Plant diversity patterns of domestic gardens in five settlements of South Africa

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Abstract

As urbanisation increases globally, domestic gardens are becoming increasingly important in terms of ecosystem service provisioning, biodiversity conservation and human health and well-being. Individually gardens are small, but collectively they comprise substantial proportions of both rural and urban areas and consequently they provide green corridors for the movement of wildlife through the urban matrix. The aim of this thesis was to collect and compare information on the flora present in the domestic gardens of five different settlements across South Africa (Tlhakgameng, Ganyesa, Ikageng, Potchefstroom and Roodepoort) and to determine if the garden management practices and socioeconomic status of householders influences the plant species richness and diversity of these domestic gardens. Additionally, the plant diversity patterns of different land-use types were compared with those of the sampled domestic gardens within each settlement. In comparison with other land-use types, domestic gardens contribute greatly to the overall species richness of both urban and rural settlements. A total of 1424 species were recorded in 598 sample sites for all five settlements and 1524 species were recorded in 256 domestic gardens. The majority of species recorded in the domestic gardens were alien cultivated, while the natural areas contained mostly indigenous species in all five settlements. However, despite the fact domestic gardens provide habitats for biodiversity conservation and support the livelihoods of householders, by introducing and spreading alien species, gardens could threaten natural ecosystems and their services. Nevertheless, domestic gardens have the potential to provide numerous ecosystem services, but this greatly depends on the management decisions, socioeconomic status and personal preferences of the householder. The results of this study showed that the species composition and richness in domestic gardens was influenced by the management activities and socioeconomic status of the householders. In most of the settlements, the floristic diversity increased as the frequency and intensity of management practices increased. Furthermore, the species richness of domestic gardens increased from a low to high SES. This study contributes to our knowledge of the different types of green infrastructure (represented by various land-use types) present in five different settlements in South Africa, their species composition and diversity. This type of research is especially important when considering the rate of urbanisation in South Africa. By understanding the contribution that different land-use types, especially domestic gardens, make to the overall diversity of an urban or rural settlement will aid policy makers and municipal governments in properly managing these areas and ensuring the provisioning of ecosystem services in an urbanising South Africa. Future domestic garden studies in South Africa should attempt to identify the motivations behind gardening in SA, the influences of culture on gardening, promote environmentally-friendly gardening practices, limit the spread of invasive species, promote the cultivation of indigenous species and encourage people to protect biodiversity in cities and towns. If the current rate of urbanisation continues, gardens may become the only source of interaction with nature that some people will have on a daily basis.

Keyword: Plant diversity patterns, domestic gardens, garden management, socio-economic status

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ANOSIM	-	Analysis of Similarities
ANOVA	-	Analysis of Variance
BCE	-	Before Common Era
BMPs	-	Best Management Practices
BUGS I	-	Biodiversity of Urban Gardens in Sheffield I
BUGS II	-	Biodiversity of Urban Gardens in Sheffield II
DFID	-	Department for International Development
DEA	-	Department of Environmental Affairs
DIY	-	Do-It-Yourself
DG	-	Domestic garden
EF	-	Ecological Footprint
ESRI	-	Environmental System Research Institute
EFA	-	Exploratory Factor Analysis
FA	-	Factor Analyses
FF	-	Fallow fields
FN	-	Fragmented natural area
G	-	Ganyesa
GPS	-	Global Positioning System
GHG	-	Greenhouse Gas
I	-	Ikageng
IG	-	Institutional gardens
IPM	-	Integrated Pest Management
IPNI	-	International Plant Names Index
IDW	-	Inverse Distance Weighting
LUT	-	Land-use types
MI	-	Management Index
MEA	-	Millennium Ecosystem Assessment
NA	-	Natural areas
NMVOC	-	Non-Methane Volatile Organic Compounds
NMS	-	Non-metric Multi-dimensional Scaling
P	-	Potchefstroom
PRIZM	-	Potential Rating Index for Zip code Markets
PCA	-	Principal Component Analysis
RV	-	Road verges
R	-	Roodepoort
RHS	-	Royal Horticultural Society

S	-	Sidewalks
SIMPER	-	Similarity Percentages
SES	-	Socio-economic Status
SA	-	South Africa
SANBI	-	South African National Biodiversity Institute
T	-	Tlhakgameng
TCM	-	Tlokwe City Municipality
UK	-	United Kingdom
UN	-	United Nations
USA	-	United States of America
USD	-	United States Dollar
UGS	-	Urban Green Space
UHI	-	Urban Heat Island
W	-	Wetlands
ZAR	-	South African Rand

Chapter 1 - Introduction

1.1 General introduction

The world population has increased by roughly one billion people over the last twelve years and is expected to increase by more than one billion within the next 15 years, reaching 8.5 billion in 2030 (United Nations, 2015). According to the World Urbanisation Prospects report compiled by the United Nations, the past six decades have been characterised by a process of rapid urbanisation (United Nations, 2014). Some of the most urbanised areas worldwide are Northern America, 82 %, the Caribbean and Latin America, 80 %, and Europe, 73 % (United Nations, 2014). In contrast, Africa and Asia have remained predominantly rural, with only 40 and 48 % of their populations living in urban areas respectively (United Nations, 2014). However, Africa and Asia are urbanizing rapidly and are estimated to become 56 and 64 % urban, respectively, by 2050 (United Nations, 2014).

Historically, the process of urbanisation has been associated with important social and economic transformations (United Nations, 2014). Cities are considered important drivers of development and poverty reduction, associated with higher levels of education and literacy, better access to social services and health care, as well as greater opportunities for political and cultural participation (United Nations, 2014). However, "rapid and unplanned urban growth threatens sustainable development when the necessary infrastructure is not developed or when policies are not implemented to ensure that the benefits of city life are equitably shared" (United Nations, 2014). Inadequately managed urban growth leads to environmental degradation, pollution, rapid urban sprawl (United Nations, 2014), biodiversity loss and biotic homogenisation (McKinney, 2002). In 2016, the United Nations Conference on Housing and Sustainable Urban Development took place in Quito, Ecuador (United Nations, 2017). During the conference world leaders adopted the New Urban Agenda which seeks to mitigate the negative impacts of urbanisation and achieve sustainable urban development (United Nations, 2017).

Urbanisation is currently one of the dominant demographic trends, is a key component of land transformation processes worldwide and interacts with global change on various levels (Grimm *et al*., 2000). Even though urban areas account for only a fraction (approximately 3 %) of the Earth's total land surface (Grimm *et al*., 2000; Grimm *et al*., 2008; Niemelä *et al*., 2011), they produce roughly 78 % of greenhouse gases, which in turn greatly contributes to global climate change (Grimm *et al*., 2000). Cities play important roles in biodiversity changes due to habitat fragmentation, alteration of global biogeochemical cycles, increases in alien species invasions and changes in land-use and -cover beyond the city's boundaries (Grimm *et al*., 2000).

1.2 Motivation

In light of this continuous trend of increasing urbanisation, the scientific knowledge gained from urban ecology is necessary to build and maintain a better, more sustainable urban future (Douglas, 2011a). Urban ecology provides opportunities to use the nature in cities to help humans live healthier lives, to adapt to climate change, to conserve biodiversity for future generations, and to improve the appearance and aesthetic appeal of cities (Douglas, 2011a) and all of these benefits depend on the provision and management of urban green spaces (Kabisch *et al*., 2015). Cities and towns consist of several different types of green spaces, such as farmlands, derelict land, wetlands, woodlands, cemeteries, churchyards, school grounds, public parks, sports fields, the edges of roads, railways, and waterways, as well as botanical, institutional, allotment and domestic gardens (Swanwick *et al*., 2003).

"There has been almost no attempt to describe the composition and distribution of garden floras" according to Thompson *et al*. (2003). This statement was true in 2003, however, since then a great deal of research had been done on domestic gardens. The Biodiversity of Urban Gardens in Sheffield (BUGS I) project included some of the first studies to investigate domestic gardens (Gaston *et al*., 2005a and 2005b; Smith *et al*., 2005, 2006a, 2006b and 2006c; Thompson *et al*., 2003, 2004 and 2005). Since then, garden research has ranged from motivations for gardening (Clayton, 2007; Zagorski *et al*., 2004), cultural influences on gardening practices (Levin, 2012; Molebatsi *et al*., 2010; Nemudzudzanyi *et al*., 2010; Taylor and Lovell, 2014), garden management practices (Bertoncini *et al*., 2012; Kiesling and Manning, 2010; Varlamoff *et al*., 2001), food production and subsistence agriculture in gardens (Reyes-García *et al*., 2013; Taylor and Lovell, 2014; Zainuddin and Mercer, 2014), ecosystem services provided by gardens (Beumer and Martens, 2015; Calvet-Mir *et al*., 2012; Cameron *et al*., 2012; Clarke *et al*., 2014; Mohri *et al*., 2013), biodiversity in gardens (Davies *et al*., 2009; Samnegård *et al*., 2011; Vergnes *et al*., 2012 and 2013) and gardening for wildlife (Goddard *et al*., 2013) to name a few.

There are several reasons why gardens are important to the urban environment and why they deserve this much attention. Collectively gardens constitute a considerable proportion of the land cover in urban areas (Gaston *et al*., 2005a; Mathieu *et al*., 2007), they contribute to biodiversity conservation (Gaston *et al*., 2005a; Goddard *et al*., 2010), provide ecosystem services (Beumer and Martens, 2015; Calvet-Mir *et al*., 2012; Clarke *et al*., 2014; Mohri *et al*., 2013), improve human health and wellbeing (Fuller *et al*., 2007; Whear *et al*., 2014), provide a means for connecting people with people (Gray *et al*., 2014; Uren *et al*., 2015; Van Heezik *et al*., 2014), people with their cultural heritage (Head *et al*., 2004; Taylor and Lovell, 2014) and people with nature (Fuller *et al*., 2007). Gardens are also used to cultivate fruits and vegetables to fulfill subsistence needs and providing additional cash income, especially in developing countries (Akinnifesi *et al*., 2010a and 2010b; Albuquerque *et al*., 2005; Bernholt *et al*., 2009; Gebauer, 2005).

Between 2007 and 2012 several domestic garden research projects have been conducted by the Urban Ecology Research Group at the North West University, namely: Plant diversity patterns of a settlement, Ganyesa in the North West province, South Africa (Masters project, Davoren (2009)), Plant diversity in urban domestic gardens along a socio-economic gradient in the Tlokwe Municipal area (Ikageng and Potchefstroom), North West province (Masters project, Lubbe (2011)), An assessment of the useful plant diversity in domestic gardens and communal land of Tlhakgameng, North West (Masters project, Molebatsi (2011)) and Plant- and insect diversity of vegetable gardens along a socio-economic gradient within the Tlokwe Municipal Area (Ikageng and Potchefstroom) (Masters project, Botha (2012)). These projects were aimed at developing a better understanding of the plant diversity of domestic gardens, and their structure and function in rural, peri-urban and urban settlements across a socio-economic gradient.

This doctoral study will make a significant contribution towards urban ecological research in South Africa in general but more importantly will provide new information on domestic gardens across a socio-economic gradient. The aim of this study is to consolidate the data from the abovementioned studies to enable a holistic evaluation of domestic gardens of different cultural groups from rural, urban and metropolitan areas. A metropolitan area was included in this study to ensure that all the different socio-economic groups in South Africa were represented.

1.3 Aims of the thesis

1.3.1 General objective:

To compare plant diversity and social information from several domestic garden studies across a socio-economic gradient from rural to urban and metropolitan areas, as well as to compare the plant diversity patterns of different land-use types with one another and in terms of the different settlements in the northern parts of South Africa.

1.3.2 Specific objectives:

- To collect floristic and socio-economic data in a high-income metropolitan area (Roodepoort), in order to ensure that all the different socio-economic groups in South Africa were represented in this study.

- To compare the plant diversity patterns of different land-use areas (domestic gardens, fallow fields, fragmented natural areas, institutional gardens, natural areas, road verges, sidewalks, and wetlands) in the studied settlements (Tlhakgameng, Ganyesa, Ikageng, Potchefstroom, and Roodepoort).
- To consolidate and compare the floristic data of previous garden studies in Tlhakgameng, Ganyesa, Ikageng and Potchefstroom with the results of the Roodepoort survey.
- To identify generalities and differences in terms of garden management practices in the studied settlements.
- To use the socio-economic data of all the studies to develop a scaling system in which different socio-economic classes can be quantified.
- To describe patterns of plant diversity along the described socio-economic gradient and explain possible correlations between plant diversity and different socio-economic factors.
- To provide recommendations for urban planners and policy makers, future domestic garden studies in South Africa and householders in term of garden management.

1.4 Thesis structure and content

This thesis consists of ten chapters, a bibliography, and ten annexures. Chapter 2 provides a broad overview of relevant literature and Chapter 3 describes the study areas. The results are discussed in chapters 4-9. These chapters were written in a standard scientific format and each was comprised of an Introduction, Methods, Results, Discussion and Conclusion. Chapter 9 was adapted from a research paper that was published in *Landscape and Ecological Engineering* (Davoren *et al*., 2016). The other results chapters are being prepared as manuscripts for submission to scientific journals and therefore a certain amount of repetition was inevitable. Chapter 10 presents the concluding remarks and provides a synopsis of the critical findings originating from the results chapters. The Bibliography contains a list of all the cited references and was included at the end of the thesis to prevent any duplication. Annexures were added to aid the description of the methods used and additional results to support the findings of this thesis.

Chapter 2:

This chapter gives a broad overview of major progress and current trends in terms of urban ecological research and domestic garden studies. It provides information on urban ecology, urban ecosystems, the importance of urban green spaces, especially focusing on domestic gardens and socio-economic status.

Chapter 3:

This chapter provides descriptions of all the study areas in terms of their topography, geology, soil, climate, vegetation, economic activities and conservation data.

Chapter 4:

The chapter provides descriptions of the patterns of plant diversity for five settlements. The aims of this chapter are to (1) compare the species diversity of the different land-use types (domestic gardens, fallow fields, fragmented natural areas, institutional gardens, natural areas, road verges, sidewalks and wetlands) across settlements (Tlhakgameng, Ganyesa, Ikageng, Potchefstroom and Roodepoort) with one another, and (2) compare the species diversity of the different land-use types within each of the studied settlements with one another. This chapter provides insights into the species composition and diversity of different land-use types and how they differ from one another within and across five South African settlements. The main focus was on the domestic gardens of settlements and how composition and diversity relates across settlements and to other land-use types.

Chapter 5:

The aim of this chapter is to compare the floristic composition of domestic gardens in the five different settlements (Tlhakgameng, Ganyesa, Ikageng, Potchefstroom, and Roodepoort). The specific objectives were to consolidate the data available for five settlements and to analyze and describe the plant diversity present in domestic gardens. This was done by determining the species classification, the dominant families, genera and species, the endemic and red data status of species, species invasiveness, the origin of cultivated and naturalised alien species and of indigenous cultivated species, useful plants and growth forms. The focus was on the contribution that domestic gardens make to the overall species composition of settlements and the potential that domestic gardens have to protect indigenous, endemic and threatened species in South Africa.

Chapter 6:

This chapter provides insights into the management practices of gardeners of five settlements (Tlhakgameng, Ganyesa, Ikageng, Potchefstroom and Roodepoort). We hypothesise that the floristic composition of domestic gardens will increase as the intensity of garden management practices increase. The aims of this chapter were to (1) compare the prevalence of selected garden management activities practiced (fertiliser application, pruning, removal of dead material, watering, weeding) between gardens and between settlements, (2) determine whether gardens are maintained through DIY gardening practices, gardening services or a gardener overall and between settlements, (3) calculate a management index (MI), which provides a single score for each participant in terms of their level of gardening activity, and (4) relate the management index value of gardens to the floristic composition thereof.

Chapter 7:

This chapter is essentially a methods chapter and aims to explore the use of census and questionnaire data to determine the SES and socio-economic classes of the participants by establishing a repeatable technique to merge and compare the data, and a statistical approach of determining the participants SES and socio-economic classes in all five settlements (Tlhakgameng, Ganyesa, Ikageng, Potchefstroom and Roodepoort).

Chapter 8:

Chapter 7 provides a detailed description of how the socio-economic status of the participants in this study was determined and this chapter investigates the link between socio-economic status and plant diversity. We hypothesised that socio-economic status (SES) might be a useful predictor of the plant diversity of domestic gardens due to the influence that SES can have on the ability of individuals to alter their surrounding environments. The aims of this chapter were to (1) determine the relationship between several socio-economic variables and the species and functional diversity of the domestic gardens sampled in five settlements (Tlhakgameng, Ganyesa, Ikageng, Potchefstroom and Roodepoort) and to (2) determine the relationship between the plant diversity and socio-economic status classes.

Chapter 9:

In this paper, we wanted to determine whether the cultural preferences in the garden design of domestic gardens changed with improved SES. We hypothesise that SES influences garden design and as the SES of Batswana residents increase, the garden design changes from cultural home garden (*tshimo*) to colonial designs. Therefore, the two main questions answered are (1) whether Batswana garden designs are associated with SES and (2) are the different garden designs characterised by specific plant species richness patterns? This chapter has been published in *Landscape and Ecological Engineering*, 12(1):129-139 (Davoren *et al*., 2016).

Chapter 10:

This chapter presents the concluding remarks and provides a synopsis of the critical findings originating from chapters 4-9 and what contribution it makes towards our existing knowledge about plant diversity in rural to urban settlements, domestic gardens, and socio-economic gradients. It also provides recommendations for future research.

Chapter 2 - Literature review

2.1 Introduction

The urban population of the world has grown rapidly since 1950, from 746 million to 3.9 billion in 2014 and was predicted to reach 6.3 billion in 2050 (United Nations, 2014). However, according to the results of the 2015 revision, the world population reached 7.3 billion in July 2015 (United Nations, 2015). In 2007, a historic milestone was achieved when more than 50 % of the global population was living in urban areas, consequently branding urban centers as the dominant habitat of the human species (United Nations, 2012). This shift from rural to urban has made urbanisation one of the most significant global trends of the twenty-first century (United Nations, 2012).

The rapid expansion of urban centers has led to the growth of megacities, in 1990 there were 10 megacities (Molina and Molina, 2004; United Nations, 2014) and in 2014, 28 (United Nations, 2014). Megacities are defined as metropolitan areas with populations greater than 10 million inhabitants (Molina and Molina, 2004; United Nations, 2014). Cities, and especially megacities, significantly shape and influence political and social relations at every level, determine advances and setbacks in modes of production, provide new content to norms, culture, and aesthetics, play important roles in environmental trends and determine the processes of sustainability (United Nations, 2012).

A study by Seto *et al*. (2012) presented spatially explicit probabilistic forecasts of global urban expansion and found that globally, more than 5.87 million km² of land had a positive probability of being converted to urban areas by 2030, while 20 % (roughly 1.2 million km²) of the 5.87 million km² had a high probability (>75 %) of urban expansion. Virtually half of the increase in global high probability urban expansion is projected to occur in Asia, with India and China absorbing 55 % of the regional total, while Africa is predicted to have the highest rate of increase in urban land cover (Seto *et al*., 2012; United Nations, 2015). According to the 2001 census, South Africa had an urbanisation level of 56.25%, and the highest level of urbanisation was found in Gauteng (96%), Western Cape (90%) and Northern Cape (80%) provinces (DEA, 2010). According to Seto *et al*. (2012), their forecasts suggest a brief window of opportunity for policy decisions to shape the long-term effects of urbanisation. Such actions are vital as urbanisation can be considered as one of the driving forces behind global environmental change (Grimm *et al*., 2008; United Nations, 2012).

2.2 Urbanisation

Based on the information collected from several reviews (McDonnell and Pickett, 1990; Niemelä, 1999b; Pickett *et al*., 2001; McKinney, 2002), urbanisation is characterised by the presence of artificial structures, impervious surfaces, high densities of people, domesticated plants and animals, air and soil pollution, increases in average ambient temperature, soil compaction and altered flows of energy and nutrients. According to McKinney (2002) the percentage impervious surface (asphalt, buildings, pavements) ranges from <20% at the urban fringe to >50% at the urban core. The land cover transformations caused by urbanisation favour organisms that are better adapted to new environmental conditions, more tolerant of human activities and capable of rapid colonization (Alberti *et al*., 2003). Consequently, urban areas are often characterised by unique combinations of organisms living in distinctive communities (Alberti *et al*., 2003).

Urbanisation is considered to be the major driving force behind habitat alteration, including habitat fragmentation and loss (Wilcove *et al*., 1998; McDonald *et al*., 2008; McKinney, 2008), biodiversity loss and biological homogenization of the physical environment (McKinney, 2002; McKinney, 2006), altering both the quality and flow of water in urban streams and rivers (Paul and Meyer, 2001; Alberti, 2008) and human induced climate change (Golden, 2004). In comparison with the surrounding natural environment, cities are constantly in a non-equilibrium state due to the importation of vast resources of both energy and materials (McKinney, 2006). However, it is important to remember that continued urbanisation is essentially human-induced and therefore the problems that have stemmed from urbanisation are also directly or indirectly caused by humans (McKinney, 2002). The number of studies concerning urbanisation and its impact on the earth’s ecosystems has increased substantially over the last few decades, especially in the field of urban ecology. According to Marzluff *et al*. (2008), “urban ecology is the study of ecosystems that include humans living in cities and urbanizing landscapes”.

2.3 Urban ecology

According to Niemelä *et al*. (2011), “the urban landscape in its diverse manifestations is becoming the most familiar environment to the majority of the human population both currently and in future generations”. Globally, urbanised areas cover less than 3 % of the earth’s surface, yet the impact on the planet has been significant (MEA, 2005; Grimm *et al*., 2008; Niemelä *et al*., 2011). Nevertheless, the impact that urbanisation has on biodiversity and ecosystems remains insufficiently understood, particularly on a global scale (Niemelä *et al*., 2011). Ecologists largely ignored urban areas for the majority of the 20th century (McDonnell, 1997; Grimm *et al*., 2008) and as a result, ecological knowledge contributed little to solving urban environmental problems (Grimm *et al*., 2008). There are several reasons for this, but the main cause can be attributed to ecologist's reluctance to work in human-dominated ecosystems (McDonnell, 1997; McDonnell, 2011). However, in recent decades, growing numbers of ecologists have collaborated with engineers, planners, and other scientists to better understand and even shape these flourishing ecosystems (Grimm *et al*., 2008).

There are several important reasons for the increasing number of ecological studies in human-dominated systems (Niemelä, 1999a; Grimm *et al*., 2000). Firstly, since earth's ecosystems are dominated by humans (Vitousek *et al*., 1997; Grimm *et al*., 2000), ecological knowledge of the effects humans have on urban ecosystems is essential to the creation of healthy and aesthetically pleasing environments (Niemelä, 1999a). Therefore, humans need to be integrated into models in order to understand the living ecological systems (Grimm *et al*., 2000). Secondly, urban areas provide useful insights into the functioning of ecosystems, which in turn provides vital information for management and planning purposes (Niemelä, 1999a). Thirdly, being able to predict the changes as urbanisation proceeds and finding explanations for the species diversity phenomena in urban habitat types challenges ecological research (Niemelä, 1999a). And lastly, the concept of a city as an ecosystem is comparatively new to the field of ecology, even though the study of ecological phenomena in urban environments is not (Grimm *et al*., 2000).

Early ecological studies in urban areas looked for nature in cities, not for the nature of cities as a whole (Sukopp, 2002). In the early 1970s, urban ecology emerged as a sub-discipline of ecology (Sukopp, 2002). Ever since its origin, the term 'urban ecology' has brought forth a variety of different meanings (Niemelä, 1999a; McDonnell, 2011). Ecologists would define the term 'urban ecology' as studies of the abundance and distribution of organisms in and around cities and on the biogeochemical budgets of urban areas (Pickett *et al*., 2001). Alberti (2008) defined 'urban ecology' as "the study of the ways that human and ecological systems evolve together in urbanizing regions". McDonnell (2011) proposed the following definition for 'urban ecology': "Urban ecology integrates both basic (i.e. fundamental) and applied (i.e. problem oriented), natural and social science research to explore and elucidate the multiple dimensions of urban ecosystems".

In comparison to developed countries, urban ecological research in South Africa was slow to develop (Lubbe, 2011). According to Du Toit (2015), the first noteworthy urban ecological research done in South Africa was a published list of bird species observed in Johannesburg and Modderfontein, compiled by Haagner in 1902. As the rate of urbanisation increased, scientists began to realise the importance of urban open spaces and the need to design municipal open space systems (Roberts, 1993). The scope of urban ecological research in

South Africa expanded and included studies concerning urban planning (Wall, 1992; Wisner, 1995; Wisner and Luce, 1995), medicinal plant usage (Dauskardt, 1990), agriculture (Rogerson, 1993; May and Rogerson, 1995; Maswikaneng *et al*., 2002; Thornton, 2008; Magidimisha *et al*., 2013; Musvoto *et al*., 2015), biodiversity (Steytler and Samways, 1995) and vegetation (Roberts, 1993; Berry *et al*., 1994; Cilliers *et al*., 1998; Cilliers and Bredenkamp, 1998; Cilliers and Bredenkamp, 2000; Shackleton *et al*., 2015), as well as urban management and governance (Wisner, 1995; McDonald, 1997).

According to Grimm *et al*. (2008), "urban ecology integrates the theory and methods of both natural and social sciences to study the patterns and processes of urban ecosystems". The interdisciplinary nature of urban ecology can be operationalised by distinguishing between two different components of urban ecology: ecology 'in' cities and ecology 'of' cities (Grimm *et al*., 2000; Wu, 2008). According to Grimm *et al*. (2000) studies concerning the ecology 'in' cities addressed basic ecological questions in urban areas, such as what are the effects of the city on the ecology of organisms, and how do ecological patterns and processes differ in cities when compared with other environments? Ecology 'of' cities considers the city as an ecosystem with both biological and socio-economic components (Wu, 2008). Studies concerning the ecology 'in' cities are usually small scale, located within an urban settlement and single discipline (Grimm *et al*., 2000; Pickett *et al*., 2001). In contrast, studies concerning the ecology 'of' cities are multiscale and interdisciplinary, incorporating both ecological and human dimensions of urban ecosystems (Grimm *et al*., 2000; Pickett *et al*., 2001).

2.4 Urban ecosystems

Urban ecosystems are in a state of perpetual change (Clergeau *et al*., 1998). Picket *et al*. (2001) defined urban ecosystems as areas where the built infrastructure covers large proportions of land and in which people live at high densities (i.e. human-dominated). However, McIntyre *et al*. (2008) stated that even though "a human-dominated ecosystem can be considered as an accurate description of an urban ecosystem, describing an ecosystem as human-dominated does not adequately take into account the sphere of influence, history of development and potential impacts required in order to understand the true nature of an urban ecosystem". According to Marzluff *et al*. (2008) urban ecosystems are compiled of sets of strongly interacting spheres, namely biotic (this biosphere is viewed as interactions between human socio-economics and urban plants and animals, the anthroposphere) and abiotic (atmosphere, hydrosphere, lithosphere, pedosphere). Alberti (2005) stated that urban ecosystems consist of several interlinked subsystems, namely economic, institutional, social and environmental.

Douglas (2011b) went even further by stating that urban ecosystems could be viewed in four ways: (1) the built-up areas that are the habitat of urban people, their pets, pests, plants and other adapted animals and organisms, (2) the patches within complex urban mosaics of habitats, such as urban streams, garden lawns or fragments of derelict land, (3) the area surrounding urban areas (peri-urban), which act as an immediate urban life-support system by providing necessary ecological services (water, areas for landfill, recreation zones, etc.) and (4) the areas affected by urbanisation which provide services to urban areas (supplies of food, energy, water, etc.). The latter has a global outreach, with the importation of food (exotic fruits, fish, meat, etc.) and energy (coal, natural gas or oil) from far-off countries (Douglas, 2011b).

According to Alberti *et al*. (2003) "planet-scale changes induced by humans are most evident in and around urbanizing landscapes". A city's ecological footprint (EF) is defined as the total biological area of productive land required to continuously produce all the resources consumed and to assimilate all the wastes produced, by a defined population (Rees and Wackernagel, 1996; Molina and Molina, 2004). The EF can be useful in describing the impact that humans have on earth's ecosystems (Alberti, 2008) or as a measure of the biological capacity of the earth to create resources and absorb waste products (Molina and Molina, 2004). However, according to Alberti (2008), "a spatially explicit definition of the ecological footprint would be necessary to capture how clustered versus dispersed urban forms affect the 'ecological footprint' of alternative urban settings".

Urban ecosystems are dynamic ecosystems that behave and interact similarly to their natural counterparts (Douglas, 2011a). However, urban ecosystems differ from natural ecosystems in several respects in terms of climate (higher temperatures and greater precipitation), hydrology (increased surface runoff), soils (higher concentrations of heavy metals) (Pickett *et al*., 2001; Alberti, 2005), species composition (native and exotic), population dynamics (species invasion and extinction), and flows of energy and matter (Rebele, 1994; Pickett *et al*., 2001). These distinctive characteristics of urban ecosystems are consequences of the fundamental changes that happen to land when cities are built and developed (Pauleit and Breuste, 2011). However, urban climates, hydrology, and biodiversity are not uniform across cities but vary widely within cities and depend on the distribution of human activities and the physical structures of urban areas (Pauleit and Breuste, 2011).

2.4.1 Climate

In recent decades, the urban climate has received increasing attention worldwide in terms of research and applications due to the global effects of climate change (Parlow, 2011). According to Parlow (2011) the political and public discussions on climate change and how it impacts our wellbeing has made people more sensitive to ecological aspects. Human activities that have strongly influenced the urban climate, include increased impervious surfaces, reduced vegetation, increased surface runoff, etc. (Parlow, 2011). These activities have greatly influenced meteorological variables, such as air pollution, temperature, heat stress, and various other variables (Parlow, 2011).

The urban climate system differs from rural climates in several ways, namely that (1) urban areas have high aerodynamic surfaces, such as skyscrapers, (2) have completely different heat budgets and radiation due to the physical properties of construction material, (3) are three-dimensional and therefore contain very complex surfaces for all exchange processes with the urban boundary layer, and (4) are significant sources of emissions from traffic, industrial sites, heating and air conditioning in terms of greenhouse gases and pollutants (Parlow, 2011). According to Parlow (2011), climate change and the dramatic growth of urban agglomerations, especially in developing countries, are significant driving forces for the consideration of urban climate on a global scale.

According to Khare and Beckman (2013), "climate change has emerged as one of the most challenging political and scientific issues of our times". Changes in global climate have resulted in elevated temperatures, shrinking glaciers, rising sea level, increased precipitation events, such as cyclones, hurricanes, and floods, increased probability of heatwave occurrence and drought (Stocker *et al*., 2013), increased wildfire incidence (Carter *et al*., 2015) and desertification (Masson *et al*., 2014). The earth's changing climate can largely be attributed to greenhouse gas emissions resulting from human activities (Younger *et al*., 2008) and rapid urbanisation (Golden, 2004), specifically in megacities (Parrish *et al*., 2011). These greenhouse gasses are partly derived from characteristics of the built environments, such as land-use planning, building construction and operation, transportation systems and infrastructure (Younger *et al*., 2008), and energy production (Schatz *et al*., 2013). Greenhouse gasses transmit incoming radiation from the sun but absorb and trap the infrared radiation subsequently emitted from the earth's surface (Golden, 2004).

2.4.1.1 Urban heat island (UHI)

The 21st-century phenomenon of rapid urbanisation has created extreme changes in land use that have resulted in unintended economic, social and especially environmental consequences (Golden, 2004). In urban areas, buildings and paved surfaces have gradually replaced pre-existing natural landscapes (Golden, 2004). The transformation of native landscapes into urban landscapes has led to increased heat generation, due to anthropogenic activities, and heat accumulation, which is attributed to substantial amounts of heat being absorbed and stored by roads, buildings and other urban infrastructures (Golden, 2004; Ewing and Rong, 2008; Luber and McGeehin, 2008; Chen *et al*., 2013). Consequently, urban areas tend to have higher temperatures than their rural counterparts (Golden, 2004; Luber and McGeehin, 2008; Chen *et al*., 2013), especially at night (Golden, 2004; Solecki *et al*., 2005; Parlow, 2011), a phenomenon which is known as the urban heat island (UHI) effect (Luber and McGeehin, 2008; Chen *et al*., 2013).

The urban heat island (UHI) effect is one of the best-documented examples of anthropogenic climate change (Grimm *et al*., 2008). According to Grimm *et al*. (2008), there are several characteristics of urban environments that amend energy budget parameters and which can affect the formation of the UHI. These include city size, land-cover patterns, increased impervious surfaces, reduced areas covered by water and vegetation, increased surface areas for absorbing solar energy and heat-trapping due to buildings (Gill *et al.*, 2007; Grimm *et al*., 2008), as well as anthropogenic heat generated by automobiles, electricity inputs into buildings and industrial activities (Mochida and Lun, 2008; Zhang *et al*., 2013). UHI not only affects local and regional climate, but also air quality, water resources (Golden, 2004), human health (Golden, 2004; Luber and McGeehin, 2008; Parlow, 2011), biodiversity and ecosystem functioning (Grimm *et al*., 2008; Luo *et al*., 2007), and promotes pollutant dispersal (Solecki *et al*., 2005; Grimm *et al*., 2008).

In recent years a plethora of research has been done to develop urban adaptation (Baker *et al*., 2012; Chhetri *et al*., 2012; Campos *et al*., 2014; Masson *et al*., 2014; Mycoo, 2014) and mitigation strategies (Dhillon and Von Wuehlisch, 2013; Lwasa *et al.*, 2014; Carter *et al*., 2015) to make cities increasingly climate change resilient. Several studies have attempted to identify mitigation strategies to reduce the UHI effect, including “cool roofs”, “cool pavements” and “cool cities” (Golden, 2004; Luber and McGeehin, 2008). According to Golden (2004), there are two methods for creating a cool pavement, namely increased surface reflection and increased permeability. Increased permeability cools the pavement either through evaporation of water, lower thermal storage or increased convection (Golden, 2004). Increased surface reflectance reduces the solar radiation absorbed by pavements (Golden, 2004, Chen *et al*., 2013).

The “cool roofs” strategy increases the albedo of rooftops (Golden, 2004). Gill *et al*. (2007) found that greening roofs in urban areas were an effective strategy in lowering surface temperatures. The ‘‘cool cities’’ strategy reduces the UHI effect by promoting tree planting which increases evapotranspiration while providing shade for buildings (Golden, 2004; Solecki *et al*., 2005; Luber and McGeehin, 2008; Chen *et al*., 2013; Carter *et al*., 2015). Reducing the solar heat gain in buildings will reduce the demand for cooling energy consumption of residential and commercial buildings through air conditioning, which will in turn, reduce greenhouse gas (GHG) emissions (Gill *et al*., 2007; Chen *et al*., 2013).

2.4.1.2 Air quality

Urban areas, as centers of population and industry, are important sources of emissions and pollutants (Parlow, 2011). Air pollution has become one of the most important environmental problems of cities and megacities in the last few decades (Molina and Molina, 2004). At first, sulphur compounds generated by burning coal were the main air pollutants, but in recent years, photochemical smog and fossil fuel emissions resulting from traffic, industrial activities, power generation and solvents, have become the main source of concern in terms of air quality in cities (Molina and Molina, 2004; Alberti, 2008). Aspects such as urban form, structure, and growth could influence the degree of fossil fuel emissions, as well as their rate of change (Pataki *et al*., 2006). In most cities, transportation is the major contributor to air pollution (Parrish *et al*., 2011; Parlow, 2011), which is especially true in developing countries (Molina and Molina, 2004). Parlow (2011) stated that "the urban atmosphere has a unique mixture of specific concentrations of gasses compared to a non-urban atmosphere".

According to Kuttler (2008) the compounds NO, NO_2, CO, O_3, SO_2, NMVOC (Non-Methane Volatile Organic Compounds), dust and soot are the most important pollutants in urban atmospheres. Air pollution can have serious impacts on public health (Molina and Molina, 2004; Alberti, 2008; Parrish *et al*., 2011), causes urban and regional haze, ecosystem degradation (Molina and Molina, 2004) and contributes significantly to climate change (Molina and Molina, 2004; Alberti, 2008; Parrish *et al*., 2011; Parlow, 2011). Effectively addressing air quality issues in cities and megacities requires an interdisciplinary approach that not only takes economic, political, social, scientific and technical factors into consideration, but also the existing infrastructure of cities (Molina and Molina, 2004). Air quality and climate change are interconnected (Alberti, 2008), the one influencing and driving the other. Improving air quality can help mitigate climate change on a local and global scale (Parrish *et al*., 2011).

2.4.2 Hydrology

In comparison with other ecosystems, the hydrology of urban ecosystems are distinctive due to the availability of piped water, organised water disposal, the addition of water due to irrigation and changes in water infiltration due to impervious surfaces (McIntyre *et al*., 2008). According to Alberti (2008), urbanisation affects the hydrology of an urban ecosystem by modifying the flow of water through changes in land cover and the building of infrastructure, as well as by altering the supply of water through water contamination and extraction. Furthermore, urbanisation leads to channel erosion and reduces the quality of water due to inputs of metals, oils, pesticides, road salts and other contaminants (Paul and Meyer, 2001). Urban lakes, rivers, streams and wetlands are in danger of being contaminated due to municipal and industrial discharge, sewage and eutrophication due to fertilisers (Grimm *et al*., 2008). According to Paul and Meyer (2001), these changes have resulted in the consistent decline of algal, invertebrate, and fish species richness in urban streams.

The continued transformation of land surfaces to impervious surfaces during urbanisation has increased the rate of surface runoff and lowered the amount of infiltration (Booth and Jackson, 1997). A 10 to 20 % increase of the total impervious surface area can double the rate of surface runoff (Alberti, 2008). This increase in surface runoff shortens the lag time between precipitation input and discharge and may also generate higher flood peak discharges during storms (Paul and Meyer, 2001). The amount, route, speed, infiltration and retention of water in urban areas, significantly influences the frequency of storm events, the size and slope of drainage basins and patterns of vegetation (Alberti, 2008). According to Walton *et al*. (2007) “urbanisation poses vexing challenges to the ecological sustainability and restoration of stream ecosystems”.

2.4.3 Biogeochemical cycles

By altering the fundamental processes that control the cycling of elements, urbanisation has adversely affected the earth’s ecosystems (Alberti, 2008). According to Grimm *et al*. (2008) “urban areas are both responsible for, and respond to changes in biogeochemical cycles”. Lawrence (2011) defines a biogeochemical cycle as a closed cycle described by elements found in living material (carbon, nitrogen, oxygen and sulfur) as they pass from the abiotic to the biotic phase and back again.

Human activities have influenced biogeochemical cycles in fundamental ways, by changing land uses, mining activities, producing and applying synthetic chemicals (Vitousek *et al*., 1997), burning fossil fuels (Vitousek *et al*., 1997, Chapin *et al*., 2011), and the expansion and intensification of agricultural practices have increased the concentrations of atmospheric gases (Chapin *et al*., 2011). These activities affect biogeochemical cycles directly, by adding nutrients, and indirectly by altering the mechanisms that control the temporal and spatial variability of nutrient sources and sinks (Alberti, 2008).

The waste products (pollutants) generated by cities, enter into air and water transport systems, are transferred within and among ecosystems, and affect biogeochemical cycles on local, as well as global scales (Dahlgren, 2006; Grimm *et al*., 2008). However, the extent of the influence depends on the vectors by which the materials are transported away from their sources

(Dahlgren, 2006; Grimm *et al*., 2008; Parrish *et al*., 2011). The coupling of human and natural processes is creating a unique biogeochemistry, despite great variability across the biophysical settings and socio-economic activities of cities (Alberti, 2008).

2.4.4 Biodiversity

Kowarik (2011) stated that "humans govern urban biodiversity directly by habitat loss, habitat fragmentation and the introduction of new species, and indirectly by changing the urban climate, soils, hydrology, and biogeochemical cycles". Urban growth is one of the greatest challenges to biodiversity conservation since it promotes the replacement of native species with widespread non-native species (McKinney and Lockwood, 1999; McKinney, 2002; Turner *et al*., 2004). Despite the fact that non-native species enrich local biodiversity (Sax and Gaines, 2003), global diversity has decreased due to the subsequent extinction of unique local species which are inadvertently lost to the global species pool (McKinney and Lockwood, 1999; McKinney, 2006).

This process of replacement is defined as biotic homogenization and it is largely driven by human activities (McKinney and Lockwood, 1999). Urban biotic homogenization is a challenge to biodiversity conservation for two fundamentally important yet different reasons (McKinney, 2006). The first being homogenization and the second human perception of nature (McKinney, 2006). A great deal of the flora and fauna in urban environments are not indigenous to the local area and consequently, the human species is becoming increasingly disconnected from the native biological environment (McKinney, 2006).

Urbanisation has led to decreases in species richness and evenness for most biotic communities in urban areas (Paul and Meyer, 2001; McKinney, 2002). Examples include investigations of invertebrates (Paul and Meyer, 2001; Moore and Palmer, 2005), fish (Paul and Meyer, 2001), bees and wasps (Zanette *et al*., 2005), spiders (Shochat *et al*., 2004), butterflies (Blair and Launer, 1997; Blair, 1999), birds (Blair, 1996; Clergeau *et al*., 1998; Blair, 1999; Chace and Walsh, 2006; Soh *et al*., 2006; Clergeau *et al*., 2006), amphibians (Parris, 2006), reptiles (Garden *et al*., 2007), and mammals (Dickman, 1987; Sauvajot *et al*., 1998; Tikhonova *et al*., 2006; Garden *et al*., 2007; Cavia *et al*., 2009).

However, in recent years several studies have found that regions of high biodiversity and human population density can coincide (Pautasso, 2007). These studies found that in some cases species richness has either remained the same or increased (McIntyre *et al*., 2001; Hope *et al*., 2003). Taxa analysed in these studies included plants (Hope *et al*., 2003; Araújo, 2003), butterflies (Luck *et al*., 2004), amphibians (Araújo, 2003; Luck et al., 2004; Diniz-Filho *et al*., 2006), reptiles (Balmford *et al*., 2001; Araújo, 2003), birds (Balmford *et al*., 2001; Luck et al., 2004; Evans and Gaston, 2005) and mammals (Balmford *et al*., 2001; Araújo, 2003; Luck et al., 2004; Vázquez and Gaston, 2006). In a review by Pautasso (2007), he found that positive correlations between human populations and species richness were typical at coarse scales (province/country scale), whereas a negative correlation between increasing human population density and species richness were predominantly at a local scale. At fine scales, higher levels of urbanisation tend to have lower proportions of natural habitats, while at coarse scales high proportions of urbanised regions may consist of natural vegetation (Pautasso, 2007).

In addition, to affecting species richness, urbanization has also been shown to cause increases in species abundance, notably tolerant fish taxa (Paul and Meyer, 2001), arthropod (Faeth *et al*., 2005), spider (Shochat *et al*., 2004) and bird species (Blair, 1996; Blair, 1999; Chace and Walsh, 2006; Clergeau *et al*., 2006), most often human commensal species (Chace and Walsh, 2006). However, according to Aronson *et al*. (2014), urban areas contain significantly lower densities of species in comparison with non-urban areas on a global scale. Pautasso (2007) stated that on one hand, species introductions, land use, pollution and climate change causes species endangerment and extinctions, while on the other conservation activities document and preserves species, hotspots of biodiversity and rare ecosystems present in urban infrastructure.

2.5 Urban green infrastructure

According to Swanwick *et al*. (2003) “urban areas are made up of the built environment and the external environment between buildings”. The external environment is made up of ‘urban green spaces’ (UGS), i.e. areas that consist mostly of permeable, unsealed surfaces such as grass, shrubs, soil and trees, and ‘grey spaces’, which consists of sealed, impermeable surfaces such as paving or concrete (Swanwick *et al*., 2003). Hence, the term ‘urban green space’ is used as an umbrella term for all areas of land covered by this definition of ‘green space’ (Swanwick *et al*., 2003). More recently the term ‘green infrastructure” has been used to refer to all the green areas in cities and include conservation areas, derelict land, forests, green corridors, green roofs, green walls, natural or semi-natural areas, open spaces, public parks, railways, road verges, sport fields, waterways and wetlands, allotments and private gardens (Li *et al*., 2005; Smith *et al*., 2005; Caula *et al*., 2009; Douglas, 2011a; Swanwick *et al*., 2003; Wolch *et al*., 2014). Urban green infrastructure provides a wide range of urban ecosystem services (Bolund and Hunhammar, 1999; Calvet-Mir *et al*., 2012; De Groot *et al*., 2002; Tzoulas *et al*., 2007; Douglas, 2011a).

Urban green infrastructure is fundamental to the conservation, maintenance and restoration of biodiversity in areas that have been severely impacted by urbanisation (Rudd *et al*., 2002; Gaston *et al*., 2005b; Thompson *et al*., 2005; Kong *et al*., 2010), creating or preserving habitat

(Smith *et al*., 2006b; Hostetler *et al*., 2011), maintaining corridors for the movement of wildlife (Smith *et al*., 2006b; Kong *et al*., 2010; Hostetler *et al*., 2011), reducing flood risks and surface runoff (Bolund and Hunhammar, 1999; Pataki *et al*., 2011; Carter *et al*., 2015), assisting water purification and sewage treatment by wetlands (Bolund and Hunhammar, 1999; Woodward and Wui, 2001; Ibarra *et al*., 2013), reducing wind speed (Mochida and Lun, 2008; Escobedo *et al*., 2011), filtering air by removing atmospheric pollutants (Beckett *et al*., 1998; Jim and Chen, 2008; Pataki *et al*., 2011), reducing noise pollution (Bolund and Hunhammar, 1999; Gidlöf-Gunnarsson and Öhrström, 2007; Escobedo *et al*., 2011), ameliorating urban climate and preventing the heat stress phenomena (Luber and McGeehin, 2008; Lafortezza *et al*., 2009; Masson *et al*., 2014; Carter *et al*., 2015). The services provided by urban green infrastructure are defined by humans who determine their importance and value (De Groot *et al*., 2002).

Urban green infrastructure provides ecosystem services that not only support the ecological integrity of cities, but can also improve the quality of life, health and psychological well-being of urban residents (Ulrich *et al*., 1991; Niemelä, 1999a; Bolund and Hunhammar, 1999; Vemuri *et al*., 2009; Ward *et al*., 2010; Wolch *et al*., 2014), by promoting quick recovery from surgery, stress relief and rehabilitation (Ulrich, 1984; Ulrich *et al*., 1991; Adevi and Lieberg, 2012; Adevi and Martensson, 2013), providing areas for sporting activities and recreation (Tzoulas *et al*., 2007) and educating urban residents about ecosystems, biodiversity and conservation (Gaston *et al*., 2005b; McKinney, 2002; McKinney, 2006; Thompson *et al*., 2005; Ward *et al*., 2010). However, the ecological functions provided by green spaces depend on their size, distribution and composition, and status i.e. indigenous, alien, etc. (Smith *et al*., 2005). According to Douglas (2011a) "green infrastructure has become a key planning concept, guiding the provision of vegetated areas in new developments and their retrofitting into existing urban areas". According to Smith *et al*. (2005) "domestic gardens can form extensive, interconnected tracts of green space". Therefore, domestic ('private') gardens can cover a considerable proportion of the urban area and consequently, have significant potential for biodiversity maintenance and conservation (Gaston *et al*., 2005b).

2.6 Gardens as green spaces

Gardens are managed at an individual level and vary widely in land cover composition and management intensity (Smith *et al*., 2006a and 2006b). In the past, gardens were a neglected green space in urban ecological studies for three reasons, firstly, private gardens are difficult to study due to their diverse nature and complex composition, second, domestic gardens have not been a direct topic of public policy (Richards *et al*., 1984), and thirdly, because domestic gardens are privately owned, obtaining permission to conduct garden research can be difficult (Gaston *et al*., 2005b). The few studies that were conducted, focussed on either a single garden

(Owen, 1991) or specific taxa, such as birds (Day, 1995), insects (Goulson *et al*., 2002) or mammals (Dickman and Doncaster, 1987 and 1989; Doncaster, 1994).

Both long-term research in single gardens (Owen, 1991) and short-term research in multiple gardens (Gaston *et al*., 2005a; Gaston *et al*., 2005b; Thompson *et al*., 2003) indicate that they are complex environments which support diverse microhabitats, resulting from the interplay of factors such as aspect, management and vegetation structure (Smith *et al*., 2005). The first research project to do a comprehensive investigation of domestic gardens and the resources that they provide for biodiversity and ecosystem functioning was the BUGS (Biodiversity in Urban Gardens in Sheffield) project (Gaston *et al*., 2005a and 2005b; Smith *et al*., 2005, 2006a, 2006b and 2006c; Thompson *et al*., 2003, 2004 and 2005). The BUGS project paved the way for domestic garden studies all over the world, including southern hemisphere countries such as New Zealand and South Africa.

2.6.1 The history of gardening

According to Van Jaarsveld (2001), "Gardens originated in the Northern Hemisphere when humans started cultivating plants that provided nourishment, medicines, clothing and building material". During the third millennium BCE (Before Common Era), the Sumerians in Mesopotamia established the first cultivated plots, which could be called gardens (Owen, 1991). These plots consisted of an enclosed area with a shade tree, vegetables grown in rows, a trained vine and water for irrigation (Owen, 1991). The cultivation of plants as crops was a defining moment in human history since it was now possible for them to supply their own food during unfavourable conditions and enabled them to build villages, towns, and cities (Raven, 2009). By 1500 BCE in Egypt and later in other countries such as Persia, gardens were not only being cultivated for utilitarian purposes but for decoration (Owen, 1991). The Romans were the first to cultivate gardens purely for aesthetical reasons (Owen, 1991) and during the Renaissance the western tradition of ornamental planting was established (Reichard and White, 2001).

By the sixteenth century in England, commercial plant nurseries were commonplace in some towns (Owen, 1991). According to Reichard and White (2001), "the wealth and interest in the natural world that flourished during the Renaissance fuelled unprecedented plant exploration". Global exploration and the discovery of new plants from all over the world led to the establishment of commercial nurseries that conducted international trade in ornamental plants (Reichard and White, 2001). According to Dehnen-Schmutz and Touza (2008), "the horticultural trade has a long tradition in transferring plants around the globe". Nurseries employed commercial plant hunters in the 19th century to travel the world in search of new plants with the potential for successful garden ornamental sales (Dehnen-Schmutz and Touza, 2008). Colonialism played a big part in the establishment of the commercial plant trade. In the nineteenth century, European settlers attempted to recreate their homelands in their new surroundings by using European plants and animals to transform the countryside (Ignatieva and Stewart, 2009).

In 1652, the arrival of the Dutch in Cape Town marked the beginning of the importation of plant species from other continents into South Africa, many of these species would eventually become invasive (Henderson, 2006). Approximately 115 and 103 new plant species were introduced to South Africa during the 1800's and 1900's respectively (Henderson, 2006). According to Henderson (2006), plants introduced prior to 1850 were predominantly utilitarian, while species introduced after 1850 were mostly ornamental. Like most countries in the southern hemisphere, gardening in South Africa was greatly influenced by European settlers (Henderson, 2006; Ignatieva and Stewart, 2009).

2.6.2 What is a garden?

According to Vogl *et al*. (2004) ethnobotanical research has distinguished between two different types of homegardens, namely rural homegardens and urban homegardens, often referred to as domestic gardens. Vogl *et al*. (2004) defines homegardens as the area of land situated next to the house where their gardener or homeowner lives. Winklerprins (2002) defined a home garden as "assemblages of plants about a dwelling which reveal much of the cultural history of places, the management decisions by individual holders and that satisfy some requirements for food, fibre and medicine". Rural homegardens are gardens next to a house in a rural settlement (such as a village or hamlet) and urban homegardens are gardens bordering a house in a city or town (Vogl *et al*., 2004). Homegardens are easily distinguished from other types of gardens, such as allotment gardens, botanical gardens, community gardens and parks (Vogl *et al*., 2004).

Gaston *et al*. (2005b) used the term 'domestic gardens' in relation to the private gardens of residential dwellings that were studied in Sheffield (UK) for the BUGS project. Domestic gardens are defined as "the private spaces adjacent to or surrounding dwellings, which may variously comprise lawns, ornamental and vegetable plots, ponds, paths, patios, and temporary buildings such as sheds and greenhouses" (Gaston *et al*., 2005b). Cameron *et al*. (2012) defined a private domestic garden as the area of land adjacent to a domestic dwelling (either privately owned or rented) over which the residents have full control, which means they may decide to delegate the responsibility to a landscape architect, gardener or other professional.

For the purpose of this study a domestic garden was defined as the area surrounding a domestic dwelling including all cultivated (ornamental plantings which included trees, shrubs and forbs, lawns, vegetable plots, hedges, orchards, herb and medicinal gardens) and non-cultivated (paving, paths, patios, swimming pools and uncultivated ground) areas within a border (fences, hedges or walls) that was actively managed or maintained by the inhabitants and/or homeowner. Apartment buildings, allotment gardens, communal gardens, institutional gardens and parks were excluded in this study. The level of garden management varied between gardens, from minimal input gardening (Zirkle *et al*., 2011) to more intensive garden management practices (See Chapter 6). In the more urbanised areas of the study, the majority of the inhabitants and/or homeowners chose to delegate the responsibility of garden management to either a gardener or gardening services.

2.6.3 What are gardens used for?

Gardens can be used for a wide range of activities, such as cultivating plants for household consumption or aesthetics (Bernholt *et al.*, 2009; Bigirimana *et al*., 2012; Smith *et al*., 2005), exercising pets (Smith *et al*., 2005), relaxation, which includes activities such as sunbathing, reading or just sitting in the garden (Clayton, 2007; Loram *et al*., 2011; Smith *et al*., 2005), recreation, for example as a play area for children (Loram *et al*., 2011; Smith *et al*., 2005), laundry, gardens provide opportunities for socializing with neighbours (Clayton, 2007; Dunnett and Qasim, 2000; Loram *et al*., 2011) and a platform for interacting with nature (Clayton, 2007). Approximately 25 % of the respondents in a study by Dunnett and Qasim (2000) stated that their gardens provided a means for them to connect with people in their neighbourhoods.

2.6.4 Why do people garden?

Gardening has long been a popular pastime (Clayton, 2007; Loram *et al*., 2011). A survey by the National Gardening Market Research Company (2016) reported that roughly 90 million U.S households participated in some form of gardening and lawn care activity in 2015. In the UK approximately 50 % of the adult population reported gardening as a free-time activity (Buck, 2016). The importance of gardening is further substantiated by the plethora of gardening material available in popular media such as books, magazines, television programmes and gardening web sites (Loram *et al*., 2011). According to Dunnett and Qasim (2000) “gardening as an activity and the garden as a place produce aesthetic, spiritual and psychological benefits that extend well beyond the simple growing of plants”.

A random survey by Dunnett and Qasim (2000) reported that 75 % of garden owners in Sheffield (UK) enjoyed their garden environment, while 10 % valued nothing about gardening as an activity or about their gardens. The respondents in Dunnett and Qasim's (2000) study listed several reasons for gardening, such as, the cultivation of plants, fresh air and exercise, the satisfaction gained from creating a neat and tidy garden and the opportunity to be creative and express their own personal style. Clayton (2007) identified two main reasons for gardening, one that involves the social benefits gained from gardening and one that involves the benefits gained from interacting with nature.

According to Smith *et al*. (2006c) "the level of interest in gardening is probably the most important factor in determining individual garden richness, and the proportion of planted species would be a direct indication of a gardener's interest". All gardens have the potential to be useful for wildlife and biodiversity conservation, regardless of its size (Gaston *et al*., 2005b; Smith *et al*. 2006c). A garden's potential for floral richness and wildlife conservation depends on the garden owner's behaviour and management decisions (Smith *et al*., 2006c). Garden management decisions are generally influenced by the advice gardeners receive (from for example books, magazines, web sites or gardening services), the gardeners level of education and the latest gardening fashions (Smith *et al*., 2006c), such as water wise gardening (Van Jaarsveld, 2013), indigenous gardening (Honig, 2014) or garden lights, and their financial resources (Hope *et al*., 2006).

2.6.5 Garden management practices

Gaston *et al*. (2005b) conducted a random telephone survey of domestic gardens in the city of Sheffield, UK to determine how often people worked in their gardens. The results of their study showed that roughly 40 % of the respondents worked in their gardens more than once a week, 34 % once a week and 25 % less than once a week (Gaston *et al*., 2005b). On average the respondents worked an hour and a half per week and roughly 10 million hours per year collectively, in their gardens (Gaston *et al*., 2005b). According to Gaston *et al*. (2005b) "this level of time investment must make domestic gardens some of the most intensively managed areas of land". But what does garden management entail?

Approaches to gardening and garden management practices are abundant and diverse (Loram *et al*., 2011). At one end of the spectrum are conventional gardening practices (Loram *et al*., 2011) and at the other end environmentally friendly (Keisling and Manning, 2010) and wildlife-friendly gardening practices (Gaston *et al*., 2007; Goddard *et al*., 2013). Conventional gardening practices promote the cultivation of alien plants, regular watering when rainfall is insufficient, multiple fertiliser applications per annum and the use of herbicides and pesticides (Keisling and Manning, 2010). Environmentally-friendly gardening promotes a consistent set of garden practices, which include water conservation, limiting the use of fertiliser, mulching bare soil, avoiding the use of pesticides and promoting the use of compost heaps to dispose of vegetative waste (Keisling and Manning, 2010). Wildlife-friendly gardening practices promote gardening practices that encourage wildlife in gardens, for example by providing bird feeders, bird baths and nest boxes, cultivating a variety of plant species to attract wildlife, avoiding the use of chemical sprays, use compost heaps, leave dead leaves and wood lying around (Gaston *et al*., 2007).

Loram *et al*. (2011) investigated the prevalence and frequency with which several garden management activities were performed in five cities in the UK. The most prevalent activities were watering, lawn-mowing, weeding, dead-heading flowering plant species and collecting leaves. Other management activities such as the use of fertilisers or pesticides and bonfires were also performed, but not as often as the above mentioned activities (Loram *et al*., 2011). According to Clayton (2007) garden management practices are driven by the concerns associated with garden usage. Concerns such as the gardens appearance, enhancing the property value of homes, garden maintenance, maintaining healthy ecosystems in gardens, weed control, minimising gardening costs, reducing the number of resources utilised, safety and meeting neighbourhood standards (Clayton, 2007).

2.6.6 Does size matter?

Individually, gardens are small in relation to other green spaces in urban settlements however, the combined areal coverage of domestic gardens is significant (Dewaelheyns *et al*., 2016; Gaston *et al*., 2005a; Smith *et al*., 2005; Thompson *et al*., 2003). In the Kirua Vunjo Division territory on Mount Kilimanjaro, Tanzania, homegardens cover roughly 19 % of the total area (Soini, 2005). The study of Pauleit *et al*. (2005) in Merseyside (UK) reported that the cover of private gardens varied greatly, from only 6 % in Wavertree to approximately 43 % in Birkdale. In Leicester, nearly 28 % of urban areas are estimated to be covered by gardens (Owen, 1991), while in Sheffield (UK) domestic gardens cover approximately 23 % of the total urban land area (Gaston *et al*., 2005a). In Scotland, 30 % of the total green space is classified as private gardens (Greenspace Scotland, 2009). Domestic gardens constitute 16.2% of the assessed land area in the central part of Stockholm, Sweden (Colding *et al*., 2006). The total garden area in Flanders, excluding the Brussels region, was calculated to be approximately 8.2 % (or 1,100 km^2) of the Flemish territory (Bomans *et al*., 2011). Nowak *et al*. (1996) found that on average 41 % of land use in United States cities is residential. In Dunedin, New Zealand, vegetated garden area covers 46 % of the residential area and 36 % of the total urban area (Mathieu *et al*., 2007). Thus, gardens vastly contribute to the extent of green space in urban settlements and as a result, their composition and structure exert a strong influence on the species pool present in urban areas (Smith *et al*., 2006c).

2.6.7 What is the physical composition of a garden?

2.6.7.1 Front and backyard

Generally speaking, homesteads consist of both a front and backyard, front yards face the street, while backyards are located at the back of a house, often hidden from public view (Daniels and Kirkpatrick, 2006b). The study of Daniels and Kirkpatrick (2006b) analysed the artificial, floristic and structural attributes present in both front and backyards in Hobart, Tasmania, Australia. The results of their study showed that plant taxa that provide culinary herbs, fruit and vegetables are predominantly located in backyards, while plant taxa that are cultivated primarily for aesthetic reasons, such as bulbs, rose bushes, shrubs and trees, are concentrated in front yards (Daniels and Kirkpatrick, 2006b). Backyard gardens provide habitats for invertebrate species, increase connectivity and dispersal within an urban environment and can contribute to the ecological restoration in urban settlements (Sperling and Lortie, 2010).

2.6.7.2 Land cover and garden area

According to Smith *et al*. (2005), the nature of the green space provided by domestic gardens depends on their composition. In general terms, the conventional domestic garden in Britain is usually comprised of a variety of different land covers, such as paved paths and patio, internal walls of stone and brick construction, a shed and/or a greenhouse, grass lawn, cultivated flower beds which contain ornamental annuals, perennials, grasses and woody plants (shrubs and trees), hedges (often used as boundaries), as well as fruit trees and vegetable patches (Smith *et al*., 2005). The study of Smith *et al*. (2005) examined the composition of domestic gardens in Sheffield in the UK and the physical factors affecting the occurrence of particular land covers. The results of their study indicated that rear garden size plays an important role in determining the internal composition of domestic gardens in Sheffield and consequently affects the amount of potential resources that domestic gardens are capable of providing for wildlife (Smith *et al*., 2005).

The role of garden size was substantial as it affected garden resources in various ways (Smith *et al*., 2005). Larger gardens are capable of supporting more and specific land covers (compost heaps, ponds, taller trees, etc.). The extents of more than three-quarters of the land-covers recorded in gardens, as well as vegetation cover, increased with the garden area (Smith *et al*., 2005). The results of Smith *et al*. (2005) were later confirmed by the study of Loram *et al*. (2008b). According to Smith *et al*. (2005), garden area determines the availability and size of particular land covers and consequently the presence of potential habitats for wildlife. The bird species richness in gardens was positively influenced by garden area (Chamberlain *et al*., 2004; Thompson *et al*., 1993). Nonetheless, as a result of continued urbanisation the pressure on available, undeveloped land has increased and consequently new housing plots will be smaller than those of older dwellings (Smith *et al*., 2005).

2.6.7.3 Garden lawns

Gaston *et al*. (2005b) estimated that roughly 60 % of the total area of domestic gardens in Sheffield is covered by lawn. In the past, very little attention was paid to the floristic composition of garden lawns. The studies of Wilson *et al*. (1992), Wilson and Watkins (1994) and Roxburgh and Wilson (2000) were the first to study lawns. However, their studies were more concerned with the stability and community assembly rules of a simple lawn and their study site was the botany lawn at the University of Otago, New Zealand. The study of Thompson *et al.* (2004) was the first to investigate the contribution of lawns to the floristic diversity of domestic gardens. The aim of their study was to determine the composition of lawn floras, what factors influence their composition and how they compare with semi-natural grasslands, in terms of composition, origin and species richness (Thompson *et al*., 2004).

Thompson *et al*. (2004) found that lawns had a tendency to accumulate individuals, either by clonal expansion or seed. Garden lawns contain an abundance of transient species (such as herbs, shrubs and/or trees) capable of rapidly transforming the biomass and appearance of a typical lawn if management practices become relaxed (Thompson *et al*., 2004). According to Thompson *et al*. (2004), lawns are a source of considerable tension between the natural process of colonization and succession and the desire of gardeners to control the composition of their gardens. Daniels and Kirkpatrick (2006b) found that backyards in Hobart, Tasmania had proportionally higher lawn cover than front yards. Lawns contribute to several ecosystem services in urban areas, including air filtering, climate regulation, noise reduction, rainwater drainage, recreational and cultural values (Bolund and Hunhammar, 1999) and carbon sequestration in garden soils (Zirkle *et al*., 2011). According to Gaston *et al*. (2005b) rainwater drainage is one of the most important contributions of lawns to domestic gardens.

2.6.8 How species rich is your garden?

Garden studies over the last few decades have shown that gardens are capable of maintaining rich assemblages of biodiversity. They support a high diversity of plant species, the majority of which is often alien (Marco *et al*., 2008; Smith *et al*., 2006c; Thompson *et al*., 2003), provide habitats for invertebrates (Fetridge *et al*., 2008; Goulson *et al*., 2002; Matteson *et al*., 2008; Samnegard *et al*., 2011; Smith *et al*., 2005 and 2006c; Sperling and Lortie, 2010), amphibians (Carrier and Beebee, 2003), birds (Bland *et al*., 2004; Cannon *et al*., 2005; Chamberlain *et al*., 2004, 2005 and 2007; Day, 1995; French *et al*., 2005; Fuller *et al*., 2008; Kinzig *et al*., 2005; Thompson *et al*., 1993) and mammals (Baker *et al*., 2003; Dickman and Doncaster, 1987 and

1989; Doncaster, 1994). Over a period of fifteen years, Owen (1991) reported a total of 2 204 species, including amphibians, birds, insects, mammals and plants in her home garden in Leicestershire. The world record for plant diversity for a specific site remains unknown, but it is almost certainly held by a garden somewhere (Thompson *et al*., 2003).

But why are gardens so species rich? Owen (1991) ascribed the high biodiversity count in her garden to gardening practices. Thompson *et al*., (2003) provided two possible reasons for the species richness of Sheffield gardens, namely, the management and maintenance conducted by gardeners and the large species pool available to gardeners. The species composition of gardens is greatly influenced by garden characteristics, such as the complex three-dimensional structure of vegetation (vegetation density and height), alien and native plant species and the addition of artificial structures such as bird feeders, ponds, and compost heaps.

2.6.8.1 Vegetation structure

The structure of garden vegetation, in other words, vegetation height and density, influences the species richness of both invertebrate and vertebrate taxa (Day, 1995; Smith *et al*., 2006a and 2006b; Van Heezik *et al*., 2008). However, these influences vary across all taxa present in gardens, i.e. individual taxa are associated with specific vegetation components (Smith *et al*., 2006b). For examples, Smith *et al* (2006b) found that canopy cover (> 2 m) was positively related to beetle species richness, while the number of sawflies, wasps, crane flies and long-legged flies recorded in Sheffield gardens were positively correlated with the number of trees. The studies of both Day (1995) and Thompson *et al*. (1993) found that vegetation structure played an important part in bird species richness since bird species richness was higher in gardens with clumped evergreen conifers. Similarly, Daniels and Kirkpatrick (2006a) found that the percentage shrub cover had an important influence on garden birds in Hobart, Tasmania, Australia.

2.6.8.2 Alien and native species

The study of Daniels and Kirkpatrick (2006a) reported that native birds favoured native plants, while alien birds predominantly utilised alien plant species. Gardens with high cover of deciduous trees tended to favour many alien bird species, while gardens with tall trees were rich in native bird species and individuals (Daniels and Kirkpatrick 2006a). Not only are gardens important for the conservation of urban bird species, but their floristic composition and structure can be manipulated to favour specific bird species (Daniels and Kirkpatrick 2006a). Day (1995) found that, although native plants were more attractive to a wider range of bird species than introduced plants in Hamilton, New Zealand, they did not necessarily attract a greater abundance of birds, and noted that a number of introduced bird species seemed to be able to meet their habitat requirements equally well from native or introduced plants. French *et al*.

(2005) found that the Australian native plant genera Banksia and Grevillea were significantly more attractive and received significantly more attention than the alien genera Hibiscus and Camellia to all birds and particularly to native species in Sutherland Shire in south-eastern Sydney, Australia.

2.6.8.3 Artificial structures

The study of Gaston *et al*. (2005a) tested five recommendations with the potential to improve the biodiversity of domestic gardens in Sheffield, UK. These five recommendations were implemented in several gardens and monitored after three years (Gaston *et al*., 2005a). The results of their experiments varied, some failed entirely, while others were successful (Gaston *et al*., 2005a). For example, artificial nests for bees, wasps and bumblebees were introduced to several gardens and while the nests for bees and wasps had been utilised in the three year period, the bumblebee nests had not (Gaston *et al*., 2005a).

Gaston *et al*. (2005b) reported that of the estimated 175 000 domestic gardens in Sheffield, 25 200 had ponds, 45 500 had nest boxes and 50 750 had compost heaps. Garden ponds have the potential to sustain large populations of frogs (Carrier and Beebee, 2003), as well as supporting a range of invertebrate species (Gaston *et al*., 2005a) in urban areas. According to Gaston *et al*. (2005b), domestic gardens with compost heaps have the potential to recycle roughly 18,200 metric tons of organic waste material per annum. Several studies have reported that bird feeders increase the number of bird species that visit an individual garden (Chamberlain *et al*., 2004 and 2005; Daniels and Kirkpatrick, 2006a), as well as influencing the abundance of bird populations at a landscape scale (Fuller *et al*., 2008).

2.6.9 What are the benefits of gardens?

Domestic gardens can provide various ecosystem services (Cameron *et al*., 2012), such as carbon sequestration in garden soils (Zirkle *et al*., 2011), storm water runoff decrease (Cameron *et al*., 2012), mitigation of the heat island effect (Skelhorn *et al*., 2014), air pollution removal (Pataki *et al*., 2011) and biodiversity conservation (Gaston *et al*., 2005a; Daniels and Kirkpatrick, 2006a; Goddard *et al*., 2010). Gardens provide a refuge for native species that are uncommon (Thompson *et al*., 2003) or have declined in the wider countryside (Gregory and Baillie, 1998; Mason, 2000). Gardens also have positive effects on the mental well-being and physical health of people who have access to them (Clayton, 2007; Dunnett and Qasim, 2000; Gross and Lane, 2007). The study of Clayton (2007) identified the several benefits for gardening in the USA: Spending time outdoors, observing nature, relaxation, controlling the appearance of the garden, working with my hands, novelty (e.g. trying out new plants), producing food or herbs, demonstrating my effort, and demonstrating my gardening expertise.

2.7 Socio-economic status

"Variations in socio-economic status (SES) are an irrefutable fact of life in our own society as well as cross-culturally" (Mueller and Parcel, 1981). People differ in terms of their origin, access to jobs, assets, earnings, and power, as well as according to their SES (Mueller and Parcel, 1981). Mueller and Parcel (1981) use the term "social stratification" to describe a social system (for example, a community or a society) in which families, groups or individuals are characterised by certain hierarchies or dimensions based on their access to or control over prised commodities such as wealth and status. An individual's SES represents his/her position on a particular hierarchy (Mueller and Parcel, 1981). Social stratification is an important contributing factor to various social phenomena and sociologists have devoted considerable time and effort towards developing reliable and valid measures of SES (Mueller and Parcel, 1981).

Social scientists have spent several decades developing good indices of an individual's socio-economic background, determining ways to quantity and use SES in their research (Entwisle and Astone, 1994; Mueller and Parcel, 1981). Mueller and Parcel (1981) identified two main purposes for using SES in sociology, (1) as an explanatory and/or control variable or (2) as one of the criteria's for selecting subjects in a study. Nevertheless, there has been much debate in regards to what exactly SES represents (Bradley and Corwyn, 2002). Some social scientists are advocates of SES representing social status or prestige, while others are advocates of it representing class or economic position (Bradley and Corwyn, 2002). The idea of capital (Coleman, 1988) perhaps best exemplifies the understanding that social scientists currently have of SES (Bradley and Corwyn, 2002; Entwisle and Astone, 1994).

Capital refers to the resources available to people and Coleman (1988) distinguished between three different types of capital, namely financial capital (resources related to wealth and income), human capital (resources such as education, skills, knowledge and experience) and social capital (resources obtained through social connections, such as families, communities, social networks, etc.). The Department for International Development (DFID, 2000) has identified two additional types of capital in people's livelihoods, namely natural capital (ecosystem goods and services) and physical capital (infrastructure and services). Capital has become the preferred way of thinking about SES because access to all forms of capital can be relayed to processes that directly affect well-being (Bradley and Corwyn, 2002). However, in most impoverished and remote rural areas, the "hard" types of capital, namely financial capital, human capital, and physical capital are in short supply (Fabricius and Collins, 2007).

2.7.1 Measuring SES

There has been much debate between sociologists with regards to what measures of SES represent the most reliable and valid single method (Mueller and Parcel, 1981). There is, however, a considerable agreement that occupation-based measures of SES represent the most reliable measures of an individual's position in a social system (Mueller and Parcel, 1981). In fact, according to Mueller and Parcel (1981), sociologists have relied almost exclusively on occupational-based measures to quantity SES over the past several decades. In an overview of several scientific papers concerning SES in social sciences, Bradley and Corwyn (2002) found that there were different ways of measuring SES and the methods used depended on the questions being asked, the method of obtaining the data and the population from which the data was collected.

2.7.2 SES as a driver of diversity

The study of Talarchek (1990) was one of the first studies to investigate the relationship between socio-economic and urban environmental data. One of the main aims of his study was to determine if the distribution of the urban forest is connected to the social geography of the area, more specifically the distribution of socio-economic status among census tracts (Talarchek, 1990). Talarchek reported that the distribution of the urban forest in New Orleans is in fact primarily related to the social status of areas of the city, i.e. residents income level was positively correlated with tree cover. In Chicago, Illinois, Iverson and Cook (2000) found that tree cover was negatively correlated with population density but positively correlated with household income. The study of Kirkpatrick *et al*. (2011) reported that increases in urban tree density were linked to increases in income level and education in six eastern Australian cities.

Clarke *et al*. (2013) studied the tree diversity in the city of Los Angeles and found that it was affected by both development age and household income. Avolio *et al*. (2015) found that the wealthier neighborhoods across three counties in Southern California had higher tree cover than poorer neighborhoods. Similarly, Pedlowski *et al*. (2002) reported that the wealthier neighbourhoods in Rio de Janeiro, Brazil, had higher tree abundances than the low income neighbourhoods. Duncan *et al*. (2014) found significantly positive correlations between sociodemographic characteristics and tree density across neighbourhoods in Boston, Massachusetts. In South Africa, the study of McConnachie *et al*. (2008) found that distribution of woody plants was unevenly distributed across the urban green spaces of different SES in several small towns in the Eastern Cape. However, the distribution was in favour of wealthier areas within these towns, meaning these areas tended to have more woody species than the green spaces in poorer areas (McConnachie *et al*., 2008). Kirkpatrick *et al*. (2007) found that household income was a predictor of household's tendency to have trees in their gardens.

Martin *et al*. (2004) found that species richness increased across a gradient of low to high SES in the residential neighborhoods of Phoenix, Arizona. The study of Luck *et al*. (2009) found that a positive relationship existed between socio-economic factors and vegetation cover. The results from the study of Kinzig *et al*. (2005) found that "neighbourhood socio-economic and cultural status appeared to be playing an important role in structuring urban biodiversity patterns, independent of the effects of population density, distance from the urban center, or time since disturbance". Lubbe *et al*. (2010) found a positive correlation between SES and the gamma diversity of domestic gardens in the Tlokwe City Municipality (TCM) in South Africa.

Socio-economic factors measured at the neighbourhood scale have been shown to be strongly associated with avian diversity, but in both directions: wealthier neighbourhoods supported more native species in Vancouver, Canada (Melles, 2005) and in Leipzig, Germany (Strohbach *et al*., 2009), whereas in Chicago income was inversely related to native bird species richness, but positively associated with exotic richness (Loss *et al*., 2009). Van Heezik *et al*. (2013) found only a weak positive association between capital value and bird richness. The association between wealth and avian richness is an indirect one, as socio-economic factors are more likely to have an impact on birds through their effect on vegetation cover (Van Heezik *et al*., 2013).

2.7.3 "Top-down" and "Bottom-up"

Humans alter patterns of urban vegetation through their degree of "bottom-up" or "top-down" influences (Martin *et al*., 2004). "Bottom-up" influences reflect the integrated outcomes of various and often unrelated small-scale, i.e. individual/household, choices or actions and are therefore reflections of the cultural, economic and social differences among households (Kinzig *et al*., 2005; Martin *et al*., 2004). According to Kinzig *et al*. (2005), "top-down influences reflect city-level land management strategies and decisions". "Bottom-up" influences can be seen in the diverse household landscaping choices made by homeowners and "top-down" influences in the municipal decisions concerning management and landscaping (Kinzig *et al*., 2005; Martin *et al*., 2004). These terms capture and describe differences in the ways in which different people at different levels of organization (household vs. government) are interacting with the landscape.

Martin *et al*. (2004) found that vegetation composition of residential neighbourhoods varied most with SES while vegetation composition in small parks varied least and reflected top-down influences because urban park management is usually under municipal control. Kinzig *et al*.

(2005) found that neighbourhood socio-economic and cultural status played an important role in structuring urban biodiversity patterns, independent of the effects of population density, distance from urban center, or time since disturbance. Martin *et al*. (2003) concluded that the emergent popularity in Phoenix of desert landscaping as a landscape design motif is largely a “top-down” social phenomenon directed by public and private interest groups.

2.7.4 The “luxury effect”

Hope *et al*. (2003) investigated to what degree a set of abiotic, biotic and human-related variables explained the spatial variation in the richness of perennial plant genera in Phoenix, Arizona. The results of their study indicated that plant diversity was positively related to median family income (Hope *et al*., 2003). Hope *et al*. (2003) defined the relationship between plant diversity and wealth as the “luxury effect”, i.e. as an individual’s economic resources increases, they tend to occupy urban landscapes with higher plant diversity. Furthermore, the relationship between plant diversity and wealth appears to be similar to the connection between socio-economic status (SES), species composition and the physical structure of vegetation in residential yards in other cities (Iverson and Cook, 2000; Martin *et al*., 2004; Talarchek, 1990; Whitney and Adams, 1980), which may suggest that the aforementioned relationship is characteristic of urban landscapes in general (Hope *et al*., 2003).

