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s11252-024-01529-x.

Author contributions All authors contributed to the study conception and design. M.M and S.S.C. collected the data and analysis were performed by all authors. M.J.D prepared Fig. 1. S.S.C., P.B., and C.N. supervised the study. The first draft of the manuscript was written by N.G. and M.M., and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Declarations

Competing interests The authors declare no competing interests.

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