Humans are capable of removing the resource limitations (for example water or nutrients) within an environment, while simultaneously maintaining high species diversity (Hope *et al*., 2003). Hope *et al*., (2003) suggested that human maintenance is altering the traditional resource availability–diversity relationships within the urban matrix, i.e. an increase in the availability of limiting nutrients leads to an increase in the number of competing species. Therefore, the diversity in human-created habitats has more to do with human preferences and less to do with variation in traditional limiting resources, such as water (Martin *et al*., 2003) along with the availability of financial resources to realise those landscapes (Hope *et al*., 2003). Residents in low SES neighbourhoods are less likely to enjoy rich assemblages of plant and bird communities than people who live in high SES neighbourhoods (Kinzig *et al*., 2005; Martin *et al*., 2004). According to Hope *et al*. (2003) “the resource–diversity relationship then becomes one of financial rather than natural resources, interacting with land use, legacy effects, and other sociocultural factors”. By incorporating socio-economic gradients in urban ecology research projects we alter our perceptions of human–environment interactions and acknowledge that the desires, preferences and wherewithal of people in urban landscapes matter (Kinzig *et al*., 2005).

Chapter 3 - Study area

3.1 Introduction

During the 1990s, South Africa underwent noteworthy political changes which greatly affected all aspects of national life (Christopher, 2001). According to Christopher (2001) the Group Areas Act of 1950 provided for the compulsory zoning of all urban areas into specifically demarcated group areas. As a result of this forced removal policy, urban populations of African, Asian and Colored people were relocated from scattered formal locations and informal settlements to larger townships (NWDACE, 2008). In conjunction with this process of forced removals was a process of political restructuring, which lead to the creation of ten “homelands” based on tribal and language lines, four of which gained what the apartheid government called “independence”, namely Bophuthatswana, Ciskei, Transkei and Venda (Christopher, 2001; NWDACE, 2008). After the first democratic election in 1994, the new Constitution of the Republic of South Africa was introduced in 1996 (NWDACE, 2008). The post-1994 government demarcated the former four provinces of South Africa into nine provinces, which assimilated the former homelands (NWDACE, 2008).

3.2 Studied settlements

The settlements studied in this thesis are the rural settlements of Tlhakgameng (Molebatsi, 2011) and Ganyesa (Davoren, 2009), the peri-urban settlement of Ikageng and the urban settlement of Potchefstroom (Lubbe, 2011) in the North West province. To ensure that all the different socio-economic groups in South Africa were represented in this study, the urban settlement of Roodepoort in Gauteng province was included as it contained more affluent citizens living in a metropolitan area, namely, the Johannesburg Metropolitan area (City of Johannesburg, 2003) (Figure 3.1).

3.2.1 North West province

The North West (NW) province is completely landlocked, as it has Botswana as a northern neighbour and is surrounded by four other provinces of South Africa: Limpopo to the east and north-east, Gauteng to the southeast, the Free State to the south and the Northern Cape to the southwest (NWDACE, 2008). The province occupies a total area of 129 821 km², approximately 11% of the total surface area of South Africa (NWDACE, 2008). The North West province is divided into four district municipalities, namely the Ngaka Modiri Molema, Dr. Kenneth Kaunda, Dr. Ruth Segomotsi Mompati and Bojanala Platinum districts (NWDACE, 2008).

The capital of North West is the city of Mafikeng and some of the most significant towns in the province are Brits, Klerksdorp, Lichtenburg, Potchefstroom, Rustenburg and Vryburg (NWDACE, 2008). The province is home to roughly 2.2 % (> 1 million people) of South Africa's total population (Statistics South Africa (StatsSA), 2014). Approximately 65 % of the people live in the rural areas and the main ethnic group is the Setswana, followed by the minority groups of the Xhosa, Sesotho, and Afrikaans speaking people (NWDACE, 2008). According to a report by Statistics South Africa (Statistics South Africa (StatsSA), 2017), 71.7 % of the population in the North West province is literate and 28.3 % is illiterate. Statistics South Africa defines literacy as the ability to read and write in at least one of South Africa's eleven official languages (Statistics South Africa (StatsSA), 2017).

Molebatsi *et al*. (2010) defined deep rural as "an inhabited area where tribal authority manages the community and 90% of the inhabitants are subsistence farmers", rural as "an inhabited area under municipal management, where less than 50% of the inhabitants are subsistence farmers" and peri-urban as "an inhabited area on the fringes of a city that falls under the management of a city council, and less than 10% of the inhabitants are subsistence farmers". Urban is defined as an inhabited area under city council management, with no subsistence farmers and a metropolitan area is defined as an inhabited area under metropolitan council management, with no subsistence farmers (Davoren *et al*., 2016). Statistics South Africa (2003) defines an urban settlement as structured and organised, containing land parcels made up of formal and permanent structures, governed by a local council or district council, with access to services such as electricity, water and refuse removal, as well as roads that are formally planned and maintained by the council. Suburbs and townships are classified as urban settlements (Statistics South Africa, 2003). Rural areas often have limited access to basic services such as electricity, water and refuse removal (NWDACE, 2008). The selected settlements (Figure 3.1) are further discussed separately.

3.2.1.1 Tlhakgameng

Tlhakgameng is a deep rural settlement situated 30 km east of Ganyesa and 171 km from Mafikeng, the nearest city in the North West province, South Africa (26° 28' 00" S, 24° 21' 00" E) (Molebatsi, 2011). Tlhakgameng was part of the former Bophuthatswana homeland (Tladi *et al*., 2002). Even though it is under municipal authority, Tlhakgameng is managed by a tribal authority and consists predominantly of subsistence farmers. Tlhakgameng is approximately 31.38 km² in size, with a population of 16 028 and 3 706 households (Frith, 2011g).

3.2.1.2 Ganyesa

Ganyesa is a rural settlement in the North West province, South Africa, which is located between 26° 35' 50" S and 24° 10' 32" E, roughly 70 km north of Vryburg and 228 km from

Mafikeng, the nearest city. Ganyesa was part of the former Bophuthatswana homeland (Tladi *et al*., 2002). It is approximately 21.46 km² in size, with a population of 19 290 and 5 204 households (Frith, 2011a). Ganyesa is municipally managed and consists of 25 – 75 % subsistence farmers.

3.2.1.3 Ikageng and Potchefstroom

During the implementation of the Group Areas Act of 1950 in Potchefstroom, Africans were relocated to Ikageng, while coloreds and Asians were relocated to Promosa and Mohadin respectively (Jansen van Rensburg, 2002). Potchefstroom and the surrounding township areas of Ikageng, the Ikageng extension, Promosa, and Mohadin (for the purpose of this study collectively referred to as Ikageng) jointly form the Tlokwe City Municipality (TCM) in the North West province, South Africa (Lubbe, 2011). Ikageng and the Ikageng extension is 17.71 km² (Frith, 2011b), Mohadin is 0.71 km² (Frith, 2011c), Promosa is 4.37 km² (Frith, 2011e) and Potchefstroom is 162.44 km² in size (Frith, 2011d). The combined surface area of the townships in the TCM is 22.79 km².

The western side of the city, which consists of the residential areas of Ikageng, Ikageng extension, Mohadin and Promosa, are situated amongst a series of small ridges and hills, while the central part of the city is laid out along the western banks of the Mooi River on a flat plain (Du Toit, 2015). Potchefstroom is situated at 26˚ 42' 32'' S and 27˚ 05' 39'' E and Ikageng is located at 26° 43' 06" S and 27° 01' 50" E. The TCM has a population size of approximately 250 000 and 49 512 households (Tlokwe City Council, 2015).

3.2.2 Gauteng province

Gauteng means "Place of Gold" in Sesotho and even though it is the smallest of the nine provinces, it is considered to be the economic powerhouse of South Africa (DACE, 2004). The province is situated on the elevated plateau of the interior, called the Highveld, and constitutes only 1.4 % (roughly 17 010 km²) of South Africa's total surface area (DACE, 2004). Gauteng is surrounded by four provinces, namely North West (west), Limpopo (north), Mpumalanga (east) and Free State (south) provinces (DACE, 2004).

Gauteng has five local government areas, namely two district municipalities, Sedibeng and the West Rand Districts, and the three metropolitan municipalities, which include the cities of Johannesburg, Tshwane, and Ekurhuleni (Gauteng Department of Agriculture and Rural Development, 2011). The city of Johannesburg is the province's capital and it extends over 1 645 km² (Gauteng Department of Agriculture and Rural Development, 2011). The province is home to approximately 24 % (> 12 million people) of South Africa's total population (Statistics

South Africa (StatsSA), 2014). Gauteng has a rich cultural diversity and the major languages spoken are Afrikaans, English, isiZulu and Sesotho (DACE, 2004). Gauteng has the highest literacy rate of all nine provinces (Statistics South Africa (StatsSA), 2017). An estimated 87.5 % of the population in Gauteng is literate and 12.5 % is illiterate (Statistics South Africa (StatsSA), 2017).

3.2.2.1 Roodepoort

Roodepoort is located at 26° 07’ 07” S and 27° 51’ 01” E. Roodepoort is approximately 161.50 km² in size (Frith, 2011f) and forms part of the Johannesburg Metropolitan area (City of Johannesburg, 2003). The Johannesburg Metropole has a population size of approximately 4 500 000, of which Roodepoort contributes roughly 326 500 and 110 000 households (Frith, 2011f).

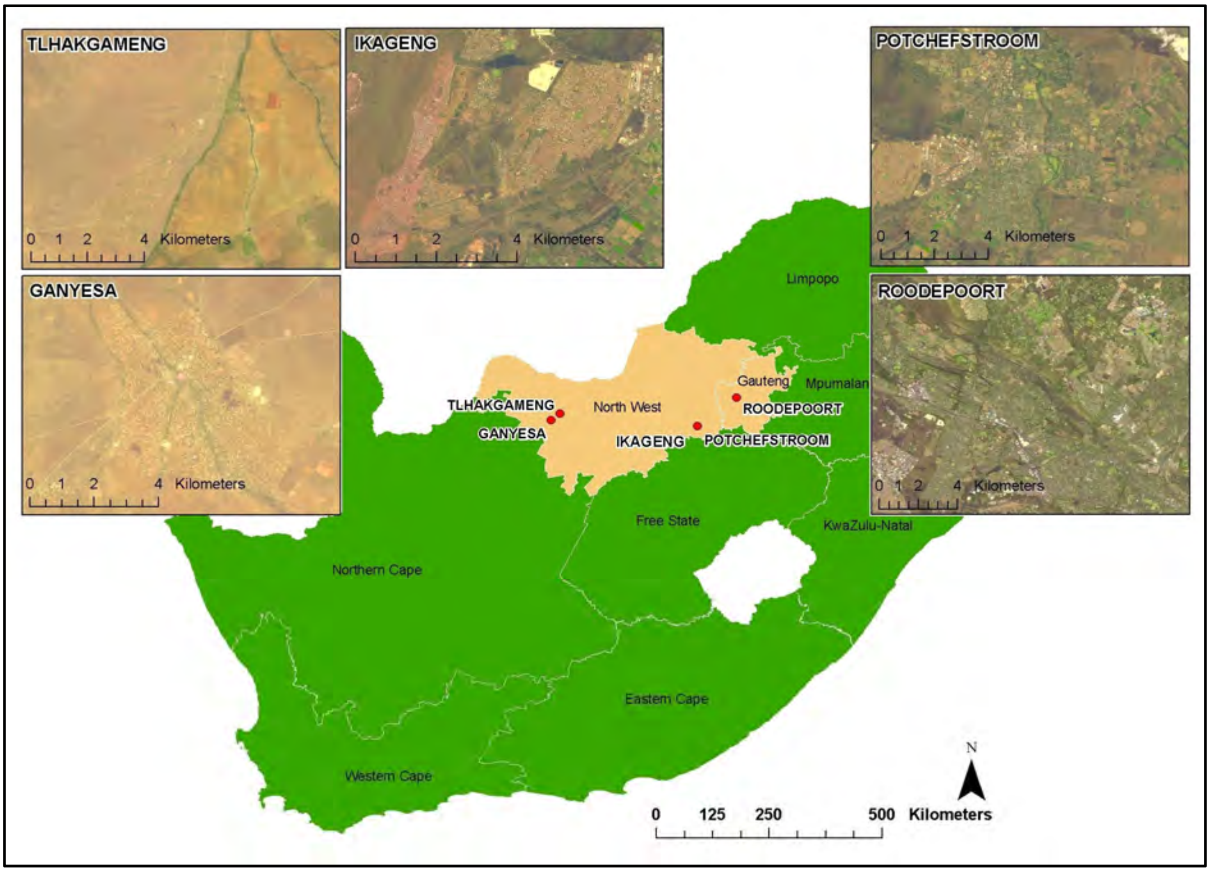

Figure 3.1: Locality of the study areas in the North West and Gauteng Provinces, South Africa (Tlhakgameng: deep rural, Ganyesa: rural; Ikageng: peri-urban; Potchefstroom: urban and Roodepoort: metropolitan).

3.3 Topography

The landscape of the North West province varies from mountains (2 000 m above level) in the east to plains (1 000 m above sea level) in the west (NWDACE, 2008). The northwestern and western parts of the province are characterised by plains, with scattered hills running in an arc from the Northern Cape (NWDACE, 2008). The central and southern parts of the province feature predominantly plains with pans, while areas to the west of Vryburg and south of Lichtenburg are characterised by slightly undulating plains (NWDACE, 2008). Potchefstroom and Rustenburg are situated in an area distinguished by lowlands and parallel hills (NWDACE, 2008). Plains and undulating plains with occasional occurrences of lowlands and hills characterise the northeastern parts of the province (NWDACE, 2008).

Gauteng is situated on the Highveld of South Africa, a high-altitude plateau of extensive grasslands approximately 1500 m above sea level (Gauteng Department of Agriculture and Rural Development, 2011). The landscape is marked by numerous ridges, one of which is a watershed that separates the Crocodile West and Vaal catchments (Gauteng Department of Agriculture and Rural Development, 2011). The ridges of the Witwatersrand run through the province in an east-west direction and are the source of nearly 40 % of the gold mined in South Africa (Gauteng Department of Agriculture and Rural Development, 2011).

3.4 Hydrography

In the North West province, water drains through three primary river catchment systems, namely the Crocodile-Marico in the east, the Molopo in the west and the Vaal in the south (Figure 3.2) (NWDACE, 2008). The main perennial rivers are the Crocodile, Elands, Groot Marico, Harts, Hex, Molopo, Mooi and Vaal rivers (NWDACE, 2008). The majority of the rivers in the province are non-perennial and only flow with seasonal rainfall, while other important surface water features include dams, pans, and wetlands (NWDACE, 2008).

Gauteng covers the convergence of watersheds of the Crocodile, Olifants and Vaal catchments (DACE, 2004). The Blesbokspruit, Kliprivier, Mooi, Natalspruit, Rietspruit, and Suikerbosrand rivers rise in the east-west band of high-lying areas of Benoni, Johannesburg, and Randfontein and drain south to join the Vaal River (DACE, 2004). The Apies River originates just south of the quartzite ridges (south of Pretoria), flows north to join the Pienaars River and together they flow into the Crocodile River (DACE, 2004).

The origin of the Crocodile River is an area close to Roodepoort that is characterised by plains with moderate relief (DACE, 2004). The Crocodile River is joined by the Jukskei River and together these flow in a northerly direction into the Limpopo River on the Botswana border (DACE, 2004). The Elands and Wilge Rivers originate from the north-eastern corner of Gauteng and together they flow north-easterly toward the Olifants River (DACE, 2004).

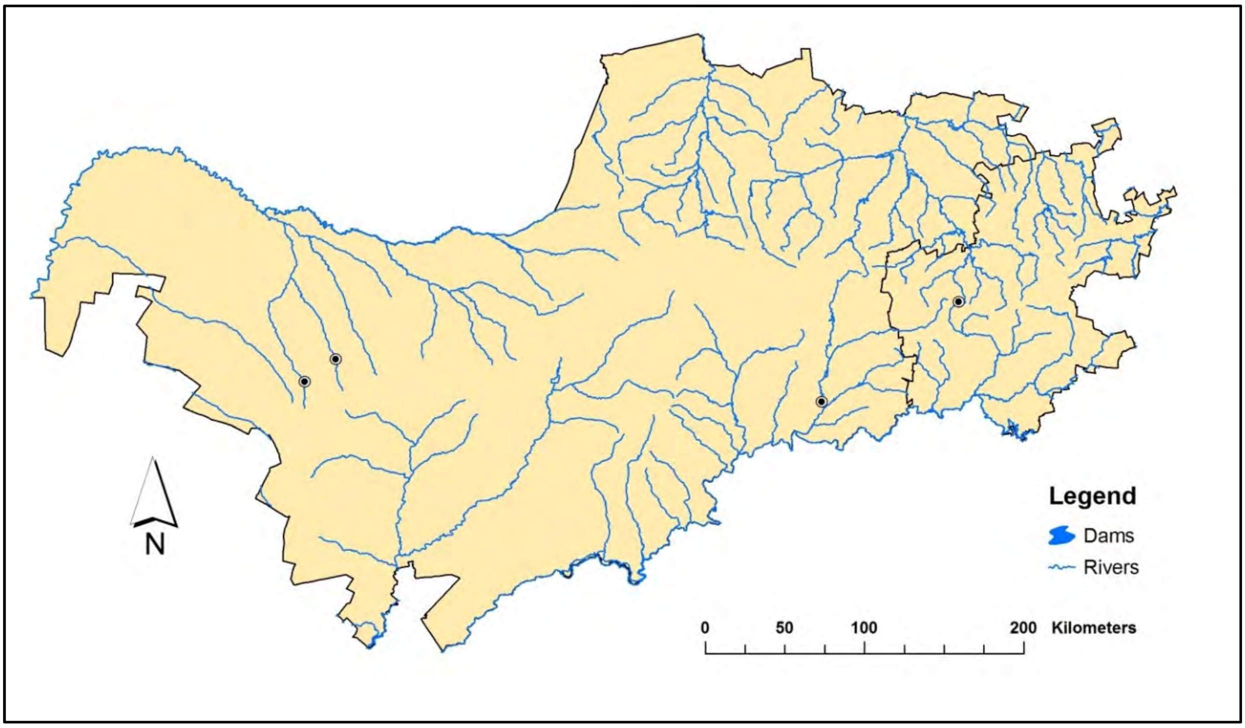

Figure 3.2: Map of the rivers and dams of the North West and Gauteng provinces (Map created by M.J du Toit of the NWU). The black dots on the map indicate the locations of the studied settlements.
*Shapefile of rivers obtained from SA Explorer Version 3.0, May 2004 (www.saexplorer.org.za).

3.5 Geology and soil

3.5.1 Geology

The North West province has a fascinating and ancient geological heritage, rich in paleontological artifacts and minerals (De Villiers and Mangold, 2002). The north-central and north-eastern regions of the province are mostly dominated by igneous rock formations, while the eastern, southern and western regions are dominated by ancient igneous volcanic rock formations that date back to the Ventersdorp age (over 2 000 million years) (De Villiers and Mangold, 2002). In the north-western corner of the province, the sedimentary rocks date back to the Quaternary period (65 million years) (De Villiers and Mangold, 2002).

Tlhakgameng and Ganyesa are characterised by the Archaean Granites (Figure 3.3), which are the oldest rock formations in the North West province and mostly form flat to slightly undulating landscapes (De Villiers and Mangold, 2002). Ikageng and Potchefstroom are characterised by chert and dolomite of the Malmani Subgroup (Transvaal Supergroup), quartzite ridges of the Pretoria Group and Witwatersrand Supergroup, Selons River Formation of the Rooiberg Group and tholeitic basalt of the Klipriviersberg Group (Randian Ventersdorp Supergroup) (Mucina and Rutherford, 2006).

Gauteng has a diverse and rich mineral deposit that is mainly responsible for South Africa's mining heritage (DACE, 2004). Between Pretoria and Johannesburg lies the oldest rock formation in Gauteng, the Johannesburg Granite Dome which formed in the Archaean period (3 500 – 2 500 million years ago) (DACE, 2004). The Johannesburg Granite Dome forms the foundation on which the younger sedimentary volcanic rocks of the Transvaal and Witwatersrand Supergroups are deposited (DACE, 2004).

The Transvaal Supergroup constitutes a large area of Gauteng and was formed during the Proterozoic era (2 500 – 570 million years ago) (DACE, 2004). It contains the gold-bearing "Black Reef" quartz-pebble conglomerate that has been mined on the East and West Rands since the late 19th century (DACE, 2004). According to Mucina and Rutherford (2006), Roodepoort is situated on various geological formations such as the Karoo, Transvaal, Ventersdorp and Witwatersrand Supergroups.

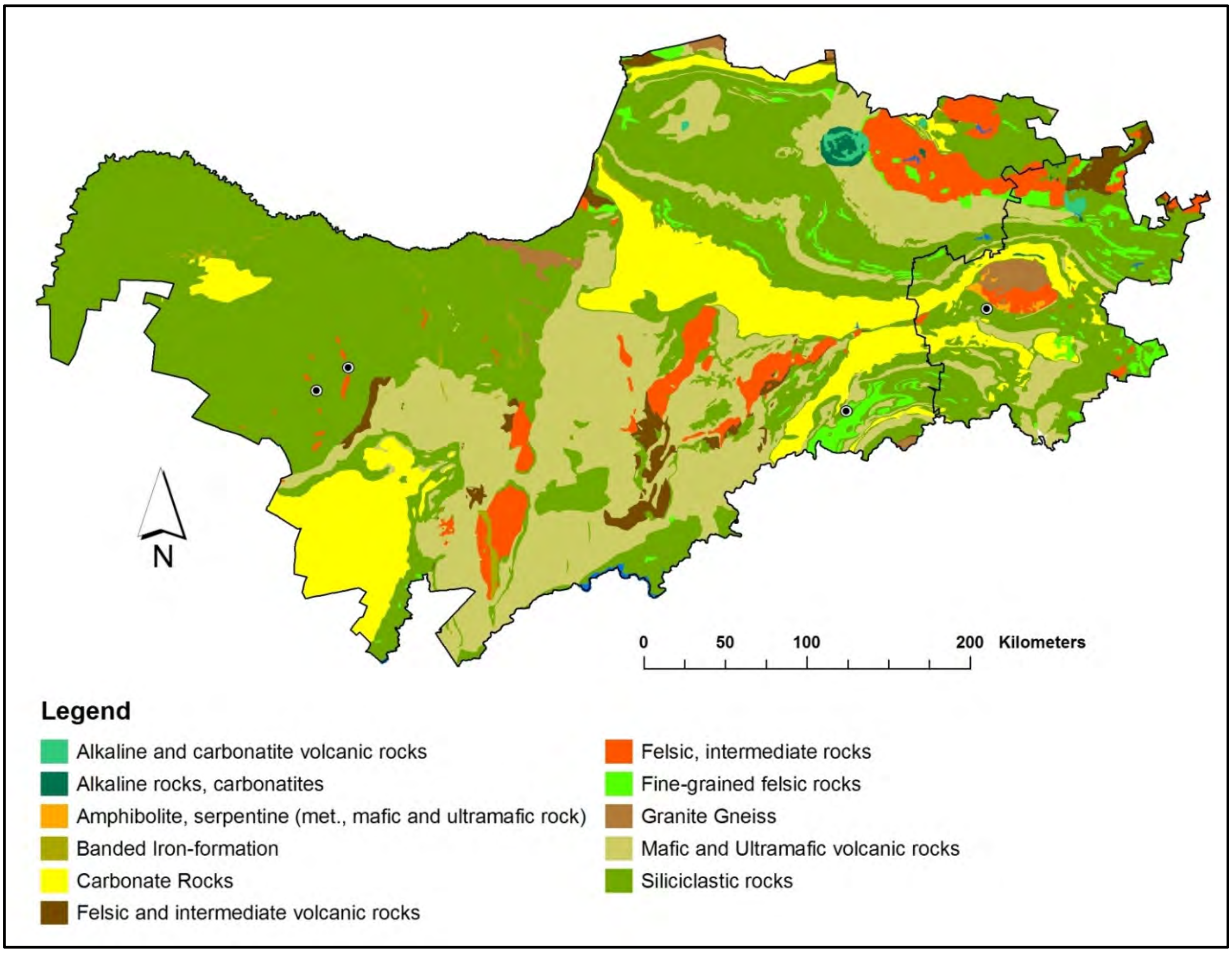

Figure 3.3: Map of the geology and rock types of the North West and Gauteng provinces (Map created by M.J du Toit of the NWU). The black dots on the map indicate the locations of the studied settlements.

*Shapefile of geology obtained from the Council for Geoscience (http://www.geoscience.org.za).

3.5.2 Soil

Due to the high evaporation rates experienced in the North West province, the moisture levels in the soil are low which often leads to high concentrations of salts such as calcium and silica (Figure 3.4) (De Villiers and Mangold, 2002). In the north-western regions, large areas of yellow shifting sands occur, while the south and eastern regions are characterised by yellowish-brown sandy loams (De Villiers and Mangold, 2002). The central region has areas covered by red or brown non-shifting sands with rock, as well as weakly developed lime soils associated with the dolomite limestone formations (De Villiers and Mangold, 2002). Undifferentiated rock and lithosols characterise the south-western region, while lithosols of arenaceous sediments characterise the north-eastern parts of the province (De Villiers and Mangold, 2002). Red and yellow arenosols dominate the drier western regions of the province, while the southwest has calcareous sands and loams, as well as arenaceous lithosols (De Villiers and Mangold, 2002).

Tlhakgameng and Ganyesa are characterised by Aeolian Kalahari sand of tertiary to recent age on flat, sandy plains at soil depths of 1.2 m or more (Mucina and Rutherford, 2006). The soils are Clovelly and Hutton soil forms and the land types are Ah, Ai, and Ae (Mucina and Rutherford, 2006). The soil of the Ikageng and Potchefstroom area is characterised as shallow, rocky, clayey soils of predominantly Mispah and Glenrosa soil forms, with the occasional occurrences of deeper red to yellow apedal soils (Hutton and Clovelly forms) (Mucina and Rutherford, 2006). The area consists of various land types such as Ab, Ba, Bb, Bc, Fa, Fb, and Ib (Mucina and Rutherford, 2006). “Land type is a class of land with specified characteristics and in South Africa, it has been used as a map unit denoting land, mappable at 1:250 000 scale, over which there is a marked uniformity of climate, terrain form and soil pattern” (Soil Classification Working Group, 2009).

Gauteng is characterised by deep, well drained, apedal soils of the Hutton form (DACE, 2004). The soils of the province are dominated by duplex, hydromorphic and plinthic soils, all three of which carry limitations for agricultural crop production (DACE, 2004). Approximately 23.1 % of the province is considered arable, while 25.3 % is deemed “marginally” arable and the remainder is considered suitable for grazing and wildlife (DACE, 2004). The soils of the Roodepoort area are characterised as shallow, coarsely grained, sandy soil and gravel lithosols of the Glenrosa and Mispah forms (Mucina and Rutherford, 2006). These soil types are considered nutrient-poor and the land types are predominantly Ba, Bb, Fb and Ib (Mucina and Rutherford, 2006). In certain areas, the soils are deep, reddish on flat plains and are typically Ba, Bb and Ea land types (Mucina and Rutherford, 2006).

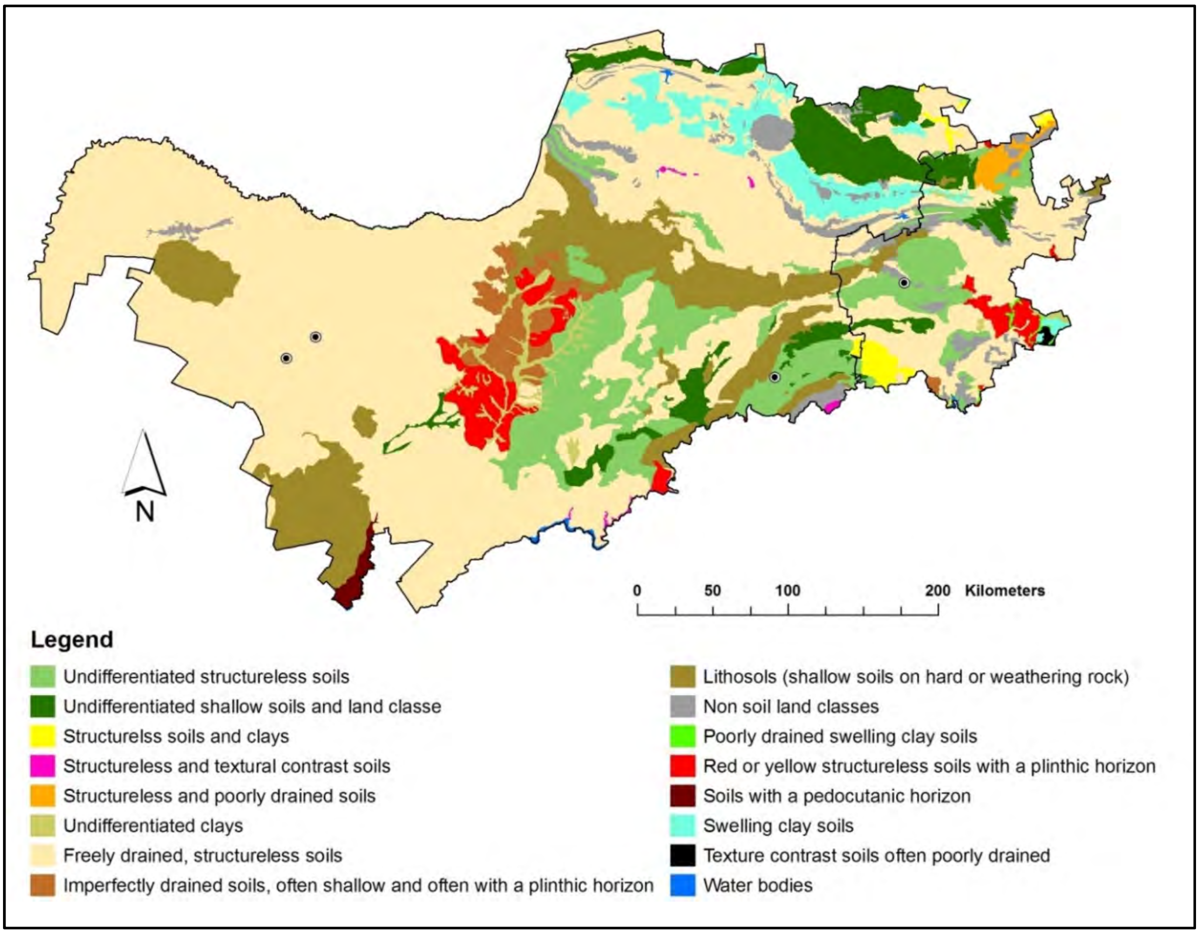

Figure 3.4: Map of the soil types of the North West and Gauteng provinces (Map created by M.J du Toit of the NWU). The black dots on the map indicate the locations of the studied settlements.
*Shapefile of soil classes obtained from AGIS (http://www.agis.agric.za).

3.6 Climate

3.6.1 Rainfall

The North West province is characterised by a mean annual rainfall of approximately 539 mm, with the highest rainfall during the summer months, October to April (NWDACE, 2008). The province is considered to be an arid region due to the low precipitation levels experienced during the winter months, an average of 3 mm falling in July (NWDACE, 2008). Thunderstorms are a frequent occurrence and are characterised by events such as heavy gusts of wind, lightning, hail and flash floods (NWDACE, 2008). All four of the North West settlements (Tlhakgameng, Ganyesa, Ikageng, and Potchefstroom) are characterised by summer rainfall (October to March), dry winters and frequent to infrequent occurrences of frost (Mucina and Rutherford, 2006). Figures 3.5 and 3.6 illustrate the mean monthly rainfall for Tlhakgameng, Ganyesa, Ikageng and Potchefstroom of the years before, during and after the plant surveys were completed.

Gauteng is characterised by a mild climate, with warm moist summers and cool dry winters (DACE, 2004). Rainfall occurs predominantly from October to March, with a mean annual precipitation of 668 mm, which varies from 556 mm in the lower lying northern and southern areas to 900 mm in the central higher lying parts of the province (DACE, 2004). Roodepoort is characterised by summer rainfall, dry winters and frequent occurrences of frost (Mucina and Rutherford, 2006). Figure 3.7 illustrates the mean monthly rainfall for Roodepoort of the years before, during and after the plant surveys were completed.

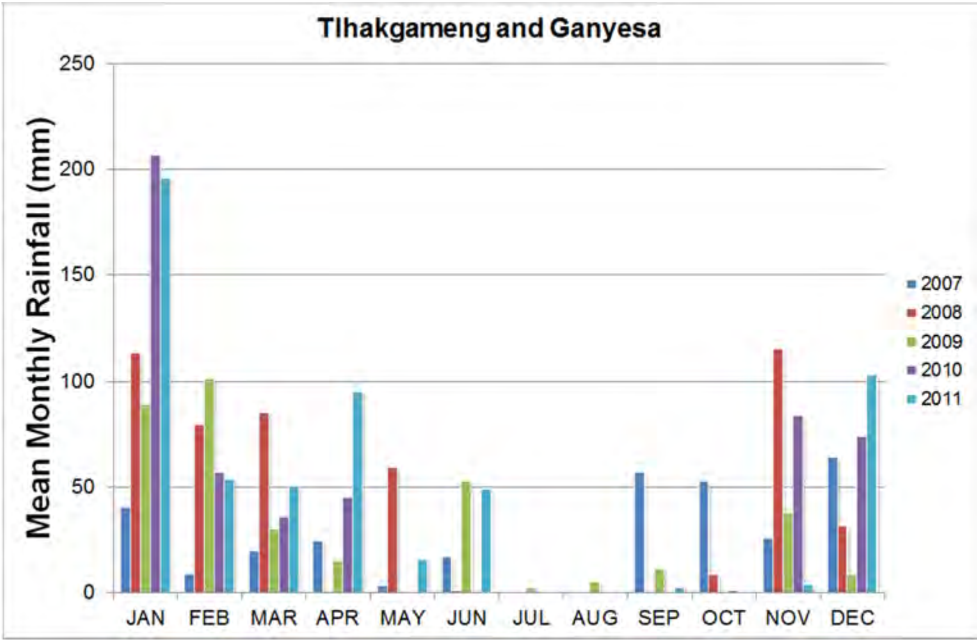

Figure 3.5: Mean monthly rainfall for Tlhakgameng and Ganyesa for the years before, during and after the plant surveys were completed (Data obtained from the South African Weather Bureau).

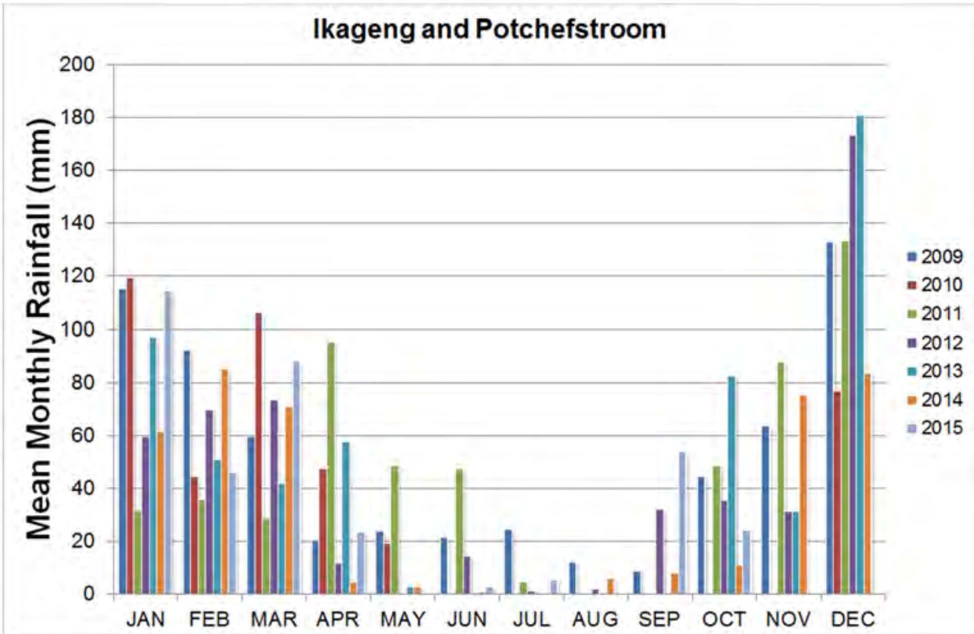

Figure 3.6: Mean monthly rainfall for Ikageng and Potchefstroom for the years before, during and after the plant surveys were completed (Data obtained from the South African Weather Bureau).

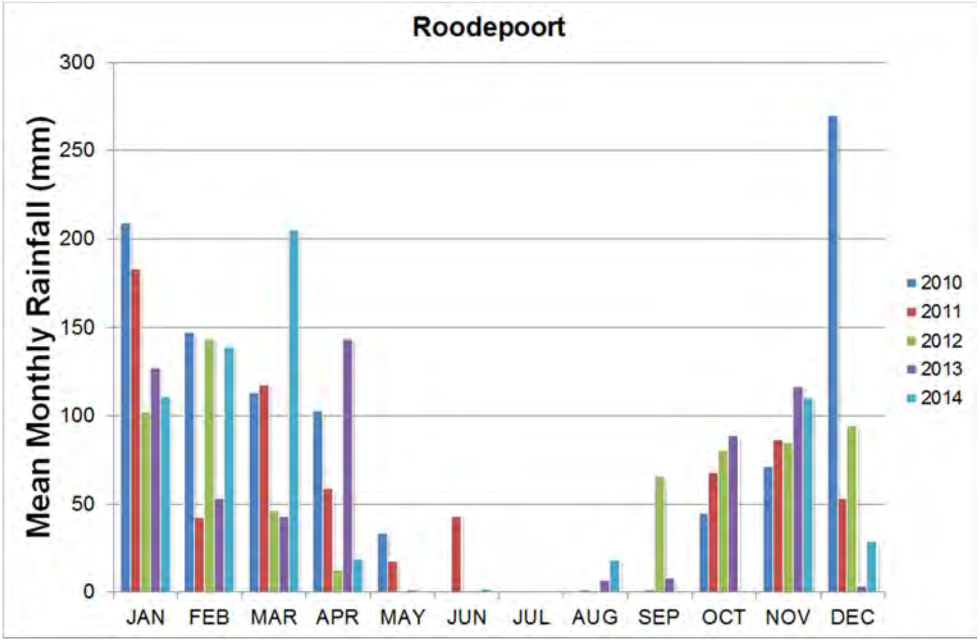

Figure 3.7: Mean monthly rainfall for Roodepoort for the years before, during and after the plant surveys were completed (Data obtained from the South African Weather Bureau).

3.6.2 Temperature

The North West province enjoys a continental climate characterised by pronounced seasonal and daily variations in temperature (NWDACE, 2008). Summers are hot with mean daily maximum temperatures ranging from 17 to 31°C and winters are cold with mean daily maximum temperatures ranging from 4 to 20°C (NWDACE, 2008). In Tlhakgameng and Ganyesa the mean monthly maximum and minimum temperatures range from 35.6°C to -1.8°C for November and June, respectively (Mucina and Rutherford, 2006). Frost is a frequent occurrence during the winter months (Mucina and Rutherford, 2006).

The mean annual temperature of Gauteng varies from approximately 16.0°C in the south to 19.3°C in the north of the province (DACE, 2004). However, the central and eastern parts of the province experience a lower mean annual temperature of about 15°C (DACE, 2004). The temperatures of the summer and winter months vary greatly and Gauteng experiences mean daily temperatures of 21.2°C in January and 9.8°C in July (DACE, 2004). Frost is a common occurrence and on average Gauteng can experience 30 days of frost per year (DACE, 2004). Roodepoort is characterised by high extremes between the maximum summer and minimum winter temperatures, with frequent occurrences of frost during the winter months (Mucina and Rutherford, 2006). Figure 3.8 illustrates the mean monthly maximum temperature and Figure 3.9 the mean monthly minimum temperature recorded for the last ten years by the South African Weather Bureau.

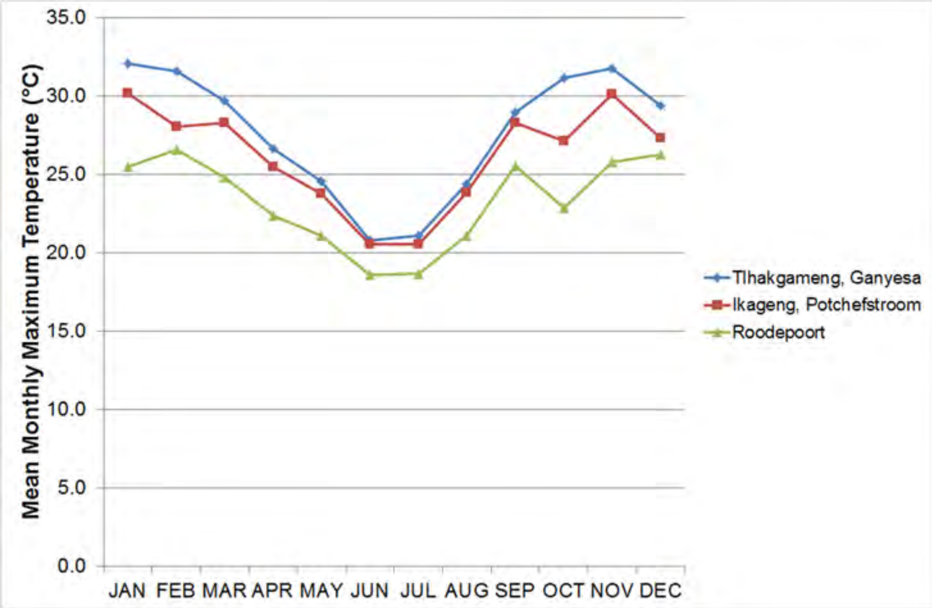

Figure 3.8: Mean monthly maximum temperature (°C) for the period 2005-2015 (Data obtained from the South African Weather Bureau). The data is given in terms of the three regions in which the five settlements are located.

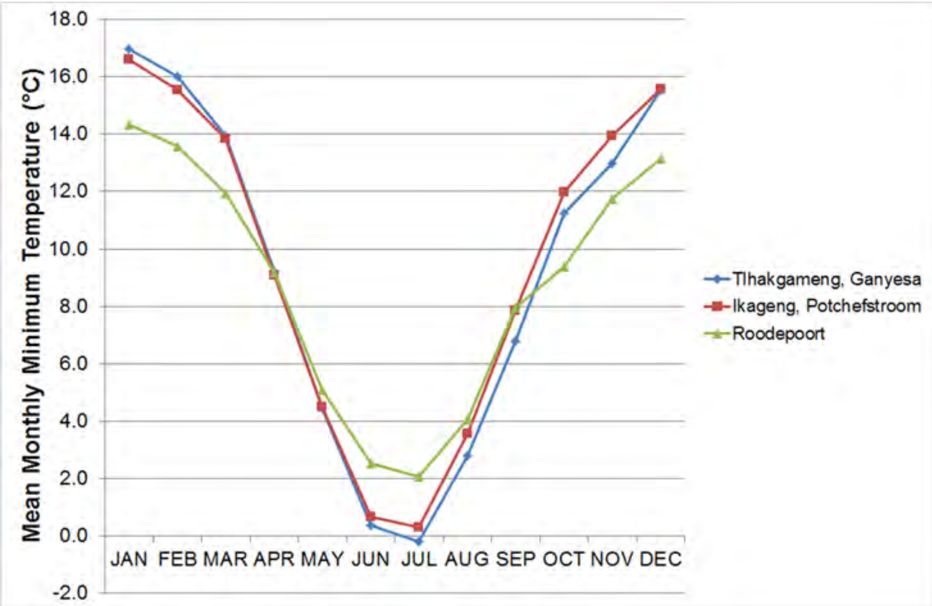

Figure 3.9: Mean monthly minimum temperature (°C) for the period 2005-2015 (Data obtained from the South African Weather Bureau). The data is given in terms of the three regions in which the five settlements are located.

3.7 Flora

South Africa has the richest temperate flora in the world, with 349 families, 2 267 genera and 19 581 indigenous species (Germishuizen *et al*., 2006). Approximately 10 % (2 057 taxa) and 10.4 % (2 153 taxa) of South Africa's total plant species are found in the North West and Gauteng provinces respectively (SANBI, 2014). In total 23 plant species in Gauteng are considered threatened according to the IUCN Red Data Category (Gauteng Department of

Agriculture and Rural Development, 2011) and 18 species in the North West province are considered threatened (SANBI, 2014). Nearly 1.2 % (20 species) of the species in the North West province are endemic and 1.2 % (25 species) in Gauteng (SANBI, 2014).

3.8 Vegetation

Two of South Africa's biomes fall within the North West and Gauteng provinces, namely the Grassland and Savanna biomes (DACE, 2004; NWDACE, 2008). The Savanna biome covers 71 % of the North West's total surface area and the Grassland biome 29 % (NWDACE, 2008). In contrast, the Grassland biome comprises 71 % of Gauteng's surface area and the Savanna 29 % (DACE, 2004).

Tlhakgameng and Ganyesa are within the Savanna biome, while Ikageng, Potchefstroom, and Roodepoort fall within both the Grassland and Savanna Biomes (Low and Rebelo, 1996; Mucina and Rutherford, 2006). Grasslands are simplistic in their structure and strongly dominated by grass species (Mucina and Rutherford, 2006), while Savannas are landscapes characterised by continuous grass layers and discontinuous tree layers (Low and Rebelo, 1996; Mucina and Rutherford, 2006; Scholes and Archer, 1997). According to Mucina and Rutherford (2006), the Savanna vegetation of South Africa and Swaziland constitutes the southernmost extension of the most widespread biome in Africa. This biome represents 32.5 % of South Africa, 74.2 % of Swaziland (Mucina and Rutherford, 2006) and is the dominant biome in Botswana, Namibia, Mozambique and Zimbabwe (Low and Rebelo, 1996).

The Grassland Biome represents 27.9 % of South Africa (Mucina and Rutherford, 2006) and is one of the most threatened biomes since only 25 % is formally conserved and 30 % is considered permanently transformed (23 % agriculture, 4 % plantation forestry, 2 % urbanisation and 1 % mining) (DACE, 2004; Mucina and Rutherford, 2006). The studied settlements all fall within different veld types (Acocks, 1988), vegetation types (Low and Rebelo, 1996) and vegetation units (Mucina and Rutherford, 2006).

3.8.1 Vegetation units

Mucina and Rutherford (2006) defined a vegetation unit as "a complex of plant communities ecologically and historically occupying habitat complexes at the landscape scale". Tlhakgameng and Ganyesa fall within the Mafikeng Bushveld vegetation unit, while Ikageng and Potchefstroom are situated at the confluence of the Andesite Mountain Bushveld, Carletonville Dolomite Grassland, and the Rand Highveld Grassland vegetation units (Figure 3.10) according to Mucina and Rutherford (2006). Roodepoort is situated at the confluence of the Egoli Granite

Grassland, Gold Reef Mountain Bushveld, and Soweto Highveld Grassland (Figure 3.10) vegetation units (Mucina and Rutherford, 2006).

3.8.1.1 Mafikeng Bushveld

The Mafikeng Bushveld vegetation unit is characterised by well-developed tree and shrub layers (Mucina and Rutherford, 2006). The tree layer is dominated by dense stands of *Terminalia sericea* and *Vachellia erioloba*, while the shrub layer consists of *Grewia flava*, *Senegalia mellifera*, *Vachellia hebeclada, Vachellia karroo* and several other species (Mucina and Rutherford, 2006). According to Mucina and Rutherford (2006), the grass layer is dominated by species such as *Aristida congesta*, *Cymbopogon pospischilii*, *Digitaria eriantha*, *Eragrostis lehmanniana* and *Eragrostis pallens*.

3.8.1.2 Carletonville Dolomite Grassland and Rand Highveld Grassland

The Carletonville Dolomite Grassland vegetation unit is characterised by slightly undulating plains that are intermittently interrupted by rocky chert ridges, while the Rand Highveld Grassland has a highly variable landscape ranging from undulating plains to series of ridges and sloping plains (Mucina and Rutherford, 2006). Both these vegetation units are characterised by a grass layer dominated by species such as *Elionurus muticus, Eragrostis curvula*, *Heteropogon contortus* and *Themeda triandra* (Mucina and Rutherford, 2006). The rocky hills and ridges of the Rand Highveld Grassland feature sparse woodlands which are dominated by species such as *Celtis africana, Protea caffra* and *Senegalia caffra* (Mucina and Rutherford, 2006).

3.8.1.3 Andesite Mountain Bushveld

The Andesite Mountain Bushveld vegetation unit is characterised by a dense thorny bushveld and a well-developed grass layer on hill slopes and valleys (Mucina and Rutherford, 2006). This vegetation unit is dominated by various species of small to medium-sized trees, such as *Celtis africana, Protea caffra*, *Senegalia caffra* and *Vachellia karroo* (Mucina and Rutherford, 2006). *Eragrostis curvula*, *Hyparrhenia hirta*, *Setaria sphacelata* and *Themeda triandra* are some of the dominant grass species present in the Andesite Mountain Bushveld vegetation unit (Mucina and Rutherford, 2006).

3.8.1.4 Gold Reef Mountain Bushveld

The Gold Reef Mountain Bushveld vegetation unit is characterised by rocky hills and ridges, often dominated by a continuous tree and shrub layers (Mucina and Rutherford, 2006). The tree layer consists of species such as *Celtis africana*, *Combretum molle*, *Protea caffra* and *Senegalia caffra*, while the shrub layer is dominated by species such as *Canthium gilfillanii*, *Ehretia rigida* and *Grewia occidentalis* (Mucina and Rutherford, 2006). The herbaceous layer of this vegetation unit consists predominantly of grass species such as *Loudetia simplex*, *Panicum natalense*, *Schizachyrium sanguineum* and *Trachypogon spicatus* (Mucina and Rutherford, 2006).

3.8.1.5 Egoli Granite Grassland

According to Mucina and Rutherford (2006), the Egoli Granite Grassland vegetation unit consists of moderately undulating plains and low hills. This vegetation unit is characterised by tall grasslands, which are dominated by *Hyparrhenia hirta*, and woody layers located on rock sheets or rocky outcrops (Mucina and Rutherford, 2006). These rocky habitats are dominated by scattered shrub groups, which consist of species such as *Anthospermum hispidulum*, *Gnidia capitata* and *Ziziphus zeyheriana*, and solitary small trees, such as *Vangueria infausta* (Mucina and Rutherford, 2006).

3.8.1.6 Soweto Highveld Grassland

The Soweto Highveld Grassland vegetation unit is a gentle to moderately undulating landscape, dominated by a medium to high, dense, tufted grassland, which is situated on the Highveld plateau (Mucina and Rutherford, 2006). According to Mucina and Rutherford (2006), this vegetation unit is almost entirely dominated by *Themeda triandra* and accompanied by several other grass species such as *Elionurus muticus*, *Eragrostis racemosa,* and *Heteropogon contortus*. This continuous grassland is only interrupted by scattered wetlands, narrow streams, and the occasional ridge or rocky outcrop (Mucina and Rutherford, 2006).

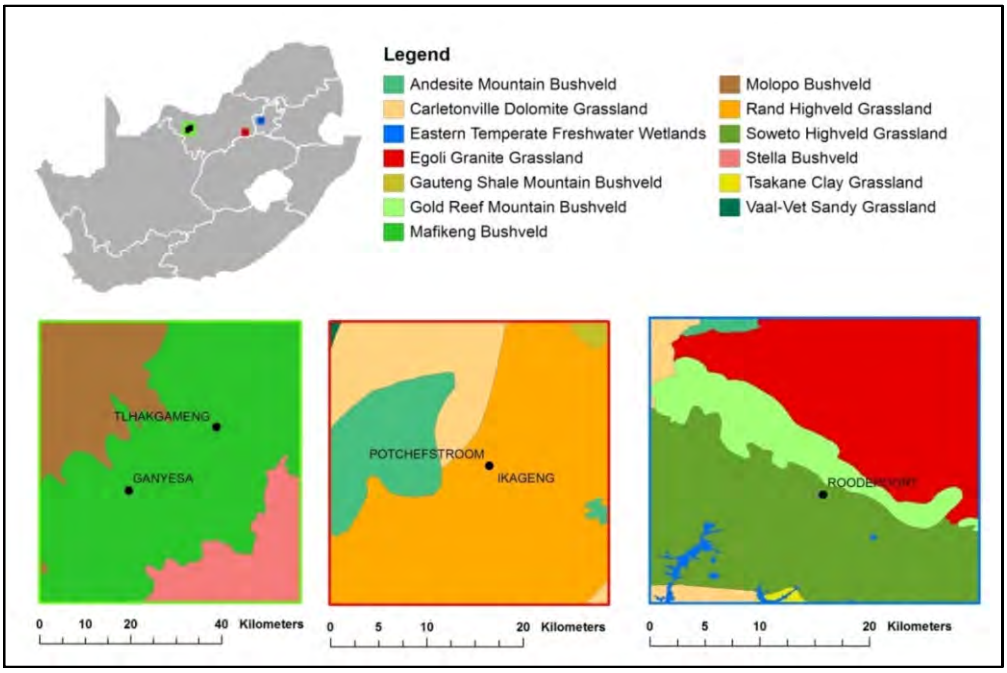

Figure 3.10: Map of the different vegetation units of each of the studied settlements as described by Mucina and Rutherford (2006).

3.9 Economy

The North West province accounts for 5.7 % of the South African gross domestic product (GDP), with agriculture, manufacturing, and mining as the major contributors (North West Department of Rural, Environment and Agricultural Development, 2014). The majority of the economic activity in the North West province is concentrated in the southern region between Klerksdorp and Potchefstroom, and especially around Rustenburg in the east, were more than 83.2 % of the GDP of the province is generated (North West Department of Rural, Environment and Agricultural Development, 2014). Mining contributed 33.6 % to the total provincial output in 2013, manufacturing 4.4 % and agriculture only contributed 2.1 % (North West Department of Rural, Environment and Agricultural Development, 2014).

Gauteng has a diverse economy that ranges from a thriving informal sector, which includes street vendors, to a high-tech manufacturing and industrial sector (DACE, 2004). In 2011, the economy of Gauteng was largely driven by the tertiary sector, which contributed 71 % to the economy of the province (Gauteng Provincial Government, 2012). The two sub-sectors of the tertiary sector that contributed the most were finance and business services (24.9 %) and the government, social and personal services (23.2 %) (Gauteng Provincial Government, 2012). The secondary sector was the second largest contributor, at 24.3 % and the dominant contributor within this sector was the manufacturing (16.3 %) sub-sector (Gauteng Provincial Government, 2012). The primary sector contributed only 4.7 % to the economy and the main contributor of this sector was the mining and quarrying (4.2 %) sub-sector (Gauteng Provincial Government, 2012).

3.10 Conservation

The North West province established two national parks (the Pilanesberg and Madikwe National Parks) and twelve provincial reserves in order to conserve plant and animal life within the province (NWDACE, 2008). However, due to the geographic spread and diversity of South Africa's plant and animal species, a traditional approach to conservation is inadequate and consequently 80 % of the biodiversity is still unprotected (NWDACE, 2008). Only 2.4 %, approximately 283 308 ha, of the North West province is formally protected, this includes protected natural environments, private nature reserves, provincial nature reserves and national parks (NWDACE, 2008).

Some of the most significant cross-provincial conservation areas are the Magaliesberg Protected Environment, the Cradle of Humankind and the Vredefort Dome (NWDACE, 2008). The Molopo Nature Reserve is the protected area nearest to Ganyesa (approximately 120 km) and Tlhakgameng (roughly 157 km), while the Boskop Dam Nature Reserve is located 20 km north-east of Potchefstroom and Ikageng (NWDACE, 2008) and the Highveld National Park (Daemane *et al*., 2010).

According to Pfab and Victor (2002) “at least 78 % of the threatened plant taxa of Gauteng occur within some sort of conservation area, ranging from fully protected provincial nature reserves to neglected municipal reserves and land under private ownership, the latter including heritage sites, private nature reserves and protected natural environments, all of which are afforded varying degrees of legislative protection”. In Gauteng, only 5 % (86 600 ha) of the province is formally protected (DACE, 2004). Conservancies, even though they are not formally protected, conserve approximately 10 859 ha (0.7 %) of Gauteng’s surface area (DACE, 2004).

The Gauteng Conservancy Association represents 34 different types of conservancies of variable size in the province (Gauteng Department of Agriculture and Rural Development, 2011). These include educational, informal settlement, rural and urban conservancies (Gauteng Department of Agriculture and Rural Development, 2011). Only 16 % of the biodiversity of the province is adequately protected, while more than 20% is not protected at all (DACE, 2004). In Roodepoort, there are a few protected areas, including the Kloofendal Nature Reserve, the Ruimsig Entomological Reserve and the Walter Sisulu Botanical Gardens (City of Johannesburg, 2003).

Chapter 4 - Comparison between the patterns of plant diversity of different land-uses in five settlements

4.1 Introduction

Cities are expanding rapidly worldwide and as a result, the future of ecosystems is dependent on the patterns of urban growth (Alberti, 2005). According to the United Nations (2015) the world population will reach 8.5 billion by 2030, an increase of roughly one billion people within the next 15 years. Most of the projected global population growth between now and 2050 is said to occur in Africa since Africa has the highest population growth rate, an estimated 2.6 % annually between 2010 and 2015 (United Nations, 2015). The United Nations (2014) reported that Africa and Asia are urbanizing faster than any other region in the world. In Africa, the number of large cities (5 – 10 million people) is estimated to increase from 3 to 12 and the number of megacities (> 10 million people) from 3 to 6 by 2030 (United Nations, 2014). According to Wu *et al*. (2003) “land-use and land-cover change is indicative of the power and will with which humans modify and conquer nature”.

Pauleit and Breuste (2011) stated that “land-use is not a state of being but rather the process whereby land is involved in human activity”. This process can be driven by either “top-down” or “bottom-up” human influences (Kinzig *et al*., 2005; Pauleit and Breuste, 2011). “Top-down” influences are those strategies and decisions made by municipal or city-level land management, while “bottom-up” influences are related to small-scale choices and actions, such as household or individual management decisions (Kinzig *et al*., 2005; Martin *et al*., 2004). As a result, urban and rural settlements (cities and towns) consist of a mosaic of different and fragmented land-use types (Pauleit and Breuste, 2011). These land-use types embody the different anthropogenic activities in a settlement (Pauleit and Breuste, 2011) and predominantly accommodate the basic needs of humans such as housing, education, commerce, manufacturing, and recreation (Pauleit and Breuste, 2011; Williams *et al*., 2009). However, urban settlements can also harbour fragmented natural areas, urban forests and agricultural land (Pauleit and Breuste, 2011).

According to Williams *et al*. (2009) urban floras must pass through four filters before they become a subset of the species pool. These four filters are habitat fragmentation, habitat transformation, urban environmental conditions and human preference. Human preference and urban environmental conditions are unique to cities, while habitat fragmentation and transformation are common in most ecosystems (Williams *et al*., 2009). Furthermore, the plant species diversity found in urban settlements is derived from three sources, namely species that are native to the area, species that are native to the region, but were absent from the area and as a result of urbanisation, colonised novel habitats, alien species that have been introduced to the area due to human influences, escaped into the natural areas surrounding urban environments and consequently established wild populations (Williams *et al*., 2009). Lubbe *et al*. (2010) recognised a fourth source of plant species diversity in urban settlements due to the large contribution it makes to the total urban flora, namely native and alien species that are cultivated and which cannot survive outside plantings in the urban environments. On a global scale, many ecologists consider climatic, historical and environmental influences to be the main factors affecting species diversity patterns (Colwell *et al*., 2004; Field *et al*., 2009; Zhang *et al*., 2014). In terms of urban settlements, species diversity isn't solely a result of the four filters identified by Williams *et al*. (2009), but also from their history. This is especially true in South Africa due to the country's rich and controversial history.

The history and origin of urban settlements in South Africa is well documented and very contentious (Du Toit, 2015). The arrival of Europeans in the Cape in 1652 was the first reason why large numbers of people were concentrated in an urban settlement in South Africa (Van der Merwe and Nel, 1981). The second reason was due to the mineral revolution of the 19th century, with the discovery of diamonds in 1861 and gold in 1886 (Feinstein, 2005; Holzner, 1970; Van der Merwe and Nel, 1981). Mining was one of the main incentives for urban growth in South Africa and as a result most of the urban development took place in the few mining centres at that time (Holzner, 1970). The effects of colonialism and the succeeding Apartheid era have had far reaching consequences on urban development and human geography in South Africa (Christopher, 1997; Christopher, 2001). After the 1994 elections, the political climate and consequently the settlement landscape changed drastically (Christopher, 2001). Driven by the realities of the past, South Africa has become a complex web of economic, political, social and environmental realities (Du Toit, 2015).

All issues considered, urban landscapes cannot be understood by focusing on individual patches but rather by focusing on the interaction between the patterns and processes within a landscape (Wu *et al*., 2003). Melo *et al*. (2009) stated that early ecologists differentiated between two components of biological diversity in a given area, namely the number of species identified at a single site or habitat (land-use type) and the change in species composition between different sites or habitats (land-use types). The question is to what extent does the species composition of different land-use types vary from one another in a South African context and especially in terms of their native and alien species richness, what are the implications for urban planning and to what extent can different land-use types contribute to biodiversity conservation?

Similar to the study of Thompson *et al*. (2003) which attempted to place garden floras in context with other urban floras in semi-natural and derelict urban land, the aim of this chapter was to compare the species diversity and composition of (1) domestic gardens and other land-use types (such as road verges, natural areas, fallow fields), (2) domestic gardens between settlements (Tlhakgameng, Ganyesa, Ikageng, Potchefstroom and Roodepoort), and (3) different land-use types within each of the settlements. Throughout the study the main focus was on domestic gardens and how they relate to other land-use types in terms of species diversity and composition.

4.2 Methods

4.2.1 Chapter layout

Figure 4.1 illustrates the composition and structure of the chapter.

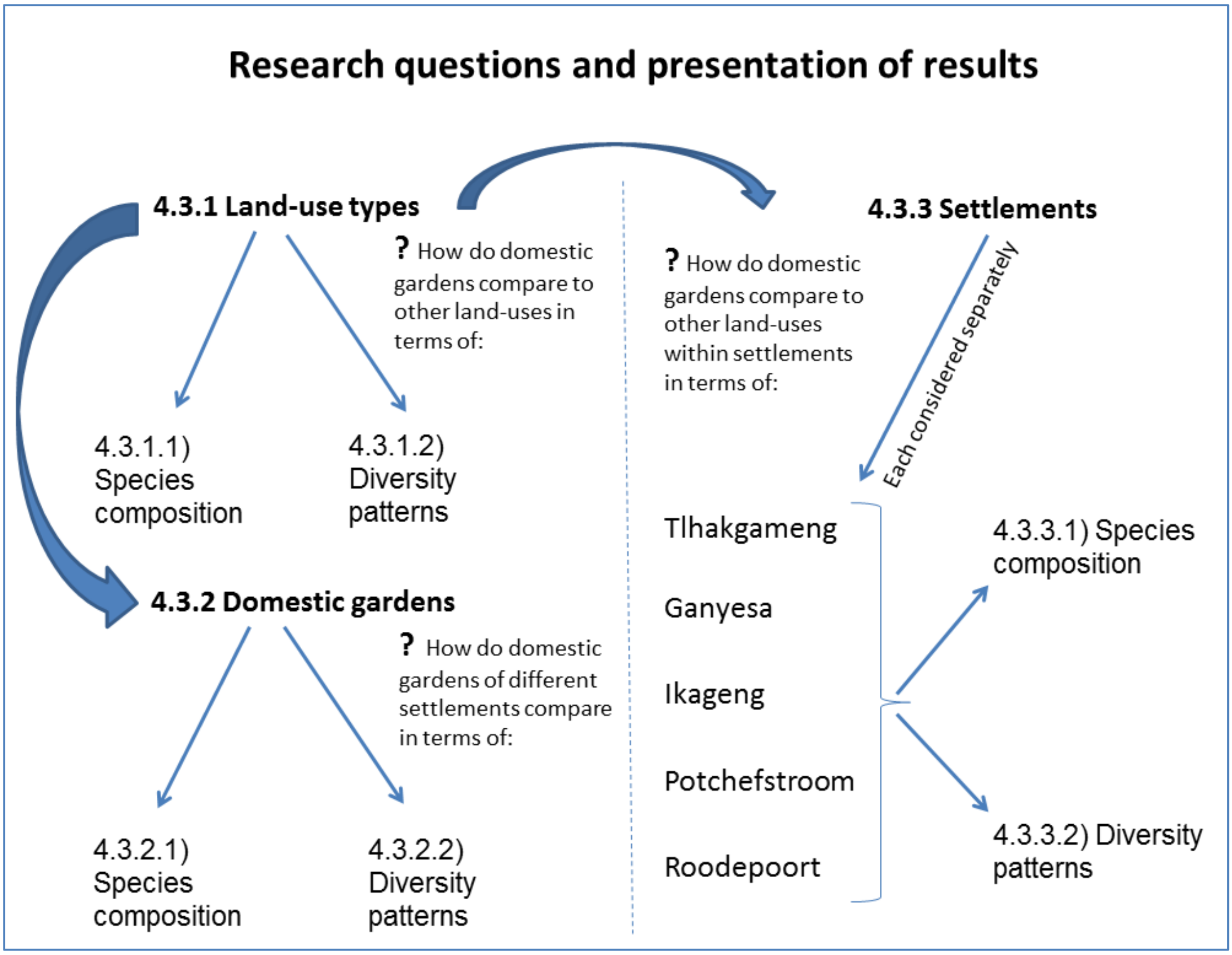

Figure 4.1: Layout of the composition and structure of the chapter

4.2.2 Vegetation sampling

The vegetation surveys for Tlhakgameng were done in 2009 (Molebatsi, 2011), Ganyesa in 2008 (Davoren, 2009), Ikageng and Potchefstroom (domestic gardens only) in 2009 (Lubbe, 2011) and completed in 2014 and 2015 (all other land-use types), while the surveys for Roodepoort were conducted in 2011 (domestic gardens only) and 2012 (all other land-use types), but since several sites had been burned in 2012, sampling was not completed until 2013.

Topographic maps of each of the five study sites were acquired and overlaid with grids of 500 m x 500 m squares in ArcView 9 (Environmental System Research Institute (ESRI), 2006). This approach provided approximately 95-150 potential sample sites per study area depending on the size of the settlement. Vegetation surveys were conducted at selected grid intersects (sample points) within the grid of each settlement, the coordinates were determined and the exact position of each point was located in the field with a Global Positioning System (GPS). Surveys were conducted as close as possible to the GPS coordinates of each grid point.

Before the survey was conducted at each sample point, the land-use type was identified and noted. Several land-use types were identified (Table 4.1 and 4.2) in each of the settlements. All the land-use types were not present in all the settlements and the number of sample points in each settlement and for each land-use type was unequal. Domestic gardens and natural areas were the only land-use types sampled in all the settlements. The data sets of all the land-use types for all five settlements were consolidated into one large dataset consisting of 598 sample sites. Sections 4.2.2.1 and 4.2.2.2 explains how the vegetation sampling was conducted for the different land-use types.

Table 4.1: The number of sample points within each of the different land-use types sampled across all five settlements (T: Tlhakgameng, G: Ganyesa, I: Ikageng, P: Potchefstroom, and R: Roodepoort).

Land-use type	**T**	**G**	**I**	**P**	**R**	**Total**
Domestic garden	51	55	51	49	50	**256**
Fallow field	16	10	-	10	-	**36**
Fragmented natural area	-	12	-	12	15	**39**
Institutional garden	-	6	-	11	-	**17**
Natural area	34	51	37	7	23	**152**
Road verge	-	3	-	16	14	**33**
Sidewalk	-	-	8	14	22	**44**
Wetland	17	4	-	-	-	**21**
Total	**118**	**141**	**96**	**119**	**124**	**598**

Table 4.2: Definitions for all the different land-use types sampled across all five settlements.

Land-use type	Definition
Domestic garden	A fenced yard of privately-owned or rented dwellings, which contained one or more of the following: ornamental plants, hedge, lawn, herb or medicinal garden, orchard and/or vegetable garden.
Fallow field	A piece of agricultural land that has been ploughed but not cultivated for one or more seasons.
Fragmented natural area	Natural areas that have become fragmented due to urbanisation (Alberti, 2008).
Institutional garden	A garden which has been cultivated on the grounds of an institution such as a church, school, university, college or business.
Natural area	"Ecosystems which persist primarily because of natural processes of plant establishment, water availability, nutrient cycling, and plant-animal interactions with minimal human manipulation" (McDonnell, 1988).
Road verge	A strip of land, consisting of grass and forbs, and sometimes trees, located between the boundary of a road and the curb (traffic islands included). Road verges fall under the control of the local municipality.
Sidewalk	A walkway along the side of a road for pedestrian usage. Consisting of a paved area or lawn and often planted with trees. Sidewalks fall under the control of the local municipality but in South Africa residents maintain the sidewalks in front of their homes.
Wetland	An area saturated with water. Wetlands include bogs, fens, salt marshes and shallow ponds (Lawrence, 2011).

4.2.2.1 Recording the vegetation of domestic gardens

The sampled domestic gardens differed in size and composition across all five settlements. All the gardens possessed both a front (located at the front of the dwelling/house) and back garden (located at the back of the dwelling/house). In some cases the front and back gardens were separated by a hedge, fence or wall. Before a garden was surveyed, the size and composition of the garden was assessed and transects were then placed in both the front and back garden. In cases where the back garden was larger than the front garden, three transects were placed in the back and two in the front garden, but in cases where the front garden was larger, three transects were placed and two in the back garden (Figure 4.2). After determining how many transects to place in the front and back garden, the placement of the transects were determined.

In each garden, different micro-gardens were identified (Molebatsi *et al*., 2010) and the transects were then placed in such a manner that the sampled data would be representative of the micro-gardens present in each garden. The following micro-gardens were identified (based on Molebatsi *et al*., 2010 and Davoren 2009), namely: lawn, medicinal or herb garden, orchard, ornamental (flower garden), vegetable patch, open space containing mostly native species (called 'naga' in the Batswana vernacular), managed areas devoid of plants ('lebala' concept – derived from the Batswana vernacular). In each garden, five transects of 20 m were placed to sample the plant species according to a 100 point frequency survey (20 x 5 = 100 points, a total area of 400 m²) (see section 4.2.2.2 for a detailed description of the frequency survey).

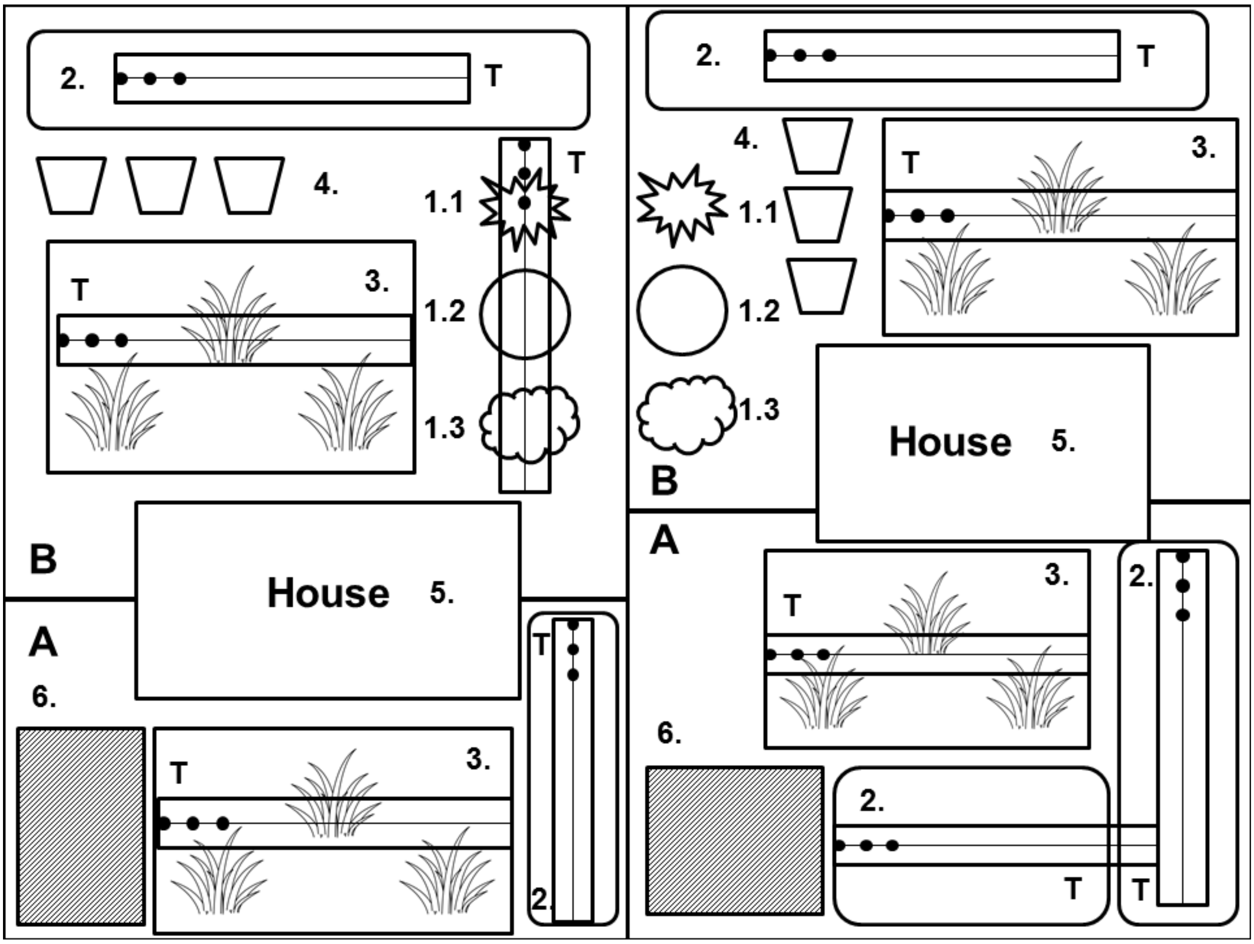

Figure 4.2: Fictional depiction of two domestic gardens to illustrate the layout of the gardens and the placement of transects for sampling within micro-gardens. Key to the map: A: Front garden; B: Back garden; T: Transect; 1.1: Medicinal or herb garden; 1.2: Orchard; 1.3: Vegetable garden; 2: Flower garden; 3: Lawn; 4: Container garden; 5: House; 6: Paving (Drawing not according to scale).

4.2.2.2 Recording the vegetation of all other land-use types

At each sample site, the plant species were sampled according to a 100 point frequency survey. Each of the sample plots was 20 x 20 m in size and five transects of 20 points each was placed inside the sample plot (20 x 5 = 100 points and a total area of 400 m², Figure 4.3). The first transect was placed 2 m from the edge of the sample plot and the rest were spaced 4 m apart. In some cases, the sample plot was too large for the sample site (road verges and sidewalks) and the transects were then placed in a manner that accommodated the sample site. In each transect, the nearest tree, shrub, grass, and forb (non-grassy) species was noted and identified at 1 m intervals along the tape measure. At each 1 m interval, individuals directly underneath or adjacent to the tape measure were recorded. If no individual was in the vicinity of the tape measure, the nearest individual within a block measuring 0.5 m forwards and backwards and 2 m left and right of the tape was recorded. However, if no individual was found in this block, the sampling point was recorded as bare ground. Species further than 2 m on either side of the tape measure were ignored. For trees to be recorded, the trunk of the tree had to be within the 2 m radius from the tape measure. No individuals were counted more than once.

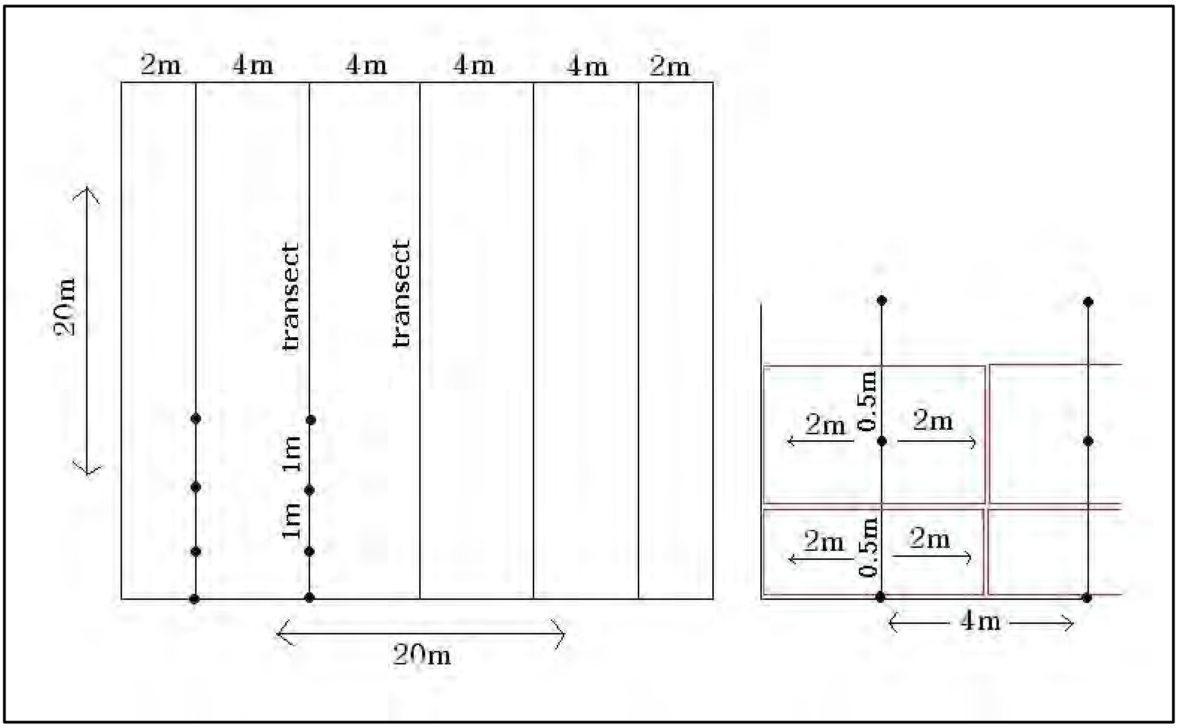

Figure 4.3: Design of a 20 X 20 m sample plot with an insert of the sampling method at 1 m point intervals along each of the transects.

4.2.3 Non-metric multi-dimensional scaling (NMS) ordinations

The floristic composition of each of the five settlements and the different land-use types within and between settlements were compared by using the non-metric multi-dimensional scaling (NMS) ordination method (Clarke, 1993). The ordinations were performed with the Primer v6 software and the Bray-Curtis similarity coefficient was used to analyse the similarity between sample sites (Clarke and Gorley, 2006). The sample sites were arranged in the ordination space according to the plant species composition of each plot. Sites that are grouped closely together in the ordination space are more similar, while sample sites that are grouped further apart are more dissimilar (Clarke and Gorley, 2006). The ordinations were performed using the frequency data recorded during the vegetation surveys for all five settlements.

According to Clarke (1993), the simplest indicator of the accuracy with which an NMS ordination perceives the relationship among samples is the stress value computed for every ordination.

Clarke and Warwick (2001) suggested the following rule of thumb for interpreting stress values in 2-dimensional ordinations; a stress value smaller than 0.05 (< 0.05) provides an excellent representation with no prospect of misinterpretation, a stress value smaller than 0.1 (< 0.1) corresponds to a good ordination, while a stress value smaller than 0.2 (< 0.2) can still provide a potentially useful ordination and stress values larger than 0.3 (> 0.3) indicate that the points are close to being randomly placed in the ordination space and have the potential to be misleading. However, according to Clarke and Warwick (2001), these guidelines are simplistic and stress tends to increase with reducing dimensionality and increasing numbers of samples.

The NMS ordinations generated were used to visually illustrate the beta (β) diversity of the studied areas. Beta diversity is defined as the rate at which species composition changes along an environmental or geographical gradient (Kent, 2012; Lawrence, 2011; Primack, 2002). Beta (β) diversity is calculated by subtracting alpha (α) diversity from gamma (γ) diversity (Zhang *et al*., 2014):

$$B = \gamma - \alpha$$

4.2.4 Diversity indices

Indices of diversity are fundamentally important to environmental conservation and monitoring since they aim to describe the general properties of communities which allow the comparison of different trophic levels, regions, and taxa (Morris *et al*., 2014). There are a plethora of methods for measuring diversity and most of them exploit some combination of just two features of the sample information, namely species richness and abundance (species evenness) (Magurran, 2004). Diversity measures fall into two categories: parametric indices and nonparametric indices (Magurran, 2004). Parametric indices are based on a parameter of a species abundance model, while nonparametric indices, such as the Simpson index, make no assumptions about the underlying distribution of species abundances (Magurran, 2004). Magurran (2004) further divides nonparametric measures into those that focus on dominance/evenness and those that emphasise species richness. The Primer v6 software (Clarke and Gorley, 2006) was used to calculate diversity indices for all sample sites which were grouped in terms of the different land-use types.

According to Magurran (2004), there are several simple species richness indices that attempt to compensate for sampling effects by dividing richness, the number of species recorded (S), by N, the total number of individuals in the sample. **Margalef's species richness index** (*d*) was used and calculated as follows:

$$\boldsymbol{d = \frac{(S-1)}{\mathrm{In} N}}$$

With S = number of species

N = sum of the total number of individuals of all recorded species

The Shannon-Wiener (or simply the Shannon) index makes the assumption that individuals are randomly sampled from an 'infinitely large' population and that all species are represented in the sample (Magurran, 2004; Kent, 2012). The **Shannon's index** (H') was calculated with the following formula:

$$H' = -\sum p_i \ln p_i$$

With p_i = the proportion of the i^{th} species in the sample

Even though Shannon's index includes the equitability of abundance of species in a sample, it is possible to calculate a separate measure of evenness with **Pielou's evenness** (J'). Evenness is an indicator of a system in climax, i.e. the best-adapted species dominant. Pielou's evenness expresses how evenly the individuals are distributed among the different species (Clarke and Warwick, 2001) and was used and calculated as follows:

$$J' = \frac{H'}{\ln(S)}$$

With H' = Shannon's index

S = number of species

The **Simpson's diversity index** (D) is used to determine the probability that any two individuals taken at random from an infinitely large community will belong to the same species (Kent, 2012) and is calculated with the following formula:

$$D = 1 - \sum (p_i \times p_i)$$

With p_i = the proportion of the i^{th} species in the sample

4.2.5 Statistical analyses

4.2.5.1 ANOSIM and SIMPER

An analysis of similarities (ANOSIM) was compiled to determine if there were any significant differences between the domestic gardens and the other land-use types and between the domestic gardens of the different settlements. ANOSIM is a procedure used for hypothesis testing that uses Bray–Curtis dissimilarities (Clarke and Warwick, 2001). ANOSIM uses a test statistic (R) based on the variance between the average of all the rank dissimilarities between and within groups (Quinn and Keough, 2002). R is scaled between +1 and –1 (Quinn and Keough, 2002). R values greater than 0, suggest that there are differences between the different test groups (Quinn and Keough, 2002). SIMPER analysis was done to determine which species contributed the most to the dissimilarity between groups. According to Quinn and Keough (2002) “SIMPER (similarity percentages) is just a list of species in order of their percentage contributions to dissimilarities between groups or similarities within groups”. The species that best discriminate between the different groups, are the species that contribute the most to the dissimilarity between sampling units (Quinn and Keough, 2002). The ANOSIM and SIMPER analyses were completed with the Primer v6 software (Clarke and Gorley, 2006).

4.2.5.2 One-way analysis of variance (ANOVA)

The software package STATISTICA 13.0 (Statsoft, 2009) was used to perform one-way analysis of variance (ANOVA) to determine if there were significant differences between the different land-use types within each of the settlements and between all the land-use types across all the studied settlements in terms of the values of the diversity indices. The purpose of an ANOVA is to determine if there are significant differences between the means of two or more groups (Urdan, 2010). The Levene test was performed to test for homogeneity of variances, i.e. group variances were unequal. Whereas the results of an one-way ANOVA informs on the likelihood of significant differences between two or more groups, post hoc testing is required to determine which groups differ from each other (Tabachnick and Fidell, 2007). Tukey’s HSD test for unequal sample size and the Welch test were performed as post-hoc tests. The Welch test is a more robust parametric test and does not assume homogeneity of variances (Quinn and Keough, 2002).

4.2.6 Inverse distance weighting (IDW)

By making use of spatial interpolation techniques it is possible to estimate and predict the values of a variable at unsampled locations in order to generate a continuous map of an area (Fortin and Dale, 2005). There are several techniques available to model spatial patterns in a given area, such as proximity polygons, trend surface analysis, inverse distance weighting and kriging (Fortin and Dale, 2005). One advantage that inverse distance weighting (IDW) has over other spatial interpolation techniques is that the complexity of local spatial patterns is preserved by the selective weighting of sample points (Fortin and Dale, 2005). According to Fortin and Dale (2005), IDW is easy to use, does not require prior knowledge about the data and can provide a map of the study area for illustrative purposes. However, IDW does not provide an accurate representation of the un-sampled locations, it merely illustrates the general patterns (Fortin and Dale, 2005). To determine the patterns of plant diversity for each of the five settlements maps were generated with IDW in ArcMap, ArcView 9.2 (Environmental System

Research Institute (ESRI), 2006). The IDW patterns of each of the five settlements were projected on street maps of each of the settlements. The IDW maps were used to visually illustrate the alpha (α) diversity for each of the studied settlements. According to Kent (2012), "alpha diversity refers to the number of species within the sample area or community".

4.3 Results

4.3.1 Species diversity and composition of domestic gardens and other land-uses

4.3.1.1 Species composition

A total of 1424 species were recorded in 598 sample sites (See Annexure A for a complete list of species). Domestic gardens had the highest gamma diversity and institutional gardens had the lowest of all the land-use types sampled across all the settlements (Figure 4.4). All the land-use types had more indigenous species than alien species. In terms of percentage contribution, the natural areas had the highest percentage indigenous species, while domestic gardens had the lowest (Table 4.3).

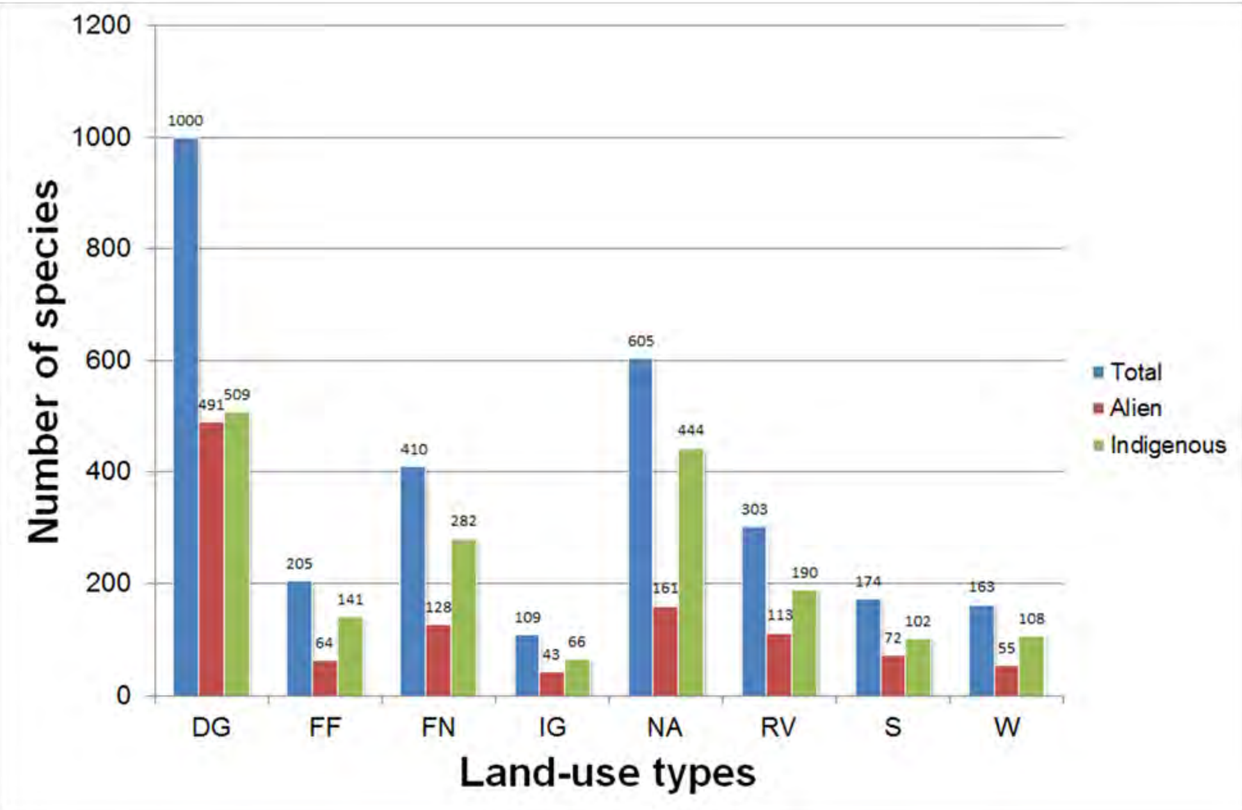

Figure 4.4: The total (gamma (γ) diversity), indigenous and alien number of species for each of the land-use types (domestic garden (DG), fallow field (FF), fragmented natural area (FN), institutional garden (IG), natural area (NA), road verge (RV), sidewalk (S) and wetland (W)) sampled across all the settlements.

Table 4.3: The percentage indigenous and alien species in each of the land-use types.

Land-use type	% Indigenous	% Alien
Domestic garden	51	49
Fallow field	69	31
Fragmented natural area	69	31
Institutional garden	61	39
Natural area	73	27
Road verge	63	37
Sidewalk	59	41
Wetland	66	34

The beta diversity values (β) were determined for each of the land-use types (Figure 4.5). The beta diversity value of the domestic gardens (26.8) was more than double that of the natural areas (13.1), while the wetlands had the lowest beta diversity (4.4).

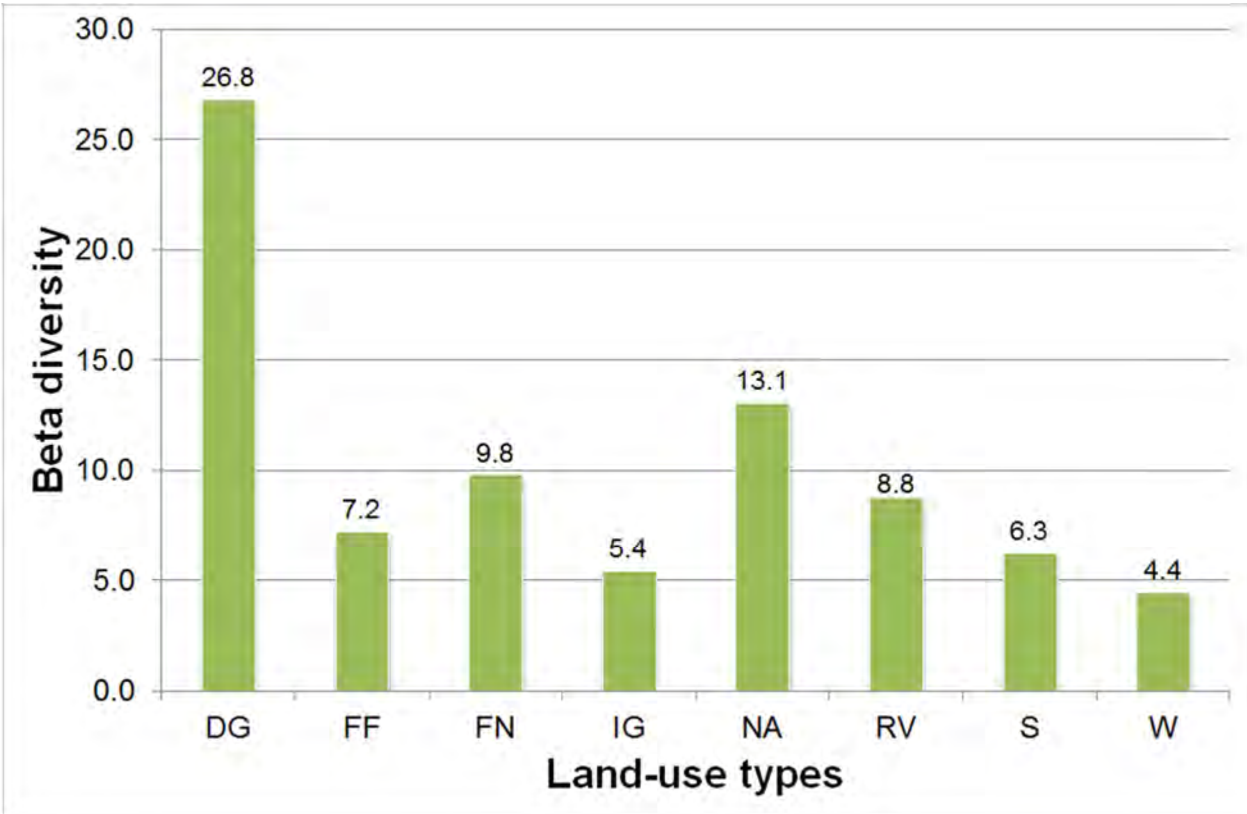

Figure 4.5: Beta diversity for each of the land-use types (domestic garden (DG), fallow field (FF), fragmented natural area (FN), institutional garden (IG), natural area (NA), road verge (RV), sidewalk (S) and wetland (W)) sampled across all the settlements, as determined with Whittaker's measure.

A NMS ordination based on the species composition of all the land-use types sampled across all the settlements (Tlhakgameng, Ganyesa, Ikageng, Potchefstroom, and Roodepoort), revealed three main groupings (Figure 4.6), the domestic gardens, natural areas and wetlands. The remaining land-use types were scattered between these three groupings. The lower parts of the domestic garden and natural area groupings are spaced very close together. In terms of the domestic gardens, these are the sites located in Tlhakgameng and Ganyesa, which had more indigenous species than the domestic gardens sampled in Potchefstroom and Roodepoort. The only wetlands that were sampled in this study, were located in Tlhakgameng and Ganyesa. The species composition of all the wetlands were very similar, since they were all located within the same vegetation unit and therefore grouped together on the ordination. The stress value of the ordination was 0.17, which indicated satisfactory groupings.

The ANOSIM showed similar results, indicating that there is less similarity between the domestic gardens and the natural areas, than between the domestic gardens and the other land-use types (Table 4.4). The Simper analysis showed that *Pennisetum clandestinum*, *Cynodon dactylon*, *Schmidtia pappophoroides*, *Themeda triandra*, *Dichondra micrantha* and *Felicia muricata* were some of the species that contributed the most to the dissimilarity between the natural areas and the domestic gardens (See Annexure B, Table B.1 for the result of the SIMPER). *Pennisetum clandestinum* and *Cynodon dactylon* were the dominant grass species in the domestic gardens, while *Schmidtia pappophoroides* and *Themeda triandra* were the dominant grass species in the natural areas. *Dichondra micrantha* was the dominant forb species in the domestic gardens and *Felicia muricata* was the dominant forb species in the natural areas.

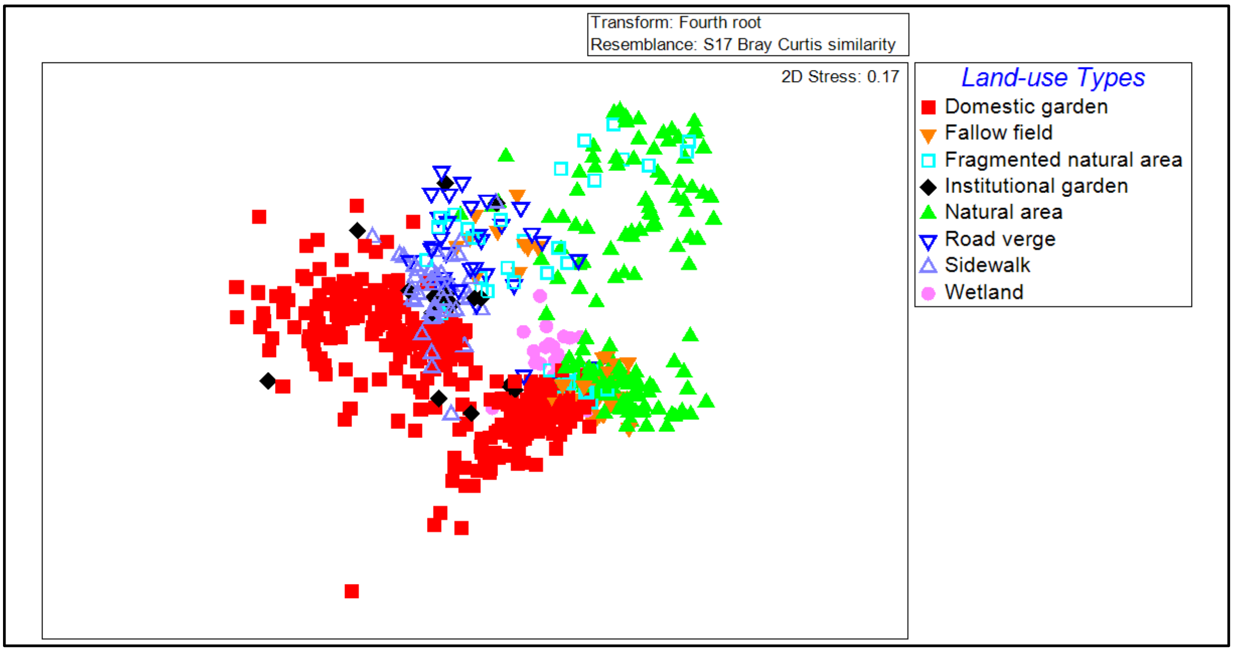

Figure 4.6: NMS ordination of the total species composition based on the sample plot data of all the land-use types sampled across all the studied settlements (Tlhakgameng, Ganyesa, Ikageng, Potchefstroom, and Roodepoort).

Table 4.4: Results of ANOSIM and SIMPER analyses for the different land-use types compared to the domestic gardens (DG) (See Annexure B for SIMPER results). Marked differences (bold) are significant at $p < 0.05$. Medium effect (bold) marked at $R \geq 0.5$.

		p-Value	R value	SIMPER overall average dissimilarity
	Fallow field	0.001	0.338	91.25
	Fragmented natural area	0.001	0.326	90.63
	Institutional garden	0.12	0.056	85.46
DG	Natural area	0.001	0.543	95.54
	Road verge	0.001	0.233	88.88
	Sidewalk	0.995	-0.08	80.09
	Wetland	0.001	0.218	89.94

4.3.1.2 Species diversity

The values of Margalef's species richness index revealed clear variations between the different land-use types, ranging from 3.01 to 7.71. The natural areas had the highest Margalef's species richness values of all the land-use types, while the institutional gardens had the lowest (Figure 4.7). The domestic gardens had the second highest and the fragmented natural areas the third highest species richness.

Land-use types differed significantly from one another based on the value of Margalef's species richness index. The results of the ANOVA were given as a p-value, which is significant if $p < 0.05$. The p-value for Margalef's species richness index was much smaller than 0.05 (Table 4.5). This result was further substantiated by the results of the Welch test which also had a p-value smaller than 0.05 (Table 4.5). Tukey's HSD test for unequal sample size was used to determine which land-use types were significantly different from one another and the results of these tests indicated that the domestic gardens differed significantly from the fallow fields, institutional gardens and sidewalks (Figure 4.7 and Annexure C, Table C.1).

Table 4.5: One-way ANOVA results between the four diversity indices (Margalef's species richness (d), Pielou's evenness (J'), Shannon's diversity index (H') and Simpson's diversity index (D)) and all the studied land-use types (LUT) (domestic gardens (DG), fallow fields (FF), fragmented natural areas (FN), institutional gardens (IG), natural areas (NA), road verges (RV), sidewalks (S) and wetlands (W)). Marked differences (bold) are significant at $p < 0.05$.

	Means								**MSE**	**p-value**	**Welch p-value**
	DG	FF	FN	IG	NA	RV	S	W			
d	7.143	4.426	6.911	3.007	7.706	5.589	4.356	5.243	**6.989**	**<0.0001**	**0.000**
J'	0.791	0.723	0.772	0.638	0.812	0.727	0.716	0.745	**0.005**	**<0.0001**	**0.000**
H'	2.774	2.296	2.789	1.778	3.032	2.475	2.239	2.505	**0.235**	**<0.0001**	**0.000**
D	0.881	0.841	0.890	0.726	0.921	0.852	0.828	0.868	**0.005**	**<0.0001**	**0.000**

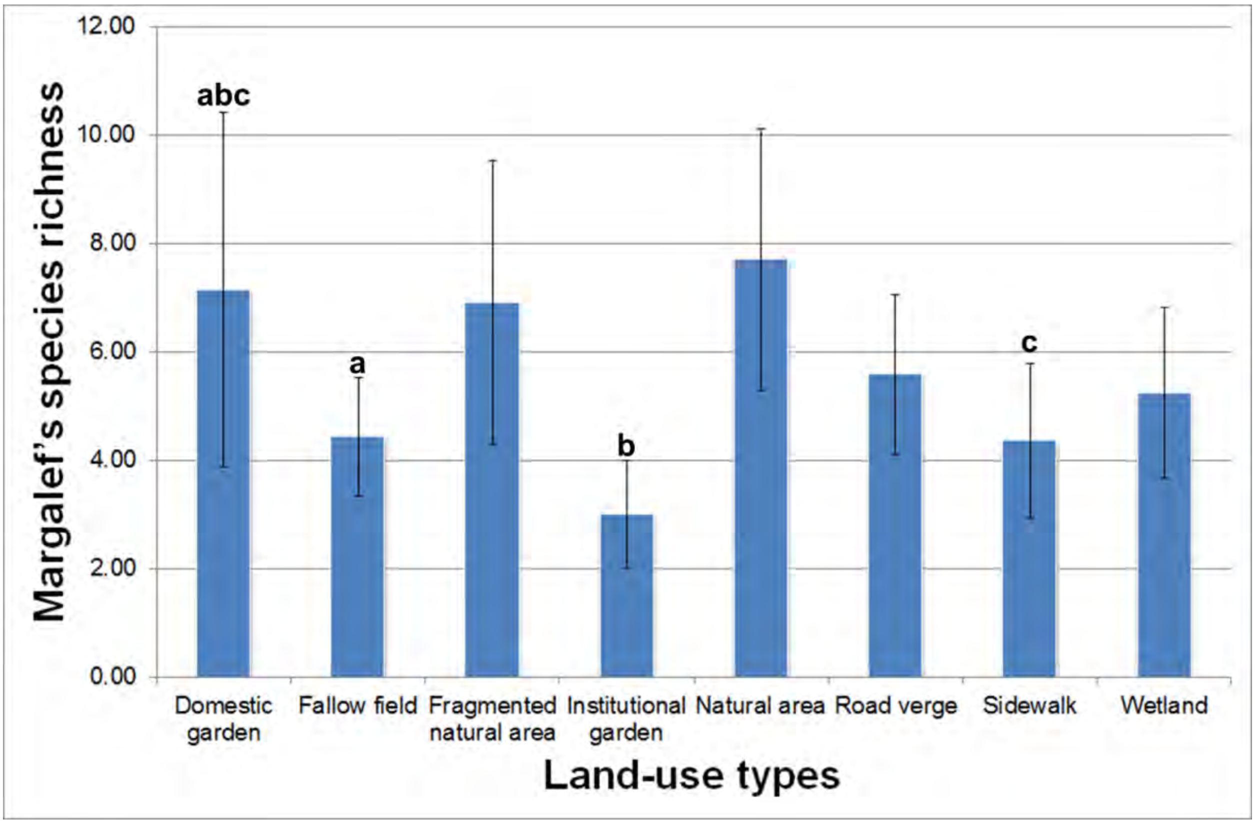

Figure 4.7: Mean values of Margalef's species richness index and standard deviation calculated for all the different land-use types sampled across all five settlements (the letters above the bars indicate which land-uses were significantly different from the domestic gardens based on Tukey's (HSD) post-hoc test. See Annexure C for the rest of the results).

Pielou's evenness index indicated that the natural areas had the highest evenness of all the land-use types, while the institutional gardens had the lowest evenness (Figure 4.8). The institutional gardens had an evenness value of 0.64, indicating a low abundance of species that were unevenly distributed among the sampled sites. In contrast, the natural areas had an evenness value of 0.81, which indicates a high abundance of species and an even distribution of individuals among the sampled sites. The domestic gardens had the second highest and the fragmented natural areas had the third highest evenness value of all the sampled land-use types. The fallow fields, road verges, and sidewalks all had low evenness values (0.72, 0.73 and 0.72 respectively). Along with the institutional gardens, these were the most disturbed land-use types.

A one-way ANOVA was performed to determine if the land-use types differed from one another based on the value of Pielou's evenness index (Table 4.5). The p-value of both the ANOVA and Welch test were much smaller than 0.05, which indicates that the results were statistically significant. Tukey's HSD test for unequal sample size was used to determine which land-use types were significantly different from one another and the results of these tests indicated that domestic gardens differed significantly from the fallow fields, institutional gardens, road verges and sidewalks (Figure 4.8 and Annexure C, Table C.2).

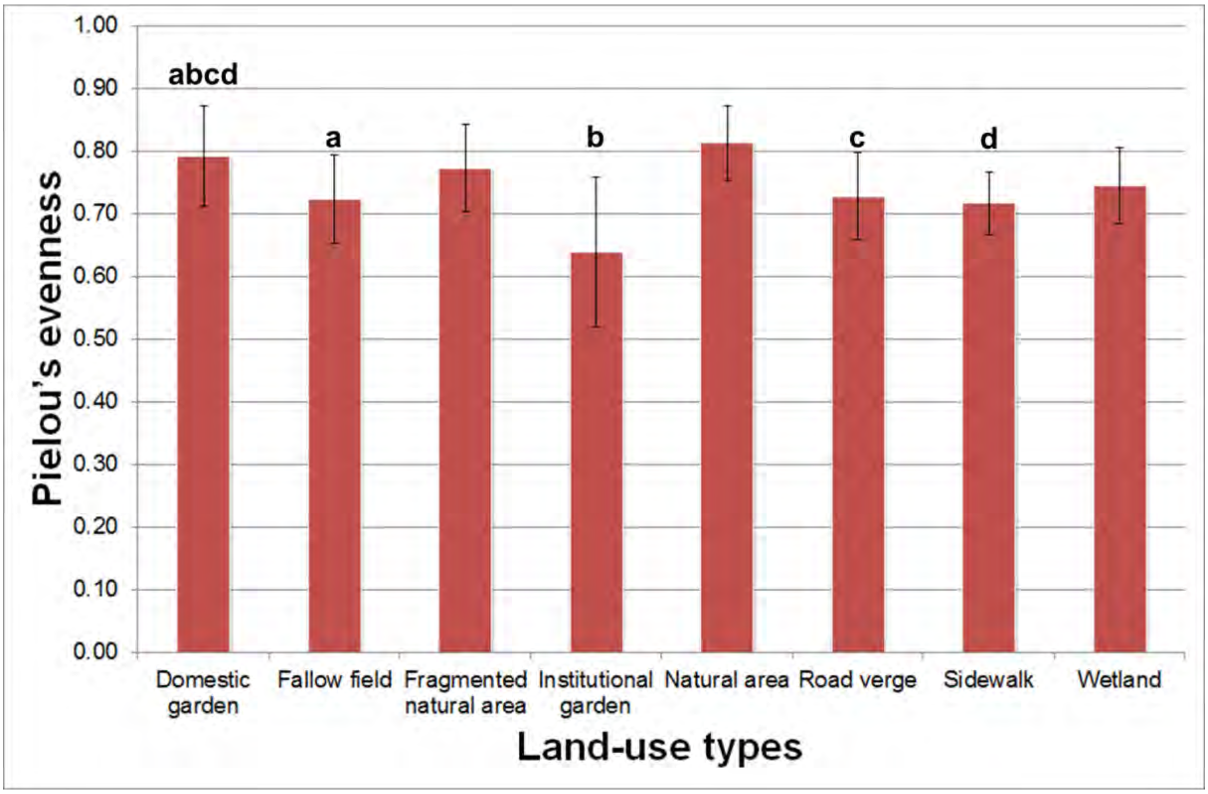

Figure 4.8: Mean values of Pielou's evenness index and standard deviation calculated for all the different land-use types sampled across all five settlements (the letters above the bars indicate which land-uses were significantly different from the domestic gardens based on Tukey's (HSD) post-hoc test. See Annexure C for the rest of the results).

The values of Shannon's index revealed ample variations between the different land-use types, ranging from 1.78 to 3.03. The results indicated that the natural areas had the highest Shannon index values of all the land-use types, while the institutional gardens had the lowest (Figure 4.9). The fragmented natural areas had the second highest and domestic gardens the third highest Shannon index values of all the sampled land-use types. Aside from having a greater number of species than all the other land-use types, the individuals in the community were distributed more evenly in the natural areas.

A one-way ANOVA was performed to determine if the land-use types differed from one another based on the values of Shannon's diversity index (Table 4.5). The p-value of both the ANOVA and Welch test were much smaller than 0.05, which indicates that the results were statistically significant. The results of a post hoc Tukey test indicated that the domestic gardens differed significantly from the fallow fields, institutional gardens, natural areas and sidewalks (Figure 4.9 and Annexure C, Table C.3).

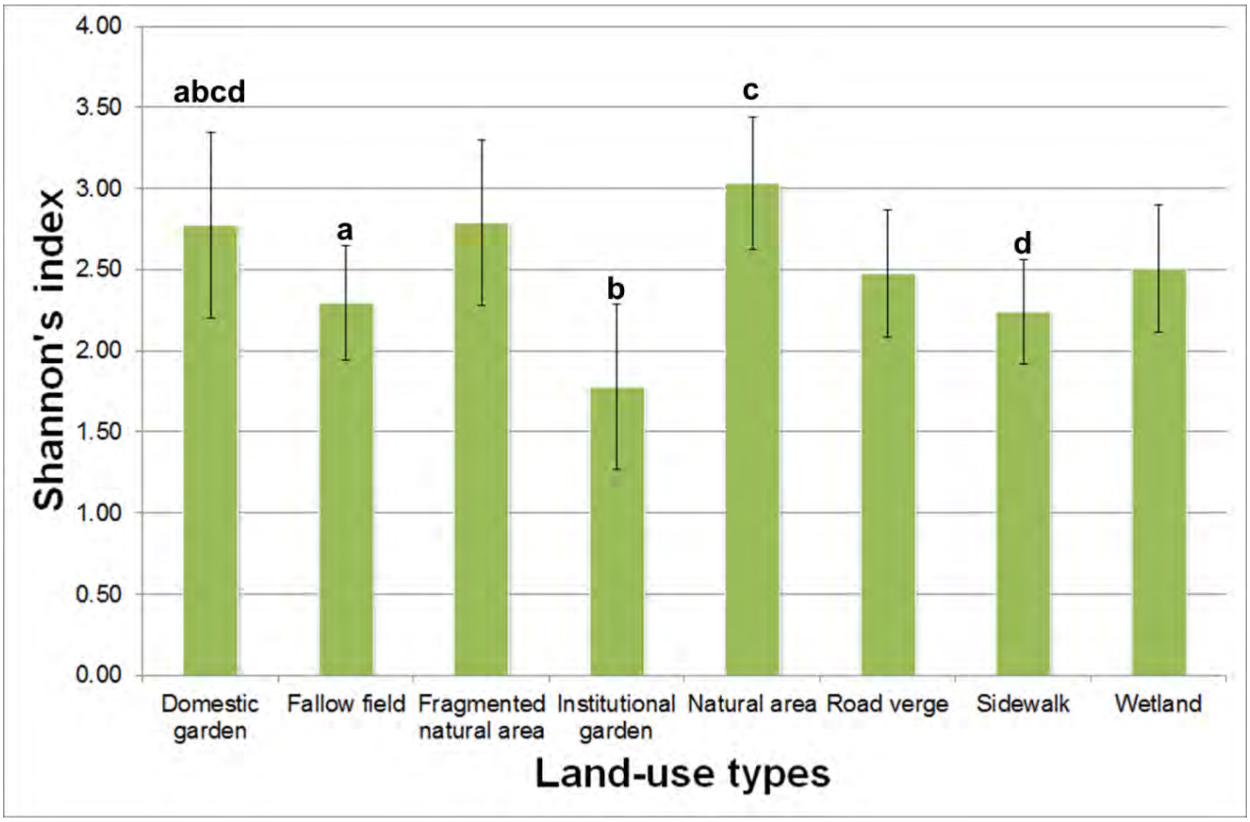

Figure 4.9: Mean values of Shannon's index and standard deviation calculated for all the different land-use types sampled across all five settlements (the letters above the bars indicate which land-uses were significantly different from the domestic gardens based on Tukey's (HSD) post-hoc test. See Annexure C for the rest of the results).

The values of the Simpson's diversity index revealed significant differences between the different land-use types, ranging from 0.73 to 0.92. Based on the results of Simpson's index, the natural areas had the highest species diversity of all the land-use types, while the institutional gardens had the lowest (Figure 4.10). The fragmented natural areas had the second highest and domestic gardens the third highest species diversity value of all the sampled land-use types. The value of Simpson's index ranges between 0 and 1, the greater the value, the greater the sample diversity. The values of Simpson's index for all the land-use types were high, which indicate high heterogeneity.

A one-way ANOVA was performed to determine if the land-use types differed from one another based on the value of Simpson's index (Table 4.5). The results were statistically significant since the p-value of both the ANOVA and Welch test were much smaller than 0.05. Tukey's HSD test for unequal sample size was used to determine which land-use types were significantly different from one another and the results of these tests indicated that domestic gardens differed significantly from the institutional gardens, natural areas and sidewalks (Figure 4.10 and Annexure C, Table C.4).

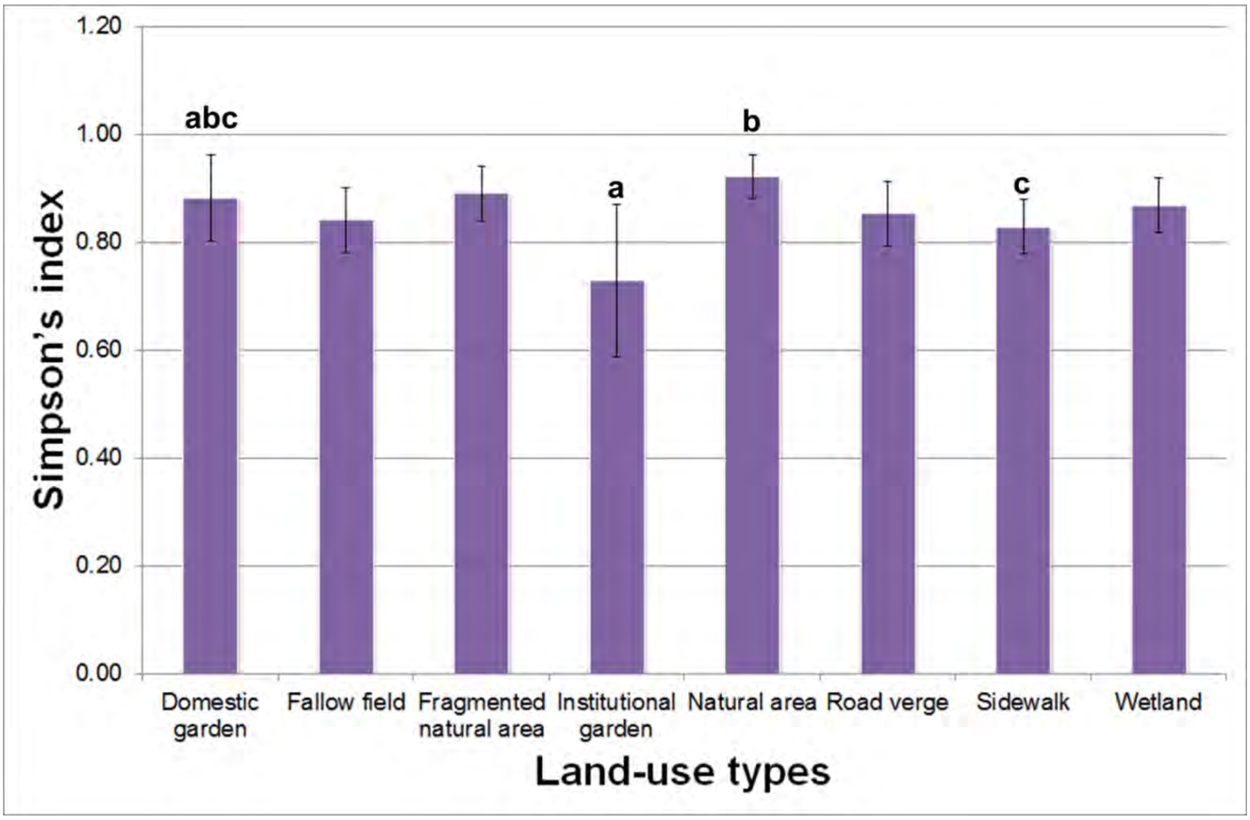

Figure 4.10: Mean values of Simpson's index and standard deviation calculated for all the different land-use types sampled across all five settlements (the letters above the bars indicate which land-uses were significantly different from the domestic gardens based on Tukey's (HSD) post-hoc test. See Annexure C for the rest of the results).

4.3.2 Species diversity and composition of domestic gardens of different settlements

4.3.2.1 Species composition

An NMS ordination based on the species composition of the domestic gardens sampled in each of the settlements, revealed four groupings (Figure 4.11). The domestic gardens in Tlhakgameng and Ganyesa grouped together, while the domestic gardens of Ikageng, Potchefstroom and Roodepoort formed separate groupings. The species composition of Roodepoort was more similar to Potchefstroom than any of the other settlements, while the domestic gardens of Ikageng were similar to both those in Tlhakgameng and Ganyesa on one side and Potchefstroom on the other. The stress value of the ordination was 0.16, which indicated satisfactory groupings.

The ANOSIM (Table 4.6) confirms the results of the NMS. The domestic gardens in Tlhakgameng and Ganyesa were very dissimilar to the domestic gardens in Ikageng, Potchefstroom, and Roodepoort. The domestic gardens of Ikageng were more similar to the gardens in Potchefstroom than the gardens in Roodepoort. The results of the SIMPER analyses are given in Annexure B. The top ten species responsible for the groupings of the settlements are listed in Table B.2.

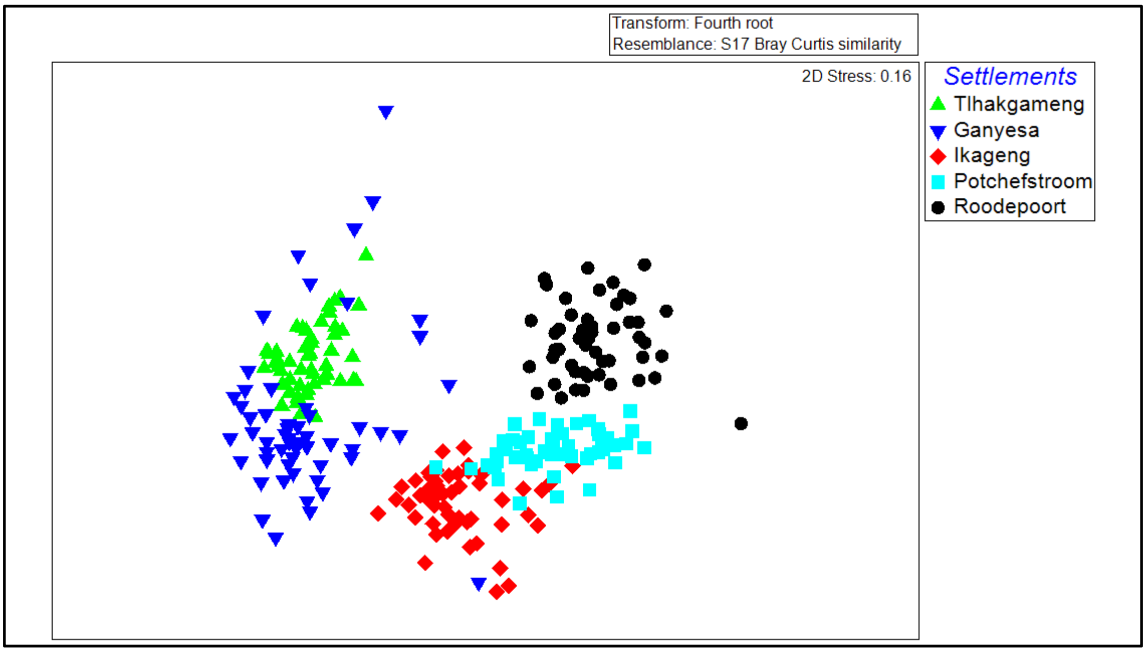

Figure 4.11: NMS ordination of the total species composition based on sample plot data of domestic gardens, grouped according to the different settlements.

Table 4.6: Results of ANOSIM and SIMPER analyses for the different settlements in terms of the domestic gardens (See Annexure B for SIMPER results). Marked differences (bold) are significant at $p < 0.05$. Large effect (bold and italics) marked at $R \geq 0.7$ and medium effect (bold) marked at $R \geq 0.5$.

		p-value	R value	SIMPER overall average dissimilarity
Ganyesa	Ikageng	**0.001**	***0.725***	87.33
	Potchefstroom	**0.001**	***0.88***	92.51
	Roodepoort	**0.001**	***0.944***	95.87
Ikageng	Potchefstroom	**0.001**	**0.592**	75.75
	Roodepoort	**0.001**	***0.945***	86.93
Potchefstroom	Roodepoort	**0.001**	**0.604**	77.51
Tlhakgameng	Ganyesa	**0.001**	0.407	78.95
	Ikageng	**0.001**	***0.97***	88.2
	Potchefstroom	**0.001**	***0.998***	93.46
	Roodepoort	**0.001**	***0.998***	95.18

4.3.2.2 Species diversity

The results of Margalef's species richness index (Figure 4.12 A) presented values between 4.6 and 10.3 for all the domestic gardens sampled in all the studied settlements. Tlhakgameng and Roodepoort had the highest mean species richness values, 10.2 and 10.3 respectively, while Ikageng had the lowest value. Pielou's evenness index indicated that Roodepoort had the highest evenness of all the studied settlements, while Ikageng had the lowest evenness (Figure 4.12 B). Roodepoort had an evenness value of 0.84, which indicates a high abundance of species and a more even distribution of individuals among the sampled sites. The results of Shannon's index indicated that Roodepoort had the highest species diversity of all the studied settlements, while Ikageng had the lowest (Figure 4.12 C). The Simpson's index indicated that Tlhakgameng and Roodepoort had the highest species diversity (0.93) of all the studied settlements, while Ikageng had the lowest (0.82) species diversity (Figure 4.12 D).

A one-way ANOVA was performed to determine if the domestic gardens studied in each settlement differed from one another based on the values of the diversity indices (Table 4.7). The p-values of the ANOVA's were much smaller than 0.05, which indicates that the data was statistically significant. Tukey's HSD test for unequal sample size was used to determine which settlements were significantly different from one another. In terms of Margalef's species richness and Simpson's index, both Tlhakgameng and Roodepoort differed significantly from Ganyesa, Ikageng, and Potchefstroom, but there were no significant differences between Tlhakgameng and Roodepoort. With regard to Pielou's evenness and Shannon's index, several of the settlements differed from one another.

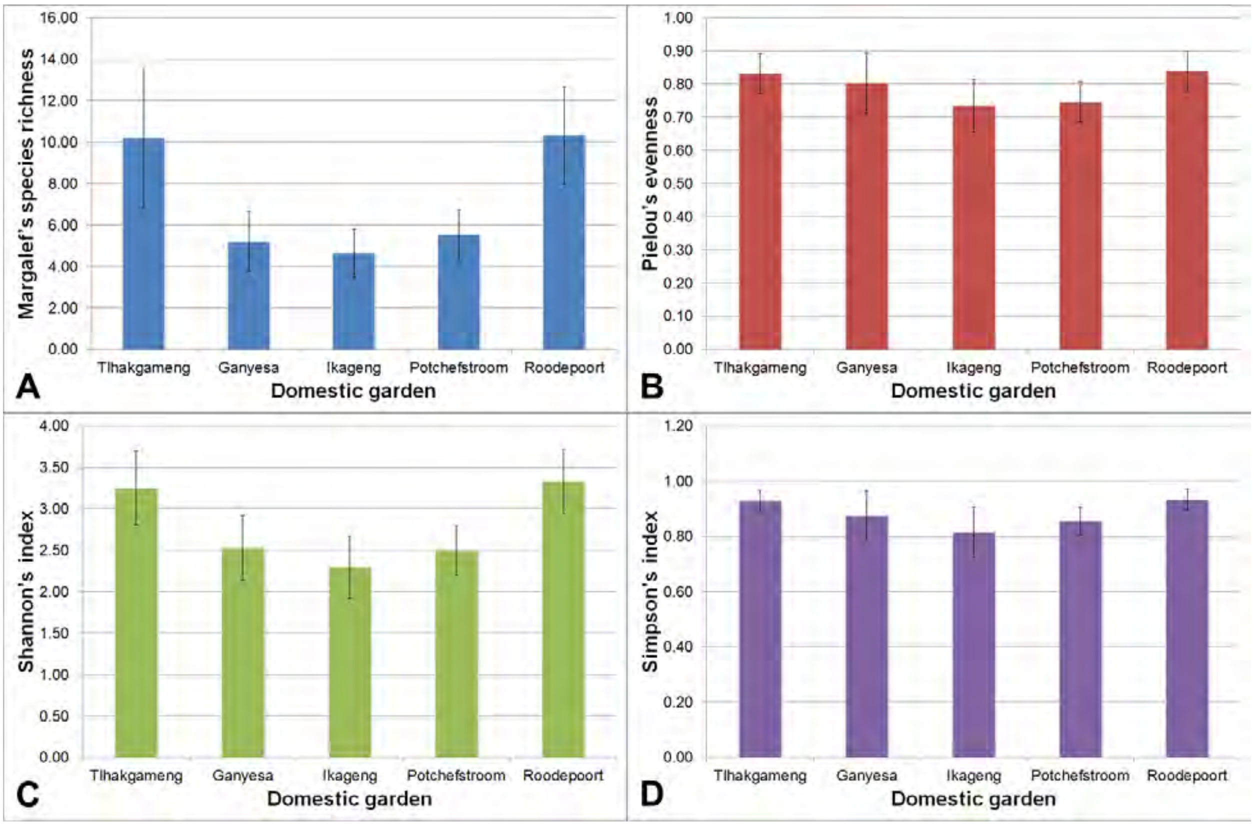

Figure 4.12: Mean values of the diversity indices and standard deviation for all the domestic gardens sampled in all the studied settlements: (A) Margalef's species richness index, (B) Pielou's evenness index (C), Shannon's index and (D) Simpson's index.

Table 4.7: One-way ANOVA and Tukey's HSD test for unequal sample size results for the four diversity indices between domestic gardens of the settlements (T: Tlhakgameng, G: Ganyesa, I: Ikageng, P: Potchefstroom, and R: Roodepoort). Marked differences (bold) are significant at $p < 0.05$.

	One way ANOVA		Post hoc Tukey Unequal N HSD
Margalef's species richness	$F_{(4,246)} = 90.09$	$p < 0.0001$	T differs from G, I & P; R from G,I &P
Pielou's evenness	$F_{(4,246)} = 20.43$	$p < 0.0001$	T differs from I & P; G from I & P; I differs from R; P from R
Shannon's	$F_{(4,246)} = 73.39$	$p < 0.0001$	T differs from G, I & P; G from I & R; I differs from R; P from R
Simpson's index	$F_{(4,246)} = 26.25$	$p < 0.0001$	T differs from G, I & P; G from I & R I from P & R; P from R

4.3.3 Species diversity and composition of domestic gardens and other land-uses within settlements

4.3.3.1 Species composition

A comparison between the gamma diversity of the entire settlements revealed that Roodepoort had the highest diversity, while Ganyesa had the lowest (Figure 4.13). Potchefstroom was the only settlement in which the number of alien species was more than the number of indigenous species. In terms of percentage contribution, Ikageng had the highest percentage indigenous species (66%), while Potchefstroom had the highest percentage alien species (55%) (Table 4.8).

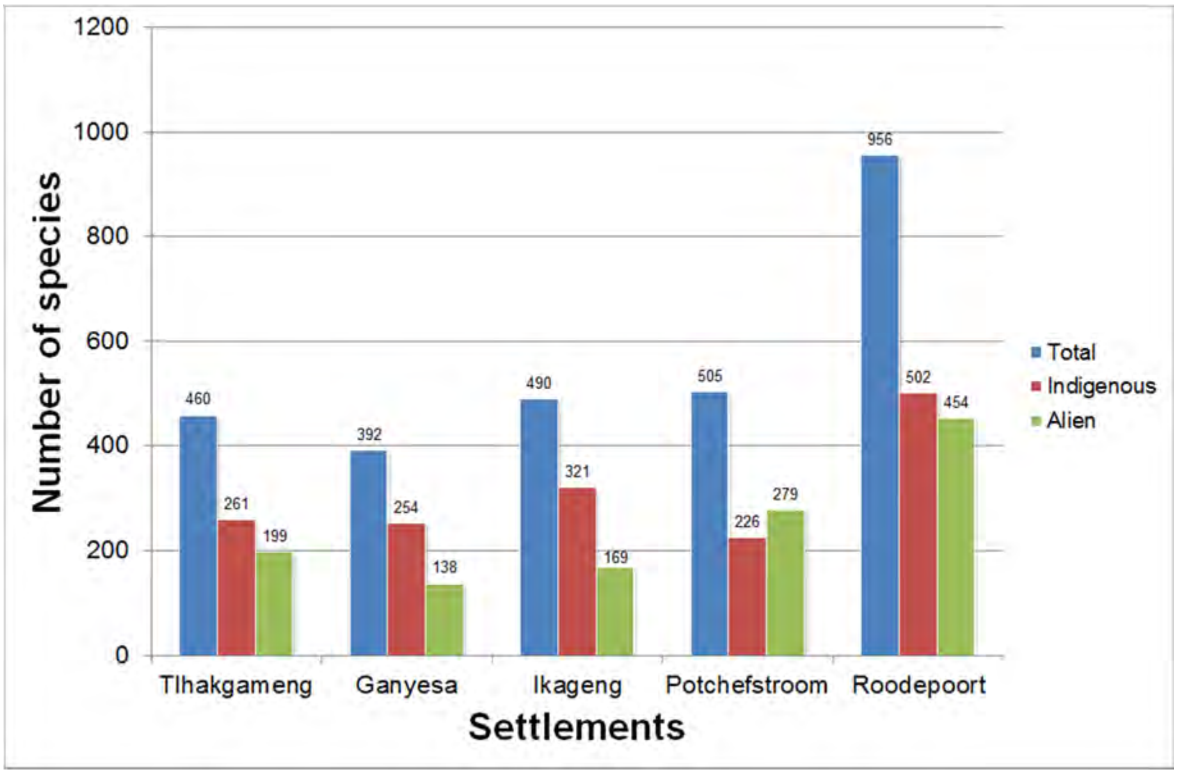

Figure 4.13: The total (gamma (γ) diversity), indigenous and alien number of species for each of the five settlements.

Table 4.8: The percentage indigenous and alien species in each of the five settlements.

Settlements	% Indigenous	% Alien
Tlhakgameng	57	43
Ganyesa	65	35
Ikageng	66	34
Potchefstroom	45	55
Roodepoort	53	47

4.3.3.1.1 Tlhakgameng

A comparison between the species richness of the different land-use types in Tlhakgameng revealed that domestic gardens had the highest species richness (α diversity) and fallow fields had the lowest (Figure 4.14). Three domestic gardens had remarkably high species richness, most of which were alien cultivated species. In contrast, the natural areas and fallow fields had the highest percentage indigenous species, while domestic gardens had the lowest (Figure 4.15). The majority of species in domestic gardens were alien cultivated species.

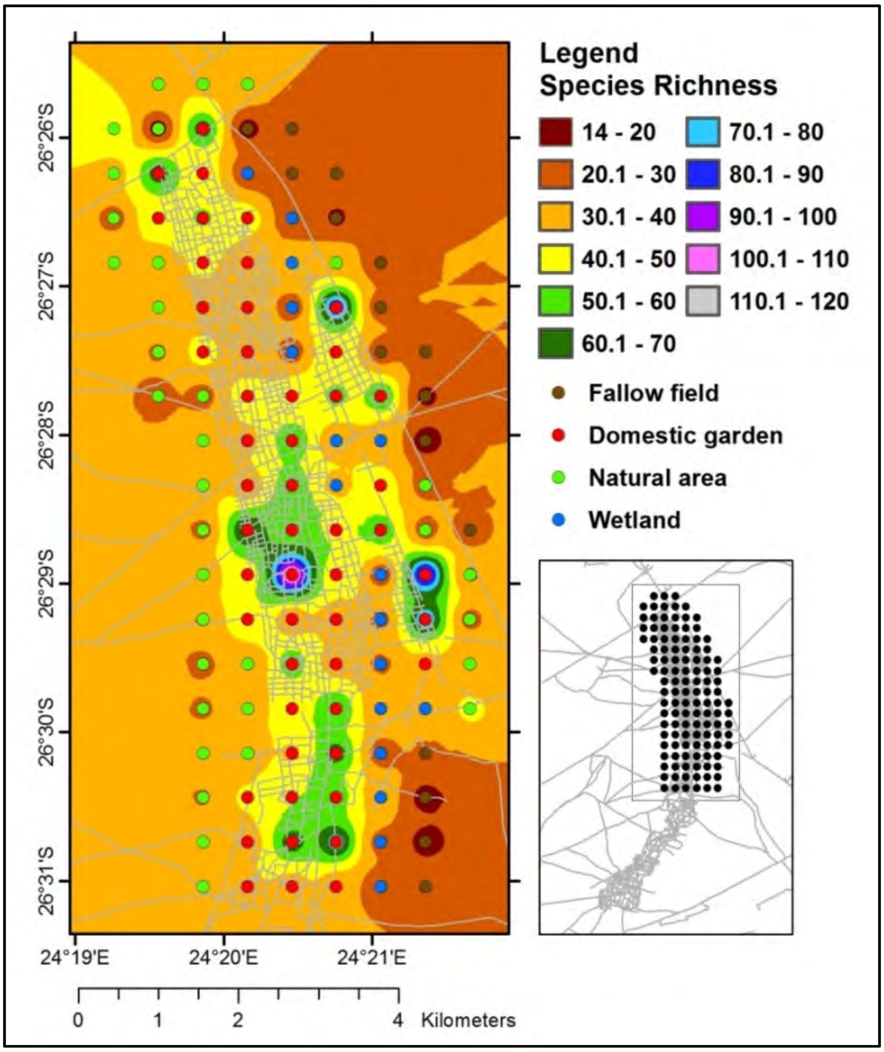

Figure 4.14: Distribution pattern of the total number of species (α diversity) in the rural settlement of Tlhakgameng. The land-use types present are indicated by different colored dots on the map.

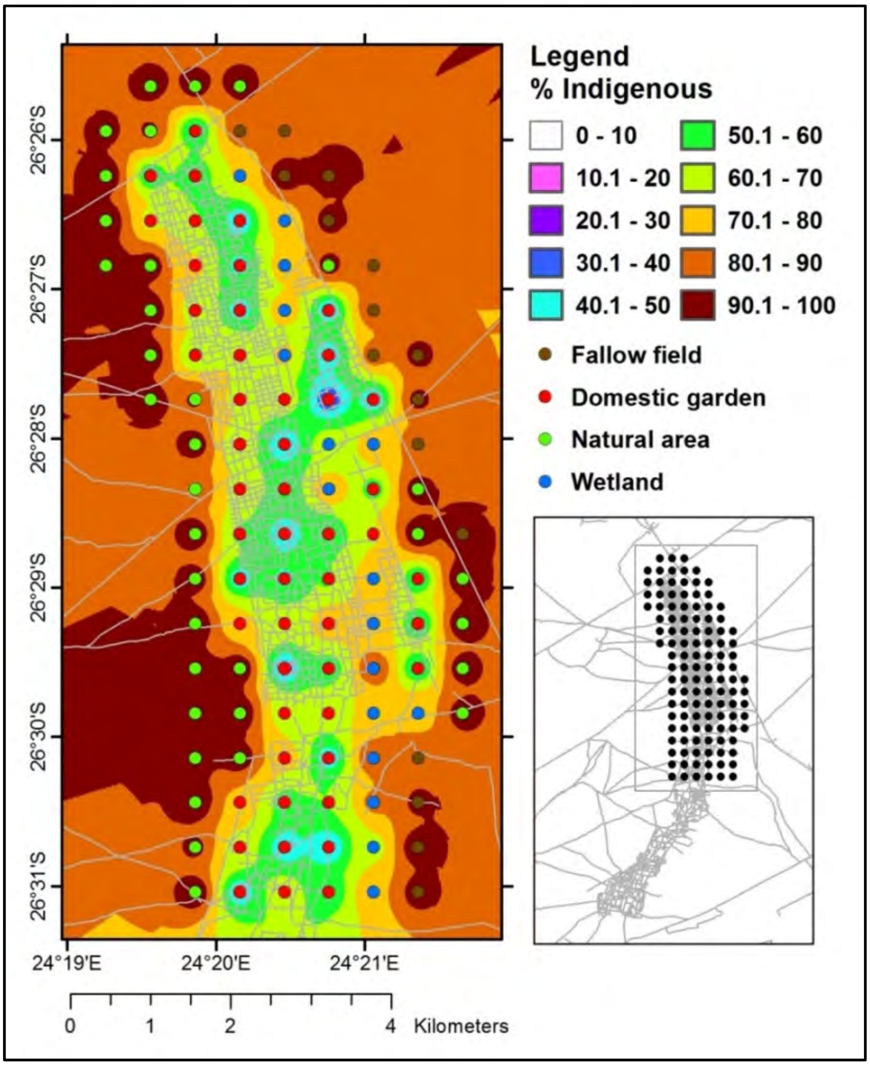

Figure 4.15: Distribution pattern of the percentage indigenous species in the rural settlement of Tlhakgameng. The land-use types present are indicated by different colored dots on the map.

The beta diversity values (β) were determined for each of the land-use types in Tlhakgameng (Figure 4.16). The domestic gardens had the highest beta diversity value (6.5), while the fallow fields had the lowest (2.9).

The NMS ordination of the total species composition of Tlhakgameng revealed four groupings in terms of the different land-use types (Figure 4.17). This indicates a general dissimilarity between the land-use types in terms of their species composition. The domestic gardens had a higher species turnover (higher β diversity, Figure 4.16) than the other land-use types since the plots appear to be more dispersed. In contrast, the fallow field plots are grouped much closer together than those of the natural areas or wetlands, which indicate that the fallow fields had a lower species turnover (lower β diversity, Figure 4.16) than the other land-use types. The stress value of the ordination was 0.16, which suggests a satisfactory ordination with clear groupings.

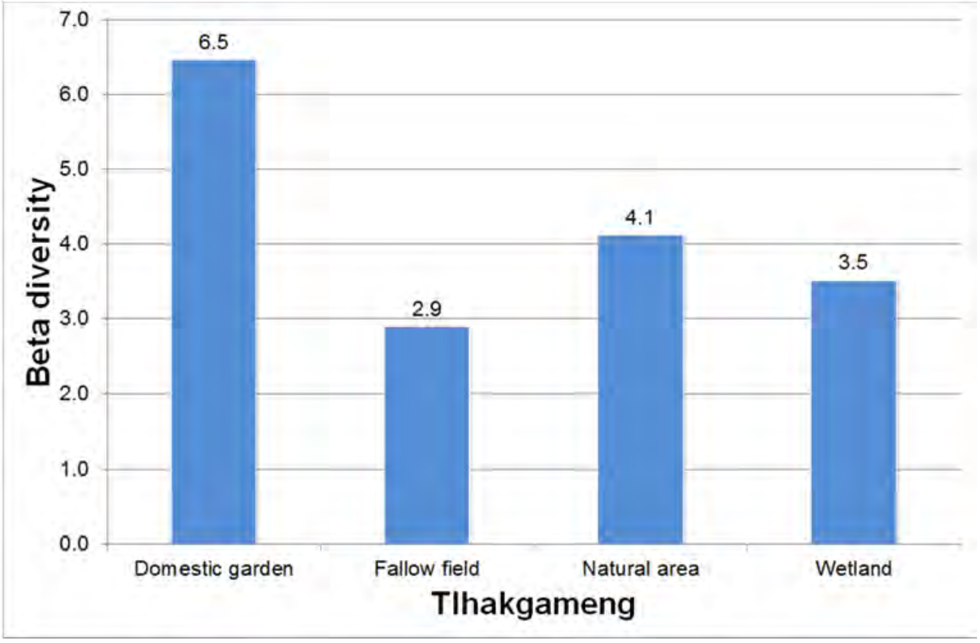

Figure 4.16: Beta diversity for each of the land-use types sampled in Tlhakgameng, as determined with Whittaker's measure.

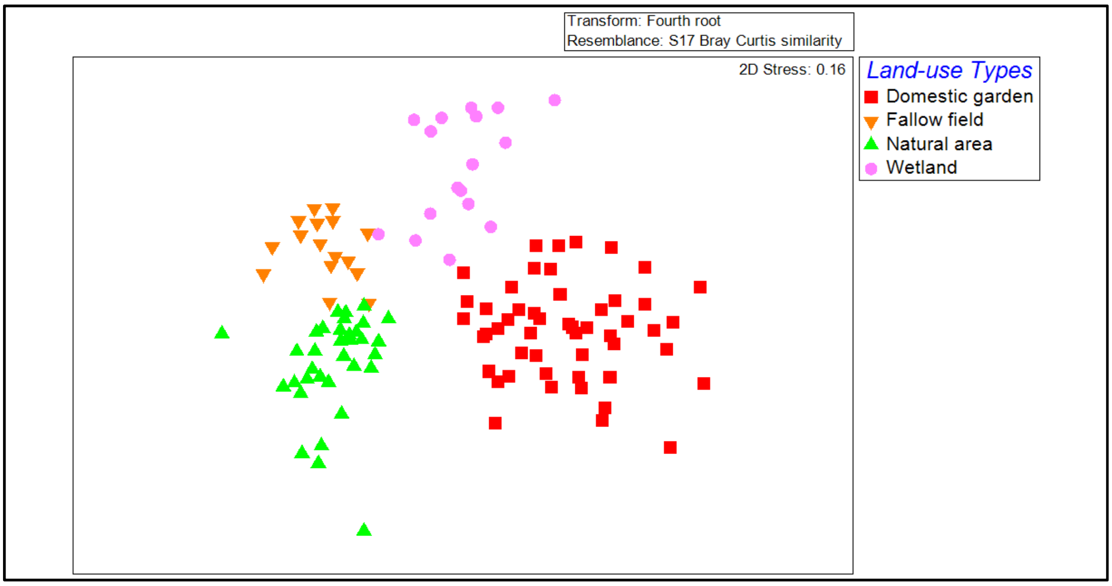

Figure 4.17: NMS ordination of the total species composition based on sample plot data in Tlhakgameng, grouped according to the different land-use types.

4.3.3.1.2 Ganyesa

In contrast to the pattern of species richness observed in Tlhakgameng, the natural areas in Ganyesa had higher species richness than all the other land-use types (Figure 4.18). Several domestic gardens along the edge of the settlement were characterised by higher species richness than those inside the settlement. These gardens were relatively new and still contained a large number of indigenous species from the surrounding natural areas. In terms of percentage indigenous species, there is a clear gradient of high to low, from the natural areas (high) on the outskirts of the settlement to the domestic gardens (low) in the center (Figure

4.19). The natural areas had the highest percentage indigenous species and domestic gardens had the lowest. Domestic gardens had a higher number of alien cultivated species than all other land-use types.

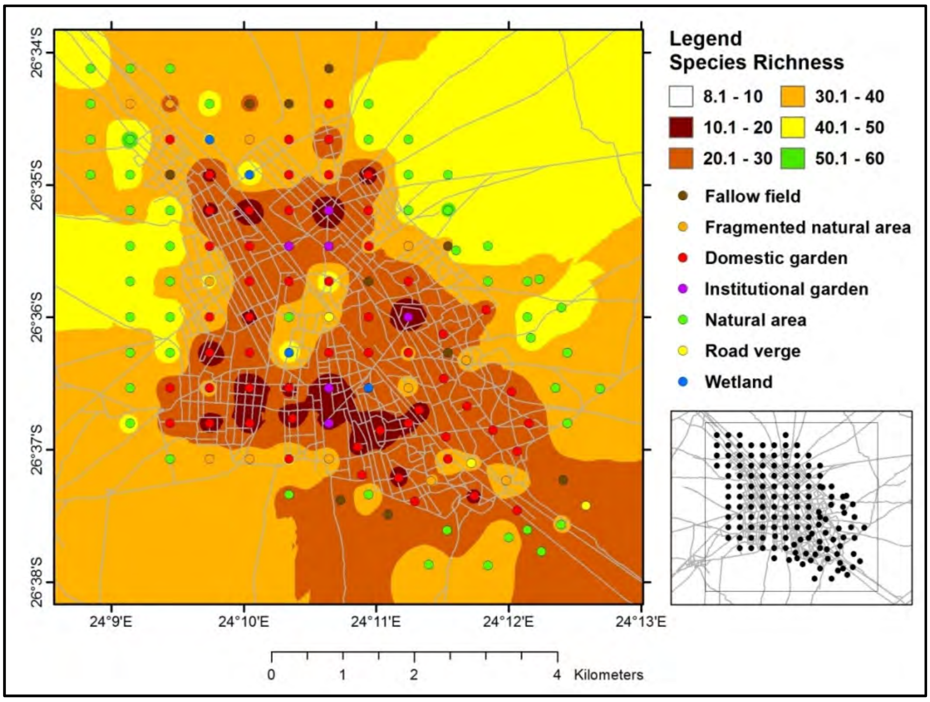

Figure 4.18: Distribution pattern of the total number of species (α diversity) in the rural settlement of Ganyesa. The land-use types present in Ganyesa are indicated by different colored dots on the map.

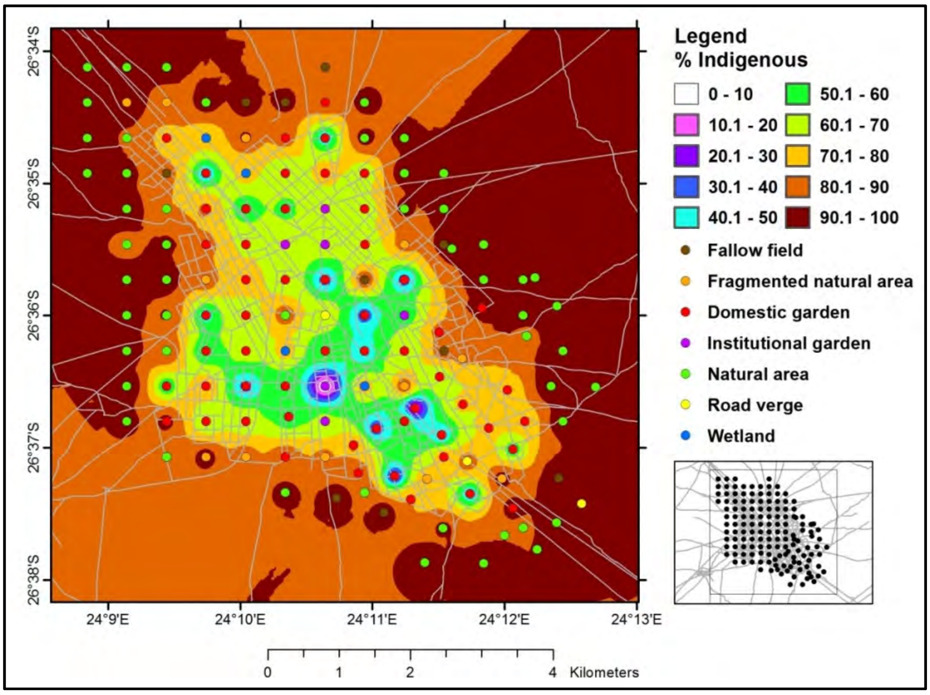

Figure 4.19: Distribution pattern of the percentage indigenous species in the rural settlement of Ganyesa. The land-use types present in Ganyesa are indicated by different colored dots on the map.

The beta diversity values (β) were determined for each of the land-use types in Ganyesa (Figure 4.20). The domestic gardens had the highest beta diversity value (9.7), while the road verges had the lowest (1.1).

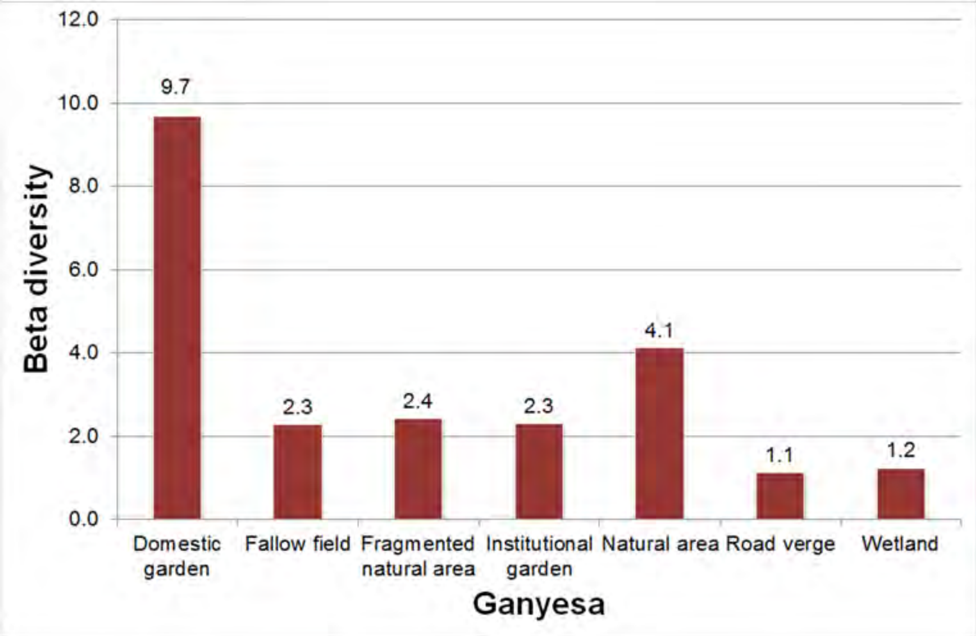

Figure 4.20: Beta diversity for each of the land-use types sampled in Ganyesa, as determined with Whittaker's measure.

The NMS ordination of the total species composition of Ganyesa revealed only two groupings between the sample plots (Figure 4.21). Based on the groupings illustrated by the ordination, the domestic gardens had a higher species turn (higher β diversity, Figure 4.20) over than those of the natural areas since the natural areas were grouped closer together (β diversity is lower than gardens, Figure 4.20), while the domestic gardens appear more dispersed. Consequently, domestic gardens had significantly more variation in terms of species composition per sample plot than any of the other land-use types. There were no clear differences in terms of species composition between the fallow fields, fragmented natural areas, road verges or wetlands since they occur scattered between the natural areas, which indicate that they have more similar species composition to the natural areas than the domestic gardens. Similarly, the institutional gardens appear dispersed between the domestic gardens. The stress value of the ordination was 0.16, meaning that the ordination was satisfactory, but the groupings were less clear.

4.3.3.1.3 Ikageng and Potchefstroom

Ikageng and Potchefstroom are separated by the industrial zone in the TCM (Figure 4.22 and 4.23). There were no sample sites inside this area since there are no residences in the industrial zone. The indicated patterns are a result of the estimation done by the IDW method between the higher and lower species richness areas. The low to moderate species richness indicated for the industrial zone (Figure 4.22 and 4.23) is consequently not a true representation. In Figure 4.22, there is a visible difference between the species richness in Potchefstroom and Ikageng. The natural areas around Ikageng had higher species richness (α diversity) than all the other land-use types in both Ikageng and Potchefstroom. In Potchefstroom and Ikageng, the domestic gardens had the lowest species richness. Domestic gardens also had the lowest percentage indigenous species and natural areas had the highest (Figure 4.23). The domestic gardens were dominated by alien cultivated species.

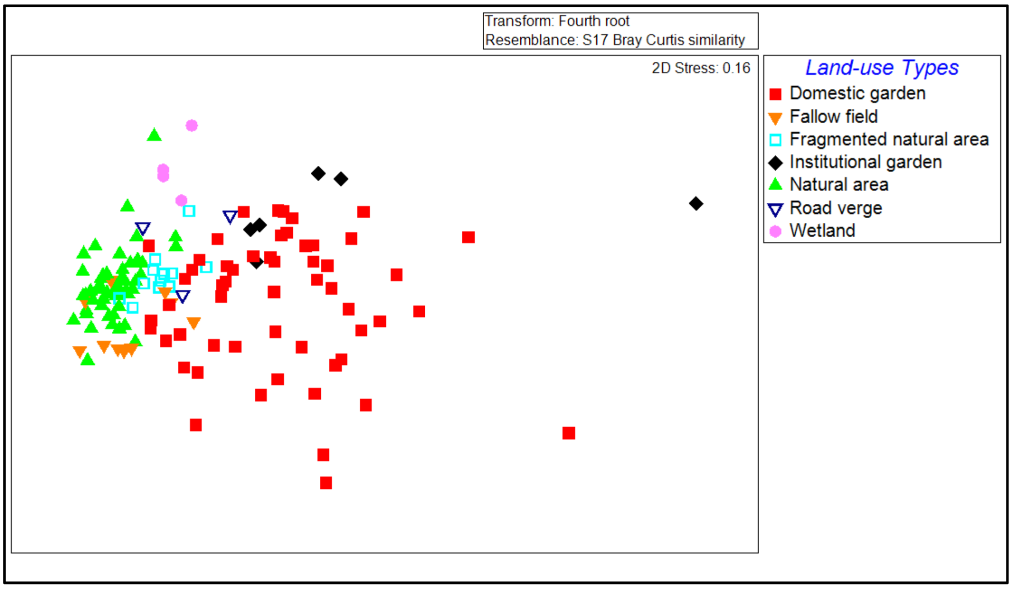

Figure 4.21: NMS ordination of the total species composition based on sample plot data in Ganyesa, grouped according to the different land-use types.

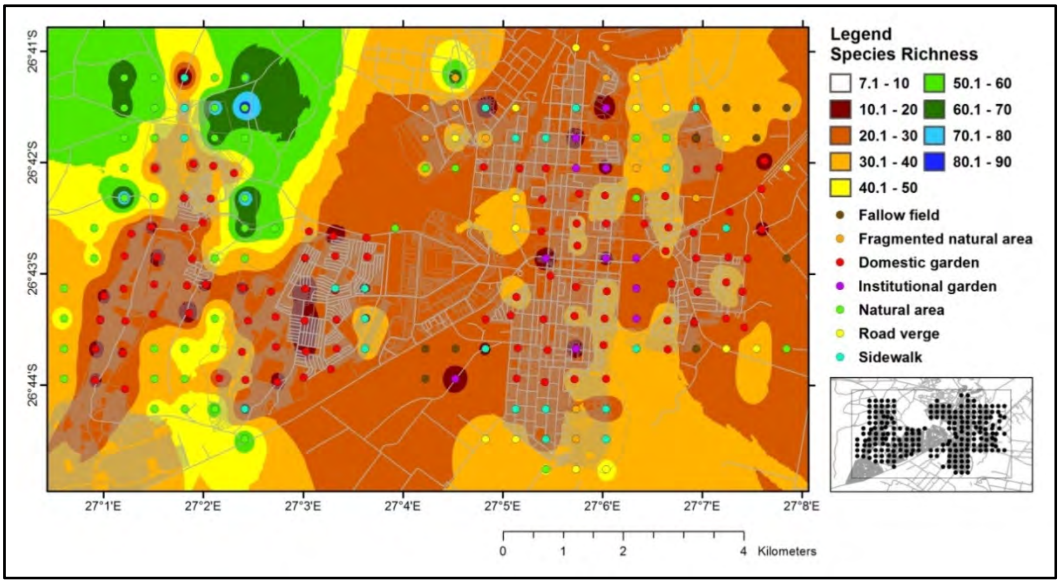

Figure 4.22: Distribution pattern of the total number of species (α diversity) in the peri-urban settlement of Ikageng and the urban settlement of Potchefstroom. The land-use types present in Ikageng (left side) and Potchefstroom (right side) are indicated by different colored dots on the map.

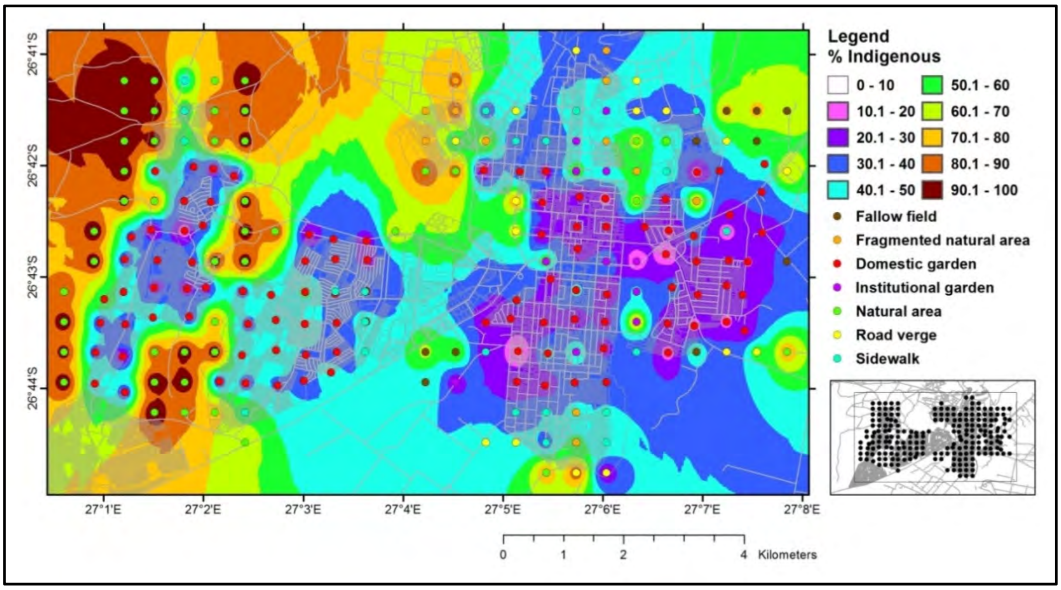

Figure 4.23: Distribution pattern of the percentage indigenous species in the peri-urban settlement of Ikageng and the urban settlement of Potchefstroom. The land-use types present in Ikageng (left side) and Potchefstroom (right side) are indicated by different colored dots on the map.

The beta diversity values (β) were determined for each of the land-use types in Ikageng (Figure 4.24). The domestic gardens had the highest beta diversity value (8.8), almost double the value of the natural areas (4.8). The sidewalks had the lowest value (1.8).

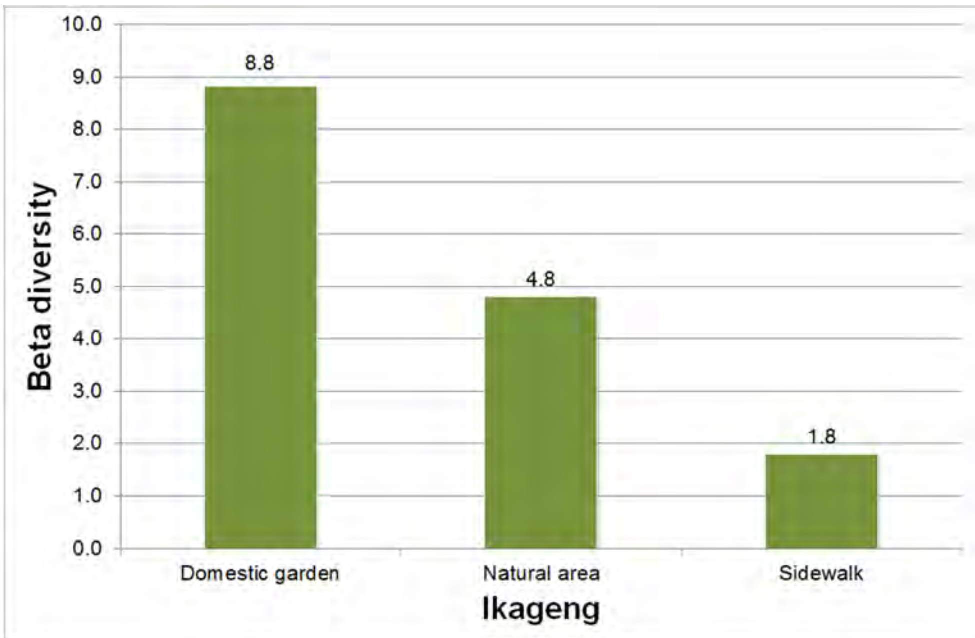

Figure 4.24: Beta diversity for each of the land-use types sampled in Ikageng, as determined with Whittaker's measure.

Based on the NMS ordination of the total species composition of Ikageng, there are very clear groupings between the different land-use types (Figure 4.25). The domestic garden, natural area, and sidewalk sample plots appear very dispersed, which indicates that their species composition varied significantly. The stress value of the ordination is 0.12.

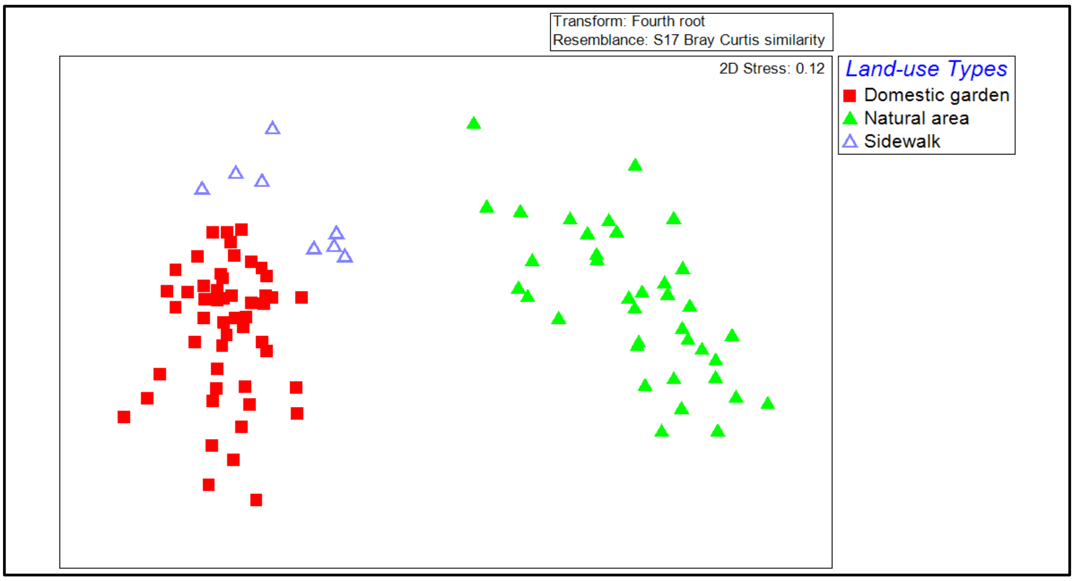

Figure 4.25: NMS ordination of the total species composition based on sample plot data in Ikageng, grouped according to the different land-use types.

The beta diversity values (β) were determined for each of the land-use types in Potchefstroom (Figure 4.26). The domestic gardens had the highest beta diversity value (9.3), while the fallow fields had the lowest (2.6).

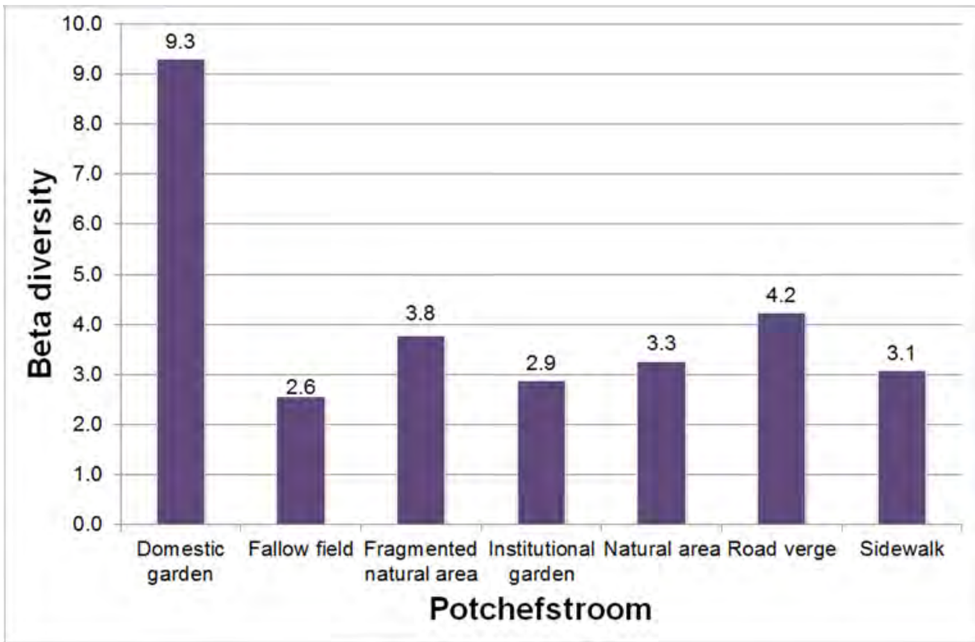

Figure 4.26: Beta diversity for each of the land-use types sampled in Potchefstroom, as determined with Whittaker's measure.

The NMS ordination of the species composition of Potchefstroom indicated that there were no clear groupings between the fallow fields, fragmented natural areas, institutional gardens, natural areas, road verges or sidewalks (Figure 4.27). These sites were once natural, but different anthropogenic impacts have influenced their species composition. They share various similar herbaceous weed species, such as *Alternanthera pungens*, *Cichorium intybus*, *Conyza podocephala*, *Guilleminea densa*, *Physalis angulata* and *Plantago lanceolata*. The domestic gardens tend to group together, however, the grouping is very dispersed, which is an indication of the dissimilarity in species composition between the domestic gardens and an indication of a higher species turnover (higher β diversity, Figure 4.26) than the other land-use types. The stress value of the ordination was 0.16, which means that the ordination was satisfactory but in this case, there were no clear groupings between the sample sites with the exception of domestic gardens.

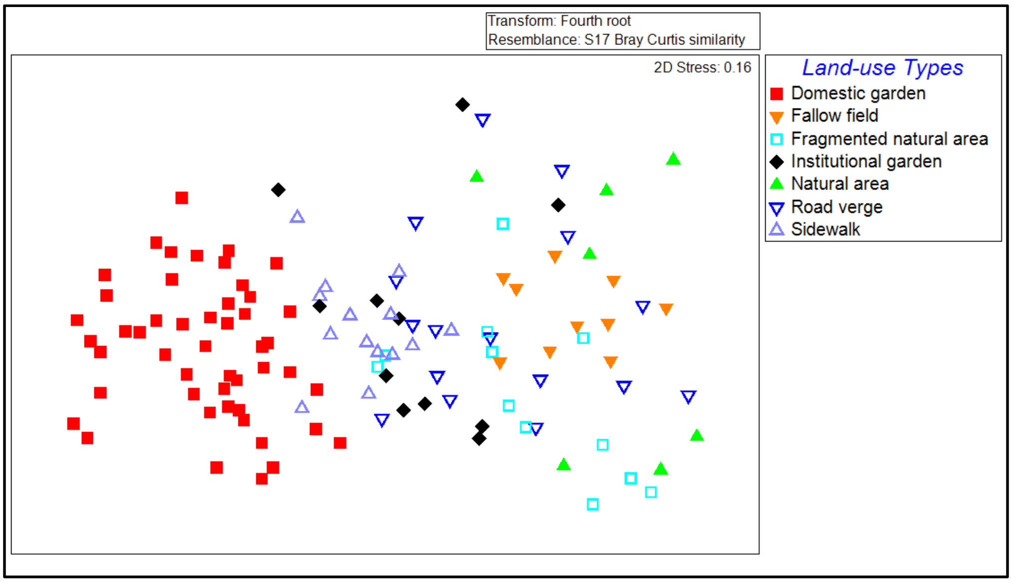

Figure 4.27: NMS ordination of the total species composition based on sample plot data in Potchefstroom, grouped according to the different land-use types.

4.3.3.1.4 Roodepoort

In Roodepoort, both the domestic gardens and natural areas had high species richness, while the fragmented natural areas, road verges, and sidewalks had the lowest species richness (Figure 4.28). A few of the domestic gardens had remarkably high species richness, the majority of which were alien species. In contrast, domestic gardens had the lowest percentage indigenous species, while the natural areas had the highest (Figure 4.29). Two of the domestic gardens had remarkably high percentages of indigenous species. These participants actively cultivated indigenous species and removed alien species due to the growing trend of indigenous gardening in South Africa. The fragmented natural areas had the second highest percentage indigenous species.

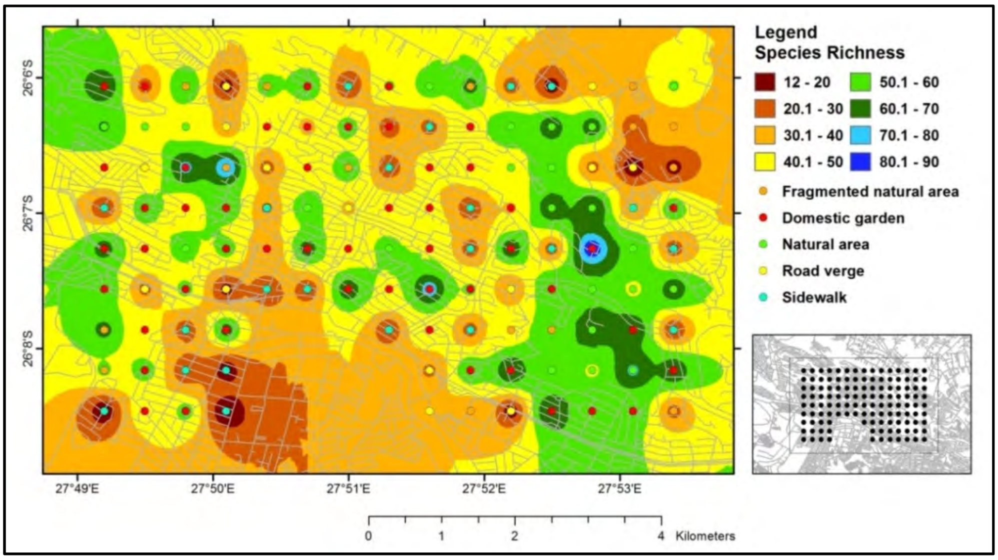

Figure 4.28: Distribution pattern of the total number of species (α diversity) in the metropolitan area of Roodepoort. The land-use types present in Roodepoort are indicated by different colored dots on the map.

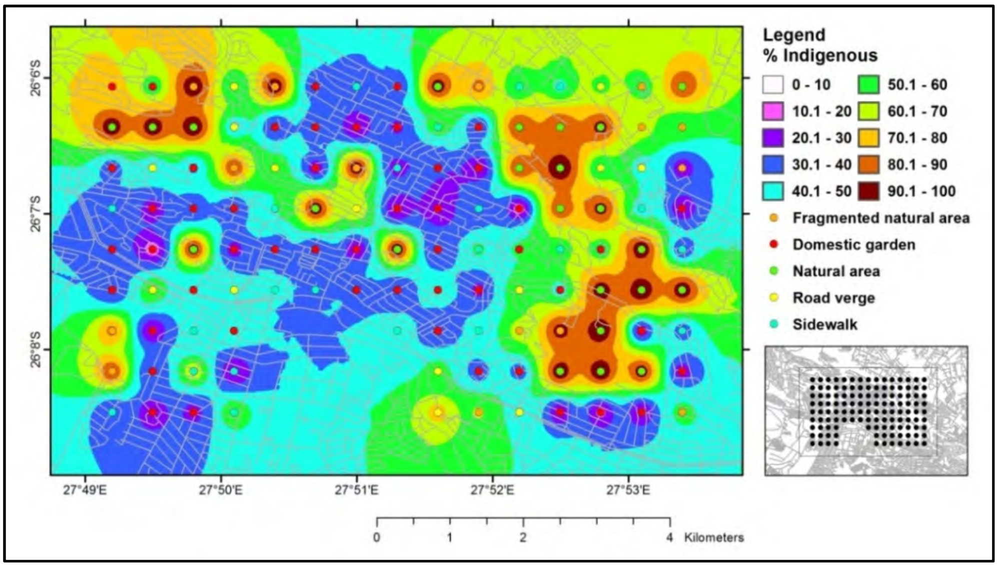

Figure 4.29: Distribution pattern of the percentage indigenous species in the metropolitan area of Roodepoort. The land-use types present in Roodepoort are indicated by different colored dots on the map.

The beta diversity values (β) were determined for each of the land-use types in Potchefstroom (Figure 4.30). The domestic gardens had the highest beta diversity value (10.9), while the natural areas and the sidewalks had the lowest (3.5). There were only marginal differences between the β diversity values of the fragmented natural areas, natural areas, sidewalks and road verges, which is also illustrated on the NMS ordination (Figure 4.31). The NMS ordination of the species composition of Roodepoort revealed three clear groupings between the sample plots (Figure 4.31). The first group represents the domestic gardens, the second, the natural areas and some of the fragmented natural areas and the third, the sidewalks, road verges and the rest of the fragmented natural areas. These groupings were indicative of the similarities in species composition between these sample sites. The domestic gardens had a higher species turnover (higher β diversity, Figure 4.30) than the other land-use types. The second group, the sidewalks, road verges and the several fragmented natural areas, were dominated by grass species, while the third group, the natural areas, and the remaining fragmented natural areas, was dominated by *Protea caffra*, which is due to the different vegetation units present in Roodepoort. The stress value of the ordination was lower than 0.11, meaning that the ordination was satisfactory with clear groupings between the sample plots.

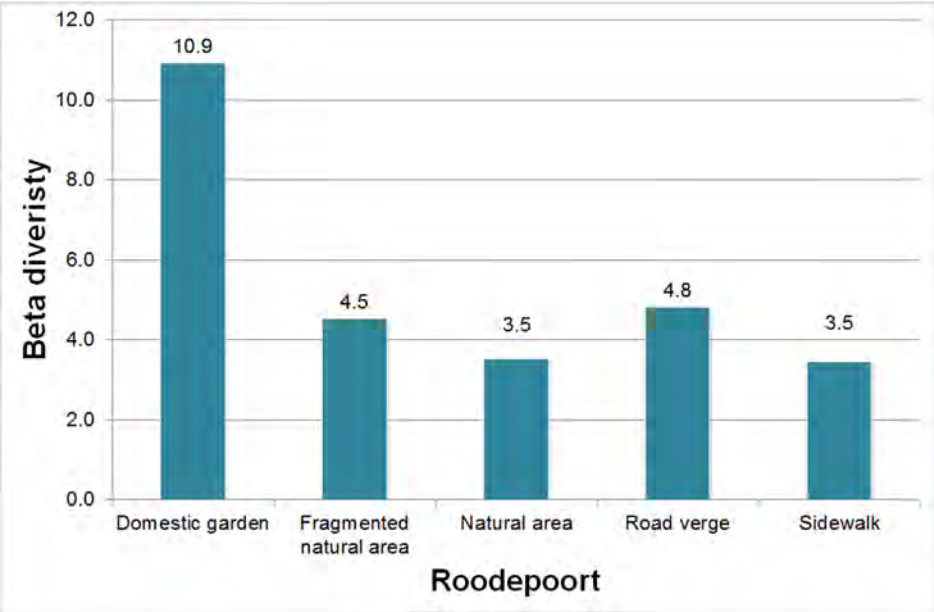

Figure 4.30: Beta diversity for each of the land-use types sampled in Roodepoort, as determined with Whittaker's measure.

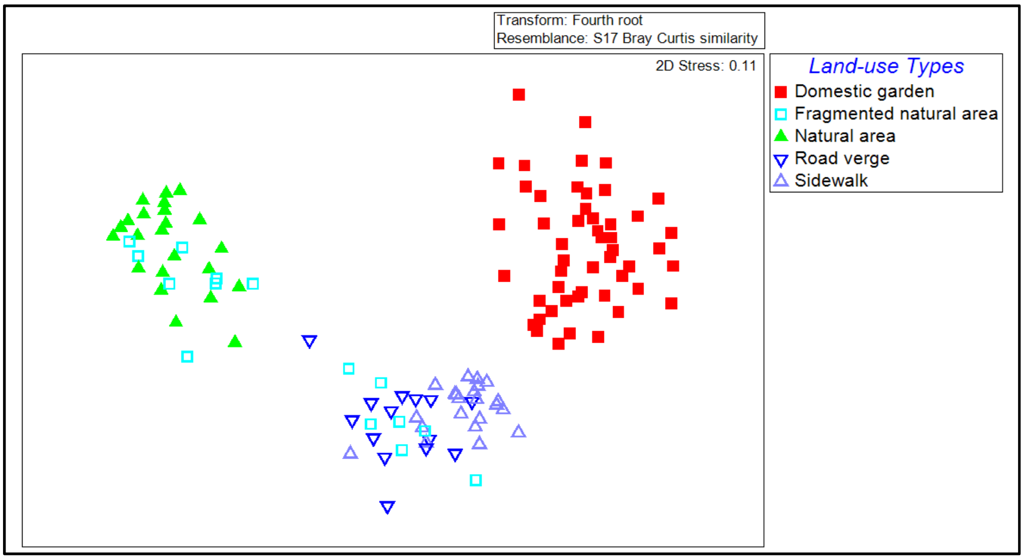

Figure 4.31: NMS ordination of the total species composition based on sample plot data in Roodepoort, grouped according to the different land-use types.

4.3.3.2 Diversity patterns

4.3.3.2.1 Tlhakgameng

The results of Margalef's species richness index showed that the domestic gardens had the highest species richness values in comparison with the other land-use types, while the fallow fields had the lowest (Figure 4.32 A). Pielou's evenness index revealed the same trend, but with far less variation between the other land-use types (Figure 4.32 B). Fallow fields had the lowest evenness value, which indicates a low abundance of species that were unevenly distributed among the sampled sites. The domestic gardens had the highest Shannon's index value (Figure 4.32 C), as well as the highest Simpson's index value of all the land-use types, while fallow fields had the lowest value in both cases (Figure 4.32 D).

A one-way ANOVA was performed to determine if the land-use types sampled in Tlhakgameng differed significantly from one another based on the values of all the diversity indices (See Annexure C for ANOVA and Tukey results). The analysis produced a statistically significant result ($p < 0.05$) and post hoc Tukey tests revealed that the domestic gardens differed significantly from the fallow fields, natural areas, and wetlands in terms of all the diversity indices (Figure 4.32 A-D and Table C.5, Annexure C).

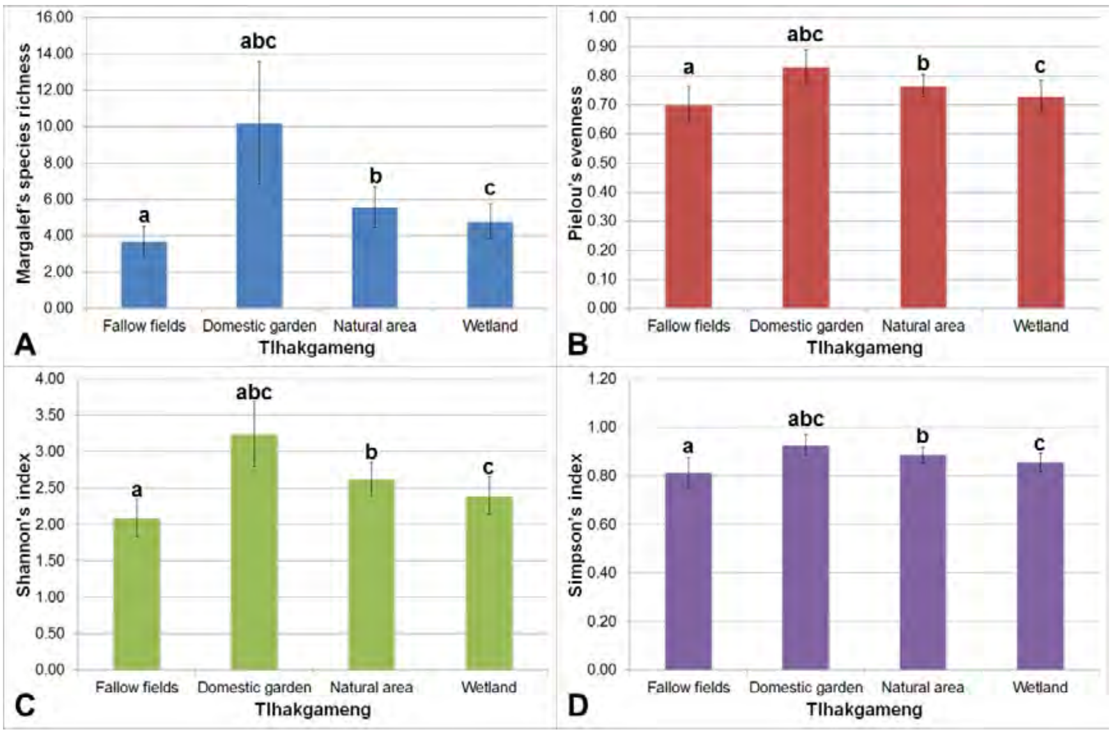

Figure 4.32: Mean values of the diversity indices and standard deviation for the different land-use types sampled in Tlhakgameng: (A) Margalef's species richness index, (B) Pielou's evenness index (C), Shannon's index and (D) Simpson's index (the letters above the bars indicate which land-uses were significantly different from domestic gardens based on Tukey's (HSD) post-hoc test).

4.3.3.2.2 Ganyesa

In Ganyesa, the natural areas and wetlands had the highest species richness of all the land-use types, while the institutional gardens had the lowest in terms of Margalef's species richness index (Figure 4.33 A). Pielou's evenness index showed far less variation between the different land-use types (Figure 4.33 B). However, the natural areas had the highest evenness, which indicates a high abundance of species and an even distribution of individuals among the sampled sites. The natural areas and wetlands had the highest species diversity and the institutional gardens the lowest in terms of both Shannon's diversity (Figure 4.33 C) and Simpson's diversity indices (Figure 4.33 D).

To determine if the land-use types sampled in Ganyesa differed from one another based on the values of all the diversity indices (See Annexure C for ANOVA and Tukey results), a one-way ANOVA was performed. The results were statistically significant ($p < 0.05$). Post hoc Tukey tests revealed that the domestic gardens differed significantly from the natural areas in terms of Margalef's species richness, Shannon's and Simpson's diversity indexes. There were no significant differences between the domestic garden and the other land-use types in terms of Pielou's evenness index (Figure 4.33 A - D and Table C.6, Annexure C).

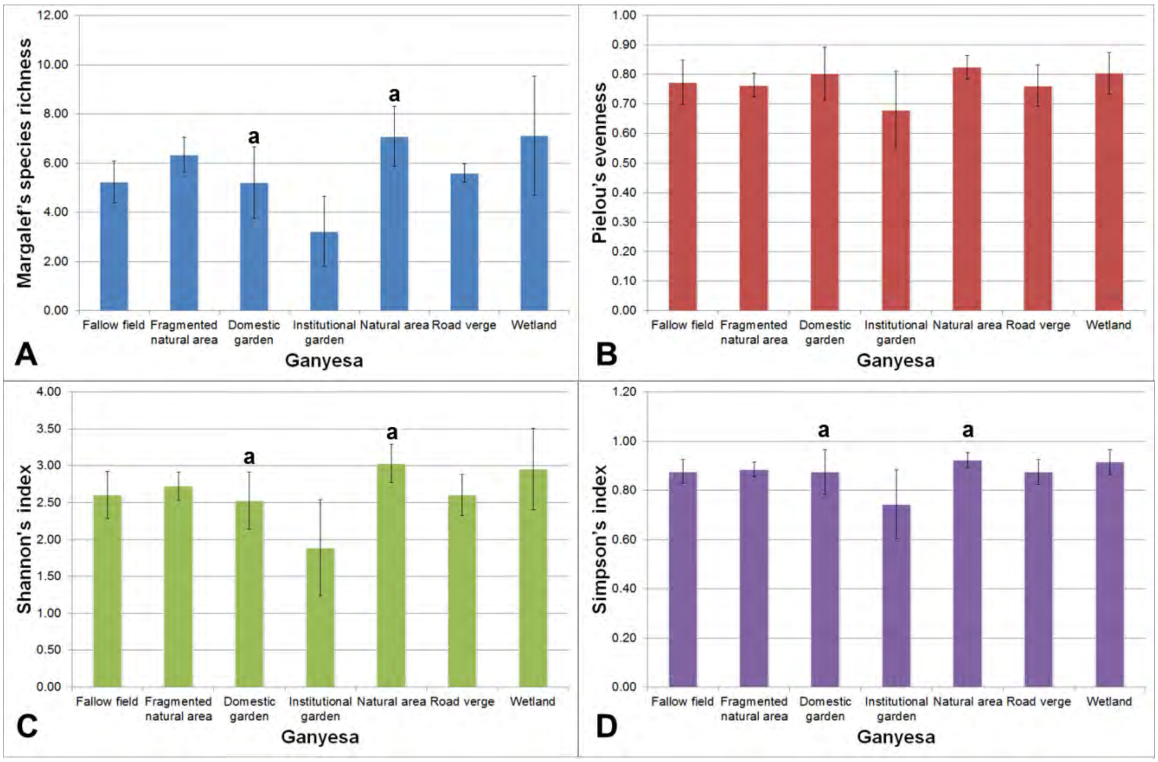

Figure 4.33: Mean values of the diversity indices and standard deviation for the different land-use types sampled in Ganyesa: (A) Margalef's species richness index, (B) Pielou's evenness index (C), Shannon's index and (D) Simpson's index (the letters above the bars indicate which land-uses were significantly different from domestic gardens based on Tukey's (HSD) post-hoc test).

4.3.3.2.3 Ikageng

The natural areas had the highest species richness (9.33) of all the land-use types sampled in Ikageng, while the sidewalks had the lowest (4.60) in terms of Margalef's species richness index (Figure 4.34 A). The values of Pielou's evenness index revealed far less variation between the different land-use types, ranging from 0.73 to 0.82 (Figure 4.34 B). The natural areas had the highest evenness value, which indicate a high abundance of species and an even distribution of individuals among the sampled sites. The domestic gardens had the lowest evenness value. Similarly, the natural areas had the highest species diversity and the domestic gardens the lowest in terms of both the Shannon's (Figure 4.34 C) and Simpson's diversity indices (Figure 4.34 D). There were only marginal differences between the Shannon's and Simpson's diversity index values for the domestic gardens and sidewalks. A one-way ANOVA was performed to determine if the land-use types sampled in Ikageng differed from one another based on the values of all the diversity indices (See Annexure C for ANOVA and Tukey results). The results were statistically significant ($p < 0.05$) and further post hoc testing was done. Tukey's HSD test for unequal sample size revealed that the domestic gardens differed significantly from the natural areas in terms of all the diversity indices (Margalef's species richness, Pielou's evenness, Shannon's and Simpson's diversity indexes) (Figure 4.34 A - D and Table C.7, Annexure C).

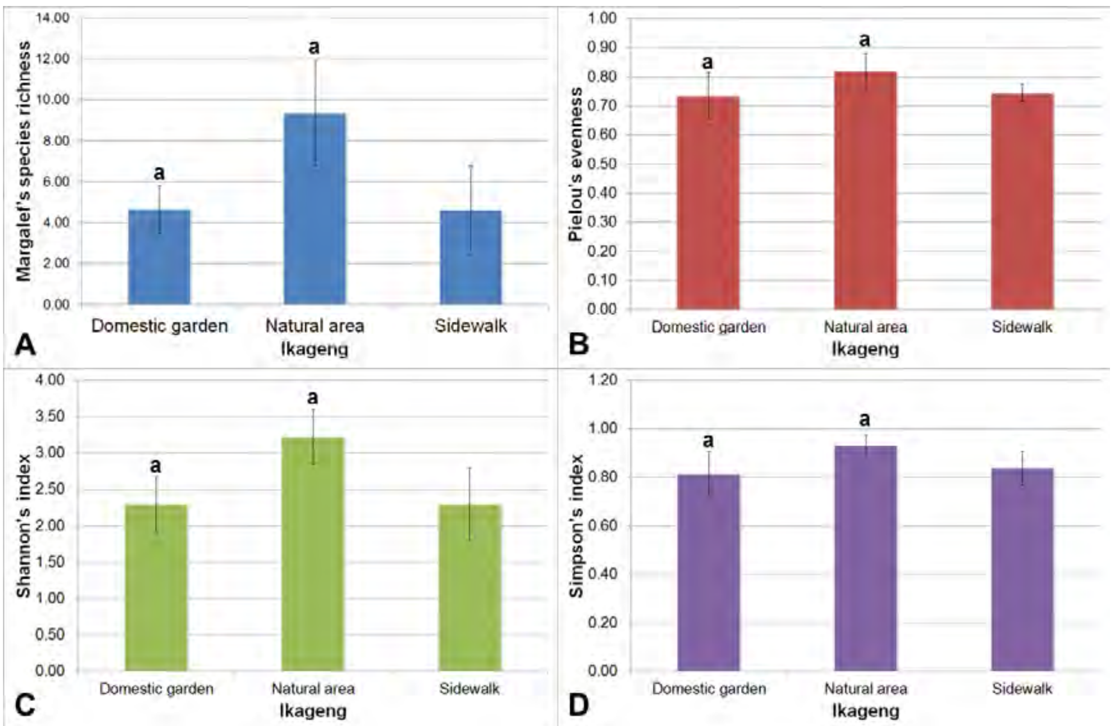

Figure 4.34: Mean values of the diversity indices and standard deviation for the different land-use types sampled in Ikageng: (A) Margalef's species richness index, (B) Pielou's evenness index (C), Shannon's index and (D) Simpson's index (the letters above the bars indicate which land-uses were significantly different from domestic gardens based on Tukey's (HSD) post-hoc test).

4.3.3.2.4 Potchefstroom

In Potchefstroom, the values of Margalef's species richness index revealed considerable variation between the different land-use types, ranging from 2.89 to 6.14 (Figure 4.35 A). The land-use with the highest species richness value was the road verges, while the institutional gardens had the lowest. In contrast, the values of Pielou's evenness index revealed marginal variations between the different land-use types, ranging from 0.62 to 0.75 (Figure 4.35 B). The domestic gardens had the highest evenness value, while the institutional gardens had the lowest. The road verges had the highest species diversity in terms of Shannon's diversity index (Figure 4.35 C), but the fragmented natural areas had the highest Simpson's diversity index value (Figure 4.35 D). For both the Shannon's and Simpson's diversity index values, the institutional gardens had the lowest species diversity. A one-way ANOVA was performed to determine if the land-use types sampled in Potchefstroom differed from one another based on the values of all the diversity indices (See Annexure C for ANOVA and Tukey results). The results were statistically significant ($p < 0.05$) and post hoc testing revealed that the domestic gardens differed significantly from the institutional gardens in terms of all the diversity indices (Margalef's species richness, Pielou's evenness, Shannon's and Simpson's diversity indexes) (Figure 4.35 A - D and Table C.8, Annexure C).

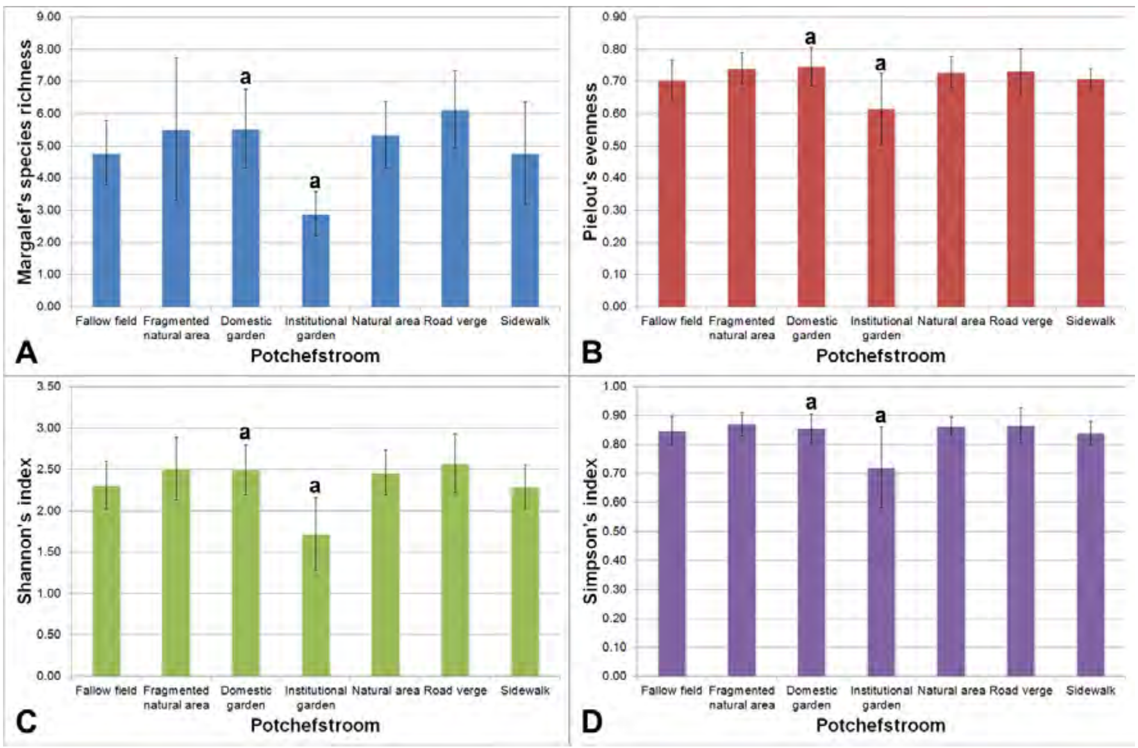

Figure 4.35: Mean values of the diversity indices and standard deviation for the different land-use types sampled in Potchefstroom: (A) Margalef's species richness index, (B) Pielou's evenness index (C), Shannon's index and (D) Simpson's index (the letters above the bars indicate which samples were significantly different from domestic gardens based on Tukey's (HSD) post-hoc test. See Annexure C for the rest of the results).

4.3.3.2.5 Roodepoort

In Roodepoort, the values of Margalef's species richness index revealed considerable variation between the different land-use types, ranging from 10.34 to 4.00 (Figure 4.36 A). The land-use with the highest species richness value was the natural areas, while the sidewalks had the lowest. Domestic gardens had the second highest species richness value (10.30). In contrast, the values of Pielou's evenness index revealed marginal variations between the different land-use types, ranging from 0.71 to 0.87 (Figure 4.36 B). The natural areas had the highest evenness value, while the sidewalks had the lowest. The natural areas had the highest species diversity in terms of Shannon's diversity index (Figure 4.36 C) and the Simpson's diversity index (Figure 4.36 D). For both the Shannon's and Simpson's diversity index values, the sidewalks had the lowest species diversity. To determine if the land-use types sampled in Roodepoort differed from one another based on the values of all the diversity indices, a one-way ANOVA was performed (See Annexure C for ANOVA and Tukey results). The results were statistically significant ($p < 0.05$) and post hoc testing revealed that the domestic gardens differed significantly from the road verges and sidewalks in terms of all the diversity indices (Margalef's species richness, Pielou's evenness, Shannon's and Simpson's diversity indexes) (Figure 4.36 A - D and Table C.9, Annexure C).

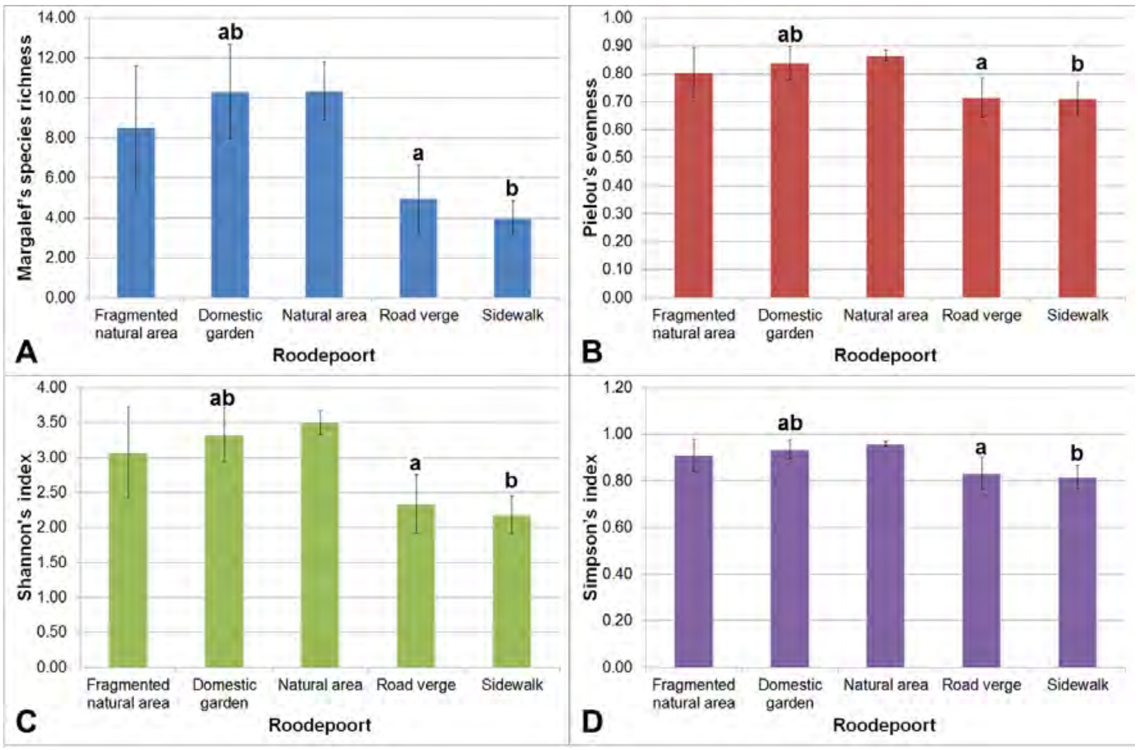

Figure 4.36: Mean values of the diversity indices and standard deviation for the different land-use types sampled in Roodepoort: (A) Margalef's species richness index, (B) Pielou's evenness index (C), Shannon's index and (D) Simpson's index (the letters above the bars indicate which samples were significantly different from the domestic gardens based on Tukey's (HSD) post-hoc test. See Annexure C for the rest of the results).

4.4 Discussion

4.4.1 Species diversity and composition of domestic gardens and other land-uses

Collectively, domestic gardens contributed more to the total, indigenous and alien species diversity sampled across all the studied settlements than any of the other land-use types. However, this could be because the domestic gardens were the dominant land-use type. These findings are consistent with those of several other studies, which reported that domestic gardens are species rich, the majority of which tends to be of alien origin (Loram *et al*., 2008a; Marco *et al*., 2008; Smith *et al*., 2006a). Thompson *et al*. (2003) found that gardens were more species rich and contained more alien species than any of the other community types selected (semi-natural and derelict land) for their study in Sheffield (UK). This can be attributed to the horticultural trade that promotes the import and cultivation of hardy alien species in gardens (Reichard and White, 2001).

The domestic gardens had a high beta diversity which indicates a high species turnover between the different sample plots. In Roodepoort 396 plant genera were represented by only one species in the domestic gardens, 320 in Potchefstroom, 217 in Ikageng, 209 in Ganyesa and 181 in Tlhakgameng. Smith et al. (2006c) reported that 490 species of the total 1166 species recorded in 61 gardens in Sheffield (UK) were only recorded once. Similarly, 52 of the total 274 ornamental plant species recorded in the gardens of Trabzon City (Turkey) were recorded only once, which indicates a high species turnover between gardens (Acar *et al*., 2007).

The species richness of the domestic gardens can be attributed to the large species pool available to gardeners (see Chapter 5), the active maintenance and management by gardeners (See Chapter 6), the financial resources that are available to more affluent gardeners (See Chapter 8) (Smith *et al*., 2006c) and the personal preferences of the homeowners. Loram *et al*. (2008a) found that domestic gardens made a considerable contribution to the species diversity and accumulated species richness across five cities in the UK compared to any other urban green space.

The natural areas had the second highest beta diversity. The natural areas were highly heterogeneous landscapes since they were located in several different vegetation units (see Chapter 3), as well as in two different provinces, which accounts for the high species richness and turnover between sample plots. Tlhakgameng and Ganyesa fall within the same vegetation unit (Mafikeng Bushveld), while Ikageng, Potchefstroom and Roodepoort are situated at the convergence of three different vegetation units, Andesite Mountain Bushveld, Carletonville Dolomite Grassland, and the Rand Highveld Grassland for Ikageng and Potchefstroom, and Egoli Granite Grassland, Gold Reef Mountain Bushveld, and Soweto Highveld Grassland for Roodepoort (Mucina and Rutherford, 2006).

Across all five settlements, the natural areas had the highest values for all the diversity indices, while domestic gardens had the second highest species richness and evenness values and the fragmented natural areas had the second highest species diversity values for both the Shannon's and Simpson's diversity indices. The natural areas sampled in Tlhakgameng and Ganyesa were very similar in their species composition since they fall within the same vegetation unit. Very few natural areas were sampled in Potchefstroom, which can be attributed to the fact that Potchefstroom is predominantly an agricultural town and most of the natural areas inside and in close proximity to the settlement were either disturbed fallow fields or fragmented natural areas. Roodepoort on the other hand, consists of ridges and valleys, in which development could not take place and these habitat types were therefore conserved (Pfab, 2002). Furthermore, the presence of the Walter Sisulu National Botanical Garden and the Kloofendal Nature Reserve (City of Johannesburg, 2003) in Roodepoort has greatly contributed to the protection of natural areas in this settlement and consequently aided their availability for sampling. Similarly, the close proximity of the proposed Highveld National Park (Daemane *et al*., 2010) west of Ikageng, has aided the protection of indigenous species and natural areas, as well as the availability of this land-use type for sampling.

4.4.2 Species diversity and composition of domestic gardens between settlements

Domestic gardens of the different settlements are also different from each other in terms of their species composition. The results of this study revealed that the species composition of the domestic gardens in Roodepoort were more similar to the domestic gardens in Potchefstroom than any of the other settlements, while the domestic gardens of Ikageng were similar to both those in Tlhakgameng and Ganyesa in one extent and Potchefstroom on the other. The domestic gardens in Ikageng are considered transitional gardens, since they contain garden characteristics that are similar to both gardens in Tlhakgameng and Ganyesa (tshimo gardens) and gardens in Potchefstroom and Roodepoort (westernised gardens) (Davoren *et al*., 2016).

Culture plays an important role in the species composition of gardens (Head *et al*., 2004). The gardens in Tlhakgameng and Ganyesa had a specific layout and function (Molebatsi *et al*., 2010), while the gardens in Potchefstroom and Roodepoort were formal, resembling those of European garden design styles, which favour species for ornamental purposes (Ignatieva and Stewart, 2009), that are readily available from local nurseries (Lubbe *et al*., 2011) (See Chapter

9). The study of Nemudzudzanyi *et al*. (2010) found that the residents in the rural settlement of Mbazwana still followed the traditional Zulu muzi garden design, while residents in the peri-urban settlement of Esikhawini in Kwazulu-Natal adopted a more westernised approach to gardening. Nevertheless, the species composition in gardens is not only influenced by cultural aspect, but also by social drivers such as the need for approval from neighbours or to fit into a community (Nassauer *et al*., 2009), the latest garden fashion trend (Kirkpatrick *et al*., 2013), gardening advice from books, garden clubs and magazines and education (Smith *et al*., 2006c), and the personal preference of the gardeners.

4.4.3 Species diversity and composition of land-use types within each settlement

The overall diversity of the five settlements gradually increased from rural to urban. Roodepoort had the highest total, indigenous and alien number of species. Similarly, Godefroid and Koedam (2007) recorded 702 plant species in Brussels, approximately half of the Belgian flora and Wania *et al*. (2006) found the total number of species in Central Germany was higher in the urban landscape than the agricultural landscape. According to Kent *et al*. (1999), “the greater the surface area of a city or town is, the more diverse its floristic composition”.

Different land-use types were identified and sampled in each settlement, but not all the land-use types were present in all the settlements, for example, parks were present in Ikageng, Potchefstroom, and Roodepoort but not in Tlhakgameng or Ganyesa, while others were present but not sampled due to the grid point sampling approach used in this study. Nowak *et al*. (1996) determined the proportion of city occupied by different land use types for US cities. Their study reported that on average residential areas comprise roughly 41 %, vacant land/wildland 24 %, commercial/industrial areas 13 %, institutional land 6 %, parks 5% and areas used for agriculture, orchards and transportation 12 % of the total surface area in US cities (Nowak *et al*., 1996). Hence, considering the above, non-garden land-uses were under-sampled in this study, which made an overall comparison weak.

Settlements were therefore considered separately, as land use types reflect the cultural, economic and historic changes in an urban area (Maurer *et al*., 2000). Both Tlhakgameng and Ganyesa were part of the former Bophuthatswana homeland (Tladi *et al*., 2002), while the implementation of the Group Areas Act of 1950 (Jansen van Rensburg, 2002) in Potchefstroom, led to the founding of townships (collectively referred to as Ikageng in this study). Roodepoort’s development, however, was greatly influenced by its proximity to Johannesburg and its topography, i.e. the occurrence of numerous ridges and valleys. According to Hope *et al*. (2006) “the history of a region can be crucial in explaining patterns in vegetation associations”. Clarke *et al*. (2013) reported that the tree diversity in Los Angeles, California (USA) was predominantly related to historical legacies.

In most of the settlements, the land-use type with the highest species diversity between sample plots was either the domestic gardens or the natural areas. In Tlhakgameng the domestic gardens had the highest species diversity, in Ganyesa, Ikageng and Roodepoort the natural areas, while in Potchefstroom the road verges had the highest species diversity. As mentioned before, there were very few natural areas in Potchefstroom and the road verges were the second most sampled land-use type, which may account for their high species diversity. Furthermore, road verges are highly disturbed patches of land and when neglected for long periods of time, they can sustain high abundances of species. In Tlhakgameng patches of natural veld are maintained (called naga) (Molebatsi *et al*., 2010), which contributes to their high species diversity. According to Molebatsi *et al*. (2010), these patches of natural veldt are maintained for grazing. In terms of evenness, the natural areas had the highest value in Ganyesa, Ikageng, and Roodepoort and the domestic gardens had the highest value in Tlhakgameng and Potchefstroom.

4.5 Conclusion

The aim of this chapter was to compare the species diversity and composition of domestic gardens and other land-use types, domestic gardens between settlements, and different land-use types within each of the settlements. Throughout the study the main focus was on domestic gardens and how they relate to other land-use types in terms of species diversity and composition. The results showed that the domestic gardens had a higher gamma diversity than the other land-use types, but natural areas had higher species richness, evenness and diversity values. Domestic gardens also had the highest percentage alien species, while natural areas had the highest percentage indigenous species. Alien ornamental species have a high probability of escaping gardens and colonizing the natural habitats surrounding settlements (Marco *et al*., 2010), which threaten the plant species richness and diversity of natural habitats.

The species composition of domestic gardens in urban and metropolitan settlements is more similar than the gardens in rural areas, while domestic gardens in peri-urban areas are a similar to both. The domestic gardens in peri-urban areas tend to adopt more westernised approaches to gardening (Nemudzudzanyi *et al*., 2010), as their financial wherewithal increases. The domestic gardens in Roodepoort had the highest gamma and beta diversity of all the settlements.

In all the settlements the domestic gardens had the highest gamma and beta diversity and consequently a higher turnover of species between sample plots. Within each of the settlements, the domestic gardens differed from the natural areas in terms composition and diversity. In conclusion, the contribution that domestic gardens make to settlements plant species diversity is similar to the contribution made by natural areas and therefore, domestic gardens are an important urban green space in South Africa.

However, in order to determine the true comparison between domestic gardens and other land-use types, equal amounts of all the land-use types need to be sampled. This is especially important considering the rate of urbanisation in South Africa. The United Nations (2014) projected that South Africa will be 77 % urban by 2050. Understanding the contribution that different land-use types make to the overall diversity of an urban or rural settlement will aid policy makers and municipal governments in properly managing these areas and ensuring the conservation of biodiversity in an urbanizing South Africa.

Chapter 5 - A floristic comparison of domestic gardens of five settlements along an urban-rural gradient

5.1 Introduction

According to Smith *et al*. (2005), “urbanisation is characterised by increased human population density and the development of commercial or industrial infrastructure”. Urbanisation causes local and global scale environmental problems, such as fragmenting or destroying natural habitats (McDonald *et al*., 2008; McKinney, 2006; McKinney, 2008), regional climate change (Golden, 2004), altering both the quality and flow of water (Alberti, 2008; Paul and Meyer, 2001) and changing the species composition (McDonald *et al*., 2008; McKinney, 2002; McKinney, 2006; McKinney, 2008) in urban areas. Urban green spaces play an important role in buffering the environmental changes caused by urbanisation (Smith *et al*., 2005) and one type of urban green space that has received increasing attention in terms of its contribution is domestic gardens (Gaston *et al*., 2005a).

On a global scale the combined areal coverage of domestic gardens is significant (Dewaelheyns *et al*., 2016; Gaston *et al*., 2005a; Smith *et al*., 2005; Thompson *et al*., 2003). Domestic gardens cover approximately 19 % of the Kirua Vunjo Division territory on Mount Kilimanjaro, Tanzania (Soini, 2005). In Merseyside (United Kingdom), the study of Pauleit *et al*. (2005) found that the cover of private gardens varied greatly, from approximately 43 % in Birkdale to only 6 % in Wavertree. Gaston *et al*. (2005a) estimated that domestic gardens in Sheffield (UK) covered approximately 23 % of the total urban land area, while 27.6 % of urban areas in Leicester are estimated to be covered by gardens (Owen, 1991). According to Colding *et al*. (2006) domestic gardens in the central part of Stockholm, Sweden, constitute 16.2% of the assessed land area. The total garden area in Flanders, which does not include the Brussels region, was calculated to be roughly 8.2 % (or 1,100 km^2) of the Flemish territory (Bomans *et al*., 2011). In Dunedin, New Zealand, 36 % of the total urban area and 46 % of the residential area is occupied by vegetated garden area (Mathieu *et al*., 2007).

However, the demand for housing continues to increase, even in highly urbanised areas (Loram *et al*., 2008a). This continued demand is a consequence of social trends, as well as the composition and size of human populations (Loram *et al*., 2008a). Current and future urban development should take the provisioning of urban green spaces (Loram *et al*., 2008a) and ecosystem services (Bolund and Hunhammar, 1999; Tzoulas *et al*., 2007) such as, the decrease of storm water runoff (Cameron *et al*., 2012), mitigation of the heat island effect (Skelhorn *et al*., 2014), air pollution removal (Pataki *et al*., 2011) and biodiversity conservation

(Gaston *et al*., 2005a; Daniels and Kirkpatrick, 2006a) into consideration. "Land sharing" and "land sparing" are two new approaches to solving the continued debate about urban development (Lin and Fuller, 2013; Stott *et al*., 2015). Both these frameworks take the provisioning of urban green space into consideration (Stott *et al*., 2015).

According to Gaston *et al*. (2005a), domestic gardens present both constraints and opportunities. On one hand, they are privately owned and consequently lie outside of the immediate control of the local government (Gaston *et al*., 2005a; Perry and Nawaz, 2008) and on the other hand, they have the potential to greatly contribute to biodiversity conservation (Gaston *et al*., 2005b; Smith *et al*., 2006c). The benefits of individual gardens most likely stem from them acting as components of a landscape that include other vegetation, as corridors through the urban matrix, or as isolated habitat patches (Smith *et al*., 2005). Domestic gardens are characterised by remarkably high levels of floristic diversity (Thompson *et al*., 2003), the occurrence of nationally and/or regionally scarce (Owen, 1991) and often endangered species and diverse wildlife populations (Gaston *et al*., 2005a; Owen, 1991). However, Smith *et al*. (2006a) stated that "quantified descriptions of the occurrence and abundance of individual plant taxa are required for understanding how garden floras may affect wildlife".

In recent years, several studies have attempted to describe the composition and distribution of garden floras. The general consensus is that gardens possess a rich floristic diversity (Akinnifesi *et al*., 2010a; Bigirimana *et al*., 2012; Loram *et al*., 2008a; Lubbe *et al*., 2011; Marco *et al*., 2008; Srithi *et al*., 2012). According to Thompson *et al*. (2003), this richness of garden floras can be attributed to two things, namely the size of the species pool available to gardeners and the active maintenance and management by gardeners (see Chapter 6). For instance, the Royal Horticultural Society (RHS) compiled a list of more than 70 000 plant species that are available from nurseries in the United Kingdom (RHS, 2015). Glen (2002) published a list of roughly 37 000 species of cultivated plants from southern Africa (Glen, 2002), compared with 19 581 species that are indigenous to South Africa (Germishuizen *et al*., 2006).

The aim of this chapter is to compare the floristic composition of domestic gardens in five different settlements (Tlhakgameng, Ganyesa, Ikageng, Potchefstroom, and Roodepoort). The specific objectives were to consolidate the data available for all five settlements (obtained from the studies of Davoren, 2009, Lubbe, 2011 and Molebatsi, 2011), and to analyze and describe the plant diversity present in domestic gardens. This was done by determining the species classification, the dominant families, genera and species, the endemic and red data status of species, species invasiveness, the origin of cultivated and naturalised alien species and of indigenous cultivated species, useful plants and growth forms. The analysis broadens our understanding of the contribution that domestic gardens make to the overall species composition of settlements and the potential that domestic gardens have to protect indigenous, endemic and threatened species in South Africa.

5.2 Methods

5.2.1 Vegetation sampling

The domestic garden surveys for Tlhakgameng were conducted in 2009 (Molebatsi, 2011), Ganyesa in 2008 (Davoren, 2009), Ikageng and Potchefstroom in 2009 (Lubbe, 2011) and Roodepoort in 2011. Topographic maps of each settlement were acquired and overlaid with grids of 500 x 500 m squares in ArcView 9 (Environmental System Research Institute (ESRI), 2006). Approximately 50 sample points (grid intersects) were chosen within the grid of each settlement, the coordinates were determined and the exact position of each point was located in the field with a Global Positioning System (GPS).

Roodepoort had 135 potential points of which 50 were sampled, Potchefstroom had 75 potential sample points of which 49 were sampled, Ikageng had 76 of which 51 were sampled, Ganyesa 141 of which 55 were sampled and Tlhakgameng 118 potential sample points of which 51 were sampled. The closest garden within a 150 m radius of each grid point was selected. In cases where access to the chosen site was denied, an adjacent garden was sampled. The data sets for all five settlements were consolidated into one large dataset consisting of 256 domestic gardens. In each garden, all plants were identified and noted, which provided presence-absence data for all sampled gardens.

5.2.2 Plant species identification

The identification of all plant species was done to species level, except in cases where it was possible to distinguish between subspecies and varieties. Literature was consulted to identify the species present in the gardens: grasses (Van Oudtshoorn, 2012), weeds (Bromilow, 2010), wildflowers (Van Wyk and Malan, 1998), food plants (Van Wyk, 2005), indigenous plants (Joffe and Oberholzer, 2012) and garden plants (Glen, 2002; Kirsten, 2007; Lancaster, 2010; Pienaar, 1994; Pienaar and Smith, 2011; Smith and Van Wyk, 2008). The accepted scientific name for each species was determined with Germishuizen *et al.* (2006) and the international plant names index (IPNI, 2012). After the initial identification was completed, the species were further categorised as indigenous cultivated, native, alien cultivated or naturalised. This classification is based on the study of Lubbe (2011) and was compiled with the aid of Germishuizen *et al.* (2006):

- Indigenous cultivated: indigenous to South Africa and not occurring naturally within the study area but cultivated in gardens;
- Native: indigenous to South Africa and occurring naturally within the study area (usually not cultivated);
- Naturalised: not indigenous to South Africa, but occurring in the study area where it sustains self-replacing populations outside of cultivation without direct intervention by people (include declared alien invasive species according to South African legislation (National Environmental Management: Biodiversity Act (NEMBA) (South Africa, 2014));
- Alien cultivated: not indigenous to South Africa and not naturalised in the study area but cultivated in gardens (includes garden hybrid species).

After the initial classification, the species data were further augmented with information on endemism, red data list status, invasiveness, the origin of cultivated and naturalised alien species, origin of indigenous cultivated species, plant uses and growth forms. The species list was cross-referenced with the South African Red Data List of plants (SANBI, 2014) to determine if any endangered or threatened species were present in the sampled domestic gardens. Invasive species were identified from the list of alien weeds and invaders compiled by the Department of Environmental affairs (South Africa, 2014), based on South African national legislation (National Environmental Management: Biodiversity Act (Act No. 10 of 2004)).

Data on endemism, growth form and the distribution patterns of indigenous species were obtained from Germishuizen *et al.* (2006). The distribution patterns were determined by grouping provinces based on their floristic composition to obtain the chosen geographic regions of origin for al indigenous cultivated species. The uses of cultivated species and the origin of cultivated alien and naturalised species were determined from the literature (Bromilow, 2010; Glen, 2002; Kirsten, 2007; Pienaar and Smith, 2011; Smith and Van Wyk, 2008; Van Wyk, 2005; Van Wyk and Gericke, 2000; Van Wyk *et al.*, 1997). Cultivated species in the domestic gardens were classified as ornamental, medicinal, food, shade, windbreak or hedge based on their uses. Several species had more than one use, but only the main use was classified to avoid counting certain species more than once.

5.3 Results

5.3.1 Species composition

In this study, a total of 1524 species were recorded in 256 gardens. The total was made up of 1134 species recorded in Roodepoort, 754 in Potchefstroom, 413 in Ikageng, 387 in Ganyesa and 390 in Tlhakgameng. Roodepoort had the highest percentage of indigenous cultivated species (28 %) and Ikageng had the lowest (14 %) (Figure 5.1). Tlhakgameng had the highest percentage of native species (34 %), while Potchefstroom had the lowest percentage (9 %). Potchefstroom had the highest percentage of alien cultivated species (59 %) and Tlhakgameng had the lowest percentage (39 %). Ikageng had the highest percentage of naturalised species (18 %) and Roodepoort had the lowest percentage (7 %).

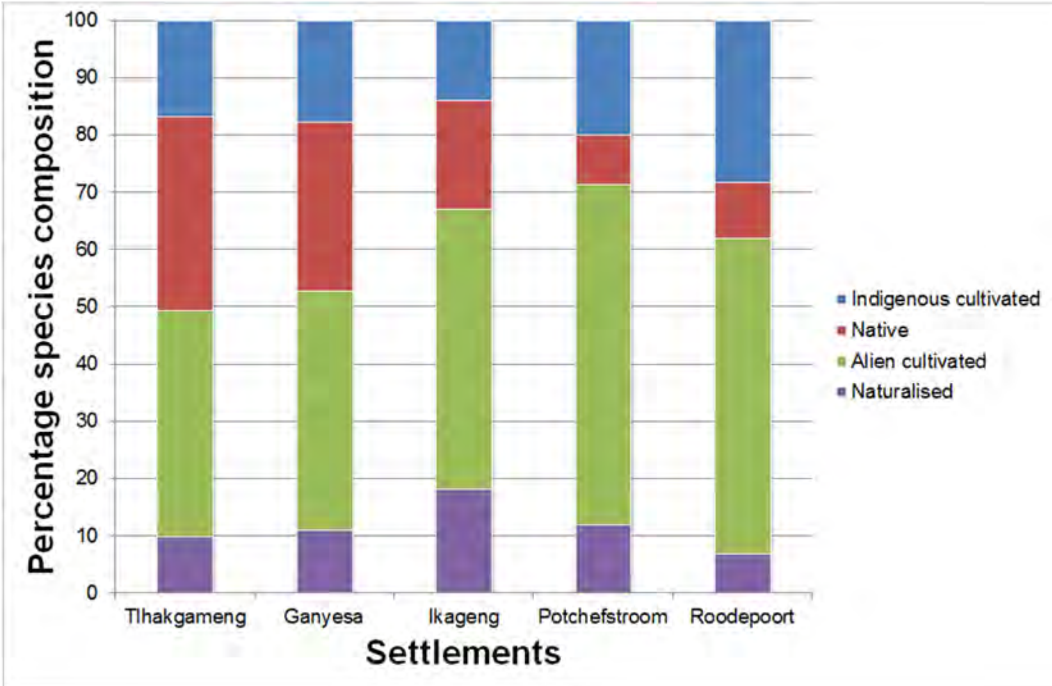

Figure 5.1: The percentage composition of indigenous cultivated, native, alien cultivated and naturalised species for all five settlements.

5.3.2 Plant families

A total of 161 plant families were recorded in Roodepoort, 145 in Potchefstroom, 102 in Ikageng, 98 in Ganyesa and 90 in Tlhakgameng. However, in Roodepoort 50 families (31 %) were represented by only a single species, likewise in Potchefstroom 55 families (38 %), in Ikageng 43 families (42 %), in Ganyesa 45 families (46 %) and in Tlhakgameng 36 families (40 %). The twenty most diverse families represent 55 % of the total number of species recorded in Roodepoort (625 species), in Potchefstroom 53 % (400 species), in Ikageng 60 % (248 species), in Ganyesa 63 % (244 species) and in Tlhakgameng 64 % (249 species) (Table 5.1). This diversity was determined by the number of species recorded for each family, regardless of their frequency of occurrence in each settlement. Ten of the 20 most diverse families in Roodepoort were also on the list of the largest plant families in South Africa, in Potchefstroom and Tlhakgameng nine, in Ikageng eight and in Ganyesa seven (Von Staden *et al*., 2013). The Asteraceae, Fabaceae, Poaceae and Apocynaceae families were amongst the twenty most diverse families of all five settlements and are also present on the list of largest plant families in South Africa.

Table 5.1: Twenty most diverse plant families present in the domestic gardens of all five settlements (T: Tlhakgameng, G: Ganyesa, I: Ikageng, P: Potchefstroom, and R: Roodepoort), the number of species in each family and percentage of the total number of species. Superscript enumerators indicate a family's position on the list of the largest plant families in South Africa (Von Staden *et al*., 2013).

Family name		**T**		**G**		**I**		**P**		**R**	
	Tot. No. sp.	**No. sp.**	**%**	**No. sp.**	**%**	**No. sp.**	**%**	**No. sp.**	**%**	**No. sp.**	**%**
Asteraceae[1]	136	55	14	50	13	52	13	66	9	92	8
Fabaceae[3]	92	38	10	32	8	11	3	33	4	54	5
Poaceae[7]	82	25	6	32	8	33	8	44	5	43	4
Crassulaceae[16]	62	11	3	11	3	7	2	21	3	58	5
Lamiaceae	57	11	3	10	3	12	3	33	4	43	4
Cactaceae	51	11	3	7	2			17	2	45	4
Rosaceae	42	8	2	10	3	16	4	33	4	37	3
Solanaceae	40	12	3	15	4	18	4	25	3	26	2
Asphodelaceae[9]	37	6	2	9	2	9	2	14	2	32	3
Mesembryanthemaceae	30	11	3	6	2			10	1	19	2
Euphorbiaceae[13]	29					7	2			26	2
Malvaceae[17]	26	9	2			9	2	12	2	17	1
Apocynaceae[8]	24	5	1	6	2	9	2	11	1	20	2
Scrophulariaceae[6]	24							12	2	17	1
Amaryllidaceae	23	6	2	7	2	11	3	11	1	15	1
Iridaceae[4]	23							11	1	21	2
Myrtaceae	20			6	2					17	1
Hyacinthaceae[11]	21	7	2	8	2						
Brassicaceae	19					10	2	9	1	14	1
Convolvulaceae	17					6	1				
Oleaceae	16			6	2			10	1	14	1
Proteaceae	16									15	1
Amaranthaceae	15	8	2	7	2	8	2	9	1		
Araceae	15			5	1	6	1	12	2		
Cyperaceae[12]	15	5	1								
Agavaceae	14	5	1	5	1	6	2				
Commelinaceae	11					6	1				
Cucurbitaceae	10	5	1	6	2						
Chenopodiaceae	8	5	1	6	2	6	1				
Portulacaceae	8	6	2								

5.3.3 Dominant genera

A total of 611 plant genera were recorded in Roodepoort, 470 in Potchefstroom, 293 in Ikageng, 281 in Ganyesa and 262 in Tlhakgameng. In Roodepoort 396 (65 %) plant genera were represented by only one species, 320 (68 %) in Potchefstroom, 217 (74 %) in Ikageng, 209 (74 %) in Ganyesa and 181 (69 %) in Tlhakgameng. The ten most diverse genera contained 12 % of the total number of recorded species in Roodepoort, Ikageng, and Tlhakgameng (Table 5.2). In Potchefstroom, the ten most diverse genera represented 9 % and in Ganyesa 11 % of the total number of recorded species. The genus *Aloe* was amongst the top five most diverse genera for all five settlements, while *Eragrostis*, *Euphorbia*, *Kalanchoe*, *Plectranthus*, *Salvia* and *Senecio* were amongst the ten most diverse genera for three out of five settlements.

Table 5.2: The ten most diverse genera of domestic gardens in all five settlements and the number of species representing each.

Genera	**Number of Species**					
	Total no. of genera	Tlhakgameng	Ganyesa	Ikageng	Potchefstroom	Roodepoort
Aloe	23	5	5	6	8	21
Euphorbia	18	4	4	4		16
Crassula	18					18
Kalanchoe	13	5	4			12
Eragrostis	13	4	4	7		
Solanum	13			7	10	
Senecio	12	6	5			12
Plectranthus	12		5		7	11
Asparagus	11	4		4	7	
Cyperus	11	4			6	
Mammillaria	11					10
Ipomoea	10			4		
Salvia	10			4	7	10
Prunus	9				6	9
Pelargonium	9					9
Begonia	8				5	
Indigofera	7	5				
Agave	7	4	3			
Opuntia	7		4			
Tradescantia	7			4	6	
Amaranthus	6	4	3	4		
Cestrum	6				5	
Rosa	5			4		
Portulaca	4		4			

5.3.4 Dominant species

Frequently recorded plant species were defined as those present in more than half of the sampled gardens in all five settlements (Table 5.3). The most dominant species for all the settlements were grasses. In Roodepoort, Potchefstroom and Ikageng it was *Pennisetum clandestinum* and in Ganyesa and Tlhakgameng it was *Cynodon dactylon*. *Pennisetum clandestinum* is the most favoured lawn grass in domestic gardens and *Cynodon dactylon* is a hardy indigenous species with a widespread distribution in South Africa. *Cynodon dactylon* was amongst the ten most frequently recorded species in all five settlements, but it is often regarded as a weed species in South Africa (Bromilow, 2010).

In Roodepoort and Potchefstroom, *Agapanthus praecox* and *Chlorophytum comosum* were the most frequently cultivated herbaceous species, while *Conyza bonariensis* and *Oxalis corniculata* were the most frequently recorded naturalised herbaceous species. *Prunus persica* was the most cultivated species in Ganyesa and Tlhakgameng and *Guilleminea densa* was the most frequent naturalised herbaceous species. In Ikageng *Conyza bonariensis*, *Guilleminea densa* and *Portulaca oleracea* were the most frequently occurring naturalised species. *Agapanthus praecox* and *Chlorophytum comosum* are popular garden plants in South Africa (Pienaar and Smith, 2011). *Conyza bonariensis*, *Guilleminea densa*, *Oxalis corniculata* and *Portulaca oleracea* all have a widespread distribution in South Africa (Germishuizen *et al.*, 2006). In Tlhakgameng and Ganyesa the most frequently recorded species were native, in Ikageng and Potchefstroom they were naturalised and in Roodepoort cultivated. In all five settlements, the best-represented plant family was the Poaceae.

5.3.5 Endemic species

A total of 152 South African endemic species were recorded in the domestic gardens of all five settlements (131 in Roodepoort, 56 in Potchefstroom, 23 in Ikageng, 22 in Ganyesa and 24 in Tlhakgameng). However, 95 endemic species (62.5 %) were recorded in 10 % or less of the domestic gardens and 57 species (37.5 %) were found only once. Four of the 152 endemic species were native and the remaining 148 species were cultivated. *Agapanthus praecox*, *Aptenia cordifolia*, *Crassula ovata*, *Euryops chrysanthemoides*, *Lampranthus roseus*, *Portulaca grandiflora* and *Tulbaghia simmleri* were the most commonly cultivated endemic species since they were recorded in all five settlements (Table 5.4).

Carpobrotus edulis was the most cultivated endemic species in Tlhakgameng, *Portulaca grandiflora* in Ganyesa and *Agapanthus praecox* in Ikageng, Potchefstroom and Roodepoort.

Carpobrotus edulis and *Portulaca grandiflora* are both hardy succulents and *Agapanthus praecox* is a very popular garden plant in South Africa (Pienaar and Smith, 2011). *Gnaphalium nelsonii* and *Sida spinosa* were the most common native species but are generally considered to be weeds in gardens (Pienaar, 1994; Germishuizen *et al.*, 2006).

Table 5.3: Ten most frequently recorded species in the domestic gardens of all five settlements (T: Tlhakgameng, G: Ganyesa, I: Ikageng, P: Potchefstroom, and R: Roodepoort), as well as their families, status and the percentage of gardens in which they were recorded (* indicates alien species).

			Percentage plots					
Species	**Families**	**Status**	T	G	I	P	R	Total
Cynodon dactylon	Poaceae	Native	100	95	90	78	76	88
*Pennisetum clandestinum**	Poaceae	Cultivated			98	100	100	58
*Guilleminea densa**	Amaranthaceae	Naturalised	94	82	75			51
Eragrostis lehmanniana	Poaceae	Native	86	73	80			49
*Conyza bonariensis**	Asteraceae	Naturalised			75	78	82	46
*Oxalis corniculata**	Oxalidaceae	Naturalised				98	98	38
*Dichondra micrantha**	Convolvulaceae	Naturalised				100	90	37
Agapanthus praecox	Agapanthaceae	Cultivated				78	90	32
*Schkuhria pinnata**	Asteraceae	Naturalised	78	76				32
*Chenopodium carinatum**	Chenopodiaceae	Naturalised	82	67				31
*Euphorbia prostrata**	Euphorbiaceae	Naturalised			73	86		31
Chlorophytum comosum	Anthericaceae	Cultivated				76	82	30
*Prunus persica**	Rosaceae	Cultivated	71	71				29
Sida cordifolia	Malvaceae	Native	75	67				29
Mollugo cerviana	Molluginaceae	Native		82				18
Portulaca quadrifida	Portulacaceae	Native	86					17
Cotula australis	Asteraceae	Native					80	16
*Poa annua**	Poaceae	Naturalised				82		16
*Portulaca oleracea**	Portulacaceae	Naturalised			78			16
*Rosa chinensis**	Rosaceae	Cultivated				84		16
Clivia miniata	Amaryllidaceae	Cultivated					76	15
*Philodendron selloum**	Araceae	Cultivated					78	15
Urochloa panicoides	Poaceae	Native			75			15
*Alternanthera pungens**	Amaranthaceae	Naturalised			71			14
*Bidens bipinnata**	Asteraceae	Naturalised			71			14
Bulbine abyssinica	Asphodelaceae	Native	69					14
Felicia muricata	Asteraceae	Native	73					14
Chloris virgate	Poaceae	Native		58				13
*Verbesina encelioides**	Asteraceae	Naturalised		62				13

Table 5.4: The twenty most frequently recorded South African endemic species present in the domestic gardens of all five settlements based on their percentage of occurrence (T: Tlhakgameng, G: Ganyesa, I: Ikageng, P: Potchefstroom, and R: Roodepoort).

Species	**Status**	**% Plots**				
		T	G	I	P	R
Agapanthus praecox	Cultivated	2	5	24	75	90
Aptenia cordifolia	Cultivated	10	9	10	12	38
Carpobrotus edulis	Cultivated	27			2	24
Crassula ovate	Cultivated	4	9	14	24	58
Cyperus textilis	Cultivated	10	9		22	6
Dietes bicolor	Cultivated			2	20	38
Dietes grandiflora	Cultivated				10	58
Euryops chrysanthemoides	Cultivated	4	2	4	27	22
Gnaphalium nelsonii	Native		29	2	8	2
Lampranthus aureus	Cultivated		11	2	4	12
Lampranthus roseus	Cultivated	6	16	10	10	40
Pelargonium peltatum	Cultivated			2	14	46
Podocarpus henkelii	Cultivated			2	2	24
Portulaca grandiflora	Cultivated	20	33	18	35	24
Ruschia perfoliata	Cultivated	14	15			
Sida spinosa	Native	4		43	10	4
Strelitzia alba	Cultivated				24	12
Strelitzia reginae	Cultivated				18	58
Tulbaghia simmleri	Cultivated	4	29	14	29	34
Tulbaghia violacea	Cultivated	10		33	25	40

5.3.6 Red data species

A total of 55 species which have a conservation status based on the criteria of the South African National Red Data List (SANBI, 2014), were recorded in the domestic gardens of all five settlements (49 in Roodepoort, 21 in Potchefstroom, 10 in Ikageng and Ganyesa, 8 in Tlhakgameng). This total consists of 25 species threatened with extinction (8 endangered and 17 vulnerable) (Table 5.5), 30 species that have the potential to become threatened (10 declining, 7 rare, 2 critically rare and 11 near threatened) (Table 5.6). *Clivia miniata* (vulnerable) and *Dietes bicolor* (rare) were the most commonly cultivated and *Vachellia erioloba* (declining) and *Gnaphalium nelsonii* (rare) the most frequently recorded native species.

Seventeen species were recorded only once, 16 of which were actively cultivated. The majority of the recorded endangered species occurred in Potchefstroom (3) and Roodepoort (6), but no endangered species were recorded in Tlhakgameng or Ikageng. There were no rare species recorded in Tlhakgameng and both critically rare species only occurred in Roodepoort. *Drimia sanguinea* was the only near threatened species that occurred in both Tlhakgameng and Ganyesa and *Haworthia fasciata* was the only one recorded in Ikageng.

Table 5.5: Species recorded in the domestic gardens of all five settlements that are listed on the South African National Red Data List as threatened (SANBI, 2014) and their number of occurrence in each settlement (T: Tlhakgameng, G: Ganyesa, I: Ikageng, P: Potchefstroom, and R: Roodepoort).

Settlement:		**Number of occurrences in each settlement**				
Species	**National status**	**T**	**G**	**I**	**P**	**R**
Begonia dregei	Endangered					2
Begonia homonyma	Endangered				3	
Encephalartos eugene-maraisii	Endangered					1
Encephalartos horridus	Endangered				1	2
Encephalartos lebomboensis	Endangered				1	
Faucaria tigrina	Endangered					2
Glottiphyllum regium	Endangered					2
Haworthia attenuata **var**. *attenuata*	Endangered		1			7
Aloe brevifolia	Vulnerable				1	
Babiana rubrocyanea	Vulnerable					1
Clivia miniata **var**. *miniata*	Vulnerable		1	4	23	38
Cotyledon tomentosa **subsp**. *tomentosa*	Vulnerable		6			1
Crinum moorei	Vulnerable			3	2	7
Crocosmia masoniorum	Vulnerable					8
Encephalartos altensteinii	Vulnerable					1
Gymnosporia bachmannii	Vulnerable					2
Kalanchoe longiflora	Vulnerable	3				1
Lampranthus aureus	Vulnerable		6	1	2	6
Lampranthus glaucus	Vulnerable	1	1		2	
Plectranthus praetermissus	Vulnerable					4
Podranea ricasoliana	Vulnerable				2	12
Protea longifolia	Vulnerable					2
Stangeria eriopus	Vulnerable					1
Thamnochortus pellucidus	Vulnerable					1
Zantedeschia pentlandii	Vulnerable			2	3	5

Endangered: A species is Endangered when the best available evidence indicates that it meets at least one of the five IUCN criteria for Endangered, indicating that the species is facing a very high risk of extinction; **Vulnerable**: A species is Vulnerable when the best available evidence indicates that it meets at least one of the five IUCN criteria for Vulnerable, indicating that the species is facing a high risk of extinction (SANBI, 2014).

Table 5.6: Species recorded in the domestic gardens of all five settlements that are listed on the South African National Red Data List as near threatened (SANBI, 2014) and their number of occurrence in each settlement (T: Tlhakgameng, G: Ganyesa, I: Ikageng, P: Potchefstroom, and R: Roodepoort).

Settlement:		**Number of occurrences in each settlement**				
Species	**National status**	**T**	**G**	**I**	**P**	**R**
Ansellia africana	Declining					1
Boophone disticha	Declining	4	8			
Crinum bulbispermum	Declining	4		2	4	8
Crinum macowanii	Declining				2	1
Eucomis autumnalis	Declining	1		3	3	5
Hypoxis hemerocallidea	Declining	2	3	2		2
Ilex mitis **var**. *mitis*	Declining					1
Phylica plumose	Declining					1
Rapanea melanophloeos	Declining					1
Vachellia erioloba	Declining	12	13		1	2
Crassula streyi	Rare					1
Dietes bicolor	Rare			1	10	19
Euphorbia grandialata	Rare					2
Freylinia tropica	Rare				2	4
Gnaphalium nelsonii	Rare		16	1	4	1
Nerine bowdenii	Rare					1
Pelargonium citronellum	Rare					2
Crassula arborescens **subsp**. *undulatifolia*	Critically Rare					1
Lampranthus coccineus	Critically Rare					4
Afrolimon capense	Near Threatened					1
Cotyledon orbiculata **var**. *flanaganii*	Near Threatened					1
Drimia sanguinea	Near Threatened	17	1			
Encephalartos ferox	Near Threatened					2
Encephalartos friderici–guilielmi	Near Threatened					5
Encephalartos natalensis	Near Threatened				2	1
Gasteria batesiana	Near Threatened					2
Haworthia fasciata	Near Threatened			4	3	1
Leucospermum cordifolium	Near Threatened					4
Nemesia strumosa	Near Threatened				2	4
Pelargonium reniforme	Near Threatened				1	2
Protea compacta	Near Threatened					1

Near Threatened: A species is Near Threatened when available evidence indicates that it nearly meets any of the IUCN criteria for Vulnerable, and is therefore likely to become at risk of extinction in the near future; **Critically Rare**: A species is Critically Rare when it is known to occur at a single site, but is not exposed to any direct or plausible potential threat and does not otherwise qualify for a category of threat according to one of the five IUCN criteria; **Rare**: A species is Rare when it meets at least one of four South African criteria for rarity, but is not exposed to any direct or plausible potential threat and does not qualify for a category of threat according to one of the five IUCN criteria; **Declining**: A species is Declining when it does not meet or nearly meet any of the five IUCN criteria and does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened, but there are threatening processes causing a continuing decline of the species (SANBI, 2014).

5.3.7 Invasive species

In contrast to the ability of domestic gardens to protect both rare and endemic species, they also have the potential to promote the occurrence of invasive alien species. A total of 139 weeds and invaders were recorded in the studied settlements, 93 Category 1 declared weeds, 12 Category 2 and 34 Category 3 declared invaders (South Africa, 2014). Roodepoort had the highest number Category 1, 2 and 3 declared weeds and invaders. Ikageng had the lowest number Category 1 declared weeds, Ganyesa the lowest Category 2 declared invaders and Tlhakgameng had the lowest Category 3 declared invaders (Table 5.7). There were no Category 2 declared invaders recorded in Ikageng. There were more Category 1 declared weeds recorded in all five settlements than Category 2 and 3 declared invaders.

Canna indica, *Catharanthus roseus*, *Ipomoea purpurea*, *Nerium oleander*, *Pennisetum clandestinum* and *Sambucus nigra*, Category 1 declared weeds, were recorded in all five settlements (Table 5.8). *Nerium oleander* had the highest number of occurrences in Tlhakgameng and Ganyesa and *Pennisetum clandestinum* in Ikageng, Potchefstroom and Roodepoort. *Pennisetum clandestinum* is a popular lawn species in South Africa (Pienaar and Smith, 2011). *Casuarina cunninghamiana*, a Category 2 declared invader, was present in three of the five settlements, but occurred predominantly in Tlhakgameng and Ganyesa. *Acacia melanoxylon* was the dominant Category 2 species in Potchefstroom and *Passiflora edulis* in Roodepoort. *Morus alba* was the highest occurring Category 3 declared invader. It was present in all five settlements, but occurred predominantly in four of the five settlements. *Ligustrum lucidum* was the dominant Category 3 species in Ikageng and Potchefstroom and *Nephrolepis exaltata* in Roodepoort.

Table 5.7: The three categories of invasiveness and the total number of species in each settlement.

	Tlhakgameng	Ganyesa	Ikageng	Potchefstroom	Roodepoort
Category 1 declared weed	36	39	28	58	72
Category 2 declared invader	4	3	0	4	6
Category 3 declared invader	9	15	12	26	31

Table 5.8: The three categories of invasiveness and the most dominant species in each settlement (T: Tlhakgameng, G: Ganyesa, I: Ikageng, P: Potchefstroom, and R: Roodepoort). The total number of species for each category is indicated in brackets (* indicates alien species).

	Number of occurrences in each settlement				
Category 1: Declared weeds (93)	T	G	I	P	R
*Pennisetum clandestinum**	7	13	50	49	50
*Nerium oleander**	24	24	3	14	10
*Catharanthus roseus**	16	13	14	11	12
*Ipomoea purpurea**	2	5	16	19	15
*Canna indica**	10	22	2	12	6
*Vinca major**		1	6	22	23
*Duchesnea indica**			1	21	28
*Malvastrum coromandelianum**			18	24	
*Sambucus nigra**	12	20	1	3	4
*Arundo donax**	14	22	1	2	
*Prosopis glandulosa**	18	15		1	
Category 2: Declared invaders (12)					
*Casuarina cunninghamiana**	11	16		1	
*Acacia melanoxylon**				5	6
Atriplex nummularia **subsp.** *nummularia**	5	6			
*Passiflora edulis**					7
*Ricinus communis**				1	2
*Acacia dealbata**					2
Category 3: Declared invaders (34)					
*Morus alba**	30	23	1	24	23
*Ligustrum lucidum**	1	5	29	34	22
*Nephrolepis exaltata**		3	3	29	37
*Hedera helix**		2	1	30	35
*Callistemon citrinus**	3	5	1	12	28
*Melia azedarach**	18	9	4	6	7

Category 1 declared weed: are prohibited in South Africa and must be controlled; **Category 2 declared invader**: cultivation only permitted under controlled conditions in demarcated areas, trading only with permits; **Category 3 declared invader**: may no longer be cultivated or traded (South Africa, 2014).

5.3.8 Geographical regions of origin for indigenous cultivated species

In Roodepoort, 320 (28 %) of the total number of species were classified as indigenous cultivated, in Potchefstroom 151 (20 %), in Ikageng 58 (14 %), in Ganyesa 69 (18 %) and in Tlhakgameng 66 species (17 %) (Germishuizen *et al*., 2006). Figure 5.2 illustrates the percentage composition of indigenous cultivated species, grouped according to their geographical regions of origin in South Africa. The species that originated from the southeastern region (Eastern Cape and KwaZulu-Natal) and those with a widespread distribution contributed the most to the indigenous cultivated garden flora (more than 40 % in all five settlements). Widespread species have fewer specific environmental preferences and were considered as such if they occurred in more than eight of the regions specified in Germishuizen *et al*. (2006).

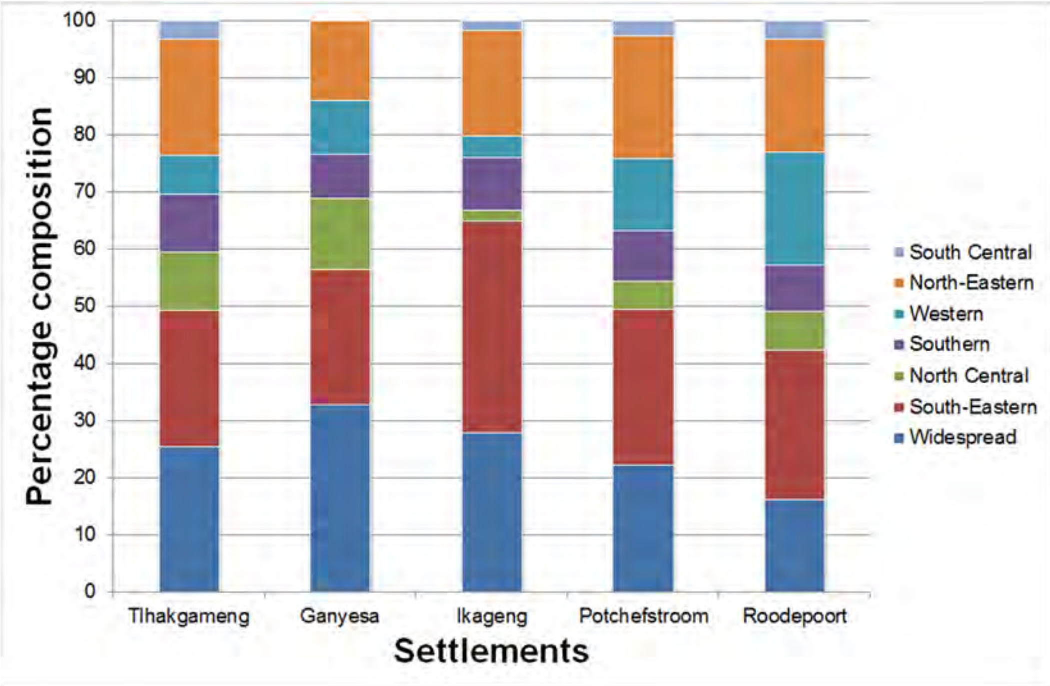

Figure 5.2: Percentage of the composition of the main geographical regions of origin for the indigenous cultivated species recorded in the domestic gardens of all five settlements. South Central (Free State; Lesotho), North Central (North West; Limpopo; Botswana), Western (Western Cape; Northern Cape; Namibia), Southern (Western Cape; Eastern Cape), North-eastern (Mpumalanga; Gauteng; Swaziland), South-eastern (KwaZulu-Natal; Eastern Cape). Widespread species were defined as occurring naturally in eight or more regions (Based on the study of Lubbe, 2011).

5.3.9 Origin of cultivated and naturalised alien species

In total, 876 naturalised and cultivated alien species were recorded for all five settlements, but for 12 of these species no information was available regarding their region of origin and 37 species originated from more than one region. The remaining 827 species were grouped according to regions of common origin and divided based on their occurrence in each settlement (Figure 5.3). The majority of naturalised and cultivated alien species recorded for all five settlements originated from the Americas (North, South and/or Central America) (in Roodepoort and Potchefstroom 43 %, in Ikageng 45 %, in Ganyesa 52 % and in Tlhakgameng 53 %). The second largest contributor to all recorded naturalised and cultivated alien species was Asia, with 20 % or more species in each settlement. Europe was the third largest contributor, with approximately 10 % or more species in four of the five settlements.

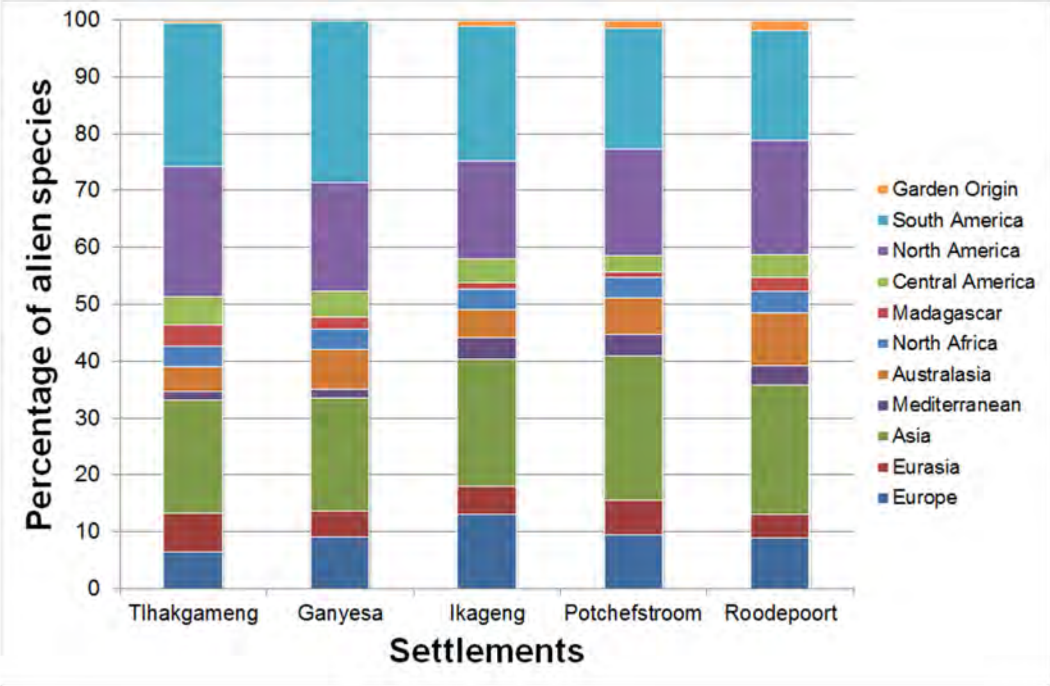

Figure 5.3: Percentage composition of the regions of origin of cultivated and naturalised alien species recorded in the domestic gardens of all five settlements.

5.3.10 Useful plants

The majority of plants cultivated in the domestic gardens of all studied settlements were for ornamental purposes. In Roodepoort, 79 % of all recorded species were ornamental, in Potchefstroom 71 %, in Ikageng 62 %, in Ganyesa 46 %, and in Tlhakgameng 47 % (Figure 5.4). In Tlhakgameng and Ganyesa more than 40 % of all cultivated species were for medicinal or food purposes, in Ikageng 31 % and in Roodepoort and Potchefstroom less than 20 %. In all five settlements shade, hedge and windbreak species accounted for 12 % or less of the total number of species recorded in each settlement.

In Tlhakgameng, Ganyesa, Ikageng and Potchefstroom, *Prunus persica* was the most cultivated fruit tree species, while in Roodepoort, *Citrus limon* and *Morus alba* were the most frequently cultivated (Table 5.9). *Zea mays* was the most cultivated grain species and *Alocasia macrorrhizos* the most cultivated tuber. The most cultivated medicinal species in Potchefstroom and Roodepoort was *Zantedeschia aethiopica*. In Ikageng, *Euphorbia inaequilatera* was the most common medicinal specie, but this species is native to the area and is not actively cultivated. In Tlhakgameng and Ganyesa, *Schkuhria pinnata* was the most common medicinal specie, but this species has naturalised in the area and is not actively cultivated. The most cultivated ornamental species in Potchefstroom and Roodepoort was *Agapanthus praecox*, in Ikageng *Rosa chinensis* and in Tlhakgameng and Ganyesa *Nerium oleander*.

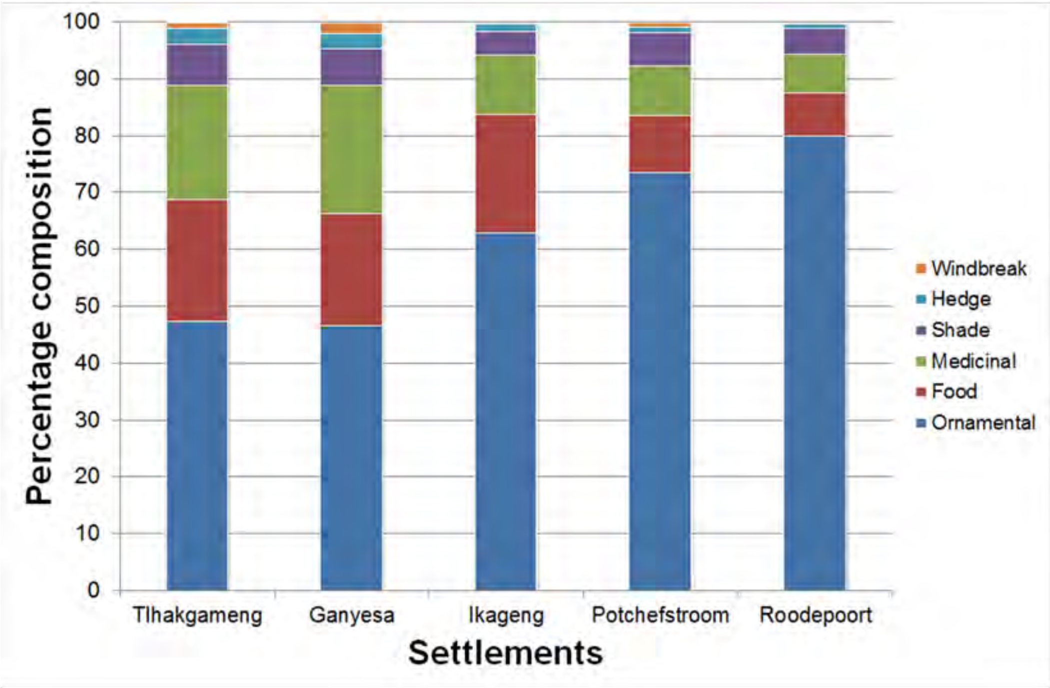

Figure 5.4: Percentage composition of species categorised into groups of plant uses based on relevance to gardening and cultivation in all five settlements.

Table 5.9: The most frequently recorded food, medicinal and ornamental species and their number of occurrence in each settlement (T: Tlhakgameng, G: Ganyesa, I: Ikageng, P: Potchefstroom, and R: Roodepoort).

		T	G	I	P	R
Food fruit tree	*Citrus limon**	19				23
Food fruit tree	*Morus alba* **var**. *alba**					23
Food fruit tree	*Prunus persica**	36	39	30	26	
Food grain	*Urochloa panicoides*			38	28	
Food grain	*Zea mays**	24	32			
Food leafy vegetable	*Portulaca oleracea**	33	23	40	29	
Food tubers	*Alocasia macrorrhizos**				36	29
Medicinal	*Euphorbia inaequilatera* **var**. *inaequilatera*			29		
Medicinal	*Schkuhria pinnata**	40	42			
Medicinal	*Sida cordifolia*	38	37			
Medicinal	*Vachellia karroo*			22	22	
Medicinal	*Zantedeschia aethiopica*				34	30
Ornamental	*Agapanthus praecox* **subsp**. *orientalis*				38	45
Ornamental	*Chlorophytum comosum*			19	37	41
Ornamental	*Nerium oleander**	24	24			
Ornamental	*Pelargonium x hortorum*	20				
Ornamental	*Philodendron selloum**					39
Ornamental	*Rosa chinensis**			20	41	

5.3.11 Growth forms

The dominant growth form in all five settlements was forbs (29 % in Roodepoort, 37 % in Potchefstroom, 45 % in Ikageng, 41 % in Ganyesa and 45 % in Tlhakgameng) (Figure 5.5). In Roodepoort, Potchefstroom and Ikageng the most commonly cultivated forb was *Chlorophytum comosum,* however, the most frequently recorded forbs in all five settlements were naturalised (*Guilleminea densa* in Tlhakgameng, Ganyesa and Ikageng and *Oxalis corniculata* in Potchefstroom and Roodepoort).

The second most diverse growth form was shrubs and the third, trees. In Roodepoort 26 % of all recorded species were shrubs and 17 % trees, 24 % shrubs and 17 % trees in Potchefstroom, 17 % shrubs and 13 % trees in Ikageng, 15 % shrubs and 15 % trees in Ganyesa and 13 % shrubs and 15 % trees in Tlhakgameng. Succulents, geophytes, and graminoids contributed to between 25 and 30 % of the total number of species recorded in all five settlements. Ferns and epiphytes were the least represented growth forms in all five settlements.

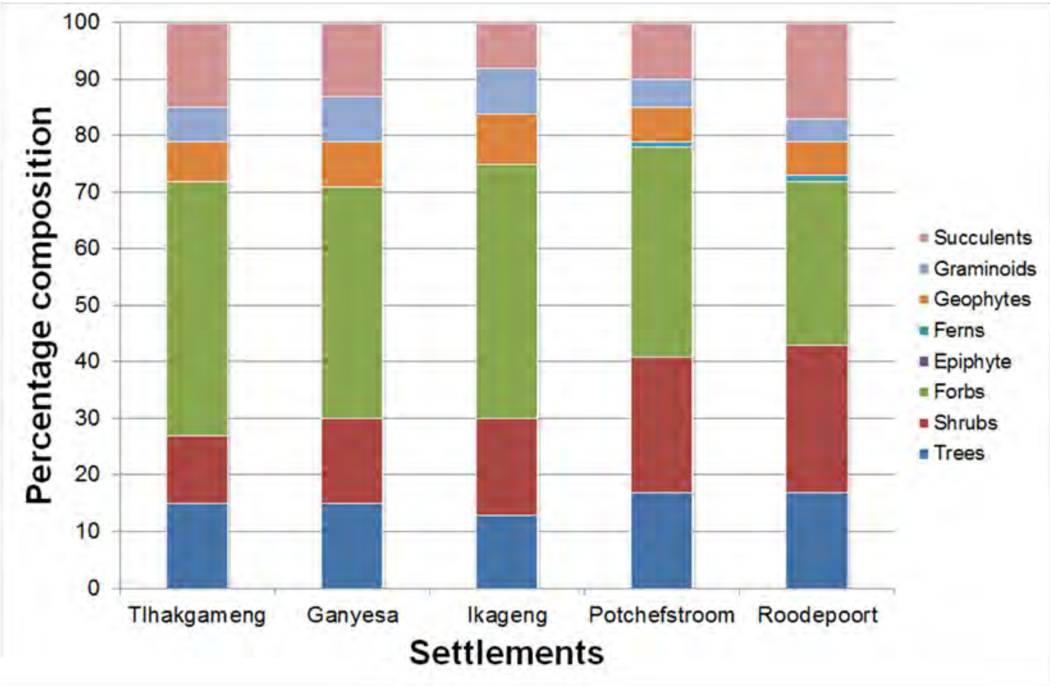

Figure 5.5: Species richness of growth forms for domestic gardens in all five settlements.

5.4 Discussion

5.4.1 Species composition and dominant taxa

5.4.1.1 Total species richness

A literature review was conducted on the plethora of garden research papers available to determine how their data compare to this study. Eighteen studies were found that compiled complete inventories of all the plant species present in their sampled gardens. The results of these studies were plotted against the results of this study in Figure 5.6. This study confirms that domestic gardens contain remarkably high species richness. In comparison to other studies, the 1524 species recorded in 256 gardens in this study, is high. Similarly to this study, Loram *et al*. (2008a) studied the composition and diversity of plant species in 267 domestic gardens in five cities in the United Kingdom. Loram *et al*. (2008a) recorded a total of 1056 species. Based on these results, the assumption can be made that high numbers of species recorded in gardens are linked to high numbers of sampled gardens. However, Smith *et al*. (2006a) recorded a total of 1166 species in only 61 gardens in Sheffield, UK and Marco *et al*. (2008) recorded 973 horticultural species in 120 gardens in Lauris, France. According to Smith *et al*. (2006a) the number of species sampled in their study would have been larger had they sampled more gardens, due to the large pool of species available to gardeners in the United Kingdom. In contrast, Bigirimana *et al.* (2012) analysed the flora of 1045 gardens in Bujumbura, Burundi and only recorded 567 species. Considering the number of gardens studied, it would be expected that the number of species recorded would be much higher. Consequently, the number of species recorded in a settlement is not necessarily linked to the number of gardens sampled.

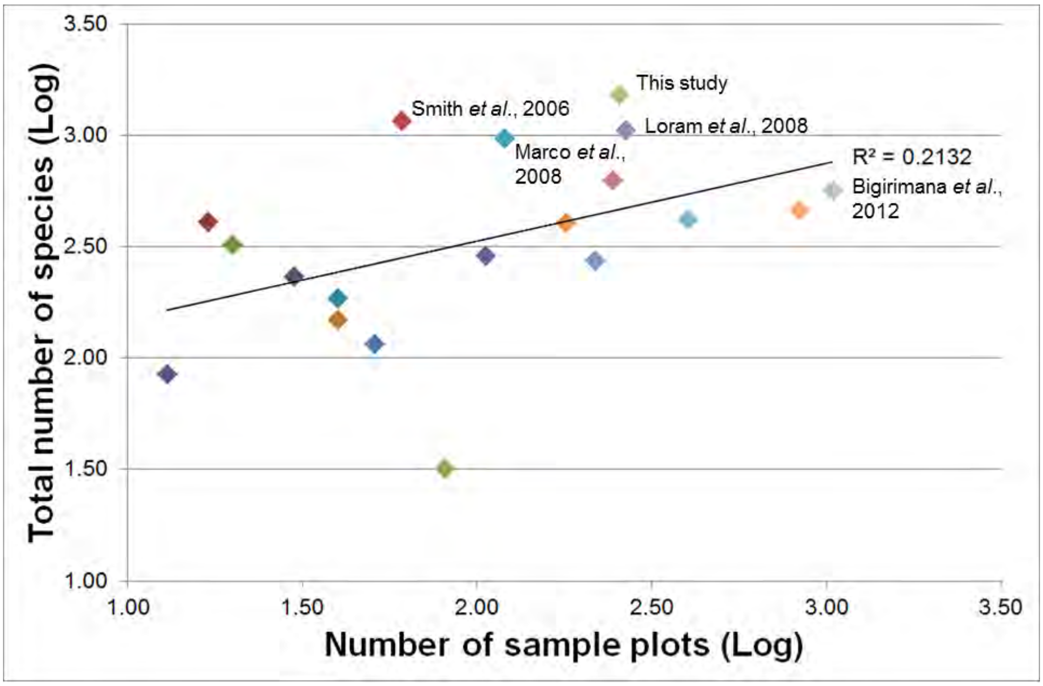

Figure 5.6: The species richness results and the total number of sample plots of this study and nineteen other garden studies.

Furthermore, the remarkably high total species richness of garden plants in the surveyed settlements is almost certainly a consequence of two factors. First, there is a very large pool of plants available to gardeners (Glen, 2002; RHS, 2015) and secondly, due to the active maintenance and management by gardeners, garden plants have a highly 'unnatural' capacity to persist at low population sizes (Thompson *et al*., 2003). In four of the five settlements, the majority of all recorded species were alien (62 % in Roodepoort, 71 % in Potchefstroom, 67 % in Ikageng, 53 % in Ganyesa and 49 % in Tlhakgameng). These results are in accordance with the results of other studies. Thompson *et al*. (2003) found that 67% of the species recorded in the gardens of Sheffield in the United Kingdom were alien, while 33% were British natives. Similarly, Loram *et al*. (2008a) and Smith *et al*. (2006a) found that >70 % of all recorded species in domestic gardens in the United Kingdom were alien. In Trabzon, Turkey, 75 % of the recorded species were alien and 25 % were native to Turkey and the Mediterranean regions (Acar *et al*., 2007) and in Lauris, France, Marco *et al*. (2008) found that 88 % of the cultivated taxa were alien and only 12 % were native.

5.4.1.2 Plant families

In total, the 1524 species were represented by 184 plant families across all the studied settlements (161 in Roodepoort, 145 in Potchefstroom, 102 in Ikageng, 98 in Ganyesa and 90 in Tlhakgameng). Considering South Africa has 20 700 indigenous vascular plant taxa in 1890 genera and 252 families (Von Staden *et al*., 2013) the total number of plant families is relatively high, higher than in most other studies. In Niamey, Niger, 116 plant species from 50 families were cultivated in home gardens (Bernholt *et al.*, 2009). A total of 186 plant species in 68 families were recorded in home gardens in São Luís, Brazil (Akinnifesi *et al*., 2010a). The study of Acar *et al*. (2007), recorded a total of 274 ornamental plants that were represented by 70 plant families in the city of Trabzon, Turkey. Marco *et al*. (2008) recorded 973 species represented by 114 plant families in Lauris, France.

5.4.1.3 Dominant genera

The number of genera recorded across all the settlements was also high. A total of 611 plant genera were recorded in Roodepoort, 470 in Potchefstroom, 293 in Ikageng, 281 in Ganyesa and 262 in Tlhakgameng. In Roodepoort 65 % of the recorded plant genera were represented by only one species, 68 % in Potchefstroom, 74 % in Ikageng, 74 % in Ganyesa and 69 % in Tlhakgameng. Similarly, Marco *et al*. (2008) recorded 376 genera in Lauris, France, 80% of which were represented by only one species.

5.4.1.4 Dominant species

In the rural areas of Tlhakgameng and Ganyesa, the majority of the ten most frequently occurring species were native, while in Ikageng and Potchefstroom the most frequent species were naturalised. These naturalised species are predominantly self-sown and are considered weeds by the gardeners. In Roodepoort, the majority of the most frequently occurring species were cultivated. In all five settlements, the most frequent surveyed species were grass species. In Tlhakgameng and Ganyesa the most frequent surveyed grass species was native to the area, while in Ikageng, Potchefstroom, and Roodepoort it was a cultivated alien species. In Sheffield, UK, the majority of the 20 most frequent species in the surveyed gardens were native or alien weeds (Thompson *et al*., 2003). The native species predominantly found their own way into gardens and are now tolerated by gardeners to varying degrees, while the other species were natives or aliens that were initially cultivated but are now largely self-sown (Thompson *et al*., 2003).

5.4.2 Endemic and Red Data listed species

The contribution of endemic (152 species) and red data species (55 species) to the total number of species in all five settlements (1524 species) may be proportionally small (10 and 4% respectively), but it indicates the potential that domestic gardens have to maintain these species. The study of Blanckaert *et al*. (2004) found that 10 % of the recorded species grown in the gardens of South-Central Mexico were protected plants. Similarly, Das and Das (2005) found that home gardens in India were important sites for in situ conservation of plant diversity, both domesticated and wild. In Benin, the study of Salako *et al*. (2014) found eleven threatened species present in home gardens.

However, the majority of the endemic and endangered species in the studied settlements were cultivated for ornamental purposes and not for conservation. According to Hope *et al*. (2006), plant diversity is driven by human choices, availability of material and irrigation. Therefore, the number of endemic and threatened species present in home gardens can change at any given moment and be replaced by alien cultivated species. The cultivation of threatened species in gardens has been considered a viable option for the conservation of Red Data species by the South African National Biodiversity Institute for many years (Winter and Botha, 1994). However, this possible solution is not without problems, such as a potential difficulty to propagate and cultivate endangered species in gardens, a large proportion of threatened species lack aesthetic qualities (Winter and Botha, 1994) and the potential threat that these cultivated species pose to the genetic integrity of natural populations (Whelan *et al*., 2006).

5.4.3 Invasive species

The majority of invasive species present in domestic gardens were actively cultivated in the past or are still cultivated and commercially available today. According to Richardson *et al*. (2005), "South Africa has one of the biggest problems with invasive alien plants in the world". The main pathway for the introduction of non-native species into a country is the commercial trade in ornamental plants and often these species can become serious threats to native biodiversity (Dehnen-Schmutz and Touza, 2008; Pyšek *et al.,* 2011). The study of Marco *et al*. (2010) found that alien ornamental species, with extraordinarily diverse phylogenetic origins, have a high probability of escaping gardens and colonizing surrounding natural habitats. In Bujumbura, Burundi, 42 alien cultivated garden plants have become naturalised in the city and 14 of these species are considered to be invasive (Bigirimana *et al*., 2012).

In South Africa, there is a growing trend of indigenous gardening (Joffe and Oberholzer, 2012; Pienaar and Smith, 2011). However, based on the high number of invasive species recorded in the studied settlements, it is evident that more needs to be done to inform the public of the threat that these hardy alien cultivated plants pose to the indigenous plant population of South Africa. Invasive alien species are known to compromise ecosystem stability, erode natural capital, reduce surface water runoff, reduce the rate of groundwater recharge and threaten biodiversity and economic productivity, in other words, invasive alien species reduce the provisioning of ecosystem services (Van Wilgen *et al*., 2008). A survey by Vilà *et al*. (2010) revealed that over 1000 alien species in Europe were known to cause ecological or economic impacts (ecosystem disservices).

5.4.4 Species origin: Indigenous cultivated and alien species

Species that originated from the south-eastern provinces were the most common in Ikageng, Potchefstroom, and Roodepoort. In Tlhakgameng and Ganyesa the majority of indigenous cultivated species had a widespread distribution throughout South Africa. Conversely, in Ikageng, Potchefstroom and Roodepoort species with a widespread distribution were the second largest contributors and in Tlhakgameng and Ganyesa, species that originated from the south-eastern provinces.

In Tlhakgameng and Ganyesa the most frequently cultivated indigenous species were *Citrullus lanatus* and *Dodonaea viscosa*. *Citrullus lanatus* is a popular food plant and *Dodonaea viscosa* is cultivated as a hedge. *Agapanthus praecox*, which is a popular ornamental species, was the most frequently cultivated indigenous species in Ikageng, Potchefstroom, and Roodepoort. Plants from the Eastern Cape are popular garden plants because they are adaptable, can tolerate harsh conditions, hybridize easily and are easy to grow (Van Jaarsveld, 2001). The rest of the geographical regions contributed between 50 and 60 % collectively to the overall species composition of each settlement. Roodepoort had the largest number of indigenous cultivated species (27 %) of all the studied settlements. This is due to the growing trend of indigenous gardening in affluent suburbs of South Africa (Joffe and Oberholzer, 2012; Pienaar and Smith, 2011) since several of the studied gardens contained predominantly indigenous species.

The majority of alien cultivated species in all five settlements originated from Asia. These species were predominantly cultivated for their ornamental (*Rosa chinensis*, *Celtis sinensis*, and *Alocasia macrorrhizos*) and food value (*Prunus persica*, *Morus alba*, and *Vitis vinifera*). The most common naturalised alien species (*Dichondra micrantha*, *Euphorbia prostrata*, and *Conyza bonariensis*) originated from the Americas (North, South and Central). According to Lubbe *et al*. (2011) "plant species from similar climates are adapted to specific environmental conditions such as temperature ranges and frost resistance, and it should thus be able to survive such conditions elsewhere". Thus, plant species from Asia and America may be best-suited for the climatic conditions in the studied settlements. Similarly, the study of Marco *et al*. (2008) found that the majority of cultivated alien taxa in Lauris, France originated from Asia and America. In Sheffield, in the United Kingdom, a large number of the recorded alien species originated from Europe and Asia, particularly Japan (Thompson *et al*., 2003). In Trabzon, Turkey, the highest percentages alien species originated from Europe, America and Asia (Acar *et al*., 2007).

5.4.5 Useful plants

The number of food and medicinal plants decreased as the number of ornamentals plants increased from poor rural areas (Ganyesa and Tlhakgameng) to more affluent urban areas (Potchefstroom and Roodepoort). In Bujumbura, Burundi, Bigirimana *et al*. (2012) found that gardens in rich neighbourhoods cultivated mainly ornamental species while gardens in poor areas contained more utilitarian species. In Niamey, Niger, the majority of cultivated plants were fruits or vegetables, very few if any ornamental species were cultivated (Bernholt *et al.*, 2009). Similarly, the home gardens in São Luís, Brazil, contained various useful plants, predominantly fruit tree species, edible crops such as cereals, legumes, vegetables and condiments, as well as several medicinal plants (Akinnifesi *et al*., 2010a). In home gardens in KwaZulu Natal, South Africa, 60% of all recorded useful species were classified as medicinal, 25% as food, 10% as spiritual and only 5% as ornamental (Nemudzudzanyi *et al*., 2010)). In contrast, Jaganmohan *et al*. (2012) found that the majority of species in domestic single residential and shared apartment gardens in Bangalore, India, were ornamental. Similarly, in the home gardens of San Rafael Coxcatlán, Mexico, the majority of the recorded plant species were ornamental and the rest was categorised as either edible or medicinal (Blanckaert *et al*., 2004).

The uses of domestic gardens vary, some are used for subsistence agriculture, some to increase household income by selling the surplus fruits and vegetables and others are purely for the enjoyment of the homeowner (Vogl *et al*., 2004). The gardens in Potchefstroom and Roodepoort are predominantly for the enjoyment of the householders, although a few participants did cultivate herbs, fruit trees and vegetables for own consumption. In contrast, the gardens in Tlhakgameng and Ganyesa are predominantly used for subsistence agriculture, while a few participants cultivated surplus vegetables to increase household income. The gardens in Ikageng are a combination of both, recreational and subsistence agriculture. Ntuli *et al*. (2012) found that in three districts of northern KwaZulu-Natal, South Africa, leafy vegetables were predominantly cultivated for household consumption. In Brazil, home gardens in urban centres provide income, but in rural areas their main purpose is for household subsistence (Akinnifesi *et al*., 2010a).

5.4.6 Growth forms

The dominant growth form in all five settlements was forbs (annuals and perennials), representing between 29 and 45 % of all recorded species. The second most diverse growth form was shrubs (between 13 and 26 %) and the third, trees (between 13 and 17 %). Similarly, the garden flora in Sheffield, United Kingdom, consisted predominantly of biennial/perennials (63 %), 10 % annuals, 18 % shrubs and 8 % trees (Smith *et al*., 2006a). Marco *et al*. (2008) found that 92 % of all recorded species in Lauris, France, were perennials, 7 % annuals and 1 % biennials.

5.5 Conclusion

The result of this study further supports those of previous studies, which found that domestic gardens contain remarkably high species richness. The more affluent urban areas were characterised by larger numbers of species, alien cultivated and ornamental species, while the rural areas had far less alien and ornamental species and more indigenous and utilitarian species. Furthermore, it is evident that domestic gardens have the potential to not only conserve endemic and endangered species but unfortunately also to promote the occurrence of invasive species in the surrounding natural areas. Considering the large sums of money required for dealing with problematic invasive species, assessing the threat that these species pose to natural environments outside of gardens is crucial. In conclusion, domestic gardens are rich and heterogeneous ecosystems that sustain a mixture of different growth forms and multipurpose species, which depend on the need and preferences of the owners. Furthermore, domestic gardens have a great deal of potential to either maintain the species occurrences of endemic and endangered species or to encourage the spread of invasive species.

Chapter 6 - Comparing the garden management practices of five settlements with their floristic data

6.1 Introduction

A closer look at both urban and rural landscapes reveal the existence of numerous domestic gardens (Blanckaert *et al*., 2004; Gaston *et al*., 2005a; Loram *et al*., 2007; Loram *et al*., 2008a; Loram *et al*., 2008b; Nemudzudzanyi *et al*., 2010; Thompson *et al*., 2003) that differ in composition, management, size and use (Dewaelheyns *et al*., 2014; Smith *et al*., 2006a). Domestic gardens can provide various ecosystem services (Cameron *et al*., 2012), such as carbon sequestration in garden soils (Zirkle *et al*., 2011), decrease of storm water runoff (Cameron *et al*., 2012), mitigation of the heat island effect (Skelhorn *et al*., 2014), air pollution removal (Pataki *et al*., 2011) and biodiversity conservation (Gaston *et al*., 2005a; Daniels and Kirkpatrick, 2006a; Goddard *et al*., 2010). Gardens also have positive effects on the mental well-being and physical health of people who have access to them (Clayton, 2007; Dunnett and Qasim, 2000; Gross and Lane, 2007).

Gardening is an important pass time for many people (Clayton, 2007). In 2015, approximately 90 million U.S. households participated in do-it-yourself (DIY) gardening and lawn activities (National Gardening Market Research Company, 2016). In the UK an estimated 87 % of households have access to a garden and approximately 50 % of the adult population report gardening as a free-time activity (Buck, 2016). Gaston *et al*. (2005b) conducted a random telephone survey of domestic gardens in the city of Sheffield, UK and determined that on average the respondents worked an hour and a half per week and roughly 10 million hours per year collectively, in their gardens. This level of time investment must make domestic gardens some of the most intensively managed areas of land (Gaston *et al*., 2005b).

However, domestic gardens, or more specifically the gardening practices of homeowners, can also have significant negative impacts on the environment (Cameron *et al*., 2012), such as increased greenhouse gas emissions and nitrogen excess due to fertiliser usage and irrigation (Livesley *et al*., 2010), increased soil sealing/compaction through paving which leads to increased surface runoff and flood risks (Pauleit *et al*., 2005; Perry and Nawaz, 2008; Verbeeck *et al*., 2011) and excessive water consumption (Runfola *et al*., 2013). Furthermore, gardens also influence the spread of non-native and invasive species (Niinemets and Penuelas, 2008; refer to chapter 5), which can have knock-on effects on native arthropod abundance and species richness (Burghardt and Tallamy, 2013; Burghardt and Tallamy, 2015), and the avian and lepidopteran carrying capacity of an ecosystem (Burghardt *et al*., 2009). The negative impacts associated with domestic gardens are often attributed to the naivety of the general public in terms of environmental issues, for example few people know what happens to water after it enters the storm drain (Thompson, 2004) or how an increase in impervious surfaces will affect storm water runoff (Pauleit *et al*., 2005).

Odum (1982) stated that the economist Alfred Kahn's premise of the "tyranny of small decisions" could be applied to environmental issues as well. Odum (1982) provided several examples of this "small decision effect", which ranged from the loss of nearly 50 % of marshlands along the coasts of Connecticut and Massachusetts to the mismanagement of the Florida Everglades. Similarly, domestic garden management is a collection of individual, small and autonomously made decisions (Dewaelheyns *et al*., 2016; Odum, 1982). According to Dewaelheyns *et al*. (2016) "governing such a complex land-use and environmental resource as domestic gardens in a sustainable way and from a regional perspective is a challenge". Domestic gardens are privately owned and managed at an individual level (Gaston *et al*., 2005a; Smith *et al*., 2006c). They also vary in terms of management intensity (Smith *et al*., 2006c) and are generally influenced by personal preference and neighbourhood rules and norms (Freeman *et al*., 2012; Giner *et al*., 2013; Kendal *et al*., 2012a; Nassauer *et al*., 2009).

Considering the amount of time invested in gardens, it's no wonder that several research projects have examined the motivation behind gardening, driven by the assumption that a better understanding of these motivations would lead to the promotion of ecological gardening practices or at the very least more sustainable gardening approaches (Clayton, 2007; Kiesling and Manning, 2010). Other studies have focused on the activities in which householders partake to influence the wildlife populations in their gardens (Daniels and Kirkpatrick, 2006a; Davies *et al*., 2009; Davies *et al*., 2012; Gaston *et al*., 2005a; Gaston *et al*., 2005b; Gaston *et al*., 2007; Goddard *et al*., 2013). However, very few studies have examined the relationship between garden management activities and garden characteristics, such as, size, plant species richness, land-use, etc. (Loram *et al*., 2011).

This chapter provides insights into the management practices of gardeners of five different settlements (Tlhakgameng, Ganyesa, Ikageng, Potchefstroom and Roodepoort) on the Highveld of South Africa. We hypothesise that the floristic composition of domestic gardens will increase as the intensity of garden management practices increase. The aim of this chapter was to (1) compare the prevalence of selected garden management activities practiced (fertiliser application, pruning, removal of dead material, watering, weeding) between gardens and between settlements, (2) determine whether gardens are maintained through DIY gardening practices, gardening services or a gardener overall and between settlements, (3) calculate a management index (MI), which provides a single score for each participant in terms of their level of gardening activity, and (4) relate the management index value of gardens to the floristic composition thereof.

6.2 Methods

6.2.1 Questionnaires

In conjunction with the floristic garden surveys conducted in each of the five settlements (see Chapter 5), a questionnaire was completed by gardeners to gather data on the management practices and socio-economics of the participants' (Annexures D to G). In Ganyesa, 96 % of the participants' completed the questionnaire (two participants' were out of town at the time the social survey was conducted), while in Tlhakgameng, Ikageng, Potchefstroom and Roodepoort all the participants' (100 %) completed the questionnaires. The purpose of the Ganyesa questionnaire was to determine the participants' perceptions concerning their gardens, level of gardening activity, socio-economic status, emotional well-being and satisfaction with life (Davoren, 2009). In Tlhakgameng, a similar questionnaire was used, but additional information was gathered regarding the gardener's indigenous knowledge (Molebatsi, 2011). In Ikageng, Potchefstroom (Lubbe, 2011) and Roodepoort, a questionnaire was used to ascertain the participants' maintenance regimes for their gardens (irrigation methods, the use of fertiliser, herbicides, and/or pesticides, etc.), as well as their social information (level of education, etc.).

For the purpose of this chapter only the data concerning the participants' garden management practices were analysed, and specifically those questions which were asked in all four questionnaires (Table 6.1). For instance, participants in Tlhakgameng, Ganyesa, Ikageng and Potchefstroom were asked whether or not they swept their gardens and how often (Annexure D to F). Residents in Tlhakgameng and Ganyesa were predominantly belonging to the Tswana ethnic group and believe that the area around their homes should be open and devoid of any vegetation (Cilliers *et al*., 2009). They consider this as an indication of the tidiness of the household ('lebala concept') (Cilliers *et al*., 2009) and subsequently, these areas are extensively swept and weeded (Molebatsi *et al*., 2010). However, this question could not be asked on the Roodepoort questionnaire, since it is not a gardening activity practiced in this area (Annexure G). Similarly, questions pertaining to lawn management were not present on the Tlhakgameng and Ganyesa questionnaires (Annexure D and E), since very few gardens in these two settlements had lawns.

Five common questions were asked on all four questionnaires to determine the participants' garden management activities and the frequency with which each activity took place, for example weekly, monthly, yearly, etc. (Table 6.1). Furthermore, to evaluate the results of the management index (see next section) each of the participants' was asked whether they used gardening services, had a gardener or if they practiced DIY gardening (Annexure D to G).

6.2.2 Management Index (MI)

Each answer was allocated a specific score (1 to 4) based on the frequency with which gardening activities took place (Table 6.1). Garden management activities that were conducted on a regular basis were given higher scores than activities that were performed per annum. During the data analysis, the scores across all activities (Questions 1 to 5) were summed for each garden to produce the respondent's level of gardening activity, termed the management index (MI).

Table 6.1: Garden management questions that were asked in all four questionnaires (Annexure D to G).

Which of the following activities takes place in your garden and how often?				
Gardening activity	1	2	3	4
1. Water the garden	Rain	Once a fortnight	Once a week	> Once a week
2. Fertilise the garden	Never	Once a year	Twice a year	Quarterly
3. Weed the garden	Never	Once a month	Once a fortnight	Once a week
4. Prune hedges or trees	Never	Once a year	Twice a year	Once a month
5. Remove any dead material	Never	Once a year	Once a month	Once a week

6.2.2.1 Exploratory factor analysis

An exploratory factor analysis (EFA) was conducted on the five garden management activities (variables) to determine whether or not these activities could be used to determine a management index (MI), which provides a single score for each participant in terms of their gardening activity. The initial factor analysis, using principal components extraction and Kaiser's criterion, produced one factor with an eigenvalue greater than 0.1. An EFA determines which variables are most strongly correlated with one another and then groups them into a factor. It then determines the next strongest batch of correlation and groups them into another factor (Urdan, 2010). This process continues until enough factors have been extracted from a set of variables to explain most of the variance possible in the data (Urdan, 2010). Kaiser's criterion was used to decide the number of factors retained for rotation (Costello and Osborne, 2005).

Next, a reliability analysis, Cronbach alpha, was performed to examine the internal consistency of the factor produced by the exploratory factor analysis. Cronbach alpha is a statistic that indicates the internal consistency of a set of variables (Urdan, 2010). The strength of the alpha depends on the number of activities and the strength of the correlation between them, the higher the alpha the more acceptable the reliability (Urdan, 2010). The software package STATISTICA 13.0 (Statsoft, 2009) was used to perform all statistical analysis.

6.2.3 Comparison between the MI and floristic data

6.2.3.1 Spearman rank order

Spearman's rank correlation coefficient (r_s) was calculated to determine relationships between the garden activities, management index and floristic data (total species richness, alien, indigenous, growth form, declared weeds and invader status, food, medicinal, ornamental and red data status). Urdan (2010) defines the Spearman rank correlation coefficient as a "correlation coefficient used to measure the association between two variables measured on an ordinal scale (e.g., ranked data)". Spearman's rank correlation coefficient (r_s) was derived from the Pearson correlation coefficient after the two variables had been separately transformed to ranks, however, the pairing was retained after ranking (Quinn and Keough, 2002).

6.2.3.2 ANOVA

An analysis of variance (ANOVA) test was performed to determine if statistically significant differences exist between the garden management activities, management index and the floristic data (total species richness, alien, indigenous, growth form, declared weeds and invader status, food, medicinal, ornamental and Red Data status) in the five settlements. According to Tabachnick and Fidell (2007) "analysis of variance is used to compare two or more means to see if there are any statistically significant differences among them". The null-hypothesis of this technique is that the means of all the samples are the same and, by computing the variance within (residual variance) and between (effect variance) sample means, it can be determined whether the samples are significantly different from one another and whether to accept or reject the null-hypothesis (Quinn and Keough, 2002). The result of an ANOVA simply informs on the possibility of significant differences, but does not indicate which groups differ from each other, therefore, post hoc testing is required (Tabachnick and Fidell, 2007). Subsequently, Tukey's honestly significant difference (HSD) post hoc test for unequal sample size was carried out. This test pairwise compares the sample mean with that of every other sample to determine which samples were significantly different from others (Quinn and Keough, 2002).

6.3 Results

6.3.1 Garden management activities and their frequency of occurrence

Based on the results of the questionnaires, 95 % of the respondents worked in their gardens at least once a week. Of these, 78 % worked in their gardens more than once a week. Table 6.2

illustrates the gardening activities that take place in each garden in terms of the percentage of participants and the regularity with which the activities take place in each settlement. The majority of the participants in each settlement water their gardens more than once a week, very few rely only on rain water and even less water their gardens once a fortnight. In Tlhakgameng and Ikageng the majority of the respondents never fertilise their gardens, 51 and 71 % respectively. In contrast, the majority of the respondents in Potchefstroom and Roodepoort fertilise their gardens once a year, 53 and 78 % respectively. In all five settlements the majority of the respondents remove weeds once a week. In Ikageng the majority of the participants never prune their hedges or trees, in Tlhakgameng, Ganyesa and Potchefstroom at least once a year and in Roodepoort, 98 % pruned their hedges or trees once a month. In Ikageng and Potchefstroom, most of the participants never removed any dead material from their gardens, while in Tlhakgameng and Roodepoort most removed dead plant material at least once a week.

Table 6.2: The percentage of participants that partake in each of the gardening activities in terms of the regularity with which each activity takes place in all of the sampled settlements (T: Tlhakgameng, G: Ganyesa, I: Ikageng, P: Potchefstroom, and R: Roodepoort).

Gardening activities	Frequency	T	G	I	P	R
Water the garden:	Rain	12	11	4	0	0
	Once a fortnight	0	2	8	0	0
	Once a week	16	13	24	18	0
	> Once a week	72	74	64	82	100
Fertilise the garden:	Never	51	36	71	31	12
	Once a year	39	33	24	53	78
	Twice a year	10	7	0	6	0
	Quarterly	0	24	5	10	10
Weed the garden:	Never	10	9	4	0	8
	Once a month	0	38	41	22	2
	Once a fortnight	0	15	12	4	8
	Once a week	90	38	43	74	82
Prune hedges or trees:	Never	10	7	39	37	0
	Once a year	90	65	25	55	0
	Twice a year	0	13	7	6	2
	Once a month	0	15	29	2	98
Remove any dead material:	Never	10	13	94	43	0
	Once a year	29	38	0	10	0
	Once a month	0	29	4	14	14
	Once a week	61	20	2	33	86

6.3.2 DIY or gardening services?

In Tlhakgameng and Ganyesa the majority of the respondents practiced DIY gardening, 100 % and 93 % respectively (Table 6.3). In Ikageng 57 % of the participants practiced DIY gardening, but there was a significant number of participants who had gardening services (35 %) and only 8 % had gardeners. In Potchefstroom and Roodepoort most of the participants employed a gardener, 69 %, and 74 % respectively. Only 6 % of the participants in Potchefstroom practiced DIY gardening and 25 % used gardening services. In Roodepoort, only 12 % of the participants practiced DIY gardening and 14 % used gardening services.

Table 6.3: The percentage of participants that use gardening services, employ a gardener or practice DIY gardening in all five settlements.

	Tlhakgameng	Ganyesa	Ikageng	Potchefstroom	Roodepoort
Gardening services	0	0	35	25	14
Gardeners	0	7	8	69	74
DIY	100	93	57	6	12

6.3.3 Management index (MI)

The initial factor analysis, using principal components extraction and Kaiser's criterion, produced one factor with an eigenvalue greater than 0.1. According to Quinn and Keough (2002) eigenvalues, "represent the amount of the original variance explained by each of the variables". Kaiser's criterion was used to decide the number of factors retained for rotation (Costello and Osborne, 2005) and only one factor was retained. This factor explained 41 % of the total variance in the activities. A subsequent factor analysis (FA) was performed and since only one factor was generated, this means all five activities were strongly correlated and explained most of the variance (Tables 6.4 and 6.5).

Each variable has a factor loading on the factor analysis (Table 6.4) and the stronger a variable loads onto a factor, the more that variable defines the factor (Urdan, 2010). The removal of dead plant material had the strongest factor loading (0.75), watering the garden had the second strongest factor loading (0.67) and pruning had the third strongest factor loading (0.63) (Table 6.4). Furthermore, the results of the factor analysis indicate that the scores across all five gardening activities could be summed for each garden to produce the respondent's level of gardening activity, i.e. the management index (MI). The Cronbach alpha reliability analysis revealed that the gardening activities formed a reliable scale (Cronbach's α = .63), the higher the alpha the more acceptable the reliability (Urdan, 2010).

Table 6.4: Correlation matrix for the five gardening activities in the exploratory factor analysis in order to determine a management index. Number in bold indicate the strongest factor loading.

Variable	**Factor 1**
Water the garden	-0.67
Fertilise the garden	-0.55
Weed the garden	-0.59
Prune hedges or trees	-0.63
Remove any dead material	**-0.75**
Explained Variance	2.05
Prp. Total	0.41

Table 6.5: Communalities extraction: Principal components rotation.

	From 1 Factor	**Multiple R-Square**
Water the garden	0.44	0.18
Fertilise the garden	0.30	0.12
Weed the garden	0.35	0.17
Prune hedges or trees	0.39	0.20
Remove any dead material	0.56	0.29

6.3.4 Comparison between the MI, gardening activities and floristic data

6.3.4.1 MI compared to total species richness

A scatterplot was generated based on the total species richness and management index (MI) value of each of the gardens sampled in this study (Figure 6.1). A simple linear regression and R^2 coefficient was calculated. The R^2 coefficient is a statistical measure of how well the regression line approximates the data points ($R^2 = 0.21$). A R^2 value of 1 indicates that the data values fit perfectly to the regression line. The scatterplot revealed a moderately positive correlation between the two variables (total species richness and management index), which means species richness, has a tendency to increase as the management index increases.

However, high species richness is not necessarily linked to a high garden MI value, since Potchefstroom had a mean garden MI value of 13 and a mean species richness of 98 (Table 6.6). Roodepoort had highest mean species richness (112) and garden MI value (18), while Ikageng had the lowest mean species richness (44) and garden MI value (11). There is very little difference between the garden MI values and species richness in the rural areas of Tlhakgameng and Ganyesa.

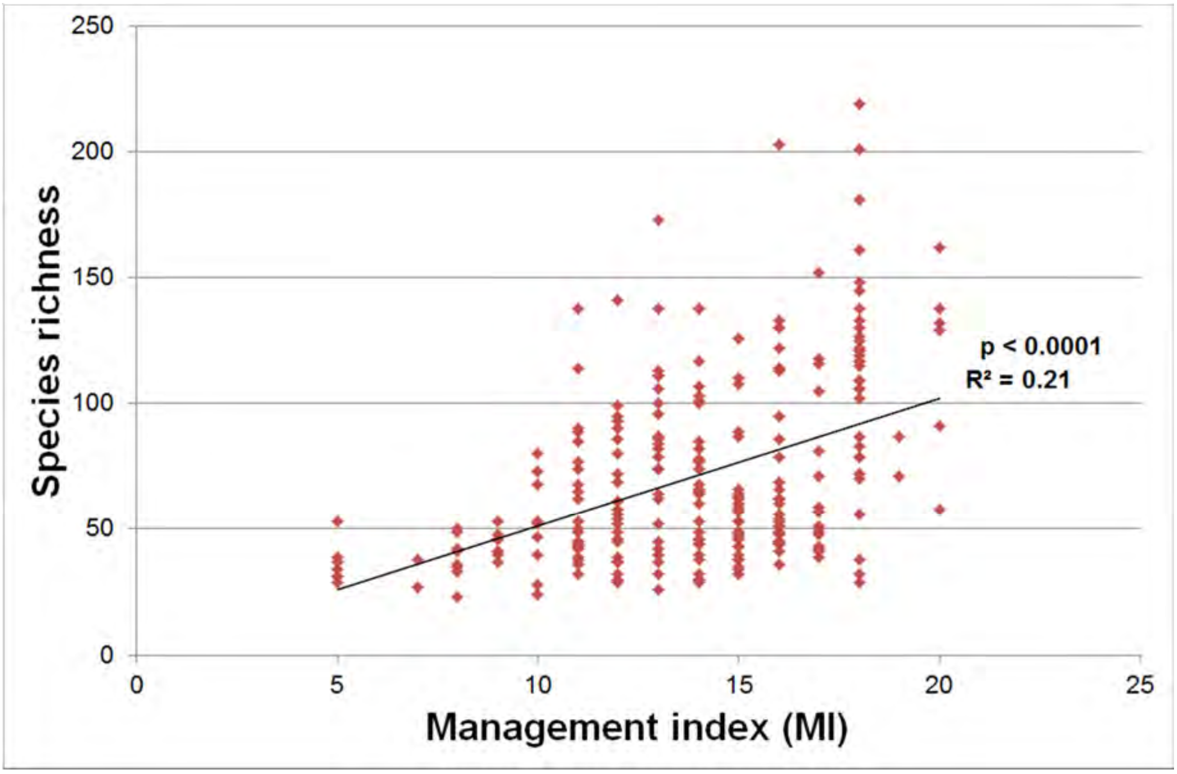

Figure 6.1: Scatterplot of the management index of each garden measured against the total species richness of each garden (R^2 = 0.21).

Table 6.6: The mean garden management index (MI) and species richness values of each settlement.

	MI	Species richness
Tlhakgameng	14	52
Ganyesa	13	53
Ikageng	11	44
Potchefstroom	13	98
Roodepoort	18	112

6.3.4.2 Gardening activities and MI compared to floristic data

The Spearman rank analysis indicated that several of the floristic variables were correlated with gardening activities and MI (Table 6.7). The total, alien and indigenous species richness were significantly correlated with all the gardening activities and MI values, as well as the number of trees, shrubs, succulent, geophytes, ferns, epiphytes, C3 invaders and ornamental species richness. All the gardening activities were significantly correlated with several of the floristic data variables, but not all of them. These results further support the results of the factor analyses which showed that the scores across all five gardening activities could be summed for each garden to produce a single MI value. The removal of dead plant material had more significant correlations with the floristic variables than any of the other gardening activities.

Table 6.7: Spearman rank order correlations between the garden activities, management index (MI) and floristic data. Marked correlations (bold) are significant at $p < 0.05$.

Variable	Water the garden	Fertilise the garden	Weed the garden	Prune the hedges/trees	Remove dead material	MI
Total species richness	**0.35**	**0.31**	**0.28**	**0.25**	**0.35**	**0.44**
Alien	**0.33**	**0.30**	**0.23**	**0.27**	**0.23**	**0.37**
Indigenous	**0.18**	**0.16**	**0.20**	**0.18**	**0.40**	**0.35**
Tree	**0.29**	**0.29**	**0.24**	**0.23**	**0.44**	**0.43**
Shrub	**0.34**	**0.31**	**0.30**	**0.33**	**0.42**	**0.50**
Succulent	**0.27**	**0.22**	**0.24**	**0.26**	**0.33**	**0.38**
Herb	**0.22**	**0.21**	**0.19**	0.10	0.12	**0.21**
Geophyte	**0.27**	**0.25**	**0.23**	**0.20**	**0.30**	**0.37**
Fern	**0.23**	**0.20**	**0.17**	**0.25**	**0.23**	**0.33**
Epiphyte	**0.12**	**0.22**	**0.13**	**0.24**	**0.22**	**0.30**
Graminoid	-0.04	**-0.17**	**-0.15**	-0.12	**-0.24**	**-0.25**
Weed	-0.02	**-0.13**	-0.09	-0.05	**-0.29**	**-0.22**
C1 weed	**0.16**	**0.15**	0.05	0.10	**0.27**	**0.22**
C2 invader	0.12	0.11	0.11	**0.13**	**0.17**	**0.20**
C3 invader	**0.23**	**0.26**	**0.20**	**0.24**	**0.29**	**0.35**
Food	0.11	0.08	0.02	-0.02	-0.03	-0.03
Medicinal	0.09	0.10	0.09	-0.05	**0.26**	**0.15**
Ornamental	**0.35**	**0.35**	**0.28**	**0.33**	**0.32**	**0.48**
Vulnerable	**0.31**	**0.35**	**0.23**	**0.40**	**0.31**	**0.48**
Declining	0.08	0.10	0.02	0.09	0.08	0.09
Rare	0.12	**0.15**	**0.13**	**0.22**	**0.23**	**0.29**
Near threatened	0.06	0.08	**0.17**	**0.20**	**0.18**	**0.21**
Critically rare	0.07	0.02	0.10	**0.19**	**0.16**	**0.19**
Endangered	**0.15**	**0.17**	0.12	**0.20**	**0.19**	**0.26**

The ANOVA produced statistically significant results since the p-values for all the variables were < 0.05 (Table 6.8). Table 6.9 lists Tukey's post hoc test results for some of the floristic data (total, alien and indigenous species richness), the garden management activities and management index in terms of the sampled settlements (See Annexure H for all the Tukey test results). The results showed that the MI of Roodepoort's participants differed significantly from those in Potchefstroom, Ikageng, Ganyesa and Tlhakgameng, while the MI of the participants in Ikageng differed significantly from those in Tlhakgameng, Ganyesa and Potchefstroom. Several of the settlements differed significantly from one another in terms of the different garden management activities. Furthermore, the post hoc test revealed statistically significant differences between the total and alien species richness of the gardens in Potchefstroom and Roodepoort with the gardens in Tlhakgameng, Ganyesa and Ikageng. In terms of the indigenous species richness, Ikageng, Potchefstroom and Roodepoort differed significantly from Tlhakgameng and Ganyesa.

Table 6.8: Analysis of variance of all garden management activities, management index, and floristic data (T: Tlhakgameng, G: Ganyesa, I: Ikageng, P: Potchefstroom, and R: Roodepoort). Marked differences (bold) are significant at $p < 0.05$.

	Means					ANOVA		
Variables	**T**	**G**	**I**	**P**	**R**	**MSE**	**$F_{(4,251)}$**	**p-value**
Total species richness	51.9	52.6	43.9	98.3	111.7	**601.04**	**80.74**	**≤0.001**
Alien species richness	24.4	25.8	30.4	77.1	76.1	**305.28**	**123.85**	**≤0.001**
Indigenous species richness	27.5	26.8	13.5	21.2	35.6	**116.05**	**29.09**	**≤0.001**
Tree species richness	7.8	7.7	3.5	15.0	17.4	**39.18**	**43.01**	**≤0.001**
Shrub species richness	5.6	5.2	3.8	22.9	28.6	**46.85**	**146.35**	**≤0.001**
Succulent	6.1	5.1	3.0	4.7	13.0	**48.79**	**15.42**	**≤0.001**
Herb	24.0	24.0	24.8	40.4	37.1	**80.02**	**40.82**	**≤0.001**
Geophyte	3.2	2.7	2.6	7.5	8.6	**9.05**	**46.52**	**≤0.001**
Fern	0.0	0.1	0.2	1.1	1.8	**0.59**	**56.09**	**≤0.001**
Epiphyte	0.0	0.0	0.0	0.0	0.3	**0.11**	**9.23**	**≤0.001**
Graminoid	5.2	7.8	6.1	6.6	4.8	**5.64**	**13.24**	**≤0.001**
Weed	10.6	12.1	19.2	21.5	15.3	**33.15**	**32.08**	**≤0.001**
C1 weed	2.5	2.6	1.0	2.9	2.9	**3.99**	**8.39**	**≤0.001**
C2 invader	2.1	2.4	2.1	2.5	2.7	**1.17**	**3.24**	**0.01**
C3 invader	2.2	2.1	1.5	7.0	6.7	**5.74**	**64.17**	**≤0.001**
Food	10.9	10.4	9.0	10.8	7.7	**24.26**	**3.92**	**≤0.001**
Medicinal	11.6	11.4	4.3	6.2	7.4	**11.47**	**47.44**	**≤0.001**
Ornamental	10.4	11.5	11.4	53.2	76.0	**352.86**	**132.98**	**≤0.001**
Vulnerable	0.1	0.3	0.2	0.7	1.8	**0.43**	**58.83**	**≤0.001**
Declining	0.5	0.4	0.1	0.2	0.4	**0.34**	**3.36**	**0.01**
Rare	0.0	0.3	0.0	0.3	0.6	**0.22**	**13.88**	**≤0.001**
Near threatened	0.3	0.0	0.1	0.2	0.5	**0.20**	**9.12**	**≤0.001**
Critically rare	0.0	0.0	0.0	0.0	0.1	**0.02**	**5.61**	**≤0.001**
Endangered	0.0	0.0	0.0	0.1	0.3	**0.10**	**9.68**	**≤0.001**
Water the garden	3.5	3.5	3.5	3.8	4.0	**0.56**	**4.98**	**≤0.001**
Fertilise the garden	1.6	2.2	1.4	2.0	2.1	**0.76**	**7.44**	**≤0.001**
Weed the garden	3.7	2.8	2.9	3.5	3.6	**0.89**	**10.01**	**≤0.001**
Prune hedges or trees	1.9	2.3	2.3	1.7	4.0	**0.57**	**70.11**	**≤0.001**
Remove any dead material	3.1	2.6	1.1	2.3	3.9	**0.88**	**58.82**	**≤0.001**
Management index (MI)	13.8	13.4	11.2	13.3	17.6	**6.69**	**39.58**	**≤0.001**

Table 6.9: Tukey's HSD test for unequal sample size results between some floristic data, the garden management activities, management index (MI) and all the studied settlements (T: Tlhakgameng, G: Ganyesa, I: Ikageng, P: Potchefstroom, and R: Roodepoort) (See Annexure H for all Tukey's test results).

Variables	Post hoc Tukey Unequal N HSD
Total species richness	P differs from T, G and I R differs from T, G and I
Alien species richness	P differs from T, G and I R differs from T, G and I
Indigenous species richness	I differs from T and G P differs from T, I and R R differs from T, G, I and P
Water the garden	R differs from T, G and I
Fertilise the garden	T differs from G and R G differs from T and I I differs from G, P and R P differs from I R differs from T and I
Weed the garden	T differs from G and I G differs from T, P and R I differs from T, P and R P differs from G and I R differs from G and I
Prune hedges or trees	T differs from G and R G differs from T, P and R P differs from G, I and R R differs from T, G, I and R
Remove any dead material	T differs from G, I, P and R G differs from T, I and R I differs from T, G, P and R P differs from T, I and R R differs from T, G, I and P
Management index (MI)	I differs from T, G, P and R P differs from I and R R differs from T, G, I and P

6.4 Discussion

6.4.1 Garden management activities and prevalence

This study found that the majority of participants worked in their gardens at least once a week, with nearly 80% of these doing so more than once. Similarly, the study of Gaston *et al*. (2005b) found that 40% of their participants in Sheffield, UK, worked in their gardens more than once a week, 34% did so once a week and 25% did so less than once a week.

Of the 256 participants in this study, 78 % watered their gardens more than once a week and 14 % did so at least once a week when rainfall was insufficient. In Potchefstroom and Roodepoort all the participants watered their gardens at least ones a week, while in Tlhakgameng and Ganyesa more than 10 % rely solely on rain water. Only a few of the residents in Tlhakgameng and Ganyesa have access to water taps inside their yards and even fewer inside their homes, the rest rely on communal water taps. However, more than 80 % of the participants in Tlhakgameng and Ganyesa manage to water their gardens at least once a week. Similarly, Loram *et al*. (2011) found that watering was an important garden-management activity in five cities in the United Kingdom, being performed by 86% of all respondents in their study.

Fertiliser application in gardens was popular with participants in this study, with 60 % applying fertiliser. Similarly, Loram *et al*. (2011) found that 58 % of all the respondents in their study fertilise their gardens. In Tlhakgameng, Ganyesa and Ikageng, the majority of the participants never fertilise their gardens, while the majority of participants in Potchefstroom and Roodepoort do so at least once a year. According to Augustin (2007), only half of all households with lawns apply lawn fertilisers during any given year in the USA. More than 20 % of the participants in Ganyesa fertilise their gardens four times a year, while in Potchefstroom and Roodepoort only 10 % have done that. Augustin (2007) found that 6 % of homeowners apply fertiliser applications three or four times a year, while 93 % fertilise once or twice per year. In Potchefstroom and Roodepoort the participants predominantly used chemical fertilisers, while in Ganyesa and Tlhakgameng all the participants who fertilise their gardens, used organic fertiliser (manure) since chemical fertiliser is too expensive. A study by Méndez *et al*. (2001), found that homegardens in the village of San Juan de Oriente, Masaya, Nicaragua rarely used fertilisers since the majority of the participants could not afford it and those that could usually applied fertiliser once a year.

Of all the participants in this study, 82 % pruned their hedges/trees at least once during the course of a year, while 18 % never pruned them. The participants in Roodepoort pruned their hedges/trees on a regular basis (monthly), while the participants in Potchefstroom, Ganyesa and Tlhakgameng do so at least once a year. The majority of participants in Ikageng however, never pruned their hedges/trees. Similarly, a survey of the residents in Sacramento, California found that 15 % of households never pruned the trees in their residential yards (McPherson *et al*., 2000; Summit and McPherson, 1998). Based on the results of a study by Dilley and Wolf (2013), 88 % of the survey respondents reported having pruned a tree in their yards. According to Xiao and McPherson (2002), "tree pruning can influence the magnitude of storm runoff reduction benefits by influencing the crown volume and the amount of leaf and stem surface area".

Approximately 32 % of the participants in this study never remove dead plant material, while 39 % remove it once a week. The majority of the participants that removed the dead plant material in their gardens lived either in deep rural Tlhakgameng or in highly urbanised Roodepoort. In Roodepoort 74 % of the participants employed a gardener who removed the dead material on a regular basis. In Tlhakgameng however, all the participants were self-reliant (DIY gardening) and most likely removed the dead plant material to keep their gardens neat and tidy ('lebala concept', Cilliers *et al*., 2009; Molebatsi *et al*., 2010). The participants who never removed the dead plant material lived predominantly in Ikageng, and used the dead plant material as compost. Similarly, Méndez *et al*. (2001) found that several of the homegardens in the village of San Juan de Oriente, Masaya, Nicaragua maintained soil fertility by allowing litter (shed leaves and branches) to decompose or by piling them as compost.

6.4.2 DIY or gardening services?

Only 14 % of the participants in this study used gardening services, 31 % employed a gardener and 55 % participated in DIY gardening activities. All the participants in Tlhakgameng and most of the participants in Ganyesa participated in DIY gardening, while the majority of participants in Potchefstroom and Roodepoort either employed a gardener or made use of gardening services. The participants in Potchefstroom and Roodepoort are more affluent (see Chapter 8) and have access to greater resources than those in rural areas. In Ikageng, nearly 60 % of the participants practiced DIY gardening, while approximately 40 % either employed a gardener or made use of gardening services. This is most likely due to Ikageng's close proximity to Potchefstroom. Urban areas are synonymous with better job opportunities and consequently higher incomes.

The study of Martin *et al*. (2003) found that more than 65% of the respondents in Phoenix, Arizona, did their own landscape maintenance. The median home value of residents who maintained their own yard was $149,000, while median home value of residents who employed local landscape firms to maintain their yard was $201,750. Augustin (2007) reported that roughly 25 % of homeowners in the USA hire a lawn service company to apply fertiliser applications, while the remaining 75 % prefer to fertilise themselves. Similarly, Clayton (2007) reported that 26 % of the respondents in her study used a lawn service. These findings were consistent with those of Robbins *et al*. (2001) who reported that 16 % of lawn owners in Ohio used a lawn care company, while 33 % did it themselves and Osmond and Hardy (2004) who reported that between 16 % and 43 % of homeowners in North Carolina used lawn care services, although this varied between communities. These findings were further supported by the National Gardening Market Research Company (2016) who reported that approximately 75 % of all U.S. households participated in DIY lawn and gardening activities in 2015.

6.4.3 Comparison between the Management Index (MI) and floristic data

The results of this study revealed that a management index could be compiled for gardeners based on their gardening activities and the prevalence of these activities. Furthermore, the results showed positive correlations between the species richness present in gardens and the participants' MI. In Roodepoort, the participants' had higher MI values than those in rural areas, mainly because these participants' had greater disposable incomes and could afford to hire either gardening services or a gardener. Conversely, high species richness is not necessarily linked to high MI values, since Potchefstroom had a relatively low mean MI value and a high mean species richness value.

Smith *et al*. (2006a) calculated an index of management intensity for 61 gardens in Sheffield, UK, which summed the questionnaire responses of garden owners based on the intensity with which they carried out various activities (collecting fallen leaves, pruning, watering, weeding, removing dead flower heads, and using herbicides, fertilisers, and pesticides). Based on the results of their study, Smith *et al*. (2006a) suggested that the intensity of management is more likely to influence the spontaneous species in gardens than cultivated species. However, Smith *et al*. (2006b) found that invertebrate abundance was closely linked to native plant species richness for a significant proportion of the taxa in their study and that appropriate garden management could have benefits for overall biodiversity.

6.5 Conclusion

This chapter provides insights into the management practices of gardeners in different settlements in South Africa. The aim was to examine the garden management activities that take place in domestic gardens and their prevalence of occurrence, to determine if a management index could be calculated that provides a single score for each participant in terms of their level of gardening activity and to relate the management index value of gardens to their floristic composition. The results of this study showed that some gardening activities were performed more frequently than others, such as watering which occurred at least once a week, while others, such as fertiliser application occurred less frequently. Furthermore, the results confirmed that a single management index value could be determined for gardens based on their management practices and the frequency with which these activities took place. A single management index value can serve as a proxy for other management activities since the frequency with which these activities took place were correlated with the single value of the management index.

We hypothesised that the floristic composition of domestic gardens would increase as the intensity of garden management practices increased. This was the case in Roodepoort, floristic diversity increased as management practices increased, however, this was not the case in Potchefstroom. There are multiple factors that could have contributed to the high species richness in Potchefstroom's gardens, such as the size of the gardens, garden age, history or the personal preferences of the householders. However, these aspects weren't tested in this study, but could be tested in future research projects. Therefore, the species richness of gardens does not solely depend on garden management practices or their prevalence of occurrence.

The financial resources available to gardeners also play an important role, which is evident in the urban areas of Potchefstroom and Roodepoort considering these two settlements predominantly made use of either gardeners or gardening services. Consequently, Roodepoort may have had the highest management index values overall, but this is because these respondents had greater disposable incomes and therefore possessed the financial means to invest in their gardens ("luxury effect", Hope *et al*., 2003). In contrast, the residents in the rural areas of Tlhakgameng and Ganyesa lack the financial resources to hire gardeners and many of them rely on their gardens for subsistence agriculture.

Future studies concerning garden management practices in South Africa should include questions concerning the cultural background of householders, their motivations for gardening, how they decide what to plant and what to remove, if they actively try and attract wildlife to their gardens and if so, how this is accomplished (ponds, bird feeders, etc.)? How do people connect with nature if they hire others to manage their gardens for them? Do they still enjoy the same benefits as those who do their own gardening? In order to better understand what is growing in South African gardens, we need a better understanding of South African gardeners. What motivates them, how can we educate and inspire them to follow environmentally-friendly gardening practices instead of conventional gardening practices? How do we change the 'tyranny of small gardening decisions' into a 'resource by small gardening actions' (Dewaelheyns *et al*., 2016) in a South African context?

Chapter 7 - How socio-economic status (SES) was determined: With or without questionnaires

7.1 Introduction

Dissimilarities in socio-economic status (SES) are an undeniable fact, both within a given society and also cross-culturally (Mueller and Parcel, 1981). Individuals and families differ in terms of their origin, access to jobs, earnings, and assets, as well as according to their socio-economic status (Mueller and Parcel, 1981). Mueller and Parcel (1981) stated that "sociologists have long recognised and argued the importance of social stratification in understanding various social phenomena, and specialists in stratification have devoted considerable time and effort toward arriving at reliable and valid measures of SES". Mueller and Parcel (1981) use the term "social stratification" to describe a social system (for example, a community or a society) in which families, groups or individuals are characterised by certain hierarchies or dimensions based on their access to or control over prised commodities such as wealth and status. An individual's position on a particular hierarchy is referred to as his/her SES (Mueller and Parcel, 1981).

SES has been a topic of continued interest to social scientists over the last few decades (Entwisle and Astone, 1994; Mueller and Parcel, 1981) and yet there is no complete consensus on what precisely SES represents (Bradley and Corwyn, 2002). Some social scientists are advocates of SES representing class (economic position), while others are advocates of it representing social status (prestige) (Bradley and Corwyn, 2002). Coleman's (1988) idea of capital best embodies the meaning that psychologists currently have of SES (Bradley and Corwyn, 2002; Entwisle and Astone, 1994). Capital refers to the resources or assets available to people (Bradley and Corwyn, 2002). There are five different types of capital in people's livelihoods, namely; natural capital (ecosystem goods and services), physical capital (infrastructure and services), human capital (resources such as education, skills, knowledge and experience), social capital (resources obtained through social connections, such as families, communities, social institutions, etc.) and financial capital (resources related to wealth and income) (DFID, 2000; Fabricius and Collins, 2007).

SES research is however not limited to the social sciences, in recent years a great deal of research has been conducted to link the socio-economic status (SES) of urban residents to various measures of biodiversity, including arthropod diversity (Botha, 2012), avian diversity (Fuller *et al*., 2008; Loss *et al*., 2009; Melles, 2005; Strohbach *et al*., 2009; Van Heezik *et al*., 2013), plant diversity (Hope *et al*., 2003 and 2006; Kinzig *et al*., 2005), and vegetation cover and composition in urban landscapes (Grove *et al*., 2006b; Luck *et al*., 2009; Martin *et al*., 2004; Troy *et al*., 2007). Several different methods have been proposed to measure SES by previous studies, most of which include some quantification of education level, percentage population and median family income (Avolio *et al*., 2015; Clarke *et al*., 2013; Hope *et al*., 2003 and 2006; Iverson and Cook, 2000; Kinzig *et al*., 2005; Luck *et al*., 2009; Martin *et al*., 2004; McConnachie *et al*., 2008; Talarchek, 1990). The method used for measuring SES depends on the question being asked, the method of obtaining the data, the population from which the data was collected (Bradley and Corwyn, 2002; Entwisle and Astone, 1994) and the databases available to the researcher (Grove *et al*., 2006b; Kinzig *et al*., 2005; Martin *et al*., 2004; Troy *et al*., 2007).

The majority of the mentioned studies used neighbourhood census block data to link socio-economic status with vegetation data (Avolio *et al*., 2015; Clarke *et al*., 2013; Hope *et al*., 2003; Luck *et al*., 2009), due to the relative ease of obtaining census data. Martin *et al*. (2004) and Kinzig *et al*. (2005) both used the PRIZM (Potential Rating Index for Zip code Markets) socio-demographic segmentation system from Claritas, Inc., in addition to census data, to identify income clusters in Phoenix, Arizona. The PRIZM data set incorporates a variety of primary data sources including census and purchasing data (consumer spending patterns, household attitudes, and tastes), to divide neighbourhoods into “lifestyle clusters” (Kinzig *et al*., 2005; Troy *et al*., 2007). In Baltimore, Maryland (USA), the study of Grove *et al*. (2006b) used the PRIZM system to determine the relative significance of population density, lifestyle behaviour, and social stratification theories to the distribution of vegetation cover in private land, public rights of way and riparian zones. In contrast to these studies, Van Heezik *et al*. (2013) used a household level approach through interviews to examine four categories of variables that are likely to influence the diversity of birds and vegetation in gardens.

As mentioned in previous chapters, several domestic garden projects have been conducted by the Urban Ecology Research Group at the North-West University (Davoren, 2009; Lubbe, 2011; Molebatsi, 2011). The study of Davoren (2009) formed the basis for these on-going projects which aim to develop a better understanding of the plant diversity of home gardens, their structure, and their function in rural, peri-urban and urban settlements across a socio-economic gradient. One of the main aims of these studies was to determine the effect of SES on the patterns of plant species diversity within domestic gardens. This chapter is essentially a methods chapter and aims to (1) to explore the use of census data and questionnaire data to determine the SES and socio-economic classes of the participants, (2) to find a way to merge and compare the data and (3) to find a statistical method of determining the participants’ SES and socio-economic classes in all five settlements (Tlhakgameng, Ganyesa, Ikageng, Potchefstroom and Roodepoort).

7.2 Methods

7.2.1 Social survey

Aside from the garden surveys conducted in each of the five settlements (see Chapter 5), a questionnaire was constructed to collect data on the management practices (see Chapter 6) and socio-economic information (see Chapter 8) concerning each of the participants (Annexures D to G). The domestic gardens extended over the entire settlement within the different socio-economic areas (poorer to more affluent) of each of the five settlements, which ensured that the data were representative of the sampled settlements.

In the Ganyesa study, the purpose of the questionnaire was to determine the participants' perceptions concerning their gardens, level of gardening activity, socio-economic status, emotional well-being and satisfaction with life (Davoren, 2009). In Tlhakgameng, a similar questionnaire was compiled but additional information was gathered with regards to the gardener (age, gender, level of education, occupation) and his/her indigenous knowledge (Molebatsi, 2011). In Tlhakgameng and Ganyesa questionnaires were used to determine the participant's socio-economic status, since the South African census data for these areas proved to be too unreliable, due to the constant unregulated expansion of the settlement and the fact that most residents lack a fixed monthly income (Davoren, 2009; Molebatsi, 2011).

In Ikageng, Potchefstroom (Lubbe, 2011) and Roodepoort the data from the 2001 National Census Survey (Municipal Demarcation Board, 2006) were used to determine the socio-economic status (SES) of all the electoral wards in each of the settlements and the questionnaire was used solely to ascertain the participants' maintenance regimes for their gardens. Since 2001, there have been two more national census surveys (2007 and 2011), however, the data from these surveys were not used because the electoral ward delineation had been changed (areas of black inhabited, informal settlements together with areas of predominantly white neighbourhoods), which was most likely due to political reasons (Christopher, 1997) and as a result, several wards were classified into SES classes that did not reflect their true SES.

7.2.2 Questionnaires

The Ganyesa questionnaire was divided into four different categories (Annexure D), namely; (1) perceptions, (2) levels of gardening activity, (3) socio-economic status (SES) and (4) satisfaction with life and emotional well-being questions (Davoren, 2009). The Tlhakgameng questionnaire (Annexure E) was developed and improved based on the Ganyesa questionnaire

(Molebatsi, 2011). The improved questionnaire was used to determine garden management, indigenous knowledge and socio-economic data in Tlhakgameng (Molebatsi, 2011). The Ikageng, Potchefstroom (Annexure F) (Lubbe, 2011) and Roodepoort (Annexure G) questionnaires were designed and improved based on the questionnaires developed for the previous studies and on existing research, but excluded questions to determine SES.

7.2.3 Procedures for completing the social survey

In Ganyesa and Tlhakgameng, the participants were interviewed in their home language, Tswana (Davoren, 2009; Molebatsi, 2011) and in Ikageng, Potchefstroom (Lubbe, 2011) and Roodepoort in English and Afrikaans. Six Tswana speaking field workers, with previous interviewing experience, were employed to interview each of the participants in Ganyesa (Davoren, 2009) and the Tlhakgameng study was conducted by a Tswana-speaking student (Molebatsi, 2011). The field workers were trained beforehand to ensure that the questionnaires were completed uniformly (Davoren, 2009). In Tlhakgameng (Molebatsi, 2011), Ikageng, Potchefstroom (Lubbe, 2011) and Roodepoort the questionnaires were completed by the researcher at the same time that the field surveys were conducted. At the start of each interview, the participants were informed that the interviews were anonymous, completion was voluntary and that there was no right or wrong answer (Davoren, 2009; Molebatsi, 2011). In Ganyesa, 96 % of the participants' completed the questionnaire (two participants' were out of town at the time the social survey was conducted), while in Tlhakgameng, Ikageng, Potchefstroom and Roodepoort all the participants' (100 %) completed the questionnaires.

7.2.4 Determining socio-economic status (SES)

7.2.4.1 Ganyesa (rural)

Questions were formulated to serve as surrogates for determining the SES of participants (Table 7.1) (Davoren, 2009). Each question had several answers for participants to choose from and scores were allocated for each specific answer based on a scoring system (Davoren, 2009). These scores were then added to determine each participant's SES (Davoren, 2009). Based on a clustering method known as Ward's method (Ward, 1963), the participants were divided into three SES classes (Davoren, 2009).

According to Hervada-Sala and Jarauta-Bragulat (2004), "Ward's clustering method is a hierarchical agglomerative method". This method incorporates many diverse techniques to identify structure within complex data sets (Hervada-Sala and Jarauta-Bragulat, 2004). The purpose of a cluster analysis is to group different variables into clusters in such a way that the elements within the cluster have high degrees of "natural association" among themselves, but at the same time, these elements must be “relatively distinct” from one another (Hervada-Sala and Jarauta-Bragulat, 2004).

Table 7.1: Several aspects used as surrogates for determining the SES of the participants in the rural settlement of Ganyesa (Davoren, 2009).

1.	Type of housing structure	**2.**	Owned or rented house
3.	Type of sanitation	**4.**	Type of water source
5.	Distance from nearest water source	**6.**	Fruit and vegetables in gardens
7.	Livestock	**8.**	Method of earning money
9.	Modes of transport	**10.**	Monthly income
11.	Number of persons living on the premises	**12.**	Number of rooms in the house
13.	Highest level of education		

Ward’s clustering method divided the variables into three distinct SES classes (Figure 7.1) (Davoren, 2009). Based on the groupings of the clusters, the participants were grouped together due to their level of education, methods of earning money, the number of residents per household and mean monthly income (Davoren, 2009). Class three had the highest SES and class one the lowest (Davoren, 2009).

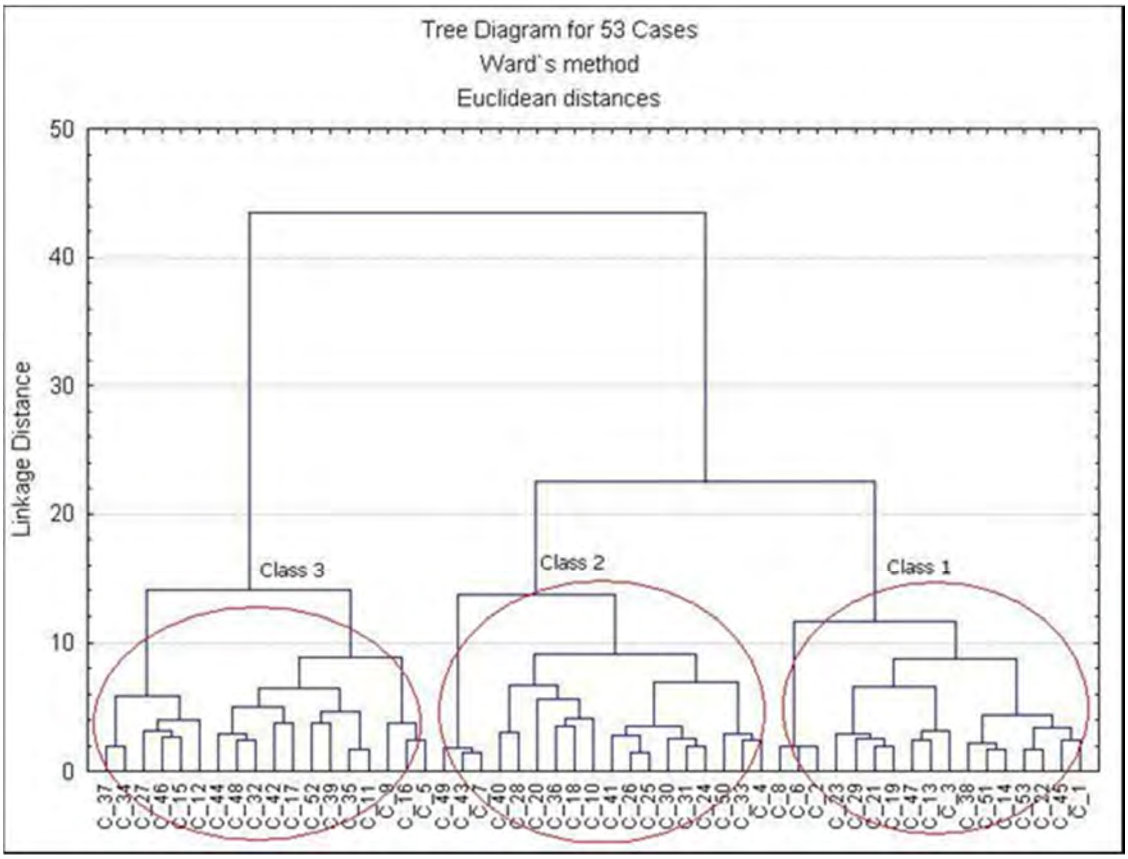

Figure 7.1: Diagram illustrating the formation of the three SES classes by Ward’s clustering method for the rural settlement of Ganyesa (Davoren, 2009).

7.2.4.2 Tlhakgameng (deep rural)

Molebatsi (2011) used four different parameters to determine the SES classes of participants in Tlhakgameng, namely; economic well-being, household factors, basic services, and education level (Table 7.2). The four parameters were then defined in terms of a scoring system (Molebatsi, 2011). The scores for the parameters were determined in such a manner that the highest score was allocated to the factor that contributes the most towards food security, financial stability and future opportunities for self-enrichment (for more information see; Molebatsi, 2011). Molebatsi (2011) added the scores for all the parameters and plotted the total scores for all the participants from highest to lowest and the resultant curve was subjected to a double intercept of an exponential trend line, which was used to delineate three SES classes (Figure 7.2).

Table 7.2: The Parameters used to determine SES classes in Tlhakgameng (Molebatsi, 2011).

Parameters	
Economic well-being:	Unemployment rate, Livestock, Transportation, Monthly income, Job security
Household:	Number of inhabitants, Number of rooms, Structure
Basic services:	Lighting, Heating, Cooking, Water source, Water availability, Sanitation
Education level:	None, Primary School, Secondary School, Grade 12, Tertiary education

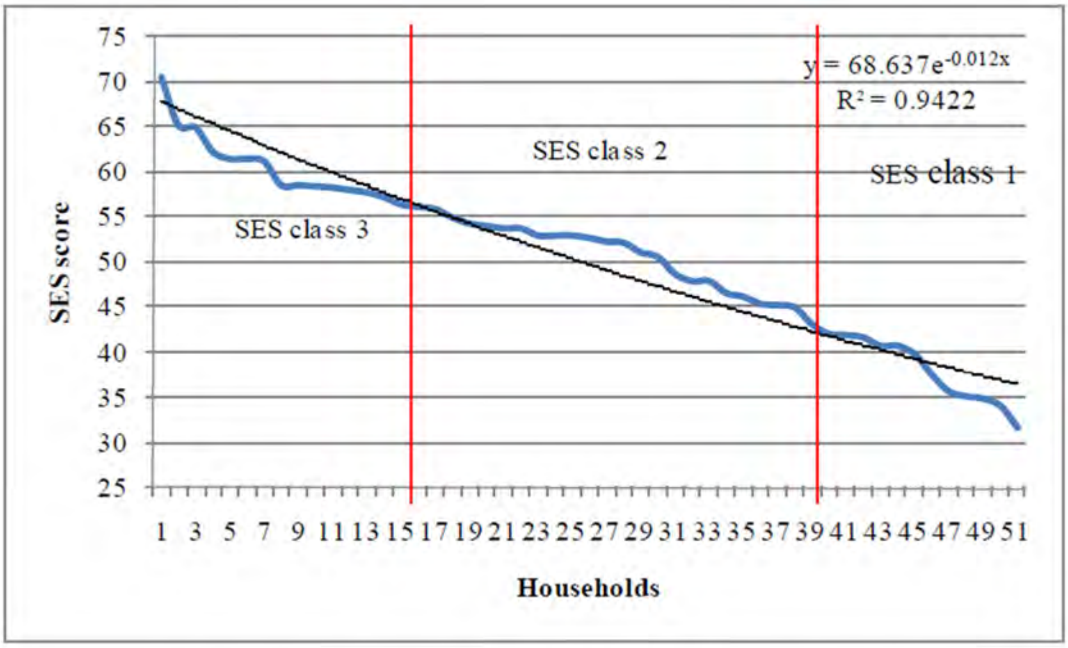

Figure 7.2: Three classes defined by the intercept of an exponential trend line based on SES scores for the participants in Tlhakgameng (Molebatsi, 2011).

7.2.4.3 Ikageng (peri-urban) and Potchefstroom (urban)

Lubbe (2011) used the data from the 2001 Census Survey (Municipal Demarcation Board, 2006) to determine the SES of all the electoral wards in the Tlokwe City Municipality (TCM).

Five different parameters were used to determine the SES classes (Table 7.3) (Lubbe, 2011; Lubbe *et al*., 2010). The wards were then divided into the five SES classes (Table 7.4), class 5 had the highest SES and class 1 the lowest (Lubbe, 2011). Lubbe (2011) calculated the number of individuals as a percentage of the total in each category, for each of the parameters. The data for each ward were given in percentages and a higher percentage for all of the parameters indicated a lower SES (Lubbe, 2011). The class with the highest SES (class 5), earned > USD 3 000 per month, while the class with the lowest SES (class 1), earned < USD 100 per month (Lubbe, 2011). Class 1 was the most economically stressed of all the SES classes (Lubbe, 2011).

Table 7.3: The five parameters used to determine the SES classes of all the wards in Ikageng and Potchefstroom (Lubbe, 2011). Higher % indicates a lower SES for all of the parameters (Lubbe, 2011).

1.	% Unemployment:	The % of unemployed people, excluding economically non-active persons
2.	Household size:	The % of households with five or more people
3.	Number of rooms:	The % of households with two or fewer rooms
4.	Access to basic services:	the % of households with piped water more than 200 m away, including those with no access to pipe water
5.	Schooling status:	the % of people with no schooling (from the grouped education category)

Table 7.4: Comparison of the parameters used to determine the five SES classes within the Tlokwe City Municipality (5 – highest SES, 1 – lowest SES) (For more information see Lubbe, 2011; Lubbe *et al*., 2010).

SES (class)	Unemployment	Household size	Number of rooms	Access to basic services	Schooling status
1	46±5	28±8	44±18	7±9	14±4
2	33±2	27±9	40±10	11±17	24±10
3	25±3	38±5	27±14	5±9	9±5
4	15±2	23±17	23±12	2±1	10±8
5	4±1	13±1	10±1	1±0	2±0

7.2.4.4 All five settlements

Six different parameters were used to determine the SES classes for each garden owner (Davoren *et al*., 2016), the five parameters listed in Table 7.3 and mean monthly income. These parameters were selected based on previous studies and tested to determine if they provide the best possible representation of the participants' SES. The parameter values of Ikageng, Potchefstroom and Roodepoort were calculated from the 2001 census data (Municipal Demarcation Board, 2006), while the values for Tlhakgameng and Ganyesa were obtained from the questionnaires collected in those areas (Davoren 2009; Molebatsi 2011). The census data for each of the settlements are given in terms of electoral wards. According to the Municipal Demarcation Board (2006), "electoral wards are local municipal delineations of a subset of housing suburbs grouped together for municipal and national political election purposes".

In order to determine the SES classes of each garden owner, they were grouped according to the wards in which they were located. Table 7.5 contains examples of the equations used to determine the values of each of the six parameters based on household data. The values of the six parameters were then used to determine the five SES classes of all the wards in the surveyed settlements. The first column is data obtained from the questionnaires in Tlhakgameng and the second column is census data obtained from the Municipal Demarcation Board (2006) for Roodepoort. Tables 7.6 and 7.7 illustrate the process used to determine the mean monthly income for one ward in Tlhakgameng and one ward in Roodepoort respectively. The USD exchange rate used to determine mean monthly income was that of the 16th of August 2013 (USD 1/10.04 ZAR).

Table 7.5: Examples of the equations used to determine the values of each of the six parameters used to determine the five SES classes of all the wards in the surveyed settlements. Column one is data obtained from questionnaires (example: Tlhakgameng, 40 households) and column two is census data (example: Roodepoort). Higher % indicates a lower SES for all of the parameters (Lubbe, 2011) (See Annexure I for the values of all the SES parameter for all the wards).

Questionnaire data:	**Census data:**
1. % Unemployment: Employed: 180 Unemployed: 29 **Total labour force: 209 (number of residents that were of income earning age across 40 households)** 29 × 100/209 = 13.9 %	**1. % Unemployment:** Employed: 13 149 Unemployed: 855 **Total labour force: 14 004** 855 × 100/14 004 = 6.1 %
2. Household size: 1 = 1 2 = 4 3 = 3 4 = 10 5 = 6 6 = 6 7 = 5 8 = 0 9 = 2	**2. Household size:** 1 = 2 019 2 = 2 325 3 = 1 425 4 = 1 425 5 = 555 6 = 228 7 = 81 8 = 27 9 = 15

10 and more = 3 **Total = 40** **% of households with five or more people:** 22 × 100/40 = 55 %	10 and more = 9 **Total = 8109** **% of households with five or more people:** 915 × 100/8 109 = 11.3 %
3. Number of rooms: 1 = 10 2 = 7 3 = 7 4 = 5 5 = 4 6 = 2 7 = 1 8 = 1 9 = 1 10 and more = 2 **Total = 40** **% of households with two or less rooms:** 17 × 100/40 = 42.5 %	**3. Number of rooms:** 1 = 1 338 2 = 483 3 = 660 4 = 1 290 5 = 1 050 6 = 1 014 7 = 774 8 = 675 9 = 324 10 and more = 510 **Total = 8 118** **% of households with two or fewer rooms:** 1 821 × 100/8 118 = 22.4 %
4. Access to basic services: Dwelling = 1 Inside yard = 7 Community stand = 1 Community stand over 200m = 19 Borehole = 12 **Total = 40** **% of households with pipe water more than 200 m away:** 19 × 100/40 = 47.5 %	**4. Access to basic services:** Dwelling = 6 201 Inside yard = 1 266 Community stand = 165 Community stand over 200m = 384 Borehole = 27 Spring = 0 Rain tank = 3 Dam/Pool/Stagnant water = 15 River/Stream = 21 Water vendor = 3 Other = 24 **Total = 8 109** **% of households with piped water more than 200 m away:** 384 × 100/8 109 = 4.7 %
5. Schooling status: No schooling = 92	**5. Schooling status:** No schooling = 591

Primary school = 57 Secondary school = 41 Grade 12 = 13 Tertiary = 6 **Total = 209** **% of people with no schooling:** 92 × 100/209 = 44.0 %	Some primary = 816 Complete primary = 339 Secondary = 3 513 Grade 12 = 5 580 Tertiary = 6 498 **Total = 17 337** **% of people with no schooling:** 591 × 100/17 337 = 3.4 %
6. Mean monthly income (See Table 7.7)**:** 4 930.2/40 = 123.3	**6. Mean monthly income** (See Table 7.8)**:** 176 310 029.58/8 112 = 21 734.5

Table 7.6: The process used to determine the mean monthly income for a ward in Tlhakgameng.

Income levels	**Midpoint of Income level**	**USD**	**Number of Households**	**USD × Number of Households**
R 0 – R 500	250	24.9	6	149.4
R 500 – R 1 000	750	74.7	21	1 568.7
R 1 000 – R 1 500	1 250	124.5	7	871.5
R 1 500 – R 2 000	1 750	174.3	2	348.6
R > 5 000	5 000	498.0	4	1 992
Total	**9 000**	**896.4**	**40**	**4 930.2**

*Mean monthly income (USD 1/10.04 ZAR, exchange rate on 16 August 2013)

Table 7.7: The process used to determine the mean monthly income for a ward in Roodepoort.

Income levels	**Midpoint of Income level**	**USD**	**Number of Households**	**USD × Number of Households**
None	0	0	243	0
R 1 – 4 800	2 400.5	239.09	162	38 733.17
R 4 801 – 9 600	7 200.5	717.18	492	352 853.19
R 9 601 – 19 200	14 400.5	1 434.31	756	1 084 340.44
R 19 201 – 38 400	28 800.5	2 868.58	615	1 764 174.05
R 38 401 – 76 800	57 600.5	5 737.10	819	4 698 686.21
R 76 801 – 153 600	115 200.5	11 474.15	1470	16 867 005.48
R 153 601 – 307 200	230 400.5	22 948.26	2076	47 640 581.47
R 307 201 – 614 400	460 800.5	45 896.46	1101	50 532 007.02
R 61 4401 – 1 228 800	921 600.5	91 792.88	225	20 653 397.66
R 1 228 801 – 2 457 600	1 843 200.5	183 585.71	78	14 319 685.16
Over R 2 457 600	2 457 600	244 780.88	75	18 358 565.74
Total	**6 139 205.00**	**611 474.60**	**8 112**	**176 310 029.58**

*Mean monthly income (USD 1/10.04 ZAR, exchange rate on 16 August 2013)

7.2.5 Statistical analyses

7.2.5.1 Principal Components Analysis (PCA)

A principal components analysis (PCA) was performed to classify the wards, of the five different settlements, into different SES classes using the six parameters. According to Jolliffe (2002), "the central idea of principal component analysis (PCA) is to reduce the dimensionality of a dataset in which there are a large number of interrelated variables while retaining as much as possible of the variation present in the data set". The principal components are ordered in such a manner that the first component extracts the most of the variance and the last component extracts the least of the variance (Tabachnick and Fidell, 2007). Quinn and Keough (2002) stated that "because it uses covariances or correlations as a measure of variable association, PCA is more effective as a variable reduction procedure when there are linear relationships between variables".

Therefore, the solution is enhanced if the variables are normally distributed, however, if the variables are not normally distributed the solution is degraded but may still be useful (Tabachnick and Fidell, 2007). The PCA was done in STATISTICA 9.0 (Statsoft, 2009) and the wards were delineated into five SES classes based on the sorted eigenvalues of factor 1 (Table 7.8). A typical PCA extracts components that explain the variability in the original variables, while an FA aims to explain correlations among the original variables (Quinn and Keough, 2002).

7.2.5.2 Factor Analysis (FA)

According to Yong and Pearce (2013), the general purpose of a factor analysis (FA) is to summarise data so that patterns and relationships can be easily understood and interpreted. FA regroups variables into a set of clusters based on shared variance and thereby isolates concepts and constructs (Yong and Pearce, 2013). There are several differences between FA and PCA, FA produces factors, PCA produces components, but the main mathematical difference is the variance that is analysed (Tabachnick and Fidell, 2007). In FA, only shared variance is analysed, while in PCA, all the variance in the observed variables is analysed (Tabachnick and Fidell, 2007). According to Tabachnick and Fidell (2007) FA attempts "to estimate and eliminate variance due to error and variance that is unique to each variable".

Tabachnick and Fidell (2007) stated that factors are believed to "cause" variables; i.e. it is the underlying factors that produce the scores on the variables. However, PCA components are simply aggregates of correlated variables, the variables "cause" or produce the component (Tabachnick and Fidell, 2007). According to Quinn and Keough (2002), "FA is based on a correlation matrix or less commonly, a covariance matrix". The correlation matrix is separated into two parts, the first is generated by the common factors (factors that explain all the correlations among the original variables) and the second is due to the unique factors (factors that represent information not explained by the common factors) (Quinn and Keough, 2002).

In order to determine which variables used in literature best measure SES, a FA was performed using STATISTICA 9.0 (Statsoft, 2009). The factors were rotated with the Varimax raw rotation method. According to Tabachnick and Fidell (2007), “the goal of Varimax rotation is to maximise the variance of factor loadings by making high loadings higher and low ones lower for each factor”.

7.3 Results

Table 7.8 shows the output summary table for the PCA results. According to Tabachnick and Fidell (2007) “the first principal component (factor 1) is the linear combination of observed variables that maximally separates subjects by maximizing the variance of their component scores, while the second component (factor 2) is formed from residual correlations, i.e. it is the linear combination of observed variability that extracts maximum variability uncorrelated with the first component”. The solution of the PCA is mathematically unique (Tabachnick and Fidell, 2007). The eigenvalues are extracted in ascending order of importance in terms of their contribution to the total variation in the data set. The result of the PCA was used to group the different wards into SES classes 1 to 5. More specifically, the SES classes were determined based on the clusters that formed from the eigenvalues of factor 1.

In FA the interest is primarily in the variables that explain the variance in the original variables, and not in extracting the maximum amount of variance from the data set with each component as with PCA (Tabachnick and Fidell, 2007). Therefore, in order to interpret FA, it is important to remember that the factors “cause” the variables i.e. it is the underlying factors that produce the scores on the variables (factor loadings) (Tabachnick and Fidell, 2007). The greater the loading, the more the variable is a measure of the factor, loadings in the excess of 0.71 (50 % overlapping variance) are considered excellent (Tabachnick and Fidell, 2007). For the current study, it identifies the measures that best describe the SES of the participants. As shown in Table 7.9 the % unemployment, household size, and monthly income each respectively correlate extremely well to the first factor, while access to basic services and schooling status correlate to the second factor. However, it is important the note that the % unemployment is based on a low %, the household size is based on smaller households and the monthly income is based on a high monthly income.

Table 7.8: Results of the Principal Component Analysis (PCA) which identifies the five SES classes based on the six parameters. The eigenvalues for factor 1 and 2 for each ward is listed, as well as the number of participants in each ward.

		Eigenvalue (Factor 1)	Eigenvalue (Factor 2)	Number of participants per ward
SES CLASS 1	Ganyesa Ward 7	-3.10	-1.03	32
	Ganyesa Ward 6	-2.99	-1.23	21
	Tlhakgameng Ward 4	-2.63	-0.83	11
	Tlhakgameng Ward 5	-2.42	0.90	40
	Ikageng Ward 17	-2.26	-1.63	13
	Ganyesa Ward 8	-2.10	-1.76	2
SES CLASS 2	Ikageng Ward 11	-1.77	-0.29	5
	Ikageng Ward 10	-1.76	-0.30	7
	Ikageng Ward 18	-1.51	0.83	1
	Ikageng Ward 16	-1.17	1.03	6
SES CLASS 3	Ikageng Ward 15	-0.72	1.80	2
	Ikageng Ward 9	-0.46	1.29	7
	Ikageng Ward 13	-0.43	0.95	2
	Ikageng Ward 14	-0.38	1.73	3
	Ikageng Ward 12	-0.26	1.66	3
	Ikageng Ward 8	-0.23	1.38	2
SES CLASS 4	Potchefstroom Ward 7	0.25	-0.80	5
	Potchefstroom Ward 1	0.51	-0.25	8
	Potchefstroom Ward 2	1.87	-0.20	8
SES CLASS 5	Potchefstroom Ward 4	2.03	0.20	9
	Roodepoort Ward 9	2.05	-0.19	5
	Roodepoort Ward 83	2.22	-0.57	15
	Potchefstroom Ward 5	2.24	0.045	8
	Roodepoort Ward 13	2.34	-0.17	8
	Roodepoort Ward 97	2.55	-0.98	6
	Potchefstroom Ward 3	2.60	-0.13	11
	Roodepoort Ward 85	2.76	-0.98	14
	Roodepoort Ward 14	2.76	-0.49	2

Table 7.9: Factor Analysis (FA) results of the six SES parameters. The factor loadings for each variable per component are listed. Values > 0.7 are highlighted in bold.

	Factor 1	Factor 2
% Unemployment	**0.891169**	0.303190
Household size	**0.945434**	0.168404
Number of rooms	0.522844	0.693639
Access to basic services	0.093692	**0.919376**
Schooling status	0.399193	**0.821953**
Monthly income	**-0.858129**	-0.262259
Explained Variance	2.865913	2.191057
Proportional Total	0.477652	0.365176

7.4 Discussion

The factor analysis indicated that percentage unemployment, household size, and monthly income are the most suitable variables for describing the socio-economic status of the participants in five different settlements. A literature review found that median household income, obtained from census data, was commonly used to determine the socio-economic status (SES) of residents or neighbourhoods (e.g. Avolio *et al*., 2015; Clarke *et al*., 2013; Hope *et al*., 2003 and 2006; Kinzig *et al*., 2005; Luck *et al*., 2009; Martin *et al*., 2004; McConnachie *et al*., 2008; Talarchek, 1990). However, median household income was predominantly used in conjunction with other variables (Avolio *et al*., 2015; Clarke *et al*., 2013; Hope *et al*., 2003 and 2006; Iverson and Cook, 2000; Kinzig *et al*., 2005; Luck *et al*., 2009; Martin *et al*., 2004; McConnachie *et al*., 2008; Talarchek, 1990). For instance, Avolio *et al*. (2015), Chen and Wang (2013), Jensen *et al*. (2004) Lowry *et al*. (2012), Pedlowski *et al*. (2002) and Talarchek (1990) all investigated the importance of socio-economic variables to urban forest cover. In addition to median income, they also used level of education (Avolio *et al*., 2015; Lowry *et al*., 2012), home value (Jensen *et al*., 2004; Talarchek, 1990) and population density (Chen and Wang, 2013; Jensen *et al*., 2004; Lowry *et al*., 2012; Talarchek, 1990) as supplementary socio-economic measures. Duncan *et al*. (2014) and Shanahan *et al*. (2014) determined if socio-economic variables influenced tree cover and diversity in an urban settlement. Level of education (Shanahan *et al*., 2014), population density and demographics (Duncan *et al*., 2014) were some of the socio-economic variables used in their respective studies in addition to median income.

Clarke *et al*. (2013), Hope *et al*. (2003), Hope *et al*. (2006), Iverson and Cook (2000), Jenerette *et al*. (2013), Kendal *et al*. (2012a), Luck *et al*. (2009) and Martin *et al*. (2004), examined the correlation between vegetation cover/composition and socio-economic variables. They used level of education (Kendal *et al*., 2012a; Martin *et al*., 2004), population density (Clarke *et al*., 2013; Hope *et al*., 2003; Kendal *et al*., 2012a; Martin *et al*., 2004) and household age (Hope *et* *al*., 2003; Hope *et al*., 2006), in addition to median income, as auxiliary socio-economic measures. Kinzig *et al*. (2005), Loss *et al*. (2009), Melles (2005) and Strohbach *et al*. (2009) evaluated the effect of socio-economic factors on bird diversity. Aside from median income, these four studies used level of education (Kinzig *et al*., 2005; Melles, 2005), household age (Loss *et al*., 2009; Strohbach *et al*., 2009), population density (Kinzig *et al*., 2005; Strohbach *et al*., 2009) and rate of unemployment (Strohbach *et al*., 2009) as socio-economic factors.

Both Martin *et al*. (2004) and Kinzig *et al*. (2005) used the Claritas PRIZM dataset, in addition to census data, to identify income clusters in Phoenix, Arizona. Martin *et al*. (2004) used the Claritas PRIZM dataset as the basis for their gradient of three SES levels (low, medium and high). The study of Grove *et al*. (2006b) found that "lifestyle behaviour was the best predictor of vegetation cover on private lands, and median housing age was significantly associated with vegetation cover for riparian areas, private lands, and public rights of way". Troy *et al*. (2007) included three additional variables (housing age, crime level, and green space) that were thought to be important to predicting urban vegetation distribution, but were not considered as defining dimensions of the PRIZM classes. The results of Troy's study indicated that in Baltimore there is a statistically significant inverse relationship between median household income and certain measures of crime (Troy *et al*., 2007). According to Troy *et al*. (2007) "crime level impacts the way that residents perceive of, use, and manage surrounding green spaces".

All of the above mentioned studies used census data to obtain the socio-economic factors for their respective studies. In contrast to these studies, Van Heezik *et al*. (2013) used household level interviews to examine the importance of garden attributes, neighbourhood characteristics, socio-economic variables, environmental attitude and knowledge of householders to the diversity of vegetation and birds in gardens. According to Van Heezik *et al*. (2013), the variation between householders and within neighbourhoods is considerable, and as a result a household level approach is the best way to determine variations in vegetation composition and cover.

7.5 Conclusion

Both questionnaires and census data were used to determine the SES of participants in this study. Census data were used, since most of the research done in regards to socio-economic determination uses census data and therefore made the results comparable to previous studies. However, by using census data much of the data may be lost especially when considering the way in which the wards are delineated in South Africa. In terms of the plant diversity of individual domestic gardens, it would be better to use questionnaires to determine the householders' SES, i.e. linking an individual garden with the SES of the householder. The main problem with this is that people prefer not to answer any questions relating to their monthly income and where some may answer the question honestly others may lie or choose not to answer the question at all. However, the same can be said of census data, since census data are collected from questionnaires and the same bias exists. Consequently, future studies should explore alternative measures of SES determination in South Africa, for example occupation or level of education, i.e. measures of SES that are not connected to income, but that can be relayed to a person's SES.

In conclusion, the method used for determining SES does not just depend on the question being asked, the method of obtaining the data or the population from which the data were collected (Bradley and Corwyn, 2002), but also the research tools available to the researcher (census data/PRIZM dataset) and the reliability of the data. This chapter attempted to contribute to our knowledge of SES determination in rural and urban areas in South Africa and the variables used in this study were similar to those used in other studies across the globe. Similarly to those studies, monthly income was one of the variables that best described the socio-economic status of the participants. Percentage unemployment and household size also best described the socio-economic status of the participants, suggesting that these variables could be used as surrogates for monthly income in future, but this needs to be investigated before assumptions can be made.

Chapter 8 - Socio-economic status as a driver of urban floristic patterns

8.1 Introduction

Humans are not merely an exogenous force, but an interactive species that alters their surroundings to achieve specific sets of environmental amenities (Kinzig *et al*., 2005). The plant diversity in and around cities may be a reflection of the cultural, economic and social influences of human beings in conjunction with those processes recognised by traditional ecological theory (Hope *et al*., 2003) such as trophic dynamics and species effects on ecosystems (Chapin *et al*., 2011). By incorporating a socio-economic gradient in urban environmental analyses we alter our perceptions of human–environment interactions and acknowledge that the desires, preferences, and wherewithal (financial resources) of people in urban landscapes matter (Kinzig *et al*., 2005). According to Martin *et al*. (2004), "the ability of individual people to affect nature in urban environments appears related to economic wherewithal [financial resources] and may be most evident in the 'human-created floras' of residential yards".

According to Gaston *et al*. (2005a), large sums of money are spent on management of domestic gardens in the United Kingdom annually. During the period of July 1999 to June 2000, the retail market of garden products in the UK was valued at £2.62 billion, with 60 % of household's spending money on their gardens and an average spending approximately £182, which is roughly 1 % of household expenditure (Gaston *et al*., 2005a). The preliminary production value calculated for agriculture in Germany during 2012, was approximately 52.2 billion €, of which commercial horticulture comprised up to 9 % (4.7 billion €) (Federal Ministry of Food and Agriculture (BMEL), 2014). The horticultural industry in New Zealand is a $4 billion industry, which utilises roughly 100,000 ha of land to produce a wide array of products (De Silva and Forbes, 2016). Junqueira and Peetz (2011) reported that the gross value of the flower and ornamental plant market in Brazil in 2010, was R$ 3.8 billion, the majority of which focused on domestic consumption. In South Africa, the gross value of individual horticultural products for the period of March 2010 to February 2011 was estimated at R 36 million (Department of Agriculture, Forestry, and Fisheries, 2012).

Based on the large sums of money associated with gardening and horticulture, there is tremendous potential for making gardens more suitable for increasing biodiversity, even the use of a small percentage of this expenditure could well make a noteworthy difference (Gaston *et al*., 2005a). Popular media, such as books, magazines, radio, and television are replete with recommendations on simple changes that can be made to increase the biodiversity in gardens

(Gaston *et al*., 2005a). However, gardeners often use garden plants as an expression of their individual identity, which is likely to be constrained by socially shared norms, such as their ability to grow their plants of choice, availability from nurseries, advice from landscapers and the potential effect that their gardening choices could have on the market value of their homes (Hope *et al*., 2006).

Ever since the pioneering study of Talarchek (1990) into the relationship between socio-economic and urban environmental data, several studies have found that the socio-economic status (SES) of urban residents serves as an important indicator of the species diversity and composition of vegetation in urban landscapes (Hope *et al*., 2003; Hope *et al*., 2006; Kinzig *et al*., 2005; Luck *et al*., 2009; Martin *et al*., 2004). These studies primarily used median household income, obtained from census data, to determine the socio-economic status (SES) of residents or neighbourhoods (Hope *et al*., 2003; Kinzig *et al*., 2005; Luck *et al*., 2009; Martin *et al*., 2004). Based on the results reported in these studies, there are significant increases in plant species diversity (Hope *et al*., 2003; Hope *et al*., 2006; Van Heezik *et al*., 2013), plant species abundance (Luck *et al*., 2009; Martin *et al*., 2004), tree cover (Avolio *et al*., 2015; Clarke *et al*., 2013; Iverson and Cook, 2000; McConnachie *et al*., 2008) and bird diversity (Fuller *et al*., 2008; Kinzig *et al*., 2005; Melles, 2005; Strohbach *et al*., 2009) in urban areas occupied by inhabitants with a higher SES.

Hope *et al*. (2003) concluded: “that a functional relationship, termed the ‘‘luxury effect,’’ may link human resource abundance (wealth) and plant diversity in urban ecosystems”. The study of Martin *et al*. (2004) found that the plant diversity in parks and surrounding neighbourhoods in Phoenix, Arizona, was best explained by both a “luxury” and “legacy” effect, suggesting that plant diversity was highest in the wealthiest and oldest residential neighbourhoods. Hope *et al*. (2006) suggested that the luxury effect in combination with land use, “legacy effects” and other sociocultural influences best explain the plant diversity in an urban settlement.

Based on the results of these studies, we hypothesised that socio-economic status (SES) might be a useful predictor of the plant diversity of domestic gardens due to the influence that SES can have on the ability of individuals to alter their surrounding environments. As mentioned in previous chapters, several domestic garden projects have been conducted by the Urban Ecology Research Group at the North-West University (Davoren, 2009; Lubbe, 2011; Molebatsi, 2011). The data obtained from these research projects (Davoren, 2009; Lubbe, 2011; Molebatsi, 2011), as well as the data sampled in Roodepoort, were consolidated and the aim of this chapter is to (1) determine the relationship between several socio-economic variables (discussed in Chapter 7) and the species and functional diversity of the domestic gardens sampled in five settlements (Tlhakgameng, Ganyesa, Ikageng, Potchefstroom and Roodepoort) and to (2) determine the relationship between the plant diversity and socio-economic status classes of the participants in these studies (see Chapter 7 for SES class determination).

8.2 Methods

In conjunction with the garden surveys conducted in each of the five settlements (see Chapter 5), a questionnaire was compiled to collect data on the management practices (see Chapter 6) and socio-economic information concerning each of the participants (Annexures D to G). In Tlhakgameng and Ganyesa questionnaires were used to determine the participants' socio-economic status (Davoren, 2009; Molebatsi, 2011), while in Ikageng, Potchefstroom (Lubbe, 2011) and Roodepoort the socio-economic status was determined with 2001 South African National census data (Municipal Demarcation Board, 2006). The method for socio-economic status determination was discussed in Chapter 7.

8.2.1 Statistical analyses

8.2.1.1 Canonical correlation analysis

Canonical correlation analysis was used to compare the socio-economic variables used to determine the socio-economic status (SES) (see Chapter 7) of each of the participants with the floristic variables collected from each garden. The socio-economic variables included % unemployment, household size, the number of rooms, access to basic services, schooling status, and monthly income. The floristic variables included total, alien and indigenous species richness, growth form (tree, shrub, succulent, herb, geophyte, fern, epiphyte, and graminoid), declared weed and invader status according to South African national legislation (National Environmental Management: Biodiversity Act (NEMBA) (South Africa, 2014)) and useful species (food, medicinal and ornamental).

Canonical correlation analysis extracts linear combinations of variables (components) from two sets of variables (socio-economic and floristic) so that the first component for one set has the maximum correlation with the first component from the second set (Quinn and Keough, 2002). According to Quinn and Keough (2002), "the components are termed canonical variates [Roots] and the first component from each set forms one pair of canonical variates, the second component from each set forms a second pair, etc." According to Tabachnick and Fidell (2007), canonical variate pairs are computed in descending order of magnitude.

The number of canonical variate pairs is limited to the number of variables in the smallest set (Tabachnick and Fidell, 2007), namely; the socio-economic variables which contain only six variables. However, in most cases, only the first two or three canonical variate pairs are statistically significant and need to be reported (Tabachnick and Fidell, 2007). In this study only the first two canonical variate pairs were statistically significant (Tables 8.1 and 8.2). The results for canonical variate pairs three to six were reported in Annexure J. Scatterplots were generated for all six canonical variate pairs, but only the first two scatterplots were discussed in the results (Figures 8.1 and 8.2) (see Annexure J for the remaining scatterplots). The software package STATISTICA 13.0 (Statsoft, 2009) was used to perform all statistical analyses.

8.2.1.2 ANOVA

An analysis of variance (ANOVA) test was performed to determine if statistically significant differences exist between the socio-economic status variables and the floristic data (total species richness, alien, indigenous, growth form, declared weeds and invader status, food, medicinal and ornamental). According to Tabachnick and Fidell (2007) "analysis of variance is used to compare two or more means to see if there are any statistically significant differences among them". The null-hypothesis of this technique is that the means of all the samples are the same and, by computing the variance within (residual variance) and between (effect variance) sample means, it can be determined whether the samples are significantly different from one another and whether to accept or reject the null-hypothesis (Quinn and Keough, 2002).

The result of an ANOVA simply informs on the possibility of significant differences, but does not indicate which groups differ from each other, therefore, post hoc testing is required (Tabachnick and Fidell, 2007). Subsequently, Tukey's honestly significant difference (HSD) post hoc test for unequal sample size was carried out. The HSD test pairwise compares the sample mean with that of every other sample to determine which samples were significantly different from others (Quinn and Keough, 2002).

8.2.1.3 Box plots

Box plots were compiled for the total, alien, indigenous and ornamental species richness and grouped according to socio-economic status classes 1 to 5. A box plot also called a box-and-whisker plot is a standardised way to visually describe the distribution of sample data (Quinn and Keough, 2002). A box plot uses a five-number summary to display the data, namely; the lowest observation (smallest number), the lower quartile (first quartile), the median, the upper quartile (third quartile) and the highest observation (largest number) (Mendenhall *et al*., 2006; Moore *et al*., 2013). The lowest observation, lower quartile, upper quartile and the highest observation all represent 25 % of the data (Quinn and Keough, 2002).

8.2.1.4 Spearman's rank correlation

Spearman's rank correlation coefficients (r_S) were generated to determine if statistically significant differences exist between the socio-economic status and the floristic data (total species richness, alien, indigenous, growth form, declared weeds and invader status, food, medicinal and ornamental) of the sampled domestic gardens in all five settlements. According to Quinn and Keough (2002), Spearman's rank correlation is derived from "the Pearson correlation coefficient after the two variables have been separately transformed to ranks but the pairing is retained after ranking".

8.3 Results

8.3.1 Comparison between socio-economic variables and floristic variables

Canonical weights show how each of the variables in each set uniquely contributes to the respective weighted sum of each canonical variate (StatSoft, Inc., 2013). The canonical weight of each variable is listed in Tables 8.1 and 8.2. The first canonical variate of the socio-economic variables was best described by household size and schooling status which had high positive contributions to the total weighted sum of the variate, while monthly income had a high negative contribution (Table 8.1). The first canonical variate of the floristic variables was best described by the number of alien species, which had a high positive contribution and the number of ornamental species, which had a high negative contribution to the total weighted sum of the variate (Table 8.2).

The second canonical variate of the socio-economic variables was best described by household size, schooling status, and monthly income, all of which had high negative contributions to the total weighted sum of the variate (Table 8.1). The second canonical variate of the floristic variables was best described by the number of trees, herb and succulent species, which had high positive contributions, while the number of indigenous and category C3 species had high negative contributions to the total weighted sum of the variate (Table 8.2).

Table 8.1: The canonical weight of each of the socio-economic variables (left set) (High positive values are indicated in bold and high negative values are indicated in bold and italics).

Variable	L_Root 1	L_Root 2
% Unemployment	-0.02	0.44
Household size	**0.38**	***-0.86***
Number of rooms	-0.15	0.46
Access to basic services	0.11	-0.12
Schooling status	**0.34**	***-1.13***
Monthly income	***-0.50***	***-1.10***

Table 8.2: The canonical weight of each of the floristic variables (right set) (High positive values are indicated in bold and high negative values are indicated in bold and italics).

Variable	R_Root 1	R_Root 2
Alien	**1.56**	-0.45
Indigenous	0.34	***-2.09***
Tree	-0.30	**1.66**
Succulent	0.52	**0.85**
Herb	-0.24	**1.02**
Geophyte	-0.03	-0.52
Fern	-0.13	-0.15
Epiphyte	-0.19	-0.41
Graminoid	-0.01	0.12
Weed	-0.24	-0.01
C1 Weed	0.03	-0.37
C2 Invader	0.12	0.09
C3 Invader	0.07	***-0.78***
Food	0.05	-0.45
Medicinal	0.06	0.13
Ornamental	***-2.37***	0.51

Figure 8.1 is a scatter plot generated for the first canonical variate pair, the first canonical variate for the socio-economic variables plotted against the first canonical variate for the floristic variables. A simple linear regression was calculated which indicates how well the data fits (R^2 = 0.99). The closer the R^2 value is to one, the better the fit of the regression equation to the data values. The first canonical variate for the socio-economic variables had a strong positive correlation with the first canonical variate for the floristic variables based on the linear regression.

Figure 8.2 illustrates a scatter plot generated for the second canonical variate pair, the second canonical variate for the socio-economic variables plotted against the second canonical variate for the floristic variables. The plot of the second canonical variate pair is a little more scattered than the first canonical variate pair, but it is still a good fit (R^2 = 0.97). The second canonical variate for the socio-economic variables had a strong positive correlation with the second canonical variate for the floristic variables based on the linear regression. Scatterplots were generated for the third, fourth, fifth and sixth canonical variate pairs (see Annexure J).

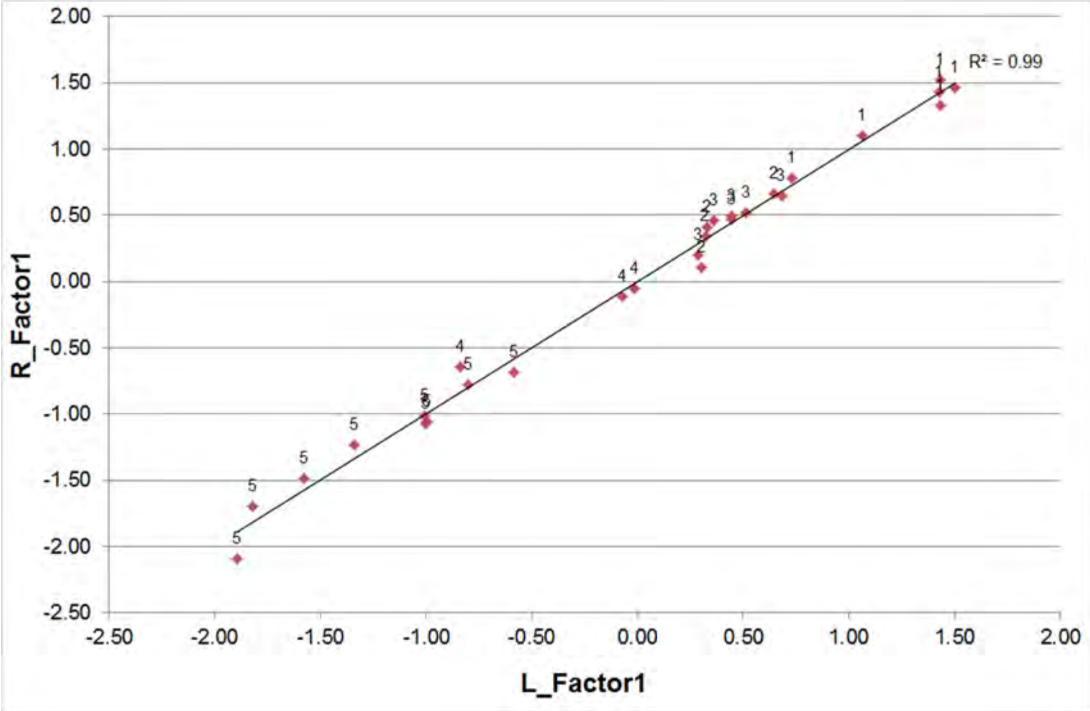

Figure 8.1: Scatterplot of the first canonical variates for the socio-economic (Left) and floristic variables (Right).

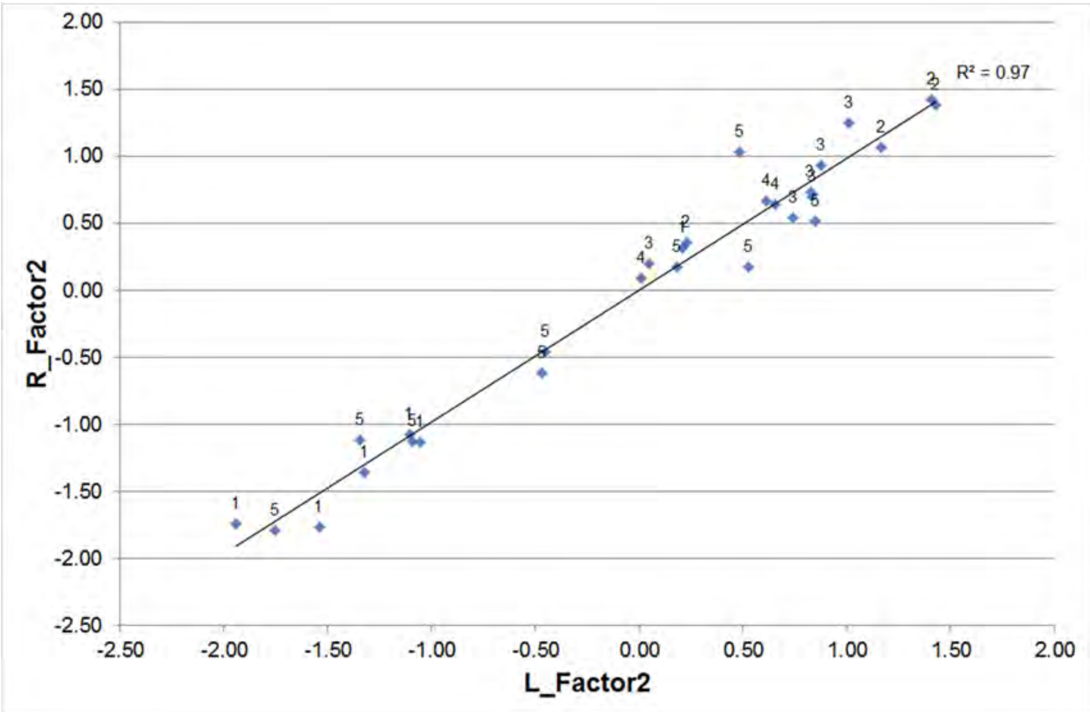

Figure 8.2: Scatterplot of the second canonical variates for the socio-economic (Left) and floristic variables (Right).

To determine if there were statistically significant differences between the SES classes in terms of the canonical variate factors, a One-way ANOVA was completed (Table 8.3). Additionally, a Post Hoc Tukey Unequal N HSD test was carried out to determine which variate factors differed significantly from one another in terms of the socio-economic status (SES) classes. The Post

Hoc Tukey test for first canonical variate factor, for both the socio-economic and floristic variables, revealed that SES class 1 differed significantly from classes 2, 3, 4, and 5, and SES class 5 differed significantly from classes 1, 2, 3 and 4.

Table 8.3: One-way ANOVA results between L_Factor1-6, R_Factor1-6, and socio-economic status (SES) classes. Marked differences (bold) are significant at p < 0.05.

	One way ANOVA		Post hoc Tukey Unequal N HSD
L_Factor1	$\boldsymbol{F_{(4,23)} = 53.16}$	$\boldsymbol{p < 0.0001}$	SES class 1 and SES class 2, 3, 4 & 5 SES class 5 and SES class 1, 2, 3 & 4
L_Factor2	$\boldsymbol{F_{(4,23)} = 8.65}$	$\boldsymbol{p = 0.000205}$	SES class 1 and SES class 2 & 3
L_Factor3	$\boldsymbol{F_{(4,23)} = 4.49}$	$\boldsymbol{p = 0.007899}$	SES class 2 and SES class 3, 4 & 5
L_Factor4	$\boldsymbol{F_{(4,23)} = 6.20}$	$\boldsymbol{p = 0.001549}$	SES class 1 and SES class 3 SES class 3 and SES class 4
L_Factor5	$F_{(4,23)} = 0.56$	$p = 0.696669$	–
L_Factor6	$F_{(4,23)} = 0.55$	$p = 0.703233$	–
R_Factor1	$\boldsymbol{F_{(4,23)} = 58.72}$	$\boldsymbol{p < 0.0001}$	SES class 1 and SES class 2, 3, 4 & 5 SES class 5 and SES class 1, 2, 3 & 4
R_Factor2	$\boldsymbol{F_{(4,23)} = 8.88}$	$\boldsymbol{p = 0.000173}$	SES class 1 and SES class 2 & 3
R_Factor3	$\boldsymbol{F_{(4,23)} = 2.86}$	$\boldsymbol{p = 0.046285}$	–
R_Factor4	$\boldsymbol{F_{(4,23)} = 4.12}$	$\boldsymbol{p = 0.011624}$	SES class 4 and SES class 5
R_Factor5	$F_{(4,23)} = 1.19$	$p = 0.941671$	–
R_Factor6	$F_{(4,23)} = 1.12$	$p = 0.371587$	–

8.3.2 Comparison between the socio-economic status (SES) classes and the floristic data

Box plots were created to illustrate the variation in the total, alien, indigenous and ornamental species richness of each garden in terms of their SES class (Figure 8.3 - 8.6). The total, alien and ornamental species richness for SES classes 4 and 5 was higher than for SES classes 1, 2 and 3 (Figures 8.3, 8.4 and 8.6). SES classes 4 and 5 had wider distributions of total, alien and ornamental species composition, based on the distance between the minimum and maximum observations, while SES classes 1, 2 and 3 have much shorter minimum and maximum observations, i.e. there is less variation in the distribution of the data (Figures 8.3, 8.4 and 8.6). The total indigenous species richness for SES classes 1 and 5 were higher than for SES classes 2, 3 and 4 (Figure 8.5). SES classes 1, 4 and 5 had wider distributions of indigenous species composition, based on the distance between the minimum and maximum observations, while SES classes 2 and 3 have much shorter minimum and maximum observations (Figure 8.5). In all four figures skewed distributions appear in all five box plots since the median is not located in the centre of the plot (Figures 8.3, 8.4, 8.5 and 8.6). SES classes 1, 3 and 5 have outliers (Figures 8.3, 8.4, 8.5 and 8.6).

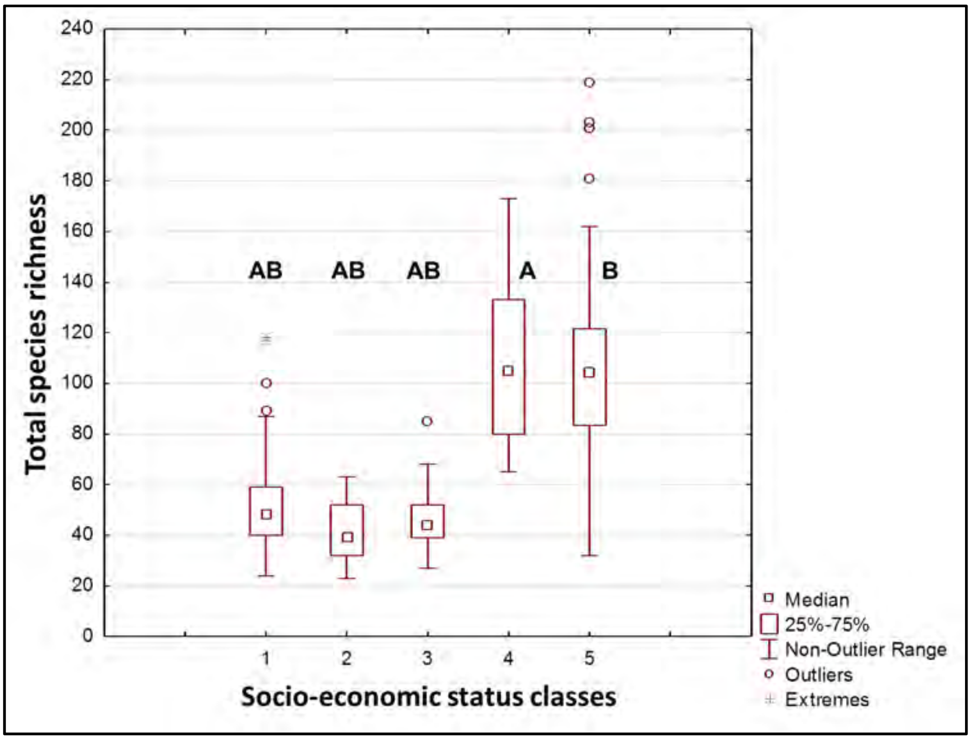

Figure 8.3: Box plots indicating the variation in the total species richness of each garden in terms of their socio-economic status (SES) class (the letters above the box plots indicate which SES classes were significantly different from one another based on Tukey's (HSD) post-hoc test, see Table 8.5).

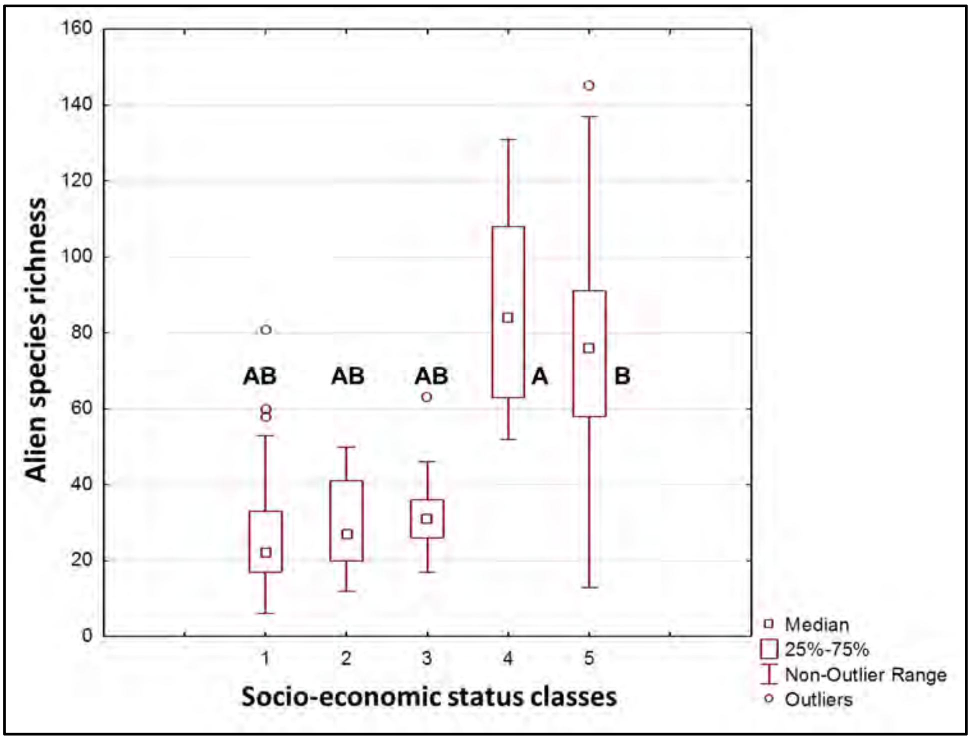

Figure 8.4: Box plots indicating the variation in the total alien species richness of each garden in terms of their socio-economic status (SES) class (the letters above or next to the box plots indicate which SES classes were significantly different from one another based on Tukey's (HSD) post-hoc test, see Table 8.5).

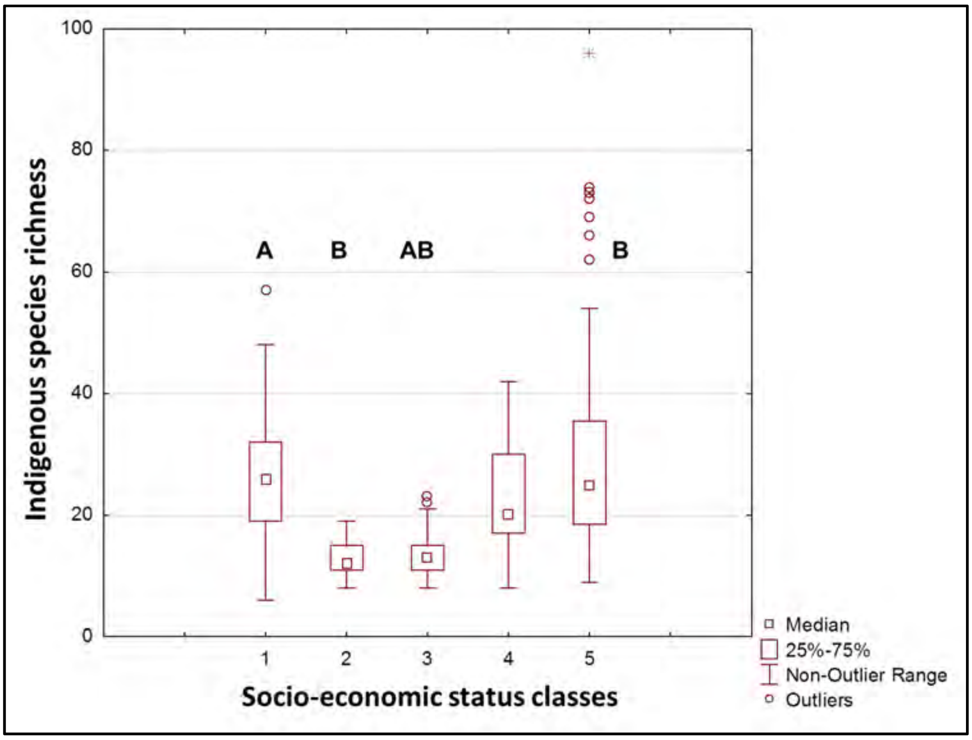

Figure 8.5: Box plots indicating the variation in the total indigenous species richness of each garden in terms of their socio-economic status (SES) class (the letters above the box plots indicate which SES classes were significantly different from one another based on Tukey's (HSD) post-hoc test, see Table 8.5).

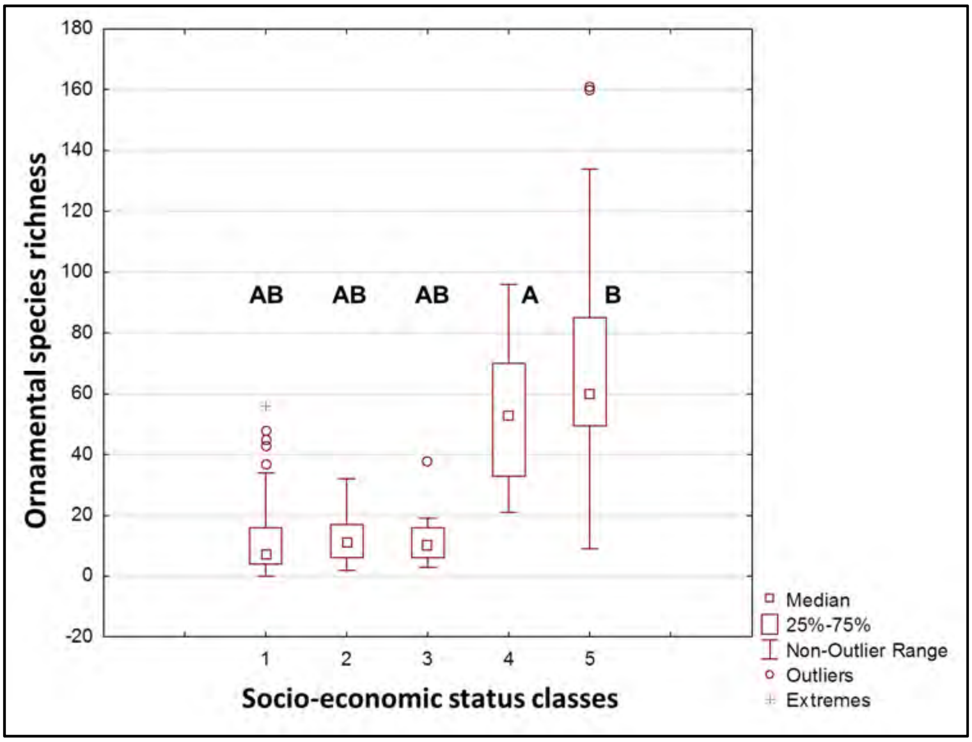

Figure 8.6: Box plots indicating the variation in the total ornamental species richness of each garden in terms of their socio-economic status (SES) class (the letters above the box plots indicate which SES classes were significantly different from one another based on Tukey's (HSD) post-hoc test, see Table 8.5).

The Spearman rank analysis indicated that several of the floristic variables were correlated with socio-economic status (Table 8.4). The total and alien numbers of species were significantly correlated with socio-economic status, as well as the number of trees, shrubs, herbs, geophytes, ferns, epiphytes, C3 invaders and ornamental species. A One-way ANOVA was performed to determine if there were statistically significant differences between the socio-economic status classes and the floristic data collected from the gardens (Table 8.5). A Post Hoc Tukey Unequal N HSD test was carried out to determine which variate factors differed significantly from one another in terms of the socio-economic status classes. The Post Hoc Tukey test revealed socio-economic status classes 4 and 5 differed significantly from classes 1, 2 and 3 in terms of the total species richness, number of alien species and the number of ornamental species. In terms of the indigenous species richness, socio-economic class 1 differed from class 3, socio-economic class 2 differed from class 5 and socio-economic class 3 differed from class 5. Socio-economic status class 4 differed significantly from classes 1, 2 and 3, and socio-economic class 5 differed significantly from classes 1, 2 and 3 in terms of the number of tree and shrub species.

Table 8.4: Spearman's rank correlation results between the socio-economic status classes and the floristic data for each garden (total species richness, alien, indigenous, growth form, declared weeds and invader status, food, medicinal, ornamental and red data status). Marked differences (bold) are significant at $p < 0.05$.

Variable	SES
Total	**0.687033**
Alien	**0.714259**
Indigenous	0.293195
Tree	**0.619710**
Shrub	**0.724779**
Succulent	0.314362
Herb	**0.619907**
Geophyte	**0.636678**
Fern	**0.798776**
Epiphyte	**0.638827**
Graminoid	-0.280278
Weed	0.243625
C1 weed	0.211019
C2 invader	0.338663
C3 invader	**0.615287**
Food	-0.268765
Medicinal	-0.074939
Ornamental	**0.790585**

Table 8.5: One-way ANOVA results between the socio-economic status classes and the floristic data for each garden (total species richness, alien, indigenous, growth form, declared weeds and invader status, food, medicinal, ornamental and red data status). Marked differences (bold) are significant at p < 0.05.

	One way ANOVA		Post hoc Tukey Unequal N HSD
Total Species richness	$\boldsymbol{F_{(4,23)} = 23.27}$	$\boldsymbol{p < 0.0001}$	SES class 4 and classes 1, 2 & 3 SES class 5 and classes 1, 2 & 3
Alien species	$\boldsymbol{F_{(4,23)} = 20.41}$	$\boldsymbol{p < 0.0001}$	SES class 4 and classes 1, 2 & 3 SES class 5 and classes 1, 2 & 3
Indigenous species	$\boldsymbol{F_{(4,23)} = 8.48}$	$\boldsymbol{p = 0.000234}$	SES class 1 and class 3 SES class 5 and classes 2 & 3
Tree	$\boldsymbol{F_{(4,23)} = 20.71}$	$\boldsymbol{p < 0.0001}$	SES class 4 and classes 1, 2 & 3 SES class 5 and classes 1, 2 & 3
Shrub	$\boldsymbol{F_{(4,23)} = 44.11}$	$\boldsymbol{p < 0.0001}$	SES class 4 and classes 1, 2 & 3 SES class 5 and classes 1, 2 & 3
Succulent	$\boldsymbol{F_{(4,23)} = 3.20}$	$\boldsymbol{p = 0.031548}$	–
Herb	$\boldsymbol{F_{(4,23)} = 8.86}$	$\boldsymbol{p = 0.000176}$	SES class 4 and classes 1, 2 & 3 SES class 5 and classes 1 & 2
Geophyte	$\boldsymbol{F_{(4,23)} = 11.03}$	$\boldsymbol{p = 0.000038}$	SES class 5 and classes 1, 2 & 3
Fern	$\boldsymbol{F_{(4,23)} = 11.57}$	$\boldsymbol{p = 0.000027}$	SES class 4 and class 2 SES class 5 and classes 1, 2 & 3
Epiphyte	$\boldsymbol{F_{(4,23)} = 4.29}$	$\boldsymbol{p = 0.009730}$	SES class 5 and classes 1 & 3
Graminoid	$F_{(4,23)} = 2.32$	$p = 0.086972$	–
Weed	$\boldsymbol{F_{(4,23)} = 7.13}$	$\boldsymbol{p = 0.000688}$	SES class 1 and classes 3 & 4 SES class 4 and class 5
C1 weed	$\boldsymbol{F_{(4,23)} = 9.02}$	$\boldsymbol{p = 0.000156}$	SES class 1 and classes 2 & 3 SES class 4 and classes 2 & 3
C2 invader	$F_{(4,23)} = 1.86$	$p = 0.151146$	–
C3 invader	$\boldsymbol{F_{(4,23)} = 31.77}$	$\boldsymbol{p < 0.0001}$	SES class 4 and classes 1, 2 & 3 SES class 5 and classes 1, 2 & 3
Food	$\boldsymbol{F_{(4,23)} = 5.79}$	$\boldsymbol{p = 0.002251}$	SES class 4 and classes 2 & 5
Medicinal	$\boldsymbol{F_{(4,23)} = 10.94}$	$\boldsymbol{p = 0.000041}$	SES class 1 and classes 2, 3, 4 & 5
Ornamental	$\boldsymbol{F_{(4,23)} = 26.51}$	$\boldsymbol{p < 0.0001}$	SES class 4 and classes 1, 2 & 3 SES class 5 and classes 1, 2 & 3

8.4 Discussion

8.4.1 Comparison between socio-economic variables and floristic variables

The socio-economic variables had a strong positive correlation with the floristic variables based on the linear regression of both the first and second canonical variate pairs. The number of alien and ornamental species contributed the most to the total sum of the first canonical variate and the number of indigenous, trees, herb, succulents and category C3 species contributed the most to the second canonical variate of the floristic variables. Household size, schooling status, and monthly income contributed the most to the total sum of both the first and second canonical variates of the socio-economic variables. The studies of Hope *et al*. (2003 and 2006) found that plant diversity was positively related to income across the urban landscape, i.e. plant diversity increased as income increased. Similarly, Jenerette *et al*. (2007) reported that income had a positive relationship with vegetation cover and Kinzig *et al*. (2005) found that median family income was most effective in explaining neighbourhood plant diversity.

Hope *et al*. (2003) termed this relationship between income (wealth) and plant diversity, the "luxury effect", which means, as an individual's economic resources increases, they occupy landscapes with higher plant diversity, either by deliberately choosing to settle in such areas or by creating them. This mirrors the well-established link between socio-economic status and vegetation structure (Iverson and Cook, 2000; Talarchek, 1990), which suggests that this relationship is characteristic of urban landscapes in general (Hope *et al*., 2003). Grove *et al*. (2006a) reported that variation in the vegetation cover on private lands in Baltimore, Maryland (USA) were best predicted by lifestyle behavior, i.e. household land management choices are influenced by the desire to uphold the prestige of a household/community or neighbourhood and a household's desire to showcase its membership in a given community/lifestyle group or neighbourhood.

8.4.2 Comparison between the SES classes and the floristic data

8.4.2.1 Species richness (total, alien and indigenous)

The results of this study revealed that positive correlations exist between socio-economic variables and floristic data across five different settlements and five SES classes. More specifically, the total and alien species richness all increased from a low to high SES, while the indigenous species richness was highest in classes 1 and 5. The respondents in class 1 all live in the rural areas of Tlhakgameng and Ganyesa, which are characterised by high indigenous species richness, predominantly species that are native to the area. These respondents (Tlhakgameng and Ganyesa) also follow a more traditional garden design, called *tshimo* (Molebatsi *et al*., 2010, see Chapter 9) and since they lack the financial means to alter their surroundings they rely heavily on their gardens. The majority of respondents in class 5 with the highest indigenous species richness all live in Roodepoort. These respondents all support the growing trend of indigenous gardening in South Africa and they have the financial resources to alter their gardens accordingly.

In contrast to the results of Martin *et al*. (2004) for high SES residential areas in Phoenix, Arizona, this study found that less alien taxa were associated with low SES residential neighbourhoods. Martin *et al*. (2004) found that neighbourhood vegetation richness had a strong positive correlation with SES, i.e. vegetation richness increased across a gradient of low to high SES. Likewise, the study of Luck *et al*. (2009) found that a positive relationship exists between socio-economic factors and vegetation cover, but their results also revealed that this relationship appeared to become stronger over time. Clarke *et al*. (2013) found that biodiversity in residential plots in Los Angeles, was influenced by both the "luxury" and "legacy" effect, i.e. the highest diversity was in old, high-income neighbourhoods. Both, Hope *et al*. (2003 and 2006) and Martin *et al*. (2004) found that their floristic data (plant diversity and vegetation abundance respectively) was best explained by socio-economic factors, the most noteworthy being median family income.

8.4.2.2 Growth forms (trees, shrubs, herbaceous, etc.)

SES classes 4 and 5 (more affluent) had higher tree and shrub species richness than SES classes 1, 2 and 3 (poorer). Similarly, Avolio *et al*. (2015), Iverson and Cook (2000) and Talarchek (1990) found that wealthier neighbourhoods in New Orleans, Chicago and across three counties in Southern California respectively, had higher tree cover than poorer neighbourhoods. The study of Clarke *et al*. (2013) focused on the city of Los Angeles and found that tree diversity was affected by both development age and household income. In Los Angeles, new, low-income neighbourhoods had the lowest tree species richness and older, wealthier neighbourhoods had the highest (Clarke *et al*., 2013).

In South Africa, the study of McConnachie *et al*. (2008) found that distribution of woody plants was unevenly distributed across the urban green spaces in several small towns in the Eastern Cape. However, the distribution was in favour of the more wealthy areas within these towns, meaning these areas tended to have more woody species than green spaces in poorer areas (McConnachie *et al*., 2008). Cilliers *et al*. (2013) found that vegetation and tree cover was higher in more affluent areas than in poorer areas in the city of Potchefstroom, South Africa. Martin *et al*. (2003) reported that high SES residential neighbourhoods and park neighbourhoods had more succulents and fewer trees than either neighbourhoods of low or medium SES, whereas this was not the case for this study.

The results of this study showed that the herbaceous cover of domestic gardens was higher in SES classes 4 and 5, i.e. the more affluent urban areas had higher herbaceous species cover than the poorer rural areas. The residents of Potchefstroom and Roodepoort planted numerous herbaceous species for aesthetic purposes (refer to Chapter 5). Similarly, the study of Clarke *et* *al*. (2013) reported that the perennial and herbaceous cover in Los Angeles, California (USA) was significantly higher in high income plots.

8.4.2.3 Ornamental, medicinal and invasive species richness

The ornamental species richness increased from a low to high SES. Similarly, the study of Bigirimana *et al*. (2012) found that the garden plants in high standing (rich) neighbourhoods in Bujumbura, Burundi mainly had an ornamental function. Eichemberg *et al*. (2009) reported that home gardens in Rio Claro municipality, southeast Brazil, were dominated by ornamental species. Ornamental plants are associated with the aesthetic role of domestic gardens in cities, since they are generally not cultivated for subsistence agriculture, except among low income residents (Nair, 1993). SES class 1 contained more medicinal species than all the other SES classes. Similarly, Mosina *et al*. (2014) reported that the domestic gardens in the more remote peri-urban areas of the Limpopo province were characterised by higher percentages of medicinal and food plants. The results of this study showed a positive correlation between income and Category 3 declared invader species richness. Similarly, McConnachie *et al*. (2008) reported that monthly income was highly correlated with the percentage of alien invasive species in several small towns in the Eastern Cape, South Africa.

8.5 Conclusion

Hope *et al*. (2006) stated that "traditional approaches used by ecologists may be inadequate and potentially misleading when applied to human-dominated landscapes because they do not explicitly include the myriad of human behaviours and actions that have produced that landscape". The aim of this chapter was to determine the relationship between several socio-economic variables and the species and functional diversity of the domestic gardens sampled in five settlements and to determine the relationship between the plant diversity and socio-economic status classes of the participants in these studies. The results of this study showed that a positive relationship exists between the floristic diversity of domestic gardens and the socio-economic status of the participants in the studied settlements.

In conclusion, our results indicate that people who live in poor rural areas in South Africa are less likely to enjoy rich assemblages of vegetation in their settlements than people who live in more affluent urban and metropolitan areas. However, gardens in poorer rural areas support fewer alien and invasive plant species than more affluent urban and metropolitan areas. These findings show the need for a better understanding of the influences that human economics, cultural differences (Chapter 9 invesitgates this aspect further), and personal preferences play in determining the floristic diversity of domestic gardens in South Africa. The results of this study may have significant implications for our understanding of the vegetation patterns in urban and rural areas, as well as the role that domestic gardens can play in terms of conservation, especially in a rapidly urbanizing South Africa. However, it is up to the householders to maximise their garden's potential, not only in terms of biodiversity conservation and ecosystem services but also to improve their own quality of life.

Chapter 9 - The influence of socio-economic status on the garden design of Batswana home gardens and its associated plant diversity patterns in northern South Africa

9.1 Overview

Over the last two decades, home garden studies have markedly increased in both developed and developing countries. However, garden design and its influence on the overall biodiversity of the urban green infrastructure remains a neglected aspect of home garden research. Home garden surveys were conducted in the North West and Gauteng provinces of South Africa to contribute to this research focus. The two questions asked in this paper were: (1) Are Batswana garden designs associated with socio-economic status (SES)? (2) Are the different garden designs characterised by specific plant species richness patterns? We hypothesised that SES influences garden design and that, as the SES of Batswana resident's increases, the garden design changes from tshimo to colonial. Our results indicated that garden design reflected less cultural influences and took on a more Westernised colonial design appearance with improvement of SES of Batswana inhabitants. Tshimo gardens tended to have more native and utilitarian species. In contrast, colonial gardens have more alien ornamental species. In affluent areas, sampled Batswana gardens completely changed from a tshimo to colonial garden design. This change indicates that improved socio-economic status overrides traditional cultural practices.

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Title: The influence of socio-economic status on the garden design of Batswana home gardens and its associated plant diversity patterns in northern South Africa

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9.2 Introduction

In the last two decades gardens have captured the attention of the scientific community and every year more studies are done about a wide range of subjects. Garden studies in developed countries have focused mainly on biodiversity conservation and manipulation (Gaston *et al*., 2005a; Smith *et al*., 2006b; Smith *et al*., 2006c), comparisons between the floristic attributes of front and back yard gardens (Daniels and Kirkpatrick, 2006b; Dorney *et al*., 1984; Richards *et al*., 1984), community gardens (Corrigan, 2011), and the correlation between socio-economic factors and floristic composition (Kirkpatrick *et a*l., 2007). In contrast, domestic garden research in developing countries focussed primarily on either ethnobotanical documentation of the diversity and uses of garden species (Das and Das, 2005; High and Shackleton, 2000; Nemudzudzanyi *et al*., 2010; Molebatsi *et al*., 2010) or the promotion of home gardening for nutritional improvement of low-income groups (Blanckaert *et al*., 2004; Koyenikan, 2007; Trinh *et al*., 2003; Wezel and Bender, 2003).

Garden design however, remains a neglected aspect of domestic garden research, including its influence on the overall biodiversity of settlements. Garden experts generally distinguish between several garden styles, the majority of which are linked to specific time periods, country of origin, landscape architecture (Turner, 2005) and cultural influences (Head *et al*., 2004). However, there are two broader categorizations that cover almost any garden style, namely formal and informal (Van den Berg and Van Winsum-Westra, 2010). Laird (1992) characterises formal gardens by their neat and manicured look, particularly the regular rhythm of repeated plantings and straight lines. In contrast, informal gardens have a more natural appearance, often seemingly disorganised (Kendle and Forbes, 1997), whilst retaining a specific layout and function (Molebatsi *et al*., 2010).

An increasing amount of studies have been done on gardens and the cultural influences that determine their species composition and layout (Graham and Connell, 2006; Head *et al*., 2004; Nemudzudzanyi *et al*., 2010). The study of Mazumdar and Mazumdar (2012) found that immigrants in Southern California appropriate their backyard gardens to create distinctive cultural spaces while in most cases their front yard mirrored typical Southern Californian garden landscapes. In contrast, Chinese migrants settling in Melbourne, Australia prefer to maintain the existing Australian garden as is in order to better fit in with societal preferences (Levin, 2012).

A pioneering study in Southern Africa by Nemudzudzanyi *et al*. (2010) also demonstrated that domestic gardens are influenced by culture and consist of structured processes (indigenous knowledge systems) to assist with the management of species with similar uses or functions. Many domestic gardens of specific ethnic groups have a distinctive layout which is repeated within and between different rural areas, reflecting the wisdom of traditional culture and ecological knowledge (Das and Das, 2005; Nemudzudzanyi *et al*., 2010). For example, Molebatsi *et al*. (2010) found that the Batswana cultural group had distinctive garden designs. These Batswana tshimo gardens consist of micro-gardens that correspond to those defined for the Zulu muzi gardens in the study by Nemudzudzanyi *et al*., (2010). Additionally socio-economic status (SES) also influences plant diversity (Martin *et al*., 2004). Lubbe *et al*. (2010) found that plant species richness of urban and peri-urban domestic gardens in South Africa were higher in more affluent areas. Hope *et al*. (2003) described this phenomenon as the 'luxury effect'.

The studies of Lubbe *et al*. (2010) and Molebatsi *et al*. (2010) were both done in home gardens of settlements in the North West province, SA. Moreover, they are inhabited by the same dominant ethnic group, the Batswana. However, the SES of these inhabitants differed widely and Lubbe *et al*. (2010) included affluent non-Batswana urban gardens as well. These gardens had a typical formal appearance with lawns and ornamentals as the dominant features. These gardens were described as colonial garden design because of their historical colonial European descent (Ignatieva and Stewart, 2009).

The study of Lubbe *et al*. (2010) correlated SES and plant diversity but did not distinguish between different garden designs, whereas Molebatsi *et al*. (2010) described the garden design and did not determine the SES of the residents. In this paper we wanted to determine whether the cultural preferences in the garden design of Batswana home gardens changed with improved SES. We hypothesise that SES influences garden design and as the SES of Batswana residents increase, the garden design changes from tshimo to colonial designs. Therefore, the two main questions we would like to answer in this paper are (1) whether Batswana garden designs are associated with SES? and (2) are the different garden designs characterised by specific plant species richness patterns?

9.3 Methods

9.3.1 Study Area

The study was conducted in the North West province and the adjacent metropolitan area of the Gauteng province, the economic hub of South Africa. Gauteng was included to steepen the socio-economic gradient as it includes more gardens of affluent citizens. In the chosen urban, rural and metropolitan areas the dominant ethnic groups were the Batswana and people of European descent. However, numerous other ethnic groups are also found in the urban and metropolitan areas, mainly IsiNdebele, IsiXhosa, IsiZulu, Sepedi and Indians. We limited our study to only include the two dominant ethnic groups across five study sites for comparative purposes. The study sites were selected based on source of local government management, population size and presence of subsistence farmers (producing crops mainly for use by the farmer and his/her family, and any surplus is then sold locally for income generation) (See Figure 3.1 for map of the study area):

- Metropolitan (metropolitan council management; no subsistence farmers, population greater than 1 000 000) – Roodepoort (as part of the Johannesburg Metropolitan area) (26° 07 ' 06.8 " S; 27° 51 ' 01.4 " E), 50 gardens sampled.
- Urban (city council management; no subsistence farmers, population greater than 100 000, but < 1 000 000) – Potchefstroom (26° 42 ' 32 " S; 27° 05 ' 39 " E), 49 gardens sampled (Lubbe, 2011).
- Peri-urban (city council management; <25 % subsistence farmers; population greater than 100 000, but < 1 000 000) – Ikageng (a suburb of Potchefstroom) (26° 43 ' 06.2 " S; 27° 01 ' 49.9 " E), 39 gardens sampled (Lubbe, 2011).
- Rural (municipal management; 25-75 % subsistence farmers) – Ganyesa (26° 35 ' 50 " S; 24° 10 ' 32 " E), 55 gardens sampled (Davoren, 2009).
- Deep rural (managed by tribal authority, although under municipal authority; >75 % subsistence farmers) – Tlhakgameng (26° 28 ' 00 " S; 24° 21 ' 00 " E), 51 gardens sampled (Molebatsi, 2011).

9.3.2 Determination of Socio-economic Status (SES) Classes

Six parameters (Table 9.1) were included in an analysis to determine the SES classes for each garden (adapted from the method of Lubbe *et al*., (2010)). Data from the 2001 National Census Survey (Municipal Demarcation Board, 2006) were gathered to calculate the parameter values of the peri-urban, urban and metropolitan areas, while questionnaires (refer to Chapter 7) were used to gather the required data for deep rural and rural areas since the census data proved to be unreliable (Davoren, 2009; Molebatsi, 2011).

The census data for each of the settlements is given in terms of the electoral wards— electoral wards are local municipal delineations of a subset of housing suburbs grouped together for municipal and national political election purposes (Municipal Demarcation Board, 2006). A higher percentage value indicated a lower SES for all the parameters (as described in Lubbe *et al*., 2010). To determine the socio-economic status of each household, they were grouped according to the wards in which they were located. Principal components analysis (PCA) was performed to classify the wards into the different socio-economic status groups using the six parameters. The wards were delineated into five SES classes based on the sorted eigenvalues of factor 1 (Table 7.8 and 7.9). The PCA was done in STATISTICA 9.0 (Statsoft, 2009).

Table 9.1: Parameters applied to determine the socio-economic status classes of the garden owners (Lubbe *et al*., 2010).

SES Classes	Number of participants	Unemployment[1]	Household size[2]	Number of rooms[3]	Access to basic services[4]	Schooling status[5]	Mean monthly income[6]
1	99	53±2	37±7	42±7	27±14	44±8	82±191
2	34	51±3	35±5	48±7	11±11	18±1	108±41
3	24	47±6	38±4	25±7	1±1	8±3	117±95
4	19	14±8	16±3	26±5	6±4	16±12	292±1212
5	80	7±2	13±3	14±5	3±2	2±1	686±2411

[1] % unemployed household members, [2] % households with five or more persons, [3] % households with one or two rooms only, [4] % households with pipe water >200 m away, [5] % individuals with no schooling per household, [6] mean monthly income (USD 1 / 10.04 ZAR, exchange rate on 16 August 2013).

9.3.3 Floristic sampling

For the purpose of this study a domestic garden in the South African context was defined as the area surrounding a house including all cultivated and non-cultivated areas within a border that was actively tended by the inhabitants. The domestic garden surveys for Ganyesa were conducted in 2008 (Davoren, 2009), with Tlhakgameng (Molebatsi, 2011), Ikageng and Potchefstroom (Lubbe, 2011) in 2009 and Roodepoort (suburb of Johannesburg) in 2011. Topographic maps of each of the five study sites were acquired and overlaid with 500 x 500 m grids in ArcView 9 (Environmental System Research Institute (ESRI), 2006). This approach provided 75 to 141 potential sample points per study site depending on the size of the settlement. Approximately 50 sample points were randomly chosen within the grid for garden surveys per settlement. In Tlhakgameng there were 118 potential sample points of which 51 were sampled, in Ganyesa 141 of which 55 were sampled, Ikageng had 76 of which 39 were sampled, Potchefstroom had 75 potential sample points of which 49 were sampled and Roodepoort had 135 potential points of which 50 were sampled. Sample points were located with a Global Positioning System. The closest garden within a 150 m radius of each random grid point was chosen. In cases where access to the chosen site was denied, an adjacent garden was sampled. The garden data from the different settled areas was consolidated into one large data set consisting of 245 domestic gardens with approximately 600 species.

The sampled gardens differed in size and therefore, five transects of 20 m each were placed in each garden to sample the areas that were representative of the micro-gardens present in each garden (micro-gardens to be described later in the methods section). In each transect the nearest tree, shrub, grass and herbaceous (non-grassy) species was noted and identified at 1 m intervals along the tape measure (20 points = 20 m). At each 1 m interval individuals directly underneath or adjacent to the tape measure was recorded. If no individual was in the vicinity of the tape measure, the nearest individual within a block measuring 0.5 m above and below and 2 m left and right of the tape was recorded. However, if no individual were found in this block, the sampling point was recorded as bare ground. Species further than 2 m on either side of the tape measure were ignored. For trees to be recorded, the trunk of the tree had to be within the 2 m radius from the tape measure. No individuals were counted more than once. The total sample therefore represented a 100 point frequency survey (20 x 5 = 100 points, and a total area of 400 m^2). Plant species were classified according to their uses (food, medicinal and ornamental); growth forms (grass, herbaceous, shrubs and trees) and origin. The origins of the species were classified following Lubbe *et al*. (2010):

- Indigenous cultivated: indigenous to South Africa and not occurring naturally within the study area, but cultivated in gardens;
- Native: indigenous to South Africa and occurring naturally within the study area, usually not cultivated;
- Naturalised: not indigenous to South Africa, but occurring in the study area where it sustains self-replacing populations outside of cultivation without direct intervention by people (includes declared alien invasive species according to South African legislation (National Environmental Management: Biodiversity Act (NEMBA) (South Africa, 2014));
- Alien cultivated: not indigenous to South Africa and not naturalised in the study area, but cultivated in gardens and including garden hybrid species.

9.3.4 Garden design

The study of Molebatsi *et al*. (2010) found that home gardens of the Batswana people in deep rural (Tlhakgameng) and rural areas (Ganyesa) had a specific garden layout: Tshimo gardens (Figure 9.1, A and B) are regarded as a model of resource management and indigenous knowledge of the Batswana people (Molebatsi *et al*., 2010) and defined as a land-use form on private or communal lands, surrounding an individual house with a definite fence as border, consisting of the following dominant micro-gardens: food gardens, medicinal gardens, ornamental gardens, structural species, open areas (lebala) and natural areas (naga) (Molebatsi *et al*. 2010), and can be regarded as informal. Lubbe *et al*. (2010) found that the affluent inhabitants of European descent in an urban settlement (Potchefstroom) followed a predominantly European garden design style (Ignatieva and Stewart, 2009): Colonial gardens (Figure 9.1, C and D) are characterised by a large number of non-native species and the presence of lawns, flowerbeds, tree and shrub groups (Ignatieva and Stewart, 2009) and can be regarded as formal. The different garden designs were determined for each garden using the presence/absence and dominance of micro-gardens.

9.3.5 Micro-gardens

To determine if garden design changes with increase in socio-economic status, the following different micro-gardens in each home garden were recorded (based on Molebatsi *et al*., 2010 and Davoren, 2009) namely: ornamental, vegetable, lawn, orchard, open space containing mostly native species (called ‘naga’ in the Batswana vernacular), managed areas devoid of plants (‘lebala’ concept – derived from the Batswana vernacular) (Figure 9.1, A and B). Scores were allocated to each of the micro-gardens based on their presence or absence and what proportion of the garden it occupied (0, 1 = <33%, 2 = 34 - 67%, 3 = >67%). For example, if a vegetable garden was present and covered 80% of the garden it would be given a score of 3. Absent micro-garden types were given a score of zero. All gardens were classified based on their scores for the different micro-gardens. A garden was considered to have a tshimo design if lebala and naga were dominant (Molebatsi *et al*., 2010) and colonial if lawns and ornamental micro-gardens were dominant (Ignatieva and Stewart, 2009).

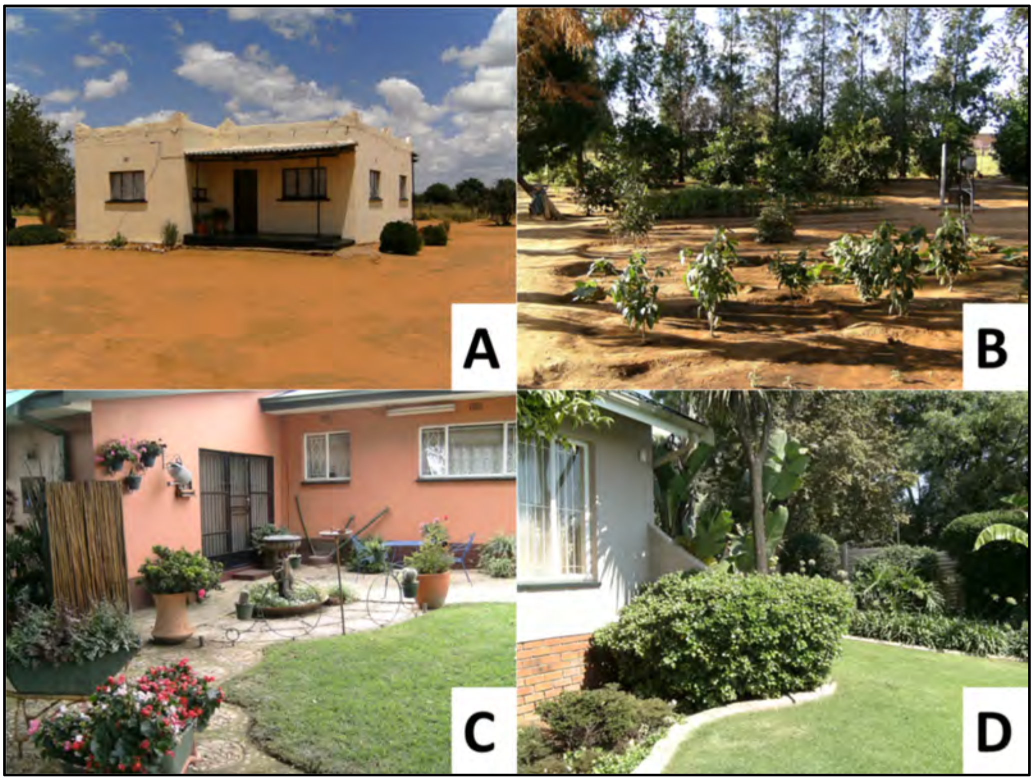

Figure 9.1: Typical Tshimo (A and B) and colonial (C and D) garden designs. Picture 9.2 A shows a large area devoid of vegetation (lebala) and picture 9.2 B a vegetable micro-garden. Pictures 9.2 C and D show lawns and ornamental that make up the majority of colonial gardens.

9.3.6 Data analysis

Non-metric multidimensional scaling (NMS) was performed with Primer 6 (Clarke and Gorley, 2006) to determine the relationship between socio-economic status and garden design based on the presence/absence and dominance of the different micro-gardens. The scores for each of the micro-gardens per home garden were converted to a similarity matrix using the Bray-Curtis Dissimilarity index with fourth-root transformation as input for the NMS (Clarke and Gorley, 2006). Spearman's rank correlation coefficient (rs) was calculated to determine relationships between garden design; SES class; and plant origin, -growth form, and -uses. Spearman's is derived from the Pearson correlation coefficient after the two variables have been separately transformed to ranks but the pairing is retained after ranking (Quinn and Keough, 2002).

Analysis of variance (ANOVA) was applied to the data to determine whether any significant differences exist between the means of two or more samples (Tabachnick and Fidell, 2007). The ANOVA tested for significant differences between garden design, mean total number of species, mean number of indigenous cultivated, mean number of indigenous native, mean number of alien cultivated, mean number of alien naturalised, mean number of trees, shrubs, herbaceous, grass, food, medicinal and ornamental species. Tukey's honestly significant difference (HSD) post-hoc test for unequal sample size compared the sample means pair wise with that of every other sample to determine which samples were significantly different from one another (Quinn and Keough, 2002). All statistical analyses were performed with STATISTICA 9.0 (Statsoft, 2009).

9.4 Results

9.4.1 Garden design and socio-economic status

The NMS ordination divided the 245 domestic gardens along a clear SES gradient (Figure 9.2) based on the frequency of occurrence of the micro-gardens in each garden. Typical tshimo and colonial gardens were clearly separated on the ordination (Figure 9.2). These groupings are in accordance with the different types of design styles documented in the previous two studies (Lubbe *et al*., 2010; Molebatsi *et al*., 2010). However, SES classes 2 and 3 gardens grouped in between the two garden designs indicating a transition from tshimo to colonial as the SES of the residents improved. We described these transitional gardens as Westernised Batswana gardens. Participants of SES class 1 predominantly followed the tshimo garden design, while classes 4, 5 and several participants of class 3 (Batswana and all Europeans) followed the colonial garden design (Figure 9.2). The link between garden design and SES is further substantiated by the results of the Spearman rank correlation analyses, which indicated a positive correlation between SES and garden design (0.92), with values significant at $p < 0.05$ (Table 9.2).

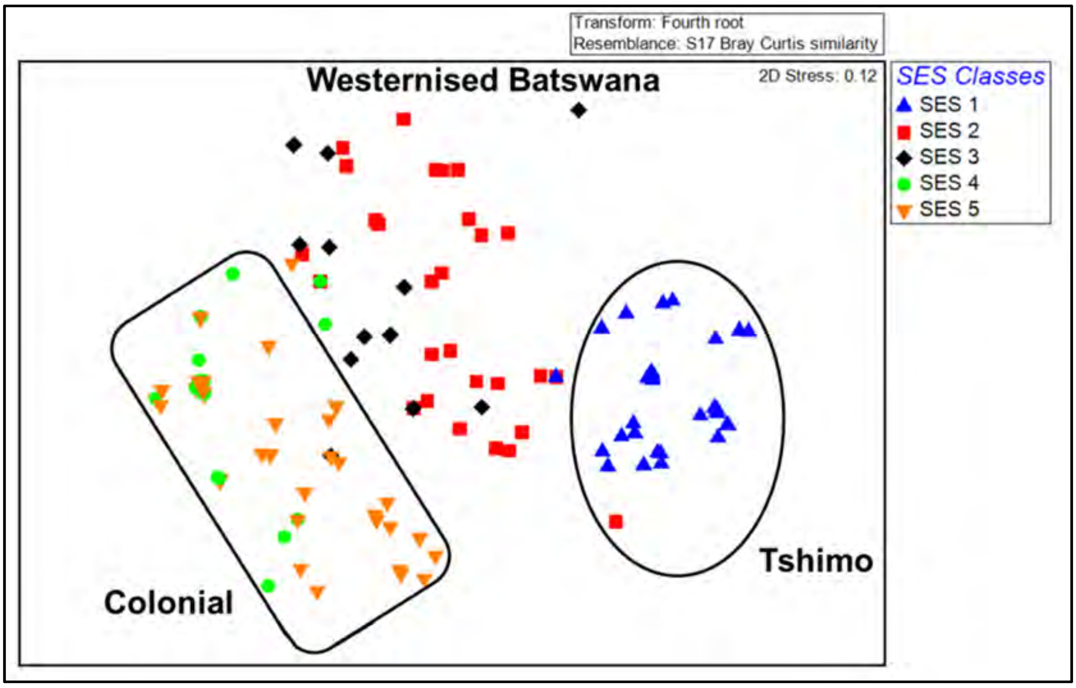

Figure 9.2: NMS ordination of domestic gardens grouped according to SES classes and garden design type indicated by polygons.

Table 9.2: Spearman rank order correlations (r_s) between socio-economic status, garden design, plant origin, plant growth form and uses. Correlations are significant at $p < 0.05$ (Indicated in bold).

	Garden design	**SES**
SES	**0.923970**	
Total number of species	0.133771	0.218367
Indigenous native	**-0.570680**	**-0.578223**
Indigenous cultivated	**0.397784**	**0.567408**
Alien cultivated	**0.506280**	**0.543654**
Alien naturalised	0.005971	0.002113
Grass	**-0.532841**	**-0.557199**
Shrubs	**0.520608**	**0.570415**
Herbaceous	-0.095655	0.056979
Trees	**0.436069**	**0.384008**
Food	**-0.705038**	**-0.568578**
Medicinal	**-0.479341**	**-0.443155**
Ornamental	**0.771360**	**0.811256**

The most frequently occurring micro-gardens in the tshimo garden design were lebala and naga (Table 9.3). On average 34.92% of all tshimo gardens consist of lebala and 24.10% of naga micro-gardens. A 100% of all tshimo gardens contained lebala and 93.88% contained naga. In colonial gardens 43.25% of the garden was covered by lawn, which was present in a 100% of all colonial gardens, and 45.04% was ornamental, which was present in 99.06% of all colonial gardens. The Westernised Batswana garden design on average consisted of 31.63% lawn and

40% lebala. Lebala was present in a 100% of all Westernised Batswana gardens and lawn was present in 97.5%. More than 60% of all tshimo and Westernised Batswana gardens contained ornamental, which on average covered less than 14% of the garden. Orchards were present in 72.45% (12.46% cover) of all tshimo gardens and vegetables in 87.76% (16.89% cover).

Table 9.3: The percentage occurrence and average percentage area of each micro-garden in the different garden design types.

Micro-gardens	**Tshimo**		**Westernised Batswana**		**Colonial**	
	% Occurrence	Average % area	% Occurrence	Average % area	% Occurrence	Average % area
Orchard	**72.45%**	**12.46%**	40%	7.44%	47.17%	8.13%
Vegetable	**87.76%**	**16.89%**	27.5%	5.58%	10.38%	1.79%
Lawn	2.04%	0.33%	***97.5%***	***31.63%***	***100%***	***43.25%***
Ornamental	**69.39%**	**11.31%**	**65%**	**13.02%**	***99.06%***	***45.04%***
Lebala	***100%***	***34.92%***	**100%**	**40%**	8.49	1.79%
Naga	***93.88%***	***24.10%***	12.5%	2.33%	0%	0%
Nr. of participants	98		40		106	

9.4.2 Plant diversity

Tshimo gardens had the highest number of total, indigenous cultivated and native plant species, while colonial gardens had the highest number of alien cultivated and naturalised species (Figure 9.3). Colonial gardens were dominated by hardier, ornamental species, while tshimo gardens had the highest number of useful species, such as food and medicinal plants (Figure 9.4). Tshimo gardens contained more grass and herbaceous species, while colonial gardens had slightly more tree and shrub species (Figure 9.5). Spearman rank analysis of these variables indicated that several were correlated with garden design and socio-economic status (Table 9.2), supporting the observed patterns.

The results of the ANOVA indicated that there were significant differences between the origin, growth forms and uses between the different garden designs (Table 9.4). Tukey's HSD tests confirmed which of these designs differed significantly from one another (Table 9.4). Westernised Batswana (W) gardens had significantly less indigenous species (Table 9.4, Figure 9.3) than tshimo (T) gardens and significantly less alien-cultivated species than colonial (C) gardens. Westernised Batswana gardens also had significantly more food plants than colonial gardens, significantly less medicinal plants than tshimo gardens (Table 9.4, Figure 9.4), and significantly less trees and shrubs than both tshimo and colonial gardens (Figure 9.5).

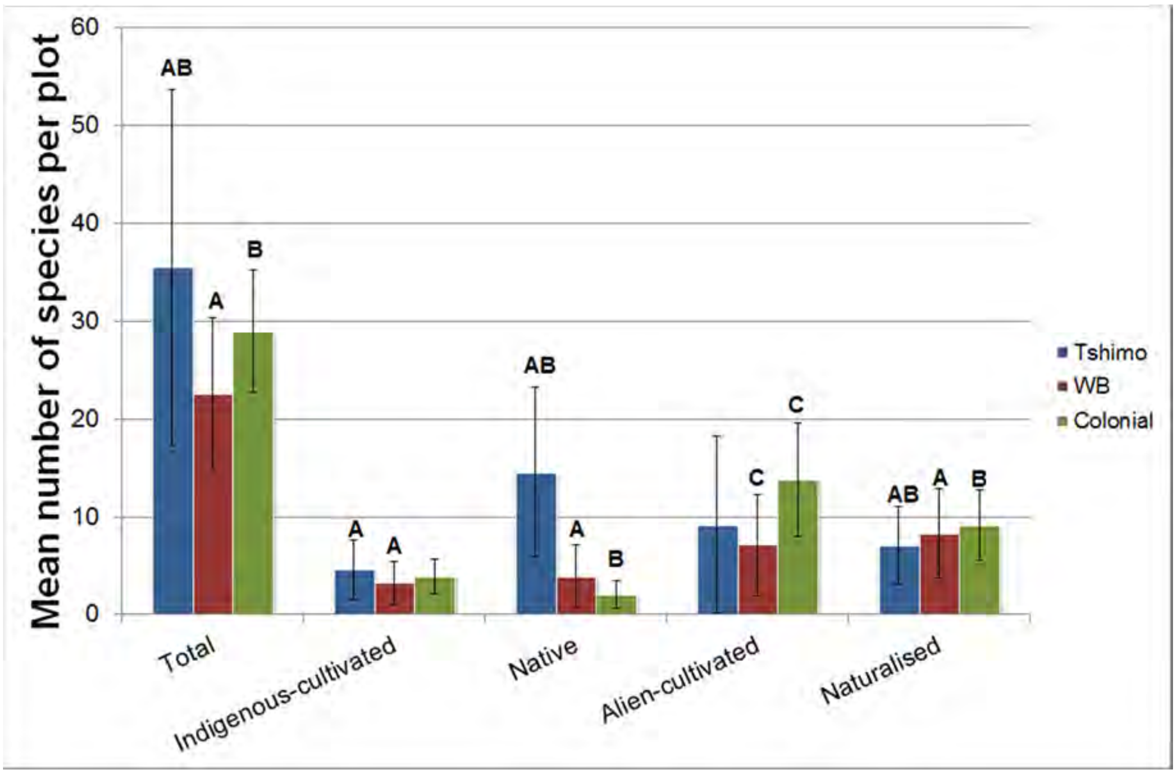

Figure 9.3: Total species richness and different origins of plant species for each garden design. Error bars indicate the standard deviation (the letters above the bars indicate which garden design types were significantly different from one another based on Tukey's (HSD) post-hoc test, see Table 9.4).

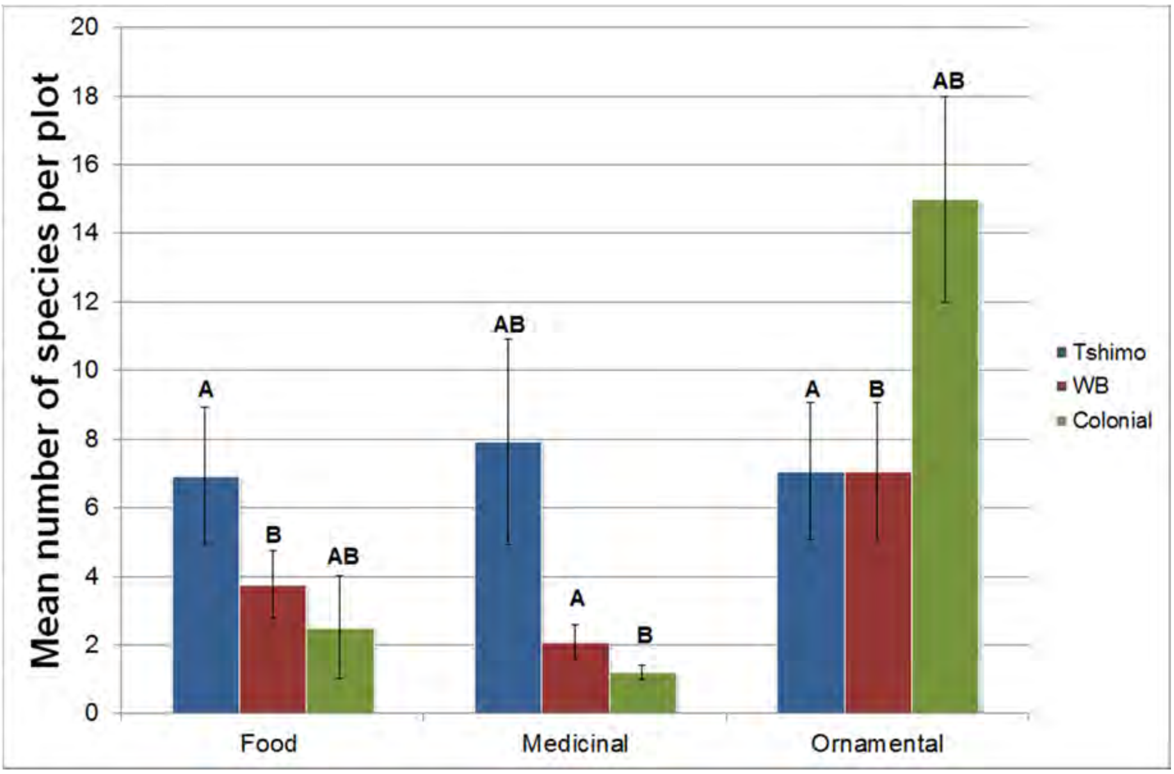

Figure 9.4: Utilitarian species for each garden design type. Error bars indicate the standard deviation (the letters above the bars indicate which garden design types were significantly different from one another based on Tukey's (HSD) post-hoc test, see Table 9.4).

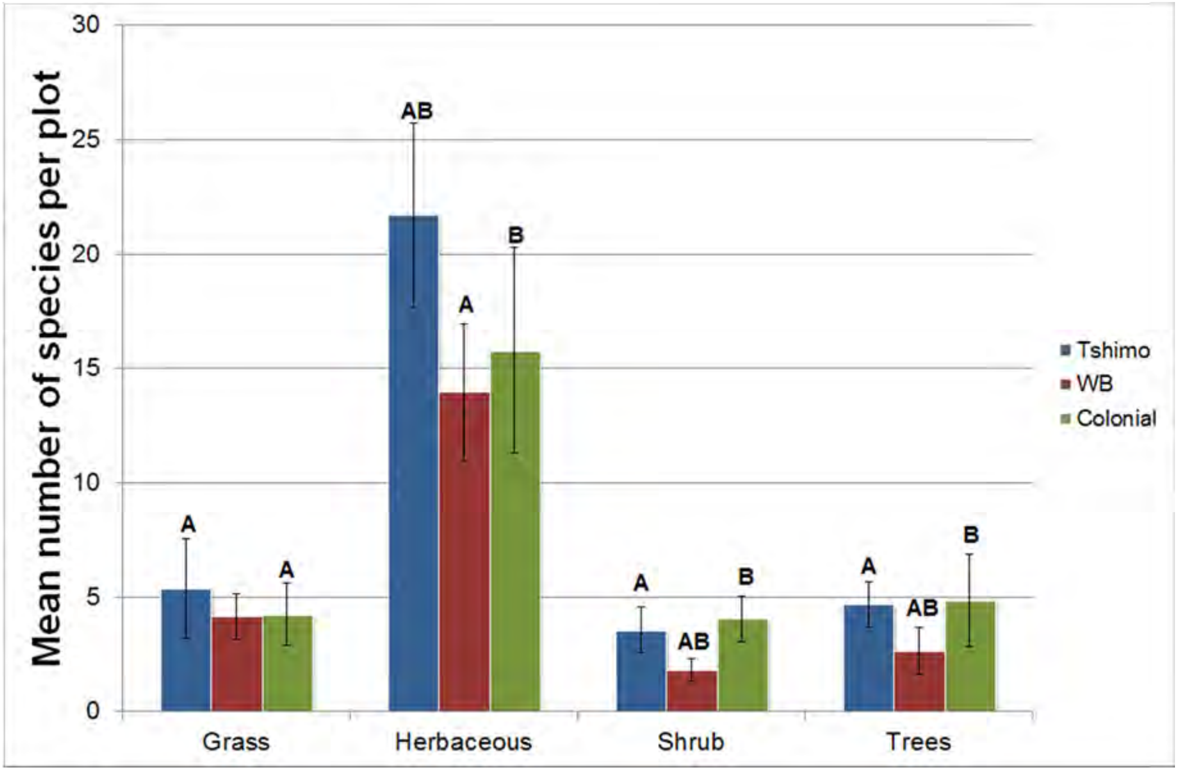

Figure 9.5: Growth forms of each garden design type. Error bars indicate the standard deviation (the letters above the bars indicate which garden design types were significantly different from one another based on Tukey's (HSD) post-hoc test, see Table 9.4).

Table 9.4: One-way ANOVAS and Post hoc Tukey unequal N HSD results between garden design and mean total number of species, mean number of indigenous cultivated, mean number of indigenous native, mean number of alien cultivated, mean number of alien naturalised, mean number of trees, shrubs, herbaceous, grass, food, medicinal and ornamental species. The different garden designs are indicated by T (*tshimo*), WB (Westernised Batswana) and C (Colonial). Correlations are significant at $p < 0.05$.

	One way ANOVA	**Post hoc Tukey Unequal N HSD**
Total number of species	$f_{(2.203)} = 23.5182$, $p < 0.0001$	T and WB, T and C
Indigenous cultivated	$f_{(2.203)} = 6.2790$, $p = 0.002260$	T and WB
Native	$f_{(2.203)} = 175.2475$, $p < 0.0001$	T and WB, T and C
Alien-cultivated	$f_{(2.203)} = 8.6696$, $p = 0.000244$	WB and C
Naturalised	$f_{(2.203)} = 21.9370$, $p < 0.0001$	T and WB, T and C
Food	$f_{(2.203)} = 21.1299$, $p < 0.0001$	T and C, WB and C
Medicinal	$f_{(2.203)} = 172.2131$, $p < 0.0001$	T and WB, T and C
Ornamental	$f_{(2.203)} = 19.3335$, $p < 0.0001$	T and C, WB and C
Grass	$f_{(2.203)} = 8.469$, $p = 0.000293$	T and C
Herbaceous	$f_{(2.203)} = 22.3395$, $p < 0.0001$	T and WB, T and C
Shrubs	$f_{(2.203)} = 14.3807$, $p = 0.000001$	T and WB, WB and C
Trees	$f_{(2.203)} = 13.7591$, $p = 0.000002$	T and WB, WB and C

9.5 Discussion

9.5.1 Garden design and socio-economic status

Westernised Batswana gardens (Figure 9.6, A and B) have developed where the western and Batswana cultures meet. These gardens exhibit both tshimo and colonial garden design elements (Molebatsi *et al*., 2010), and represents a hybrid design between formal and informal gardens (Figure 9.6). The Tshimo gardens of the Batswana were productive garden systems, whilst the colonial gardens of residents of European descent were more aesthetically orientated with the focus on ornamental species. This finding is similar to that of Head *et al*. (2004) who indicated that backyard gardens of three migrant groups in Australia differed based on preference for certain species and garden uses. They stated that “particular combinations of foods results in distinctive landscapes that can be identified with particular ethnic groups” (Head *et al*., 2004). They found that Macedonian and Vietnamese gardens were predominately productive gardens, in contrast to British gardens which were more floristically diverse with the focus on ornamental plants (Head *et al*., 2004).

Figure 9.6: Transition between Tshimo and Colonial, identified as the Westernised Batswana garden design.

Moreover, our results agree with other studies which indicated that individuals with access to resources, labour or financial means, are capable of affecting change in their urban environment, whereas those individuals with limited resources are not (Lubbe *et al*., 2010; Martin *et al*., 2004). Diversity in human-created habitats has less to do with variation in the traditional limiting resources and more to do with human preferences for particular landscapes along with the availability of financial resources to realise those landscapes (Hope *et al*., 2003). Studies in other countries have contrasted socio-economic status to the species richness of neighbourhood vegetation (Martin *et al*., 2004), percentage area covered by tree canopy

(Talarchek, 1990), and tree presence in gardens (Kirkpatrick *et al*., 2007), all of which correlated positively with socio-economic status.

9.5.2 Plant diversity

The tshimo gardens of deep rural and rural areas contained less alien-cultivated species and more indigenous species than the colonial gardens of urban and metropolitan areas. However, the westernised Batswana gardens of the peri-urban area contained more native species than the colonial gardens and more naturalised species than tshimo gardens. They also contained less indigenous- and alien-cultivated species than both tshimo and colonial gardens. Similarly, the Zulu gardens in the rural areas of Kwa-Zulu-Natal had characteristically higher percentages of indigenous species than those in the peri-urban areas (Nemudzudzanyi *et al*., 2010). According to Nemudzudzanyi *et al*., (2010), the residents of peri-urban areas are predominantly first or second-generation residents that prefer well-known and readily available alien species over the local indigenous flora of which they possess little knowledge.

Colonial gardens contained less utilitarian species than both tshimo and westernised Batswana gardens and in turn westernised Batswana gardens contained less utilitarian species than tshimo gardens. This validates the status of westernised Batswana gardens as a transitional design type between tshimo and colonial. Gardens in the rural areas of developing countries contain species that are selected based on their medicinal, food or spiritual value (Blanckaert *et al*., 2004; Jaganmohan *et al*., 2012; Winklerprins and De Souza, 2005). In contrast, Kirkpatrick *et al*. (2007) found that the gardens in Hobart, Tasmania, Australia, rarely contained utilitarian plants, while Loram *et al*. (2008b) reported that 20 % of the gardens sampled in their study in the UK contained vegetable patches.

In the current study, there were no apparent differences between the mean tree and shrub species richness of the colonial gardens and that of the tshimo gardens. These findings are in contrast to the study of Iverson and Cook (2000) who found that the wealthy regions of the Chicago metropolitan area had a higher percentage tree cover than poorer regions. In traditional tshimo gardens, trees and shrubs are actively planted for specific purposes, such as wind breaks, shade, as lightning deflectors and for spiritual reasons (Molebatsi *et al*., 2010). This might be the reason why tshimo and colonial gardens had the similar mean tree and shrub species richness despite major differences in SES. However, tshimo and colonial gardens had more tree and shrub species than the westernised Batswana gardens, which may be an indication of new preferences associated with the emerging African middle class and the abandonment of cultural practices. The study of Nemudzudzanyi *et al*. (2010) also found that indigenous knowledge systems were in danger of being lost under the impact of modernization and the on-going globalisation process, since the Zulu home gardens of peri-urban areas in KwaZulu-Natal tended to follow a more westernised landscaping approach. Kendal *et al*. (2012b) found that some Ballarat residents in Australia with higher incomes preferred to live in new housing estates with lower levels of tree cover than on areas with established housing and higher levels of tree cover.

9.6 Conclusion

Tshimo gardens are models of indigenous knowledge systems (Molebatsi *et al*., 2010), whilst colonial gardens are of European origin reflecting aesthetic preferences (Lubbe *et al*., 2010). We identified the westernised Batswana garden as a transitional garden design between the colonial and tshimo designs. Based on the results represented in this article (Figure 9.3), Tshimo gardens were floristically more diverse than both the Westernised Batswana and Colonial garden design types. However, in terms of the total species composition of the gardens (presence/absence, refer to chapter 5), the Colonial gardens in urban and metropolitan areas were floristically more diverse than the tshimo gardens in rural and deep rural areas, since the SES of the former allowed financial freedom (the 'luxury effect' Hope *et al*., 2003), access to water and other resources which enabled the cultivation of a wide variety of species. The recognition of the Westernised Batswana design type confirmed our hypothesis that socio-economic status overrides cultural preferences in the Batswana home gardens. As Batswana residents of the peri-urban area gain access to resources needed to affect change in their gardens, these gardens take on a more westernised appearance.

Chapter 10 - Concluding remarks

10.1 Introduction

The aim of this thesis was to the compare plant diversity and social information from several domestic garden studies across a socio-economic gradient from rural settlements to a metropolitan area, as well as to compare the plant diversity patterns of different land-use types with one another and in terms of the different settlements in the northern parts of South Africa. This was done in the form of six results chapters (Chapters 4-9). The next sections provide a brief summary of the results chapters, followed by a general conclusion and recommendations for future research. The general conclusion highlights the contributions of the results to our knowledge of green infrastructure, domestic gardens and socio-economics.

10.2 Summary of results

Chapter 4 compared the species diversity and composition of domestic gardens and other land-use types across all five settlements and within each settlement with one another. The main focus was on domestic gardens and how they relate to other land-use types in terms of species diversity and composition. The results showed that domestic gardens contributed more to the total, indigenous and alien species diversity sampled across all the studied settlements than any of the other land-use types. However, the natural areas had the highest values for all the diversity indices across all five settlements, while domestic gardens had the second highest species richness and evenness values and the fragmented natural areas had the second highest species diversity values for both the Shannon's and Simpson's indices.

The results of Chapter 5 broadens our understanding of the contribution that domestic gardens make to the overall species composition of settlements, the potential that domestic gardens have to maintain indigenous, endemic and threatened species and to promote the spread of alien and invasive species in South Africa. The more affluent urban areas were characterised by larger numbers of species, alien cultivated and ornamental species, while the rural areas had far less alien and ornamental species and more indigenous and utilitarian species.

Chapter 6 provided insights into the management practices of gardeners in the five studied settlements. The results showed that some gardening activities were performed more frequently than others, a single management index value could be determined for gardens based on their management practices and the frequency with which these activities took place and that the financial resources available to gardeners play an important role in both garden management and species richness. This was evident in the urban areas of Potchefstroom and Roodepoort considering these two settlements predominantly made use of either gardeners or gardening services. Roodepoort had the highest management index values overall, but this is because these respondents had greater disposable incomes and therefore possessed the financial means to invest in their gardens ("luxury effect", Hope *et al*., 2003). In contrast, the residents in the rural areas of Tlhakgameng and Ganyesa lack the financial resources to hire gardeners and many of them rely on their gardens for subsistence agriculture.

Chapter 7 was a methods chapter which explored the use of both census data and questionnaire data to determine the SES and socio-economic classes of the participants in this study and focused on finding a statistical method to determine the SES and socio-economic classes of the participants' in all five settlements. A principal components analysis (PCA) was used to classify the wards, of the five different settlements, into different SES classes and a factor analysis indicated which of the six parameters best described SES. The results indicated that a low % unemployment, small household size and high monthly income best described the SES of the participants in this study.

Chapter 8 determined the relationship between the socio-economic variables discussed in Chapter 7 and the species and functional diversity of the domestic gardens sampled in all five studied settlements. Furthermore, this chapter determined the relationship between the plant diversity and SES classes of the participants' in these studies. The results of this chapter showed positive correlations between the socio-economic variables and floristic data across the studied settlements. Moreover, the total, alien and ornamental species richness increased from low to high SES, while the indigenous species richness was highest in classes 1 and 5.

Chapter 9 determined whether the cultural preferences in the garden design of Batswana home gardens changed with improved SES. The results of this chapter revealed that Westernised Batswana gardens have developed where the western and Batswana cultures meet, since these gardens exhibited elements of both tshimo and colonial garden designs (Ignatieva and Stewart, 2009; Molebatsi *et al*., 2010). Therefore, the Westernised Batswana garden design type is considered a transitional design, which indicates that as householders gain access to resources needed to affect change in their gardens, these gardens take on a more westernised appearance.

10.3 General conclusions and recommendations for future research

Green infrastructure provides a variety of ecosystem services (Calvet-Mir *et al*., 2012; Douglas, 2011a) in both urban and rural areas. Ecosystem services that support the ecological integrity of cities and towns, improves the quality of life, health and psychological well-being of urban residents (Vemuri *et al*., 2009; Ward *et al*., 2010; Wolch *et al*., 2014), promotes recovery from surgery, stress relief and rehabilitation (Adevi and Lieberg, 2012; Adevi and Martensson, 2013), provides areas for sport and recreation (Tzoulas *et al*., 2007) and educates urban residents about biodiversity, ecosystems and conservation (Gaston *et al*., 2005b; Thompson *et al*., 2005; Ward *et al*., 2010). Hence, current and future urban development should take the provisioning of green infrastructure (Loram *et al*., 2008a) and ecosystem services (Bolund and Hunhammar, 1999; Tzoulas *et al*., 2007) into consideration. The question is: How to develop settlements that provide enough green infrastructures and consequently, enough ecosystem services?

The first step is to know the size, composition and distribution of the green infrastructures present in settlements (Smith *et al*., 2005). This study contributes to our knowledge of the different types of green infrastructure (represented by various land-use types) present in five different settlements in South Africa, their species composition and diversity. This type of knowledge is especially important considering the rate of urbanisation in South Africa. The United Nations (2014) projected that by 2050, South Africa will be 77 % urban. Thus, understanding the contribution that different land-use types make to the overall diversity of an urban or rural settlement will aid policy makers and municipal governments in properly managing these areas and ensuring the provisioning of ecosystem services in an urbanising South Africa. However, in order to determine the true contribution that different land-use types make to a settlement, future studies should not only follow a random sampling method, but should also sample equal amounts of all the land-use types present in a settlement and study the effects of other potential covariates such as, geology, rainfall, soil type, etc.

Nevertheless, the results of this study revealed that domestic gardens contributed the most to the overall plant diversity and species richness of all the settlements in comparison with the other land-use types sampled in this study. Therefore, the contribution made by the domestic gardens in this study, is comparable with the contribution made by the natural areas. Similarly, Loram *et al*. (2008a) found that domestic gardens made significant contributions to the species diversity and accumulated species richness across five cities in the UK compared to any other urban green space. The remarkably high total species richness recorded in the domestic gardens of this study can be attributed to several factors. Firstly, there is a very large species pool available to gardeners (Glen, 2002; RHS, 2015), secondly, due the active maintenance and management by gardeners (Thompson *et al*., 2003; refer to Chapter 6), thirdly, the financial resources that are available to more affluent gardeners (Smith *et al*., 2006c; refer to Chapter 8) and finally, the personal preferences and cultural background of the householders (refer to Chapter 9).

However, the increasing rate of urbanisation is putting pressure on the development of housing stock in South Africa and the first causality is the remnants of natural areas and abandoned agricultural fields. In Roodepoort several of these sites have been developed, what was once a fragmented natural area is now a mall and a fallow field is now a townhouse complex (own observation). If all the remnants of natural areas and abandoned agricultural lands have been developed, the division of domestic gardens into smaller yards could become a reality in the future. This is already evident in Potchefstroom, where several old houses have been converted into apartment buildings for student housing (own observation).

The pressure of development has decreased the average parcel size of housing plots. These developments are paired with increases in impervious surfaces such as paving for parking areas (Pauleit *et al*., 2005; Perry and Nawaz, 2008), reductions in the area available for biodiversity and consequently a decrease in the extent of green infrastructure in urban settlements (Gaston *et al*., 2005b). Considering the number of potential ecosystem services provided by domestic gardens, the loss of these land-use types could have far reaching environmental consequences in South Africa and other countries. However, to fully understand what the consequences may be if domestic and home gardens are displaced by infrastructure, we must first have a better understanding of the floristic composition of gardens in South Africa, their management, and the influences of socio-economic status and culture.

This study provides insights into all the aforementioned aspects, but more research needs to be done, not only in South Africa but globally. Van Heezik et al. (2012) stated that “because attitudes and values driving landscape preferences in gardens are complex and often not conducive to biodiversity, a gap exists between the possession of knowledge or values and the expression of pro-environmental behaviour and as a result facilitating change in gardening behaviour is challenging”. Van Heezik et al. (2012) attempted to improve the knowledge and thereby alter the attitudes and gardening behaviour of several household owners in favour of environmentally-friendly gardening practices. Their study reported that 40 % of their participants had a greater understanding of wildlife, 26 % made changes to their gardens in order to improve wildlife and 13 % to support native biodiversity (Van Heezik et al., 2012). Research by Daniels and Kirkpatrick (2006a) demonstrated that gardeners played a positive role in conservation efforts by designing and managing gardens for the advantage of particular species in Australia.

Future research should attempt to close the gap between knowledge and pro-environmental gardening practices in South Africa, not only to promote the conservation of indigenous, endemic and rare plant species, but also to promote wildlife gardening in South Africa. Encouraging householders to not only maintain biodiversity in their gardens but also to promote it can be crucial to a sustainable urban ecosystem, especially considering the combined areal coverage of domestic gardens. Smith *et al*. (2006a) stated that “gardens of all sizes have the potential to be useful for wildlife, since both planting and, importantly, management decisions depend heavily on the owner”. South Africa is a very diverse country, from its rich array of cultures to its unequal distribution of wealth, differences that are clearly portrayed in the domestic gardens of the five settlements.

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Annexure A – Species list

Table A.1: Complete species list of all the vascular plant species recorded in the five studied settlements. The abbreviations indicate the land-use types and settlements were the species were recorded (**Land-use types**: DG: Domestic gardens, FF: Fallow fields, FN: Fragmented natural areas, IG: Institutional gardens, NA: Natural areas, RV: Road verges, S: Sidewalks and W: Wetlands; **Settlements**: T: Tlhakgameng, G: Ganyesa, I: Ikageng, P: Potchefstroom, and R: Roodepoort).

	Family name	Land-use Types								Settlements				
*Abelia floribunda Decne.**	Caprifoliaceae	DG											P	R
*Abelia x grandiflora (Rovelli ex André) Rehder**	Caprifoliaceae	DG										I	P	R
*Abutilon hybridum Voss**	Malvaceae	DG												R
*Abutilon megapotamicum (Spreng.) A.St.Hil. & Nauden**	Malvaceae	DG											P	
*Abutilon pictum (Gillies ex Hook.) Walp.**	Malvaceae	DG											P	R
*Acacia dealbata Link**	Fabaceae	DG		FN			RV							R
*Acacia decurrens Willd.**	Fabaceae	DG								T				
*Acacia elata A. Cunn. ex Benth.**	Fabaceae	DG												R
*Acacia longifolia (Andrews) Willd.**	Fabaceae	DG												R
*Acacia mearnsii De Wild.**	Fabaceae	DG					RV	S						R
*Acacia melanoxylon R.Br.**	Fabaceae	DG		FN		NA	RV	S					P	R
*Acacia saligna (Labill.) H.L.Wendl.**	Fabaceae	DG												R
*Acalypha amentacea Roxb. subsp. wilkesiana (Müll. Arg.) Fosberg**	Euphorbiaceae	DG												R
Acalypha angustata Sond.	Euphorbiaceae			FN		NA	RV					I		R
*Acalypha hispida Burm.f**	Euphorbiaceae	DG										I		R
Acalypha indica L.	Euphorbiaceae	DG				NA						I		R
Acalypha villicaulis Hochst.	Euphorbiaceae					NA								R
Acanthosicyos naudinianus (Sond.) C.Jeffrey	Cucurbitaceae	DG	FF			NA				T	G			

Acanthospermum australe (Loefl.) Kuntze	Asteraceae			FN							G			
*Acanthospermum glabratum (DC.) Wild**	Asteraceae	DG	FF	FN		NA	RV		W	T	G			
*Acanthospermum hispidum DC.**	Asteraceae	DG		FN		NA	RV	S	W	T	G			R
*Acanthus mollis L.**	Acanthaceae	DG										I	P	R
*Acca sellowiana (O. Berg) Burret**	Myrtaceae	DG										I	P	R
*Acer buergerianum Miq.**	Aceraceae	DG					RV	S				I	P	R
*Acer negundo L.**	Aceraceae	DG	FF				RV	S			G		P	R
*Acer palmatum Thunb.**	Aceraceae	DG										I	P	R
*Acer pensylvanicum L.**	Aceraceae							S						R
*Achillea millefolium L.**	Asteraceae	DG								T	G	I		
*Achyranthes aspera L. var. aspera**	Amaranthaceae	DG				NA	RV			T			P	R
Acokanthera oppositifolia (Lam.) Codd	Apocynaceae	DG										I	P	
Acroceras macrum Stapf	Poaceae	DG					RV						P	R
Acrotome inflata Benth.	Lamiaceae	DG		FN		NA				T	G			
Adenia glauca Schinz	Passifloraceae	DG												R
*Adiantum raddianum C.Presl**	Adiantaceae	DG											P	
*Aechmea caudata Lindm.**	Bromeliaceae	DG												R
*Aechmea fasciata (Lindl.) Baker**	Bromeliaceae	DG											P	R
*Aechmea fulgens var. discolor Brongn. in Baker**	Bromeliaceae	DG											P	R
*Aechmea gamosepala Wittm.**	Bromeliaceae	DG												R
*Aeonium arboreum (L.) Webb & Berthel.**	Crassulaceae	DG								T			P	R
*Aeonium canariense Webb & Berthel.**	Crassulaceae	DG											P	R
Aerva leucura Moq.	Amaranthaceae					NA						I		
Afrolimon capense (L.Bolus) Lincz.	Plumbaginaceae	DG												R
Agapanthus africanus (L.) Hoffmans.	Agapanthaceae	DG											P	R
Agapanthus praecox Willd. subsp. orientalis (F.M.Leight)	Agapanthaceae	DG								T	G	I	P	R

F.M.Leight									
*Agave americana L. subsp. americana**	Agavaceae	DG			T	G	I	P	R
*Agave attenuata Salm–Dyck**	Agavaceae	DG							R
*Agave decipiens Baker**	Agavaceae	DG			T	G			
*Agave filifera Salm–Dyck**	Agavaceae	DG			T	G	I	P	R
*Agave parryi Engelm.**	Agavaceae	DG							R
*Agave tequilana F.A.C.Weber**	Agavaceae	DG							R
*Agave victoriae–reginae T. Moore**	Agavaceae	DG			T		I		
*Ageratum houstonianum Mill.**	Asteraceae	DG							R
*Agrostis montevidensis Spreng. ex Nees**	Poaceae	DG						P	
*Ailanthus altissima (Mill.) Swingle**	Simaroubaceae	DG			T	G	I	P	R
*Ajuga reptans L.**	Lamiaceae	DG						P	R
*Albizia julibrissin (Willd.) Durazz.**	Fabaceae	DG						P	R
*Alcea rosea L.**	Malvaceae	DG			T	G	I	P	R
*Allamanda cathartica L.**	Apocynaceae	DG							R
*Allium ampeloprasum L.**	Alliaceae	DG					I	P	
*Allium cepa L.**	Alliaceae	DG			T	G	I	P	R
Alloteropsis semialata (R.Br.) Hitchc.	Poaceae		FN	NA					R
*Alluaudia procera (Drake) Drake**	Didiereaceae	DG							R
*Alocasia macrorrhizos (L.) G.Don**	Araceae	DG			T	G	I	P	R
*Alocasia sanderiana hort. ex Bull**	Araceae	DG						P	
Aloe arborescens Mill.	Asphodelaceae	DG			T	G	I	P	R
Aloe aristata Haw.	Asphodelaceae	DG					I	P	R
Aloe barberae T.–Dyer	Asphodelaceae	DG							R
Aloe brevifolia Mill.	Asphodelaceae	DG						P	
*Aloe camperi Schweinf.**	Asphodelaceae	DG							R

Aloe castanea Schönland	Asphodelaceae	DG								R
Aloe chabaudii Schönland var. chabaudii	Asphodelaceae	DG								R
Aloe ciliaris Haw. var. ciliaris	Asphodelaceae	DG								R
Aloe cryptopoda Baker	Asphodelaceae	DG								R
Aloe falcata Baker	Asphodelaceae	DG								R
Aloe ferox Mill.	Asphodelaceae	DG							P	R
Aloe grandidentata Salm–Dyck	Asphodelaceae	DG		FN	NA	T	G	I	P	R
Aloe greatheadii Schönland var. davyana (Schönland) Glen & D.S.Hardy	Asphodelaceae	DG	FF	FN	NA	T	G	I	P	R
Aloe marlothii A.Berger	Asphodelaceae	DG					G			R
Aloe microstigma Salm–Dyck	Asphodelaceae	DG								R
Aloe perfoliata L.	Asphodelaceae	DG								R
Aloe striata Haw.	Asphodelaceae	DG				T				R
Aloe striata Haw. x maculata All.	Asphodelaceae	DG				T	G		P	R
Aloe striatula Haw.	Asphodelaceae	DG				T		I		R
Aloe swynnertonii Rendle	Asphodelaceae	DG								R
Aloe tenuior Haw.	Asphodelaceae	DG					G	I		R
*Aloe vera (L.) Burm.f.**	Asphodelaceae	DG							P	R
Aloe verecunda Pole Evans	Asphodelaceae				NA					R
Aloe zebrina Baker	Asphodelaceae	DG			NA			I	P	
*Aloysia triphylla (L'Her.) Britton**	Verbenaceae	DG							P	R
*Alpinia nutans K.Schum.**	Zingiberaceae	DG								R
*Alstroemeria aurea Graham**	Alstroemeriaceae	DG							P	R
*Alstroemeria psittacina Lehm.**	Alstroemeriaceae	DG				T		I	P	R
*Alstroemeria pulchella L.f.**	Alstroemeriaceae	DG							P	
*Alternanthera ficoidea (L.) P. Beauv.**	Amaranthaceae	DG								R

*Alternanthera pungens Kunth**	Amaranthaceae	DG	FF	FN	IG	NA	RV	S	W	T	G	I	P	R
*Amaranthus caudatus L.**	Amaranthaceae	DG								T	G	I		
*Amaranthus deflexus L.**	Amaranthaceae	DG	FF			NA					G	I	P	
*Amaranthus hybridus L. subsp. cruentus (L.) Thell.**	Amaranthaceae	DG		FN	IG	NA	RV	S		T	G	I	P	R
*Amaranthus hybridus L.**	Amaranthaceae	DG								T	G	I	P	R
*Amaranthus spinosus L.**	Amaranthaceae	DG											P	
Amaranthus thunbergii Moq.	Amaranthaceae	DG		FN			RV		W	T				R
*Amaranthus viridis L.**	Amaranthaceae	DG		FN				S		T		I	P	
Amaryllis belladonna L.	Amaryllidaceae	DG									G			R
*Ambrosia artemisifolia L.**	Asteraceae	DG												R
*Ambrosia psilostachya DC.**	Asteraceae	DG	FF	FN	IG	NA	RV						P	R
*Ammi majus L.**	Apiaceae	DG	FF	FN		NA	RV						P	R
Ammocharis coranica (Ker Gawl.) Herb.	Amaryllidaceae	DG									G	I		
*Amphilophium buccinatorium (DC.) L.G.Lohmann**	Bignoniaceae	DG												R
*Amphilophium laxiflorum (DC.) L.G.Lohmann**	Bignoniaceae	DG												R
*Anchusa azurea Mill.**	Boraginaceae	DG											P	
Ancylobotrys capensis (Oliv.) Pichon	Apocynaceae					NA								R
Andropogon schirensis A.Rich.	Poaceae			FN		NA						I		R
*Anemone coronaria L.**	Ranunculaceae	DG										I	P	R
*Anethum graveolens L.**	Apiaceae	DG												R
Anisodontea elegans (Cav.) Bates	Malvaceae	DG											P	
Anisodontea julii (Burch. ex DC.) Bates	Malvaceae	DG											P	
Anisodontea scabrosa (L.) Bates	Malvaceae	DG												R
*Anredera cordifolia (Ten.) Steenis**	Basellaceae	DG								T		I	P	R
Ansellia africana Lindl.	Orchidaceae	DG												R
Anthephora pubescens Nees	Poaceae					NA						I		

Anthospermum herbaceum L.f.	Rubiaceae						RV						P	
Anthospermum hispidulum E.Mey. ex Sond.	Rubiaceae					NA				T	G			
Anthospermum rigidum Eckl. & Zeyh. subsp. rigidum	Rubiaceae	DG		FN		NA	RV	S	W		G	I	P	R
*Anthurium andraeanum Linden ex André**	Araceae	DG												R
*Anthurium crystallinum Linden ex André**	Araceae	DG											P	
*Anthurium scherzerianum Schott**	Araceae	DG												R
*Antigonon leptopus Hook. & Arn.**	Polygonaceae	DG								T			P	R
*Antirrhinum majus L.**	Scrophulariaceae	DG										I	P	R
Antizoma angustifolia (Burch.) Miers ex Harv.	Menispermaceae	DG		FN		NA				T	G	I		
*Apium graveolens L.**	Apiaceae	DG									G		P	R
Apodytes dimidiata E. Mey. ex Arn. subsp. dimidiata	Icacinaceae	DG												R
Aponogeton junceus Lehm.	Aponogetonaceae	DG											P	
Aptenia cordifolia (L.f.) Schwantes	Mesembryanthemaceae	DG								T	G	I	P	R
Aptosimum elongatum Engl.	Scrophulariaceae	DG	FF	FN		NA				T	G			
Aptosimum procumbens (Lehm.) Steud.	Scrophulariaceae	DG				NA			W	T				
*Aquilegia coerulea E.James**	Ranunculaceae	DG												R
*Arachis hypogaea L.**	Fabaceae	DG								T				
*Araujia sericifera Brot.**	Apocynaceae	DG		FN				S				I	P	R
*Arbutus unedo L.**	Ericaceae	DG												R
Arctotheca calendula (L.) Levyns	Asteraceae	DG												R
Arctotis arctotoides (L.f.) O.Hoffm.	Asteraceae	DG		FN		NA			W	T	G		P	
Arctotis hirsuta (Harv.) Beauverd	Asteraceae	DG												R
Arctotis venusta Norl.	Asteraceae	DG								T	G			
*Argemone ochroleuca Sweet subsp. ochroleuca**	Papaveraceae	DG	FF	FN		NA	RV	S	W	T	G	I	P	R
Argyroderma delaetii C.A.Maass	Mesembryanthemaceae	DG												R
Aristida adscensionis L.	Poaceae		FF			NA						I	P	R

Aristida bipartita (Nees) Trin. & Rupr.	Poaceae		FF			NA	RV					I	P	R
Aristida canescens Henrard subsp. canescens	Poaceae	DG		FN	IG	NA	RV			T	G	I	P	R
Aristida congesta Roem. & Schult. subsp. barbicollis (Trin. & Rupr.) De Winter	Poaceae					NA	RV							R
Aristida congesta Roem. & Schult. subsp. congesta	Poaceae	DG	FF	FN	IG	NA	RV		W	T	G	I	P	R
Aristida diffusa Trin. subsp. burkei (Stapf) Melderis	Poaceae	DG	FF	FN		NA			W	T	G	I		R
Aristida junciformis Trin. & Rupr. subsp. Junciformis	Poaceae			FN		NA								R
Aristida meridionalis Henrard	Poaceae					NA						I		
Aristida pilgeri Henrard	Poaceae					NA					G			
Aristida stipitata Hack. subsp. graciliflora (Pilg.) Melderis	Poaceae	DG	FF	FN		NA	RV		W	T	G			
Aristida transvaalensis Henrard	Poaceae			FN		NA								R
*Aristolochia littoralis D.Parodi**	Aristolochiaceae	DG											P	R
*Armeria maritima (Mill.) Willd.**	Plumbaginaceae	DG											P	R
*Armoracia rusticana P.Gaertn., B.Mey & Scherb.**	Brassicaceae	DG										I		
*Artemisia absinthium L.**	Asteraceae	DG								T		I	P	
Artemisia afra Jacq. ex Willd.	Asteraceae	DG				NA			W	T	G	I		R
*Artemisia lactiflora Wall.ex DC.**	Asteraceae	DG										I		
*Arum palaestinum Boiss.**	Araceae	DG											P	
*Arundo donax L.**	Poaceae	DG								T	G	I	P	
Asclepias albens (E.Mey.) Schltr.	Apocynaceae					NA								R
Asclepias aurea (Schltr.) Schltr.	Apocynaceae					NA						I		
Asclepias brevipes (Schltr.) Schltr.	Apocynaceae					NA	RV					I	P	
Asclepias meliodora (Schltr.) Schltr.	Apocynaceae					NA						I		
Asclepias stellifera Schltr.	Apocynaceae			FN		NA								R
Asparagus aethiopicus L.	Asparagaceae	DG												R
Asparagus africanus Lam.	Asparagaceae	DG		FN		NA						I	P	

Asparagus asparagoides (L.) Druce	Asparagaceae	DG											R
Asparagus cooperi Baker	Asparagaceae				NA					G			
Asparagus densiflorus (Kunth) Jessop	Asparagaceae	DG							T	G	I	P	R
Asparagus exuvialis Burch. forma exuvialis	Asparagaceae				NA								R
Asparagus falcatus L.	Asparagaceae	DG										P	R
Asparagus laricinus Burch.	Asparagaceae	DG	FF	FN	NA	RV			T	G	I	P	R
*Asparagus officinalis L.**	Asparagaceae	DG											R
Asparagus plumosus Baker	Asparagaceae	DG								G		P	R
Asparagus racemosus Willd.	Asparagaceae	DG			NA			W	T				
Asparagus setaceus (Kunth) Jessop	Asparagaceae	DG			NA						I	P	R
Asparagus suaveolens Burch.	Asparagaceae	DG	FF	FN	NA	RV	S	W	T	G	I	P	R
Asparagus virgatus Baker	Asparagaceae	DG					S					P	R
*Aspidistra elatior Blume**	Convallariaceae	DG									I	P	R
Aspilia mossambicensis (Oliv.) Wild	Asteraceae				NA								R
*Asplenium nidus L.**	Aspleniaceae	DG										P	
*Aster laevis L.**	Asteraceae	DG			NA				T	G		P	R
*Aster novi–belgii L.**	Asteraceae	DG									I	P	R
*Aster squamatus (Spreng.) Hieron.**	Asteraceae	DG										P	
*Aster tradescantii L.**	Asteraceae	DG										P	R
Asteraceae species [LYM49]	Asteraceae	DG			NA			W	T				
*Astrophytum myriostigma Lem.**	Cactaceae	DG											R
*Astrophytum ornatum (D.C.) Britton & Rose**	Cactaceae	DG											R
Athrixia elata Sond.	Asteraceae			FN	NA								R
*Athyrium filix–femina (L.) Roth**	Woodsiaceae	DG										P	R
*Atriplex nummularia Lindl. subsp. nummularia**	Chenopodiaceae	DG							T	G			
*Atriplex semibaccata R.Br. var. typica Aellen**	Chenopodiaceae	DG	FF	FN		RV	S			G	I	P	R

*Aucuba japonica Thunb.**	Garryaceae	DG										P	R
*Austrocylindropuntia subulata (Muehlenpf.) Backeb.**	Cactaceae	DG											R
Babiana rubrocyanea (Jacq.) Ker Gawl.	Iridaceae	DG											R
*Baccharis pingraea DC.**	Asteraceae	DG								G			
*Bambusa multiplex (Lour.) Raeusch. ex Schult. & Schult.f.**	Poaceae	DG										P	R
*Bambusa vulgaris Schrad. ex J.C.Wendl.**	Poaceae	DG											R
*Banksia coccinea R.Br.**	Proteaceae	DG										P	
Barleria galpinii C.B.Clarke	Acanthaceae			FN		NA							R
Barleria macrostegia Nees	Acanthaceae	DG	FF	FN		NA	RV			G	I	P	
Barleria obtusa Nees	Acanthaceae	DG							T			P	R
Bauhinia galpinii N.E.Br.	Fabaceae	DG											R
Bauhinia natalensis Oliv. ex Hook.	Fabaceae	DG											R
Bauhinia petersiana Bolle subsp. macrantha (Oliv.) Brummitt & J.H.Ross	Fabaceae	DG											R
*Bauhinia variegata L. var. variegata**	Fabaceae	DG										P	R
*Beaucarnea recurvata Lem.**	Nolinaceae	DG								G			R
*Begonia coccinea Hook.**	Begoniaceae	DG										P	R
Begonia dregei Otto & A.Dietr.	Begoniaceae	DG											R
Begonia homonyma Steud.	Begoniaceae	DG										P	
*Begonia masoniana Irmsch. ex Ziesenh.**	Begoniaceae	DG									I	P	R
*Begonia semperflorens Link & Otto**	Begoniaceae	DG								G		P	R
Begonia sutherlandii Hook.f. subsp. Sutherlandii	Begoniaceae	DG										P	
*Begonia x rex–cultorum L. H. Bailey**	Begoniaceae	DG											R
*Begonia x tuberhybrida Voss**	Begoniaceae	DG											R
*Bellis perennis L.**	Asteraceae	DG											R
*Berberis julianae C.K.Schneid.**	Berberidaceae	DG										P	R

*Berberis thunbergii DC.**	Berberidaceae	DG								T		I	P	R
*Bergenia cordifolia (Haw.) Sternb.**	Saxifragaceae	DG												R
Bergia decumbens Planch. ex Harv.	Elatinaceae					NA						I		
Berkheya insignis (Harv.) Thell.	Asteraceae					NA							P	R
Berkheya radula (Harv.) De Wild.	Asteraceae	DG	FF	FN	IG	NA	RV	S				I	P	R
Berula erecta (Huds.) Coville	Apiaceae	DG											P	
*Beschorneria yuccoides Hort. ex. Hook.**	Agavaceae	DG										I	P	R
*Beta vulgaris L. subsp. cicla (L.) W.D.J. Koch.**	Chenopodiaceae	DG								T	G			R
*Beta vulgaris L. subsp. vulgaris**	Chenopodiaceae	DG								T	G	I	P	R
*Betula pendula Roth.**	Betulaceae	DG												R
Bewsia biflora (Hack.) Gooss.	Poaceae			FN		NA						I		R
*Bidens bipinnata L.**	Asteraceae	DG	FF	FN		NA	RV	S	W	T	G	I	P	R
*Bidens ferulifolia (Jacq.) Sweet**	Asteraceae	DG												R
*Bidens pilosa L.**	Asteraceae	DG		FN		NA	RV	S				I	P	R
Bijlia dilatata H.E.K.Hartmann	Mesembryanthemaceae	DG												R
Blechnum tabulare (Thunb.) Kuhn	Blechnaceae	DG											P	
Blepharis integrifolia (L.f.) E.Mey. ex Schinz var. integrifolia	Acanthaceae	DG	FF	FN		NA	RV	S	W	T	G	I	P	R
Blepharis serrulata (Nees) Ficalho & Hiern	Acanthaceae	DG	FF	FN		NA			W	T	G	I	P	
*Bletilla striata Rchb.f.**	Orchidaceae	DG												R
*Boehmeria nivea (L.) Gaudich.**	Nyctaginaceae				IG						G			
*Boerhavia cordobensis Kuntze**	Nyctaginaceae		FF	FN		NA						I	P	R
*Boerhavia diffusa L. var. diffusa**	Nyctaginaceae	DG											P	
*Boerhavia erecta L.**	Nyctaginaceae	DG		FN		NA				T	G	I	P	
Bolusanthus speciosus (Bolus) Harms	Fabaceae	DG											P	
Bonatea speciosa (L.f.) Willd.	Orchidaceae					NA						I		R
Boophone disticha (L.f.) Herb.	Amaryllidaceae	DG				NA				T	G	I		R

Boscia albitrunca (Burch.) Gilg & Gilg-Ben.	Capparaceae					NA						I		
Boscia foetida Schinz subsp. minima Tölken	Capparaceae					NA					G			
Bothriochloa insculpta (A.Rich.) A.Camus	Poaceae					NA						I		
*Bougainvillea buttiana Holttum & Standl.**	Nyctaginaceae	DG												R
*Bougainvillea glabra Choisy**	Nyctaginaceae	DG								T	G		P	R
Brachiaria eruciformes (Sm.) Griseb.	Poaceae	DG				NA			W		G	I	P	R
Brachiaria marlothii (Hack.) Stent	Poaceae	DG				NA					G		P	
Brachiaria nigropedata (Ficalho & Hiern) Stapf	Poaceae	DG	FF	FN		NA			W	T	G	I		R
Brachiaria serrata (Thunb.) Stapf	Poaceae			FN		NA	RV					I		R
*Brachychiton acerifolius Macarthur & C. Moore**	Sterculiaceae	DG												R
*Brachychiton populneus (Schott & Endl.) R.Br.**	Sterculiaceae	DG								T	G		P	R
Brachylaena discolor DC.	Asteraceae	DG												R
Brachylaena rotundata S.Moore	Asteraceae					NA								R
*Brassica juncea (L.) Czern. var. juncea**	Brassicaceae	DG										I		R
*Brassica nigra (L.) Koch**	Brassicaceae	DG												R
*Brassica oleracea L. var. acephala (DC.) Schübler & Martens**	Brassicaceae	DG												R
*Brassica oleracea L. var. botrytis L.**	Brassicaceae	DG												R
*Brassica oleracea L. var. gemmifera DC.**	Brassicaceae	DG												R
*Brassica oleracea L.**	Brassicaceae	DG								T		I	P	R
*Brassica rapa L. var. rapa**	Brassicaceae	DG								T				
*Breynia disticha J.R.Forst. & G.Forst.**	Euphorbiaceae	DG									G	I		R
*Bromus catharticus Vahl**	Poaceae	DG	FF	FN	IG	NA	RV	S				I	P	R
*Browallia speciosa Hook.**	Solanaceae	DG												R
*Brugmansia x candida Pers.**	Solanaceae	DG											P	R
*Brunfelsia pauciflora (Cham. & Schltdl.) Benth.**	Solanaceae	DG										I	P	R
*Bryophyllum delagoense (Eckl. & Zeyh.) Schinz**	Crassulaceae	DG								T	G		P	R

Buddleja saligna Willd.	Buddlejaceae	DG										I	P	R
Buddleja salviifolia (L.) Lam.	Buddlejaceae	DG		FN			RV						P	R
Bulbine abyssinica A.Rich.	Asphodelaceae	DG	FF	FN	IG	NA	RV		W	T	G	I		R
Bulbine capitata Poelln.	Asphodelaceae					NA						I		
Bulbine frutescens (L.) Willd.	Asphodelaceae	DG									G		P	R
Bulbine latifolia (L.f.) Spreng.	Asphodelaceae	DG												R
Bulbine narcissifolia Salm–Dyck	Asphodelaceae	DG		FN		NA			W	T	G	I	P	
Bulbostylis burchellii (Ficalho & Hiern) C.B.Clarke	Cyperaceae			FN		NA						I		R
Bulbostylis hispidula (Vahl) R.W.Haines subsp. pyriformis (Lye) R.W.Haines	Cyperaceae	DG	FF	FN	IG	NA	RV			T	G	I	P	R
Bulbostylis humilis (Kunth) C.B.Clarke	Cyperaceae					NA	RV	S						R
Burkea africana Hook.	Fabaceae	DG												R
*Butia capitata (Mart.) Becc.**	Arecaceae	DG											P	
*Buxus sempervirens L.**	Buxaceae	DG											P	R
Cadaba aphylla (Thunb.) Wild	Capparaceae					NA				T				
*Caesalpinia ferrea Mart. ex Tul.**	Fabaceae	DG											P	R
*Caesalpinia gilliesii (Wall. ex Hook.) Benth.**	Fabaceae	DG								T	G			R
*Calathea musaica (W.Bull.) L.H.Bailey**	Marantaceae	DG										I	P	
Calathea ornata (Lem.) Körn.	Marantaceae	DG												R
*Calendula officinalis L.**	Asteraceae	DG											P	
*Calibrachoa x hybrida**	Solanaceae	DG												R
*Calliandra brevipes Benth.**	Fabaceae	DG											P	R
*Callisia repens L.**	Commelinaceae	DG											P	R
*Callistemon citrinus (Curtis) Skeels**	Myrtaceae	DG								T	G	I	P	R
*Callistemon pinifolius (Wendl.) Sweet**	Myrtaceae	DG												R
*Callistemon viminalis (Gaertn.) G.Don**	Myrtaceae	DG									G	I	P	R

Calodendrum capense (L.f.) Thunb.	Rutaceae	DG									R
Calpurnia aurea (Aiton) Benth. subsp. aurea	Fabaceae	DG									R
*Camellia japonica L.**	Theaceae	DG								P	R
*Campanula carpatica Jacq.**	Campanulaceae	DG								P	R
*Campanula trachelium L.**	Campanulaceae	DG								P	R
*Campsis grandiflora (Thunb.) K.Schum.**	Bignoniaceae	DG					T	G		P	R
*Campuloclinium macrocephalum (Less.) DC.**	Asteraceae		FN		RV						R
*Canna indica L.**	Cannaceae	DG	FN				T	G	I	P	R
*Canna x generalis L.H.Bailey**	Cannaceae	DG					T		I	P	R
*Cannabis sativa L.**	Cannabaceae	DG							I		
Canthium gilfillanii (N.E.Br.) O.B.Mill.	Rubiaceae	DG	FN								R
Canthium mundianum Cham. & Schltdl.	Rubiaceae		FN	NA							R
*Capsella bursa–pastoris (L.) Medik.**	Brassicaceae	DG				S			I	P	R
*Capsicum annuum L. var. glabriusculum (Dunal) Heiser & Pickersgill**	Solanaceae	DG					T	G	I	P	R
*Capsicum annuum L.**	Solanaceae	DG									R
*Capsicum frutescens L.**	Solanaceae	DG						G		P	R
Carex glomerabilis Krecz.	Cyperaceae	DG									R
*Carex oshimensis Nakai**	Cyperaceae	DG								P	R
Carissa bispinosa (L.) Desf. ex Brenan	Apocynaceae	DG									R
Carissa macrocarpa (Eckl.) A.DC.	Apocynaceae	DG									R
Carpobrotus dimidiatus (Haw.) L.Bolus	Mesembryanthemaceae	DG					T	G	I	P	
Carpobrotus edulis (L.) L.Bolus subsp. edulis	Mesembryanthemaceae	DG			RV		T	G		P	R
*Carya illinoinensis (Wangenh.) K.Koch**	Juglandaceae	DG							I	P	R
*Castanea sativa L.**	Fabaceae	DG									R
*Casuarina cunninghamiana Miq**	Casuarinaceae	DG			RV		T	G		P	R

*Catalpa bignonioides Walter**	Bignoniaceae	DG												R
*Catharanthus roseus (L.) G.Don.**	Apocynaceae	DG								T	G	I	P	R
*Cedrus deodara (Roxb. ex D.Don) G.Don**	Pinaceae	DG											P	R
*Celosia argentea L.**	Amaranthaceae	DG												R
*Celosia cristata L.**	Amaranthaceae	DG										I	P	R
Celtis africana Burm.f.	Celtidaceae	DG				NA	RV	S		T	G	I	P	R
*Celtis australis L.**	Ulmaceae	DG					RV	S		T			P	R
*Celtis occidentalis L.**	Ulmaceae	DG											P	R
*Celtis sinensis Pers.**	Ulmaceae	DG		FN		NA	RV	S		T	G	I	P	R
Cenchrus ciliaris L.	Poaceae					NA						I		
*Centaurea cineraria L.**	Asteraceae	DG								T	G	I	P	R
*Centaurea cyanus L.**	Asteraceae	DG										I	P	R
Centella asiatica (L.) Urb.	Apiaceae							S						R
Centropodia glauca (Nees) Cope	Poaceae	DG			IG	NA				T	G			
*Ceratonia siliqua L.**	Fabaceae	DG								T	G		P	R
*Ceratostigma willmottianum Stapf**	Plumbaginaceae	DG											P	R
Ceratotheca triloba (Bernh.) Hook.f.	Pedaliaceae	DG				NA					G	I		R
*Cercis siliquastrum L.**	Fabaceae	DG											P	
*Cereus jamacaru DC.**	Cactaceae	DG								T	G		P	R
*Cereus peruvianus (L.) Mill.**	Cactaceae	DG												R
Ceropegia linearis E.Mey. subsp. woodii (Schltr.) H.Huber	Apocynaceae	DG												R
*Cestrum aurantiacum Lindl.**	Solanaceae	DG												R
*Cestrum diurnum L.**	Solanaceae	DG								T		I	P	R
*Cestrum elegans (Brongn.) Schltdl.**	Solanaceae	DG											P	R
*Cestrum laevigatum Schltdl.**	Solanaceae	DG					RV	S	W		G		P	R
*Cestrum nocturnum L.**	Solanaceae	DG									G	I	P	R

*Cestrum parqui L'Her.**	Solanaceae	DG									G		P	R
*Chaenomeles speciosa (Sweet) Nakai**	Rosaceae	DG											P	
Chaetacanthus costatus Nees	Acanthaceae			FN		NA						I	P	
Chamaecrista biensis (Steyaert) Lock	Fabaceae	DG	FF	FN		NA	RV			T	G	I	P	R
Chamaecrista comosa E.Mey.	Fabaceae			FN		NA	RV					I		R
Chamaecrista mimosoides (L.) Greene	Fabaceae			FN		NA	RV	S				I	P	R
*Chamaecyparis lawsoniana (A.Murray bis) Parl.**	Cupressaceae	DG								T		I	P	R
*Chamaecyparis obtusa (Siebold & Zucc.) Endl.**	Cupressaceae	DG								T	G	I	P	R
*Chamaecyparis pisifera (Siebold & Zucc.) Endl.**	Cupressaceae	DG												R
*Chamaedorea cataractarum Mart.**	Arecaceae	DG												R
*Chamaedorea elegans Mart.**	Arecaceae	DG										I	P	R
*Chamaemelum nobile (L.) All.**	Asteraceae	DG										I	P	R
Chascanum hederaceum (Sond.) Moldenke	Verbenaceae	DG				NA				T		I		
Chascanum pinnatifidum (L.f.) E.Mey.	Verbenaceae					NA				T		I		
Cheilanthes hirta Sw.	Pteridaceae	DG		FN		NA								R
Cheilanthes viridis (Forssk.) Sw. var. viridis	Pteridaceae	DG		FN		NA								R
*Chenopodium album L.**	Chenopodiaceae	DG	FF	FN		NA	RV	S		T	G	I	P	R
*Chenopodium ambrosioides L.**	Chenopodiaceae	DG				NA			W	T	G	I		
*Chenopodium carinatum R.Br.**	Chenopodiaceae	DG	FF	FN	IG	NA	RV	S	W	T	G	I	P	R
Chenopodium mucronatum Thunb.	Chenopodiaceae							S				I		
*Chenopodium multifidum L.**	Chenopodiaceae		FF				RV				G		P	R
Chloris gayana Kunth	Poaceae							S						R
Chloris pycnothrix Trin.	Poaceae	DG	FF	FN		NA	RV	S				I	P	R
Chloris virgata Sw.	Poaceae	DG		FN	IG	NA	RV	S	W	T	G	I		
Chlorophytum capense (L.) Voss	Anthericaceae	DG												R
Chlorophytum comosum (Thunb.) Jacq.	Anthericaceae	DG								T	G	I	P	R

Chlorophytum cooperi (Baker) Nordal	Anthericaceae					NA						I		
Chlorophytum fasciculatum (Baker) Kativu	Anthericaceae		FF			NA			W	T	G			
Chlorophytum saundersiae (Baker) Nordal	Anthericaceae	DG												R
Chlorophytum transvaalense (Baker) Kativu	Anthericaceae			FN	IG	NA	RV					I	P	R
Chondropetalum tectorum (L.f.) Raf.	Restionaceae	DG											P	R
*Chorisia speciosa A.St.–Hil.**	Bombacaceae	DG												R
Chrysanthemoides monilifera (L.) Norl.	Asteraceae	DG												R
*Chrysanthemum frutescens L.**	Asteraceae	DG											P	R
*Chrysanthemum maximum Ramond**	Asteraceae	DG								T		I	P	R
*Chrysanthemum morifolium Ramat.**	Asteraceae	DG								T	G	I	P	R
Chrysocoma obtusata (Thunb.) Ehr.Bayer	Asteraceae	DG	FF			NA				T				
*Cichorium intybus L. subsp. intybus**	Asteraceae	DG	FF	FN	IG	NA	RV	S					P	R
*Ciclospermum leptophyllum (Pers.) Sprague**	Apiaceae	DG	FF	FN	IG	NA	RV	S	W	T		I	P	R
*Cinnamomum camphora (L.) T.Nees & C.H.Eberm.**	Lauraceae	DG									G		P	R
*Cirsium vulgare (Savi) Ten.**	Asteraceae	DG	FF	FN	IG		RV	S				I	P	R
Citrillus lanatus (Thunb.) Matsum. & Nakai	Cucurbitaceae	DG								T	G		P	
*Citrus aurantiifolia (Christm.) Swingle**	Rutaceae	DG											P	
*Citrus limon (L.) Burm.f.**	Rutaceae	DG								T	G	I	P	R
*Citrus madurensis Lour.**	Rutaceae	DG											P	
*Citrus reticulata Blanco**	Rutaceae	DG									G		P	R
*Citrus sinensis (L.) Osbeck**	Rutaceae	DG								T	G	I	P	R
Clematis brachiata Thunb.	Ranunculaceae	DG	FF	FN		NA			W	T	G	I	P	R
*Clematis campaniflora Brot.**	Ranunculaceae	DG											P	R
Cleome gynandra L.	Cleomaceae	DG	FF			NA	RV			T	G			
*Cleome hassleriana Chodat**	Cleomaceae	DG									G		P	R
Cleome monophylla L.	Cleomaceae			FN		NA								R

Cleome rubella Burch.	Cleomaceae	DG	FF	FN		NA			W	T	G	I		
Clerodendrum glabrum E.Mey. var. glabrum	Lamiaceae	DG												R
Clivia miniata (Lindl.) Regel var. miniata	Amaryllidaceae	DG									G	I	P	R
Clutia pulchella L. var. pulchella	Euphorbiaceae			FN		NA								R
*Codiaeum variegatum (L.) A.Juss.**	Euphorbiaceae	DG											P	R
Coleochloa setifera (Ridl.) Gilly	Cyperaceae					NA								R
Coleonema album (Thunb.) Bartl. & H.L.Wendl.	Rutaceae	DG												R
Coleonema pulchellum I.Williams	Rutaceae	DG											P	R
*Colocasia esculenta (L.) Schott**	Araceae	DG											P	
Combretum apiculatum Sond. subsp. apiculatum	Combretaceae	DG												R
Combretum bracteosum (Hochst.) Brandis	Combretaceae	DG												R
Combretum erythrophyllum (Burch.) Sond.	Combretaceae	DG		FN	IG			S			G	I	P	R
Combretum molle R.Br. ex G.Don	Combretaceae			FN		NA								R
Commelina africana L. var. africana	Commelinaceae	DG		FN		NA	RV			T	G	I		R
Commelina benghalensis L.	Commelinaceae	DG		FN		NA	RV	S	W		G	I	P	R
Commelina eckloniana Kunth	Commelinaceae							S					P	
Commelina livingstonii C.B.Clarke	Commelinaceae	DG	FF	FN		NA			W	T	G	I	P	
Conophytum bilobum (Marloth) N.E.Br.	Mesembryanthemaceae	DG												R
*Convolvulus arvensis L.**	Convolvulaceae	DG				NA						I	P	
Convolvulus sabatius Viv.	Convolvulaceae	DG												R
Convolvulus sagittatus Thunb.	Convolvulaceae	DG	FF	FN		NA	RV	S	W	T	G	I	P	R
*Conyza bonariensis (L.) Cronquist**	Asteraceae	DG		FN	IG	NA	RV	S	W	T	G	I	P	R
*Conyza canadensis (L.) Cronquist**	Asteraceae	DG								T		I	P	
Conyza podocephala DC.	Asteraceae	DG	FF	FN	IG	NA	RV	S				I	P	R
*Coprosma repens A.Rich.**	Rubiaceae	DG										I	P	R
*Coprosma x kirkii Cheeseman**	Rubiaceae	DG											P	R

Corchorus asplenifolius Burch.	Tiliaceae	DG	FF	FN		NA	RV	S	W	T	G	I	P	R
*Cordyline australis (G.Forst.) Endl.**	Agavaceae	DG									G	I	P	R
*Coreopsis grandiflora Hogg ex Sweet**	Asteraceae	DG							W	T	G	I	P	R
*Coriandrum sativum L.**	Apiaceae	DG											P	R
*Coronopus didymus (L.) Sm.**	Brassicaceae	DG										I	P	
*Cortaderia selloana (Schult.) Asch. & Graebn.**	Poaceae	DG		FN									P	R
*Cosmos bipinnatus Cav.**	Asteraceae	DG					RV		W	T	G	I	P	R
*Cosmos sulphureus Cav.**	Asteraceae	DG								T			P	R
*Cotoneaster franchetii Bois.**	Rosaceae	DG										I	P	R
*Cotoneaster frigidus Wall. ex Lindl.**	Rosaceae	DG									G		P	R
*Cotoneaster horizontalis Decne.**	Rosaceae	DG											P	R
*Cotoneaster hupehensis Rehder & E.H.Wilson**	Rosaceae	DG											P	R
*Cotoneaster pannosus Franch.**	Rosaceae	DG											P	R
*Cotoneaster salicifolius Franch.**	Rosaceae	DG												R
Cotula australis (Spreng.) Hook.f.	Asteraceae	DG			IG		RV	S	W	T		I	P	R
Cotyledon campanulata Marloth	Crassulaceae	DG												R
Cotyledon orbiculata L. var. flanaganii (Schönland & Baker f.) Toelken	Crassulaceae	DG												R
Cotyledon orbiculata L. var. oblonga (Haw.) DC.	Crassulaceae	DG								T	G	I	P	R
Cotyledon orbiculata L. var. orbiculata	Crassulaceae	DG												R
Cotyledon orbiculata L. var. spuria (L.) Toelken	Crassulaceae	DG												R
Cotyledon tomentosa Harv. subsp. tomentosa	Crassulaceae	DG									G			R
Crabbea acaulis N.E.Br.	Acanthaceae			FN		NA	RV					I	P	R
Crabbea angustifolia Nees	Acanthaceae			FN		NA	RV			T		I	P	R
Crabbea hirsuta Harv.	Acanthaceae			FN		NA							P	
Crassula arborescens (Mill.) Willd. subsp. arborescens	Crassulaceae	DG												R

Crassula arborescens (Mill.) Willd. subsp. undulatifolia Toelken	Crassulaceae	DG									R
Crassula capitella Thunb. subsp. capitella	Crassulaceae	DG		NA			T	G	I	P	R
Crassula capitella Thunb. subsp. nodulosa (Schönland) Tölken	Crassulaceae		FN	NA							R
Crassula coccinea L.	Crassulaceae	DG									R
*Crassula helmsii (Kirk) Cockayne**	Crassulaceae	DG									R
Crassula lanceolata (Eckl. & Zeyh.) Endl. ex Walp.	Crassulaceae			NA		W	T				R
Crassula macowaniana Schönland & Baker f.	Crassulaceae	DG									R
Crassula multicava Lem.	Crassulaceae	DG								P	R
Crassula muscosa L. var. muscosa	Crassulaceae	DG									R
Crassula nudicaulis L. var. nudicaulis	Crassulaceae	DG									R
Crassula ovata (Mill.) Druce	Crassulaceae	DG					T	G	I	P	R
Crassula ovata 'Gollum'	Crassulaceae	DG									R
Crassula pellucida L. subsp. pellucida	Crassulaceae	DG									R
Crassula perfoliata L.	Crassulaceae	DG									R
Crassula rupestris Thunb. subsp. rupestris	Crassulaceae	DG									R
Crassula sarcocaulis Eckl. & Zeyh. subsp. sarcocaulis	Crassulaceae	DG									R
*Crassula sarmentosa Harv.**	Crassulaceae	DG									R
Crassula setulosa Harv.	Crassulaceae			NA							R
Crassula streyi Toelken	Crassulaceae	DG									R
Crassula swaziensis Schönland	Crassulaceae			NA							R
Crassula tetragona L.	Crassulaceae	DG								P	R
*Crataegus crus–galli L.**	Rosaceae	DG									R
*Crataegus pubescens (Kunth) Steud.**	Rosaceae	DG								P	R
Craterostigma wilmsii Engl. ex Diels	Scrophulariaceae		FN								R
Crinum bulbispermum (Burm.f.) Milne–Redh. & Schweick.	Amaryllidaceae	DG		NA	RV		T		I	P	R
Crinum crassicaule Baker	Amaryllidaceae	DG						G			

Crinum macowanii Baker	Amaryllidaceae	DG										P	R
Crinum moorei Hook.f.	Amaryllidaceae	DG									I	P	R
Crocosmia aurea (Pappe ex Hook.f.) Planch. subsp. aurea	Iridaceae	DG									I	P	R
Crocosmia masoniorum (L.Bolus) N.E.Br.	Iridaceae	DG											R
Crocosmia paniculata (Klatt) Goldblatt	Iridaceae	DG									I	P	R
*Crotalaria agatiflora Schweinf. subsp. agatiflora**	Fabaceae	DG		FN								P	R
Crotalaria barkae Schweinf. subsp. barkae	Fabaceae							W		G			
Crotalaria eremicola Baker f. subsp. eremicola	Fabaceae					NA					I		
Crotalaria lotoides Benth.	Fabaceae	DG	FF	FN	IG	NA		W	T	G	I		R
Crotalaria sphaerocarpa Perr.ex DC. subsp. sphaerocarpa	Fabaceae	DG	FF	FN	IG	NA	RV	W	T	G			
Cryptolepis oblongifolia (Meisn.) Schltr.	Apocynaceae			FN		NA							R
*Cryptomeria japonica (L.f.) D.Don**	Cupressaceae	DG											R
Cucumis hirsutus Sond.	Cucurbitaceae		FF			NA				G			
Cucumis melo L. subsp. agrestis (Naudin) Pangalo	Cucurbitaceae	DG								G			R
Cucumis myriocarpus Naudin subsp. leptodermis (Schweick.)	Cucurbitaceae	DG	FF			NA				G	I		
Cucumis myriocarpus Naudin subsp. myriocarpus	Cucurbitaceae	DG								G			
Cucumis zeyheri Sond.	Cucurbitaceae	DG	FF			NA			T		I	P	R
*Cucurbita maxima Duchesne ex Lam.**	Cucurbitaceae	DG							T	G			R
*Cucurbita pepo L.**	Cucurbitaceae	DG							T	G	I	P	R
*Cuphea hyssopifolia Kunth**	Lythraceae	DG										P	R
*Cuphea ignea A.DC.**	Lythraceae	DG									I		R
*Cuphea micropetala Kunth.**	Lythraceae	DG										P	R
*Cupressus arizonica Greene var. arizonica**	Cupressaceae	DG								G		P	R
*Cupressus macrocarpa Hartw.**	Cupressaceae	DG									I	P	R
*Cupressus sempervirens L. var. sempervirens**	Cupressaceae	DG										P	R
*Cuscuta campestris Yunck.**	Convolvulaceae	DG				NA					I		R

Cussonia paniculata Eckl. & Zeyh. subsp. sinuata (Reyeneke & Kok) De Winter	Araliaceae	DG				NA							P	R
Cussonia spicata Thunb.	Araliaceae	DG												R
Cussonia transvaalensis Reyneke	Araliaceae	DG												R
Cyanotis speciosa (L.f.) Hassk.	Commelinaceae			FN		NA						I		R
*Cyathea australis (R.Br.) Domin**	Cyatheaceae	DG											P	R
Cyathea dregei Kunze.	Cyatheaceae	DG												R
Cyathula cylindrica Moq. var. cylindrica	Amaranthaceae						RV							R
*Cycas circinalis L.**	Cycadaceae	DG												R
*Cycas revoluta Thunb.**	Cycadaceae	DG									G	I	P	R
*Cyclamen persicum Mill.**	Primulaceae	DG												R
*Cydonia oblonga Mill.**	Rosaceae	DG								T	G	I	P	
*Cylindropuntia imbricata (Haw.) F.M.Knuth**	Cactaceae	DG				NA			W	T	G			R
*Cymbidium cultivar**	Orchidaceae	DG												R
*Cymbidium insigne Rolfe**	Orchidaceae	DG											P	
Cymbopogon excavatus (Hochst.) Stapf ex Burtt Davy	Poaceae			FN		NA					G	I		R
Cymbopogon nardus (L.) Rendle	Poaceae	DG		FN		NA							P	R
Cymbopogon pospischilii (K.Schum.) C.E. Hubb.	Poaceae	DG		FN		NA	RV			T		I	P	R
*Cynara scolymus L.**	Asteraceae	DG												R
*Cynodon aethiopicus Clayton & Harlan**	Poaceae	DG											P	
Cynodon dactylon (L.) Pers.	Poaceae	DG	FF	FN	IG	NA	RV	S	W	T	G	I	P	R
Cynodon hirsutus Stent	Poaceae	DG	FF	FN	IG	NA	RV	S	W		G	I	P	R
*Cynodon nlemfuensis Vanderyst**	Poaceae			FN										R
Cynodon transvaalensis Burtt Davy	Poaceae	DG			IG	NA	RV	S			G		P	R
Cyperus albostriatus Schrad.	Cyperaceae	DG	FF			NA				T		I	P	
Cyperus capensis (Steud.) Endl.	Cyperaceae					NA						I		

Cyperus difformis L.	Cyperaceae								W		G			
Cyperus esculentus L. var. esculentus	Cyperaceae	DG	FF	FN	IG	NA	RV	S		T	G	I	P	R
Cyperus haematocephalus C.B.Clarke	Cyperaceae	DG											P	
Cyperus indecorus Kunth var. decurvatus (C.B.Clarke) Kuk.	Cyperaceae	DG		FN	IG	NA	RV				G			
Cyperus involucratus Rottb.	Cyperaceae	DG										I	P	R
Cyperus laevigatus L. subsp. laevigatus	Cyperaceae					NA	RV						P	
Cyperus longus L. var. tenuiflorus (Rottb.) Boeck.	Cyperaceae	DG												R
Cyperus margaritaceus Vahl var. margaritaceus	Cyperaceae	DG	FF	FN		NA			W	T	G			
Cyperus marginatus Thunb.	Cyperaceae								W		G			
Cyperus obtusiflorus Vahl var. flavissimus (Schrad.) Boeck.	Cyperaceae			FN		NA								R
Cyperus obtusiflorus Vahl var. obtusiflorus	Cyperaceae					NA						I		R
Cyperus papyrus L. subsp. papyrus	Cyperaceae	DG												R
Cyperus prolifer Lam.	Cyperaceae	DG											P	
Cyperus rotundus L. subsp. rotundus	Cyperaceae	DG		FN		NA						I	P	R
Cyperus rupestris Kunth var. rupestris	Cyperaceae						RV							R
Cyperus textilis Thunb.	Cyperaceae	DG							W	T	G		P	R
*Cyphomandra betacea (Cav.) Sendtn.**	Solanaceae	DG												R
Cyphostemma currorii (Hook.f.) Desc.	Vitaceae	DG												R
Cyrtanthus loddigesianus (Herb.) R.A.Dyer	Amaryllidaceae	DG										I		
*Cyrtomium falcatum (L.f.) C.Presl**	Dryopteridaceae	DG											P	R
Dactyloctenium aegyptium (L.) Willd.	Poaceae	DG									G			R
Dactyloctenium australe Steud.	Poaceae	DG						S					P	R
Dactyloctenium giganteum Fisher & Schweick.	Poaceae	DG									G			
*Dahlia excelsa Benth.**	Asteraceae	DG								T	G	I	P	R
*Dahlia imperialis Roezl ex Ortgies**	Asteraceae	DG								T		I	P	R
*Dahlia pinnata Cav.**	Asteraceae	DG												R

Dais cotinifolia L.	Thymelaeaceae	DG											P	R
*Dasylirion wheeleri S. Watson ex Rothr.**	Nolinaceae	DG											P	R
*Datura ferox L.**	Solanaceae	DG				NA	RV	S		T		I	P	
*Datura inoxia Mill.**	Solanaceae	DG									G		P	
*Datura stramonium L.**	Solanaceae	DG				NA	RV			T	G	I	P	R
*Daucus carota L.**	Apiaceae	DG								T	G	I	P	R
*Delonix regia (Bojer ex Hook.) Raf.**	Fabaceae	DG								T				
Delosperma herbeum (N.E.Br.) N.E.Br.	Mesembryanthemaceae	DG				NA						I	P	
*Delphinium grandiflorum L.**	Ranunculaceae	DG												R
Deverra burchellii (DC.) Eckl. & Zeyh.	Apiaceae			FN									P	
*Dianella intermedia Endl.**	Phormiaceae	DG											P	
*Dianella tasmanica Hook.f.**	Phormiaceae	DG												R
*Dianthus barbatus L.**	Caryophyllaceae	DG									G	I	P	R
*Dianthus caryophyllus L.**	Caryophyllaceae	DG										I		R
*Dianthus chinensis L.**	Caryophyllaceae	DG											P	R
*Dianthus deltoides L.**	Caryophyllaceae	DG												R
Dianthus mooiensis F.N.Williams	Caryophyllaceae					NA						I		R
Diascia integerrima E.Mey. ex Benth.	Scrophulariaceae	DG												R
Dicerocaryum eriocarpum (Decne.) Abels	Pedaliaceae					NA				T				
Dichapetalum cymosum (Hook.) Engl.	Dichapetalaceae					NA								R
*Dichondra micrantha Urb.**	Convolvulaceae	DG	FF	FN	IG		RV	S				I	P	R
Dichrostachys cinerea (L.) Wight & Arn.	Fabaceae					NA				T				
*Dicksonia antarctica Labill.**	Dicksoniaceae	DG											P	R
Diclis reptans Benth.	Scrophulariaceae	DG												R
Dicoma anomala Sond.	Asteraceae			FN		NA						I		R
Dicoma macrocephala DC.	Asteraceae	DG	FF	FN		NA			W	T	G	I		R

Dicoma schinzii O.Hoffm.	Asteraceae	DG	FF	FN		NA	RV			T	G			
Dietes bicolor (Steud.) Sweet ex Klatt	Iridaceae	DG										I	P	R
Dietes grandiflora N.E.Br.	Iridaceae	DG											P	R
Dietes iridioides (L.) Sweet ex Klatt	Iridaceae	DG											P	R
Digitaria argyrograpta (Nees) Stapf	Poaceae					NA						I		R
Digitaria diagonalis (Nees) Stapf var. diagonalis	Poaceae			FN		NA								R
Digitaria eriantha Steud.	Poaceae	DG	FF	FN		NA	RV		W	T	G	I	P	R
Digitaria monodactyla (Nees) Stapf	Poaceae			FN		NA								R
*Digitaria sanguinalis (L.) Scop.**	Poaceae	DG				NA			W	T	G	I		R
Digitaria ternata (A.Rich.) Stapf	Poaceae	DG		FN			RV					I		R
Digitaria tricholaenoides Stapf	Poaceae			FN		NA	RV					I		R
Digitaria velutina (Forssk.) P.Beauv.	Poaceae			FN										R
Diheteropogon amplectens (Nees) Clayton	Poaceae			FN		NA						I		R
Dimorphotheca ecklonis DC.	Asteraceae	DG								T		I	P	R
Dimorphotheca jucunda E.Phillips	Asteraceae	DG										I	P	
Dimorphotheca pluvialis (L.) Moench	Asteraceae	DG												R
Dimorphotheca sinuata DC.	Asteraceae	DG												R
Diospyros austro–africana De Winter var. microphylla (Burch.) De Winter	Ebenaceae	DG				NA					G			
Diospyros lycioides Desf. subsp. guerkei (Kuntze) De Winter	Ebenaceae	DG		FN		NA	RV				G			R
Diospyros lycioides Desf. subsp. lycioides	Ebenaceae	DG				NA			W	T	G			R
Diospyros whyteana (Hiern) F.White	Ebenaceae	DG												R
Dipcadi glaucum (Ker Gawl.) Baker	Hyacinthaceae	DG				NA				T	G			
Dipcadi viride (L.) Moench	Hyacinthaceae	DG										I		
*Disocactus ackermannii (Lindl.) Barthlott**	Cactaceae	DG											P	R
*Disocactus flagelliformis (L.) Barthlott**	Cactaceae	DG								T				R

*Disocactus phyllanthoides (DC.) Barthlott**	Cactaceae	DG									P	R
Dodonaea viscosa Jacq. var. angustifolia (L.f.) Benth.	Sapindaceae	DG						T	G	I		R
*Dolichandra unguis–cati (L.) L.G.Lohmann**	Bignoniaceae	DG							G	I	P	R
Dolichos angustifolius Eckl. & Zeyh.	Fabaceae				RV							R
Dombeya burgessiae Gerrard ex Harv.	Sterculiaceae	DG										R
Dombeya rotundifolia (Hochst.) Planch. var. rotundifolia	Sterculiaceae	DG		NA				T		I		R
Dorotheanthus bellidiformis (Burm.f.) N.E.Br. subsp. bellidiformis	Mesembryanthemaceae	DG										R
Dovyalis caffra (Hook.f. & Harv.) Hook.f.	Salicaceae	DG						T	G	I	P	R
Dovyalis zeyheri (Sond.) Warb.	Salicaceae	DG										R
*Dracaena deremensis Engl.**	Dracaenaceae	DG							G	I	P	R
*Dracaena fragrans (L.) Ker Gawl.**	Dracaenaceae	DG										R
*Dracaena marginata Lam.**	Dracaenaceae	DG										R
Dracophilus dealbatus (N.E.Br.) Walgate	Mesembryanthemaceae	DG									P	
Drimia sanguinea (Schinz) Jessop	Hyacinthaceae	DG	FF	NA			W	T	G			
Drosanthemum hispidum (L.) Schwantes	Mesembryanthemaceae	DG										R
Drosanthemum species [LYM 65]	Mesembryanthemaceae	DG						T				
*Duchesnea indica (Andrews) Focke**	Rosaceae	DG				S				I	P	R
*Duranta erecta L.**	Verbenaceae	DG							G		P	R
Duvernoia adhatodoides E.Mey ex Nees	Acanthaceae	DG										R
*Dypsis lutescens (H.Wendl.) Beentje & J.Dransf.**	Arecaceae	DG									P	R
*Echeveria derenbergii J.A.Purpus**	Crassulaceae	DG										R
*Echeveria elegans (Rose) A.Berger**	Crassulaceae	DG						T	G	I	P	R
*Echeveria nodulosa Otto**	Crassulaceae	DG										R
*Echeveria pringlei (S.Watson) Rose**	Crassulaceae	DG									P	
*Echeveria pulvinata Rose**	Crassulaceae	DG									P	R
*Echeveria runyonii Rose ex E.Walther**	Crassulaceae	DG										R

*Echeveria secunda Booth ex Lindl.**	Crassulaceae	DG										I	P	R
*Echinacea purpurea (L.) Moench**	Asteraceae	DG												R
*Echinocactus grusonii Hildm.**	Cactaceae	DG								T		I	P	R
*Echinocactus texensis Hopffer**	Cactaceae	DG							W	T				R
*Echinocereus dasyacanthus Engelm.**	Cactaceae	DG												R
*Echinocereus rigidissimus Rose**	Cactaceae	DG												R
*Echinopsis chamaecereus Friedrich & Glaetzle**	Cactaceae	DG											P	R
*Echinopsis oxygona (Link) Zucc. Ex Pfeiff.**	Cactaceae	DG								T			P	R
*Echinopsis pachanoi (Britton and Rose) H.Friedrich and G.D. Rowley**	Cactaceae	DG												R
*Echinopsis spachiana (Lem.) Friedrich & G.D.Rowley**	Cactaceae	DG								T	G			R
Ehretia rigida (Thunb.) Druce subsp. nervifolia Retief & A.E.van Wyk	Boraginaceae	DG				NA				T	G	I		R
Ekebergia capensis Sparrm.	Meliaceae	DG												R
*Elaeagnus pungens Thunb.**	Elaeagnaceae	DG									G		P	R
Elephantorrhiza elephantina (Burch.) Skeels	Fabaceae	DG	FF	FN		NA	RV			T	G	I		R
Eleusine coracana (L.) Gaertn. subsp. africana (Kenn.–O'Byrne) Hilu & De Wet	Poaceae	DG		FN	IG	NA	RV	S	W	T	G	I	P	R
Eleusine indica (L.) Gaertn.	Poaceae	DG												R
*Eleutherine bulbosa (Mill.) Urb.**	Iridaceae	DG								T	G			
Elionurus muticus (Spreng.) Kuntze	Poaceae			FN		NA	RV					I	P	R
Emex australis Steinh.	Polygonaceae	DG		FN			RV		W	T	G		P	R
Encephalartos altensteinii Lehm.	Zamiaceae	DG												R
Encephalartos eugene–maraisii I. Verd.	Zamiaceae	DG												R
Encephalartos ferox G.Bertol.	Zamiaceae	DG												R
Encephalartos friderici–guilielmi Lehm.	Zamiaceae	DG												R

Encephalartos horridus (Jacq.) Lehm.	Zamiaceae	DG											P	R
Encephalartos lebomboensis I.Verd.	Zamiaceae	DG											P	
Encephalartos natalensis R.A.Dyer & I.Verd.	Zamiaceae	DG											P	R
Encephalartos transvenosus Stapf & Burtt Davy	Zamiaceae	DG												R
Encephalartos villosus Lem.	Zamiaceae	DG												R
Englerophytum magalismontanum (Sond.) T.D Penn.	Sapotaceae	DG		FN		NA								R
Enneapogon cenchroides (Roem. & Schult.) C.E.Hubb.	Poaceae					NA						I		
Enneapogon scoparius Stapf	Poaceae	DG				NA						I		
Ensete ventricosum (Welw.) Cheesman	Musaceae	DG											P	R
*Epiphyllum chrysocardium Alexander**	Cactaceae	DG												R
*Epipremnum aureum (Linden ex André) G.S.Bunting**	Araceae	DG												R
Equisetum ramosissimum Desf.	Equisetaceae	DG											P	
Eragrostis barbinodis Hack.	Poaceae	DG					RV						P	
Eragrostis biflora Hack. ex Schinz	Poaceae	DG		FN		NA					G		P	R
Eragrostis capensis (Thunb.) Trin.	Poaceae					NA								R
Eragrostis chloromelas Steud.	Poaceae		FF	FN	IG	NA	RV	S		T	G	I	P	R
Eragrostis cilianensis (All.) Vignolo ex Janch.	Poaceae	DG				NA				T		I		
Eragrostis curvula (Schrad.) Nees	Poaceae	DG	FF	FN	IG	NA	RV	S			G	I	P	R
Eragrostis gummiflua Nees	Poaceae			FN		NA					G	I		R
Eragrostis inamoena K.Schum.	Poaceae	DG										I	P	
Eragrostis lehmanniana Nees var. chaunantha (Pilg.) De Winter	Poaceae	DG		FN						T	G	I	P	R
Eragrostis lehmanniana Nees var. lehmanniana	Poaceae	DG	FF	FN	IG	NA	RV		W	T	G	I	P	
Eragrostis micrantha Hack.	Poaceae					NA				T	G			
Eragrostis nindensis Ficalho & Hiern	Poaceae			FN		NA	RV	S				I		R
Eragrostis obtusa Munro ex Ficalho & Hiern	Poaceae	DG		FN		NA			W	T	G	I	P	
Eragrostis pallens Hack.	Poaceae	DG			IG		RV				G			R

Eragrostis patentipilosa Hack.	Poaceae						RV	S					P	R
Eragrostis plana Nees	Poaceae		FF	FN	IG	NA	RV	S					P	R
Eragrostis racemosa (Thunb.) Steud.	Poaceae			FN		NA								R
Eragrostis rigidior Pilg.	Poaceae	DG	FF			NA				T		I		
Eragrostis sclerantha Nees subsp. Sclerantha	Poaceae						RV							R
Eragrostis superba Peyr.	Poaceae	DG		FN		NA	RV		W	T	G	I	P	R
*Eragrostis tef (Zucc.) Trotter**	Poaceae	DG										I		
Eragrostis trichophora Coss. & Durieu	Poaceae	DG	FF	FN	IG	NA			W	T	G	I	P	
Eragrostis viscosa (Retz.) Trin.	Poaceae	DG	FF			NA					G			
Eragrostis x pseud-obtusa De Winter	Poaceae							S	W	T		I		
Erica versicolor Andrews var. versicolor	Ericaceae	DG												R
*Erigeron karvinskianus DC.**	Asteraceae	DG												R
*Eriobotrya japonica (Thunb.) Lindl.**	Rosaceae	DG					RV					I	P	R
Eriosema burkei Harv. var. burkei	Fabaceae					NA						I		
Eriosema cordatum E.Mey.	Fabaceae			FN		NA								R
Eriospermum cooperi Baker var. cooperi	Eriospermaceae					NA								R
Eriospermum porphyrium Archibald	Eriospermaceae	DG		FN		NA			W	T	G			
*Eruca sativa Mill.**	Brassicaceae	DG												R
Erysimum cheiri (L.) Crantz	Brassicaceae	DG												R
Erythrina caffra Thunb.	Fabaceae	DG												R
*Erythrina crista–galli L.**	Fabaceae	DG											P	
Erythrina humeana Spreng.	Fabaceae	DG												R
Erythrina lysistemon Hutch.	Fabaceae	DG								T	G			R
*Escallonia rubra (Ruiz & Pav.) Pers.**	Escalloniaceae	DG											P	R
*Eschscholzia californica Cham.**	Papaveraceae	DG											P	R
*Eucalyptus camaldulensis Dehnh.**	Myrtaceae	DG		FN		NA	RV				G		P	R

*Eucalyptus cinerea Benth.**	Myrtaceae	DG												R
*Eucalyptus rhodantha Blakely & H.Steedman**	Myrtaceae	DG											P	
*Eucalyptus sideroxylon A.Cunn.**	Myrtaceae	DG									G			
Euclea crispa (Thunb.) Gurke subsp. crispa	Ebenaceae	DG		FN		NA						I		R
Euclea undulata Thunb.	Ebenaceae					NA						I		
Eucomis autumnalis (Mill.) Chitt.	Hyacinthaceae	DG		FN						T		I	P	R
Eucomis pallidiflora Baker subsp. pallidiflora	Hyacinthaceae	DG											P	R
Eulophia ovalis Lindl. var. ovalis	Orchidaceae			FN										R
*Euonymus fortunei (Turcz.) Hand.–Mazz.**	Celastraceae	DG											P	R
*Euonymus japonicus Thunb.**	Celastraceae	DG		FN						T	G	I	P	R
Euphorbia clavarioides Boiss. var. clavarioides	Euphorbiaceae	DG												R
Euphorbia enopla Boiss. var. enopla	Euphorbiaceae	DG												R
Euphorbia grandialata R.A.Dyer	Euphorbiaceae	DG												R
*Euphorbia helioscopia L.**	Euphorbiaceae					NA	RV					I	P	
Euphorbia heptagona L.	Euphorbiaceae	DG												R
*Euphorbia heterophylla L.**	Euphorbiaceae	DG		FN			RV	S			G			R
*Euphorbia hirta L.**	Euphorbiaceae	DG			IG		RV	S				I	P	R
Euphorbia inaequilatera Sond. var. inaequilatera	Euphorbiaceae	DG	FF	FN	IG	NA	RV	S	W	T	G	I	P	R
*Euphorbia indica Lam.**	Euphorbiaceae	DG												R
Euphorbia ingens E.Mey. ex Boiss.	Euphorbiaceae	DG												R
*Euphorbia lugardiae (N.E.Br.) Bruyns**	Euphorbiaceae	DG												R
*Euphorbia milii Des Moul.**	Euphorbiaceae	DG								T				R
*Euphorbia peplus L.**	Euphorbiaceae	DG										I	P	R
*Euphorbia prostrata Aiton**	Euphorbiaceae	DG	FF	FN	IG	NA		S	W	T	G	I	P	R
*Euphorbia pulcherrima Willd. ex Klotzsch**	Euphorbiaceae	DG											P	R
Euphorbia schinzii Pax	Euphorbiaceae	DG												R

*Euphorbia serpens Kunth**	Euphorbiaceae	DG	FF			NA			W	T				R
Euphorbia tirucalli L.	Euphorbiaceae	DG									G			R
*Euphorbia trigona Mill.**	Euphorbiaceae	DG												R
Euryops chrysanthemoides (DC.) B.Nord.	Asteraceae	DG								T	G	I	P	R
Euryops laxus (Harv.) Burtt Davy	Asteraceae	DG				NA								R
Euryops pectinatus (L.) Cass. subsp. pectinatus	Asteraceae	DG												R
Euryops tenuissimus (L.) DC. subsp. tenuissimus	Asteraceae	DG												R
Eustachys paspaloides (Vahl) Lanza & Mattei	Poaceae	DG				NA	RV					I	P	
*Evolvulus glomeratus Nees & Mast.**	Convolvulaceae	DG											P	
Faidherbia albida (Delile) A.Chev.	Fabaceae	DG											P	
Falkia oblonga Bernh. ex C.Krauss	Convolvulaceae	DG			IG	NA	RV	S				I	P	R
*Fallopia convolvulus (L.) Holub **	Polygonaceae	DG										I		
Farfugium japonicum (L.) Kitam	Asteraceae	DG												R
Faucaria tigrina (Haw.) Schwantes	Mesembryanthemaceae	DG												R
Felicia amelloides (L.) Voss	Asteraceae	DG										I	P	R
Felicia fascicularis DC.	Asteraceae	DG				NA					G			R
Felicia filifolia (Vent.) Burtt Davy subsp . filifolia	Asteraceae	DG												R
Felicia fruticosa (L.) G.Nicholson subsp. fruticosa	Asteraceae	DG												R
Felicia mossamedensis (Hiern) Mendonca	Asteraceae	DG	FF	FN		NA	RV	S			G			R
Felicia muricata (Thunb.) Nees subsp. cinerascens Grau	Asteraceae	DG									G	I		
Felicia muricata (Thunb.) Nees subsp. muricata	Asteraceae	DG	FF	FN	IG	NA	RV	S	W	T	G	I	P	R
*Ferocactus hamatacanthus (Muehlenpf.) Britton & Rose**	Cactaceae	DG											P	
*Ferocactus histrix (DC.) G.E.Linds.**	Cactaceae	DG												R
*Ferocactus latispinus (Haw.) Britton & Rose**	Cactaceae	DG												R
*Festuca glauca Lam.**	Poaceae	DG												R
*Festuca rubra L.**	Poaceae	DG											P	R

*Ficus benjamina L.**	Moraceae	DG											P	R
*Ficus carica L.**	Moraceae	DG		FN	IG					T	G	I	P	R
*Ficus elastica Roxb. ex Hornem.**	Moraceae	DG										I	P	R
Ficus ingens (Miq.) Miq. var. ingens	Moraceae	DG												R
*Ficus lyrata Warb.**	Moraceae	DG											P	R
*Ficus maclellandi King**	Moraceae	DG												R
*Ficus pumila L.**	Moraceae	DG											P	R
Ficus salicifolia Vahl	Moraceae					NA								R
*Flaveria bidentis (L.) Kuntze**	Asteraceae					NA							P	
*Foeniculum vulgare Mill. var. vulgare**	Apiaceae	DG									G		P	R
*Fortunella japonica (Thunb.) Swingle**	Rutaceae	DG											P	
*Fortunella margarita (Lour.) Swingle**	Rutaceae	DG											P	
*Fragaria ananassa Duchesne ex Rozier**	Rosaceae	DG									G	I	P	R
*Fraxinus angustifolia Vahl**	Oleaceae	DG								T	G		P	R
*Fraxinus pennsylvanica Marshall**	Oleaceae	DG								T	G	I	P	R
*Fraxinus velutina Torr. var. velutina**	Oleaceae	DG									G	I		
Freesia laxa (Thunb.) Goldblatt & J.C.Manning subsp. laxa	Iridaceae	DG												R
Freesia x hybrida	Iridaceae	DG										I	P	R
Freylinia lanceolata (L.f.) G.Don	Scrophulariaceae	DG												R
Freylinia tropica S.Moore	Scrophulariaceae	DG											P	R
*Fuchsia hybrida Hort. ex Siebold & Voss**	Onagraceae	DG											P	R
*Fuchsia magellanica Lam.**	Onagraceae	DG												R
*Fuchsia triphylla L.**	Onagraceae	DG												R
*Fumaria muralis Sond. ex. W.D.J.Koch subsp. muralis**	Fumariaceae	DG										I	P	
*Furcraea foetida (L.) Haw.**	Agavaceae	DG												R
*Gaillardia aristata Pursh**	Asteraceae	DG								T	G	I		

*Galinsoga parviflora Cav.**	Asteraceae	DG		FN			RV	S				I	P	R
Galium spurium L. subsp. africanum Verdc.	Rubiaceae					NA						I		
*Gamochaeta pennsylvanica (Willd.) Cabrera**	Asteraceae	DG												R
*Gardenia augusta (L.) Merr.**	Rubiaceae	DG											P	R
Gardenia cornuta Hemsl.	Rubiaceae	DG												R
Gasteria batesiana G.D.Rowley	Asphodelaceae	DG												R
Gasteria bicolor Haw. var. bicolor	Asphodelaceae	DG										I	P	R
Gasteria excelsa Baker	Asphodelaceae	DG												R
Gazania krebsiana Less.	Asteraceae	DG								T	G		P	R
Gazania krebsiana Less. subsp. arctotoides (Less.) Roessler	Asteraceae	DG									G		P	
Gazania krebsiana Less. subsp. serrulata (DC.) Roessler	Asteraceae	DG	FF	FN	IG	NA	RV	S	W	T	G	I	P	R
Gazania rigens (L.) Gaertn.	Asteraceae	DG												R
Gazania x hybrida	Asteraceae	DG								T	G	I	P	R
Geigeria burkei Harv. subsp. burkei	Asteraceae	DG	FF	FN		NA			W	T	G	I		
Geigeria ornativa O.Hoffm.	Asteraceae					NA					G			
Geissorhiza aspera Goldblatt	Iridaceae	DG												R
Geranium incanum Burm.f.	Geraniaceae	DG											P	
*Geranium macrorrhizum L.**	Geraniaceae	DG											P	
*Geranium sanguineum L.**	Geraniaceae	DG									G			
Gerbera jamesonii Bolus ex Adlam	Asteraceae	DG								T	G	I	P	R
Gerbera piloselloides (L.) Cass.	Asteraceae			FN		NA								R
*Ginkgo biloba L.**	Ginkgoaceae	DG											P	
Gisekia africana (Lour.) Kuntze var. africana	Gisekiaceae					NA					G	I		
Gisekia pharnacioides L. var. pharnacioides	Gisekiaceae	DG	FF	FN		NA	RV			T	G	I		R
Gladiolus crassifolius Baker	Iridaceae			FN		NA						I		R
Gladiolus dalenii Van Geel subsp. dalenii	Iridaceae	DG								T	G		P	R

Gladiolus elliotii Baker	Iridaceae					NA						I		
Gladiolus permeabilis D.Delaroche subsp. edulis (Burch. ex Ker Gawl.) Oberm.	Iridaceae			FN		NA								R
*Gleditsia triacanthos L.**	Fabaceae	DG				NA	RV			T	G		P	R
Gloriosa superba L.	Colchicaceae	DG												R
Glottiphyllum regium N.E.Br.	Mesembryanthemaceae	DG												R
Gnaphalium confine Harv.	Asteraceae	DG												R
Gnaphalium nelsonii Burtt Davy	Asteraceae	DG	FF	FN	IG	NA					G	I	P	R
Gnidia burchellii (Meisn.) Gilg	Thymelaeaceae			FN		NA								R
Gnidia capitata L.f.	Thymelaeaceae			FN		NA						I	P	R
Gnidia kraussiana Meisn. var. kraussiana	Thymelaeaceae					NA								R
Gnidia polycephala (C.A.Mey.) Gilg	Thymelaeaceae	DG	FF	FN		NA			W	T	G			
Gnidia sericocephala (Meisn.) Gilg ex Engl.	Thymelaeaceae					NA						I		
Gomphocarpus fruticosus (L.) Aiton f.	Apocynaceae	DG	FF	FN		NA	RV		W	T			P	R
Gomphocarpus physocarpus E.Mey.	Apocynaceae	DG				NA				T	G			
Gomphostigma virgatum (L.f.) Baill.	Buddlejaceae	DG											P	
*Gomphrena celosioides Mart.**	Amaranthaceae	DG	FF	FN	IG	NA	RV	S	W	T	G	I	P	R
Graderia subintegra Mast.	Orobanchaceae			FN		NA								R
Graptopetalum paraguayense (N.E.Br.) E.Walther	Crassulaceae	DG												R
*Grevillea banksii R.Br.**	Proteaceae	DG												R
*Grevillea glabrata (Lindl.) Meisn.**	Proteaceae	DG												R
*Grevillea lanigera A.Cunn. ex R. Br.**	Proteaceae	DG												R
*Grevillea lavandulacea Schltdl.**	Proteaceae	DG												R
*Grevillea robusta Cunn. ex R.Br.**	Proteaceae	DG								T	G		P	R
*Grevillea rosmarinifolia A.Cunn.**	Proteaceae	DG			IG						G	I	P	R
Grewia bicolor Juss.	Tiliaceae								W		G			

Grewia flava DC.	Tiliaceae	DG	FF	FN		NA			W	T	G	I		
Grewia occidentalis L. var. occidentalis	Tiliaceae	DG				NA			W	T	G	I		R
Greyia sutherlandii Hook. & Harv.	Greyiaceae	DG												R
*Guilleminea densa (Willd. ex Roem. & Schult.) Moq.**	Amaranthaceae	DG	FF	FN	IG	NA	RV	S	W	T	G	I	P	R
*Gunnera manicata Linden ex André**	Gunneraceae	DG										I	P	R
*Gymnocalycium monvillei (Lemaire) Britton & Rose**	Cactaceae	DG												R
Gymnosporia bachmannii Loes.	Celastraceae	DG												R
Gymnosporia buxifolia (L.) Szyszyl.	Celastraceae					NA				T		I		R
Gymnosporia glaucophylla Jordaan	Celastraceae					NA						I		
Gymnosporia polyacantha (Sond.) Szyszyl. subsp. vaccinifolia (P.Conrath) Jordaan	Celastraceae					NA						I		
*Gypsophila elegans M.Bieb**	Caryophyllaceae	DG											P	
Haemanthus albiflos Jacq.	Amaryllidaceae	DG											P	R
*Hakea salicifolia (Vent.) B.L.Burtt**	Proteaceae	DG												R
Halleria lucida L. var. crispa Drège	Scrophulariaceae	DG												R
Haplocarpha lyrata Harv.	Asteraceae				IG	NA						I	P	
Haplocarpha scaposa Harv.	Asteraceae						RV							R
Harpagophytum procumbens (Burch.) DC. ex Meisn. subsp. procumbens	Pedaliaceae	DG	FF	FN		NA	RV			T	G			
Harpephyllum caffrum Bernh.	Anacardiaceae	DG												R
Harpochloa falx (L.f.) Kuntze	Poaceae			FN										R
*Hatiora gaertneri (Regel) Barthlott**	Cactaceae	DG												R
*Hatiora rosea (Lagerheim) Barthlott**	Cactaceae	DG												R
Haworthia attenuata (Haw.) Haw. var. attenuata	Asphodelaceae	DG									G			R
Haworthia cymbiformis (Haw.) Duval	Asphodelaceae	DG											P	R
Haworthia fasciata (Willd.) Haw.	Asphodelaceae	DG										I	P	R

Haworthia reinwardtii (Salm–Dyck) Haw.	Asphodelaceae	DG										P	
*Hebe andersonii Cockayne**	Scrophulariaceae	DG										P	R
*Hebe pimeleoides (Hook.f.) Cockayne & Allan**	Scrophulariaceae	DG										P	
*Hebe salicifolia (G.Forst.) Pennell**	Scrophulariaceae	DG									I	P	R
*Hebe speciosa (R.Cunn ex A.Cunn) J.C.Andersen**	Scrophulariaceae	DG										P	R
*Hedera canariensis Willd.**	Araliaceae	DG										P	R
*Hedera helix L.**	Araliaceae	DG								G	I	P	R
*Hedychium gardnerianum Ker Gawl.**	Zingiberaceae	DG											R
*Helianthus annuus L.**	Asteraceae	DG							T			P	R
Helichrysum acutatum DC.	Asteraceae			FN	NA	RV						P	R
Helichrysum arenicola M.D.Hend.	Asteraceae				NA					G			
Helichrysum argyrosphaerum DC.	Asteraceae	DG	FF	FN	NA			W	T				R
Helichrysum caespititium (DC.) Harv.	Asteraceae		FF	FN	NA	RV	S		T	G			R
Helichrysum callicomum Harv.	Asteraceae				NA		S						R
Helichrysum candolleanum H.Buek	Asteraceae			FN	NA								R
Helichrysum cephaloideum DC.	Asteraceae				NA								R
Helichrysum cerastioides DC. var. cerastioides	Asteraceae	DG	FF	FN	NA				T	G			
Helichrysum lineare DC.	Asteraceae			FN						G			
Helichrysum nudifolium (L.) Less. var. nudifolium	Asteraceae			FN	NA	RV					I	P	R
Helichrysum pallidum DC.	Asteraceae				NA								R
Helichrysum rotundatum Harv.	Asteraceae			FN	NA	RV							R
Helichrysum rugulosum Less.	Asteraceae		FF	FN	NA	RV	S				I	P	R
*Heliopsis helianthoides (L.) Sweet**	Asteraceae	DG										P	
*Heliotropium amplexicaule Vahl**	Asteraceae			FN	NA								R
*Heliotropium curassavicum L.**	Asteraceae					RV						P	
*Heliotropium europaeum L.**	Asteraceae			FN			S						R

Heliotropium lineare (A.DC.) Gurke	Boraginaceae	DG	FF	FN		NA	RV		W	T	G			
Hemarthria altissima (Poir.) Stapf & C.E.Hubb.	Poaceae			FN	IG	NA	RV						P	
*Hemerocallis aurantiaca Baker**	Hemerocallidaceae	DG											P	R
*Hemerocallis fulva (L.) L.**	Hemerocallidaceae	DG								T			P	R
*Hemerocallis lilioasphodelus L.**	Hemerocallidaceae	DG								T			P	R
Hemizygia pretoriae (Gürke) M.Ashby	Lamiaceae	DG		FN		NA	RV					I	P	R
Hermannia coccocarpa (Eckl. & Zeyh.) Kuntze	Sterculiaceae					NA							P	
Hermannia depressa N.E.Br.	Sterculiaceae		FF	FN		NA	RV	S	W		G	I	P	R
Hermannia floribunda Harv.	Sterculiaceae					NA						I		
Hermannia grandistipula (Buchinger ex Hochst.) K.Schum.	Sterculiaceae					NA						I		
Hermannia lancifolia Szyszyl.	Sterculiaceae			FN		NA								R
Hermannia linnaeoides (Burch.) K.Schum.	Sterculiaceae								W	T				
Hermannia modesta (Ehrenb.) Mast.	Sterculiaceae		FF			NA				T				
Hermannia quartiniana A.Rich.	Sterculiaceae	DG		FN		NA				T	G			
Hermannia stellulata (Harv.) K.Schum.	Sterculiaceae	DG	FF	FN		NA				T	G			
Hermannia tomentosa (Turcz.) Schinz ex Engl.	Sterculiaceae	DG	FF	FN		NA	RV		W	T	G	I		R
Herniaria erckertii Herm.	Caryophyllaceae	DG	FF						W	T			P	
Heteromorpha arborescens (Spreng.) Cham. & Schltdl. var. abyssinica	Apiaceae	DG				NA								R
Heteromorpha arborescens (Spreng.) Cham. & Schltdl. var. arborescens	Apiaceae	DG												R
Heteropogon contortus (L.) Roem. & Schult.	Poaceae		FF	FN		NA	RV			T	G	I	P	R
Heteropyxis natalensis Harv.	Heteropyxidaceae	DG												R
Hibiscus microcarpus Garcke	Malvaceae					NA						I		R
Hibiscus pusillus Thunb.	Malvaceae	DG	FF	FN		NA	RV		W	T	G	I	P	R
*Hibiscus rosa–sinensis L.**	Malvaceae	DG								T			P	R

Hibiscus sidiformis Baill.	Malvaceae					NA						I		
*Hibiscus syriacus L.**	Malvaceae	DG										I	P	R
Hibiscus trionum L.	Malvaceae			FN		NA	RV	S	W	T	G		P	R
*Hippeastrum puniceum (Lam.) Kuntze**	Amaryllidaceae	DG										I	P	
*Hoffmannia ghiesbreghtii (Lem.) Hemsl.**	Rubiaceae	DG												R
Hoffmannseggia burchellii (DC.) Benth. ex Oliv.	Fabaceae					NA					G			
*Houttuynia cordata Thunb.**	Saururaceae	DG											P	R
*Hoya carnosa (L.f.) R.Br.**	Apocynaceae	DG											P	R
Huernia hystrix (Hook.f.) N.E.Br.	Apocynaceae	DG											P	R
*Hyacinthoides hispanica (Mill.) Rothm.**	Hyacinthaceae	DG												R
*Hydrangea macrophylla (Thunb.) Ser.**	Hydrangeaceae	DG											P	R
*Hydrangea quercifolia W. Bartram**	Hydrangeaceae	DG										I		R
*Hydrangea serrata (Thunb.) Ser.**	Hydrangeaceae	DG										I	P	
Hydrocotyle bonariensis Lam.	Apiaceae	DG												R
*Hymenocallis festalis Hort. ex Schmarse**	Amaryllidaceae	DG								T		I		
*Hymenocallis littoralis (Jacq.) Salisb.**	Amaryllidaceae	DG	FF							T	G	I	P	R
*Hymenocallis speciosa (L.f. ex Salisb.) Salisb.**	Amaryllidaceae	DG												R
*Hymenosporum flavum (Hook.) F. Muell.**	Pittosporaceae	DG												R
*Hyophorbe lagenicaulis (L.H. Bailey.) H.E. Moore.**	Arecaceae	DG												R
Hyparrhenia hirta (L.) Stapf	Poaceae	DG	FF	FN	IG	NA	RV	S				I	P	R
Hyparrhenia tamba (Steud.) Stapf	Poaceae			FN			RV	S						R
*Hypericum calycinum L.**	Hypericaceae	DG										I		R
*Hypericum patulum Thunb.**	Hypericaceae	DG												R
Hypericum revolutum Vahl subsp. revolutum	Hypericaceae	DG											P	R
*Hypericum x moserianum Luquet ex André**	Hypericaceae	DG												R
Hypertelis arenicola Sond.	Molluginaceae	DG							W	T	G			

Hypertelis salsoloides (Burch.) Adamson var. salsoloides	Molluginaceae	DG									G			
Hyperthelia dissoluta (Nees ex Steud.) Clayton	Poaceae					NA								R
*Hypochaeris radicata L.**	Asteraceae	DG	FF	FN	IG		RV	S				I	P	R
Hypoestes aristata (Vahl) Sol. ex Roem. & Schult.	Acanthaceae	DG											P	R
*Hypoestes phyllostachya Baker**	Acanthaceae	DG												R
Hypoxis argentea Harv. ex Baker	Hypoxidaceae					NA			W	T		I		
Hypoxis hemerocallidea Fisch., C.A.Mey. & Ave–Lall.	Hypoxidaceae	DG				NA	RV			T	G	I	P	R
Hypoxis iridifolia Baker	Hypoxidaceae			FN		NA								R
Hypoxis rigidula Baker	Hypoxidaceae			FN		NA						I		R
*Iberis sempervirens L.**	Brassicaceae	DG											P	R
*Iberis umbellata L.**	Brassicaceae	DG										I	P	
*Ilex aquifolium L.**	Aquifoliaceae	DG											P	R
*Ilex cornuta Lindl. & Paxton**	Aquifoliaceae	DG												R
*Ilex crenata Thunb.**	Aquifoliaceae	DG											P	R
Ilex mitis (L.) Radlk. var. mitis	Aquifoliaceae	DG												R
*Ilex wilsonii Loes.**	Aquifoliaceae	DG											P	R
*Impatiens balsamina L.**	Balsaminaceae	DG											P	R
*Impatiens hawkeri W. Bull**	Balsaminaceae	DG											P	
*Impatiens niamniamensis Gilg.**	Balsaminaceae	DG												R
*Impatiens sodenii Engl. & Warb.**	Balsaminaceae	DG												R
*Impatiens walleriana Hook.f.**	Balsaminaceae	DG										I	P	R
Imperata cylindrica (L.) Raeusch.	Poaceae			FN		NA	RV						P	R
Indigastrum argyraeum (Eckl. & Zeyh.) Schrire	Fabaceae	DG		FN	IG	NA					G			
Indigastrum burkeanum (Benth. ex Harv.) Schrire	Fabaceae					NA	RV	S				I	P	
Indigastrum costatum (Guill. & Perr.) Schrire subsp. macrum (E.Mey.) Schrire	Fabaceae					NA						I		

Indigofera adenoides Baker f.	Fabaceae					NA								R
*Indigofera australis Willd.**	Fabaceae	DG												R
Indigofera comosa N.E.Br.	Fabaceae			FN		NA								R
Indigofera cryptantha Benth. ex Harv. var. cryptantha	Fabaceae	DG	FF	FN		NA			W	T	G	I	P	R
Indigofera daleoides Benth. ex Harv. var. daleoides	Fabaceae	DG	FF	FN		NA	RV			T	G	I	P	R
Indigofera filipes Benth. ex Harv.	Fabaceae	DG	FF	FN		NA				T	G		P	R
Indigofera hedyantha Eckl. & Zeyh.	Fabaceae			FN		NA								R
Indigofera heterotricha DC.	Fabaceae	DG	FF	FN		NA				T	G	I	P	
Indigofera hilaris Eckl. & Zeyh. var. hilaris	Fabaceae			FN		NA						I	P	R
Indigofera melanadenia Benth. ex Harv.	Fabaceae					NA								R
Indigofera oxytropis Benth. ex Harv.	Fabaceae					NA								R
Indigofera pechuelii Kuntze	Fabaceae	DG										I		
Indigofera rhytidocarpa Benth. ex Harv. subsp. rhytidocarpa	Fabaceae	DG		FN		NA			W	T	G			
Indigofera trita L.f. subsp. subulata (Vahl ex Poir.) Ali	Fabaceae					NA								R
Indigofera zeyheri Spreng. ex Eckl. & Zeyh.	Fabaceae					NA		S				I		
*Ipomoea alba L.**	Convolvulaceae	DG												R
Ipomoea albivenia (Lindl.) Sweet	Convolvulaceae	DG								T				
*Ipomoea batatas (L.) Lam.**	Convolvulaceae	DG								T	G	I	P	R
Ipomoea bathycolpos Hallier f.	Convolvulaceae					NA								R
*Ipomoea carnea Jacq. subsp. fistulosa (Mart. ex Choisy) D.F.Austin**	Convolvulaceae	DG									G			
Ipomoea crassipes Hook.	Convolvulaceae	DG				NA						I		R
*Ipomoea hederifolia L.**	Convolvulaceae	DG												R
Ipomoea hochstetteri House	Convolvulaceae	DG	FF							T				
Ipomoea holubii Baker	Convolvulaceae					NA								R
*Ipomoea indica (Burm.f.) Merr.**	Convolvulaceae	DG												R

Ipomoea oblongata E.Mey. ex. Choisy	Convolvulaceae	DG		FN	NA	RV					I		R
Ipomoea obscura (L.) Ker Gawl. var. obscura	Convolvulaceae			FN	NA	RV					I	P	
Ipomoea ommaneyi Rendle	Convolvulaceae		FF		NA				T	G	I	P	
*Ipomoea purpurea (L.) Roth**	Convolvulaceae	DG			NA	RV	S		T	G	I	P	R
*Iresine herbstii Hook.f.**	Amaranthaceae	DG								G		P	R
*Iris cycloglossa Wendelbo**	Iridaceae	DG											R
*Iris ensata Thunb.**	Iridaceae	DG										P	
*Iris germanica L.**	Iridaceae	DG							T	G	I	P	R
*Iris japonica Thunb.**	Iridaceae	DG											R
*Iris pallida Lam.**	Iridaceae	DG											R
*Iris pseudacorus L.**	Iridaceae	DG										P	R
*Iris pumila L.**	Iridaceae	DG											R
*Iris xiphium L.**	Iridaceae	DG									I	P	R
*Jacaranda mimosifolia D.Don.**	Bignoniaceae	DG			NA	RV			T				R
Jamesbrittenia atropurpurea (Benth.) Hilliard subsp. Atropurpurea	Scrophulariaceae			FN	NA				T	G	I		R
Jamesbrittenia aurantiaca (Burch.) Hilliard	Scrophulariaceae			FN	NA			W	T	G	I	P	
Jamesbrittenia grandiflora (Galpin) Hilliard	Scrophulariaceae	DG											R
*Jasminum humile L.**	Oleaceae	DG							T		I	P	R
Jasminum multipartitum Hochst.	Oleaceae	DG										P	
*Jasminum nudiflorum Lindl.**	Oleaceae	DG										P	R
*Jasminum officinale L.**	Oleaceae	DG										P	R
*Jasminum polyanthum Franch.**	Oleaceae	DG							T			P	R
*Jasminum sambac (L.) Aiton**	Oleaceae	DG											R
*Jatropha multifida L.**	Euphorbiaceae	DG	FF						T			P	
*Jatropha podagrica Hook.**	Euphorbiaceae	DG											R
Juncus effusus L.	Juncaceae	DG										P	R

Juncus exsertus Buchenau subsp. exsertus	Juncaceae	DG								R
*Juniperus scopulorum Sarg.**	Cupressaceae	DG							P	R
*Juniperus squamata Buch.–Ham. ex D.Don**	Cupressaceae	DG								R
*Juniperus virginiana L.**	Cupressaceae	DG			RV	T		I	P	R
*Juniperus x media Melle**	Cupressaceae	DG							P	R
*Justicia brandegeeana Wassh. & L.B.Sm.**	Acanthaceae	DG							P	R
*Kalanchoe beharensis Drake**	Crassulaceae	DG								R
*Kalanchoe blossfeldiana Poelln.**	Crassulaceae	DG				T	G	I	P	R
Kalanchoe crenata (Andrews) Haw.	Crassulaceae	DG							P	
*Kalanchoe daigremotiana Raym.–Hamet & H.Perrier**	Crassulaceae	DG								R
*Kalanchoe fedtschenkoi Raym.–Hamet & H.Perrier**	Crassulaceae	DG							P	R
Kalanchoe longiflora Schltr. ex J.M.Wood	Crassulaceae	DG				T				R
Kalanchoe paniculata Harv.	Crassulaceae		FN	NA						R
*Kalanchoe pinnata (Lam.) Pers.**	Crassulaceae	DG				T	G			R
Kalanchoe rotundifolia (Haw.) Haw.	Crassulaceae	DG	FN	NA			G			R
Kalanchoe sexangularis N.E.Br. var. sexangularis	Crassulaceae	DG								R
Kalanchoe thyrsiflora Harv.	Crassulaceae	DG		NA		T	G	I	P	R
*Kalanchoe tomentosa Baker.**	Crassulaceae	DG								R
*Kalanchoe uniflora (Stapf.) Raym. –Hamet.**	Crassulaceae	DG								R
*Kalanchoe waldheimii Raym.–Hamet & H.Perrier**	Crassulaceae	DG				T				R
Karomia speciosa (Hutch. & Corbishley) R.Fern. f. speciosa	Lamiaceae	DG							P	
Kigelia africana (Lam.) Benth.	Bignoniaceae	DG								R
Kiggelaria africana L.	Achariaceae	DG								R
Kleinia fulgens Hook.f.	Asteraceae	DG								R
Kleinia longiflora DC.	Asteraceae	DG				T	G			
Kniphofia ensifolia Baker subsp. ensifolia	Asphodelaceae	DG								R

Kniphofia praecox Baker	Asphodelaceae	DG										P	R
*Kochia scoparia (L.) Schrad.**	Amaranthaceae	DG							T				
*Koelreuteria paniculata Laxm.**	Sapindaceae	DG											R
Kohautia amatymbica Eckl. & Zeyh.	Rubiaceae	DG			NA	RV						P	R
Kohautia caespitosa Schnizl. subsp. brachyloba (Sond.) D.Mantell	Rubiaceae			FN	NA	RV							R
Kohautia subverticillata (K.Schum.) D.Mantell subsp. Subverticillata	Rubiaceae		FF		NA			W	T				
Kohautia virgata (Willd.) Bremek.	Rubiaceae				NA								R
Kyllinga alba Nees subsp. alba	Cyperaceae		FF		NA				T		I		
Kyphocarpa angustifolia (Moq.) Lopr.	Amaranthaceae			FN	NA				T	G	I		
*Lactuca indica L.**	Asteraceae	DG											R
Lactuca inermis Forssk.	Asteraceae	DG	FF	FN	NA	RV	S	W	T		I	P	R
*Lactuca sativa L.**	Asteraceae	DG							T		I	P	R
*Lactuca serriola L.**	Asteraceae	DG		FN		RV	S				I	P	R
*Lagerstroemia indica L.**	Lythraceae	DG							T		I	P	R
*Lagunaria patersonia (Andrews) G.Don**	Malvaceae	DG											R
*Lamium galeobdolon (L.) Crantz**	Lamiaceae	DG									I	P	R
Lampranthus aureus (L.) N.E.Br.	Mesembryanthemaceae	DG								G	I	P	R
Lampranthus blandus (Haw.) Schwantes	Mesembryanthemaceae	DG									I	P	
Lampranthus coccineus (Haw.) N.E.Br.	Mesembryanthemaceae	DG											R
Lampranthus glaucoides (Haw.) N.E.Br.	Mesembryanthemaceae	DG										P	
Lampranthus glaucus (L.) N.E.Br.	Mesembryanthemaceae	DG							T	G		P	
Lampranthus roseus (Willd.) Schwantes	Mesembryanthemaceae	DG							T	G	I	P	R
*Lantana camara L.**	Verbenaceae	DG		FN	NA			W	T	G		P	R
*Lantana montevidensis (Spreng.) Briq.**	Verbenaceae	DG										P	R

Lantana rugosa Thunb.	Verbenaceae	DG				NA			W	T	G	I		R
*Lathyrus latifolius L.**	Fabaceae	DG									G		P	
*Lathyrus odoratus L.**	Fabaceae	DG										I		
*Laurus nobilis L.**	Lauraceae	DG											P	R
*Lavandula angustifolia Mill. var. angustifolia**	Lamiaceae	DG										I	P	R
*Lavandula dentata L.**	Lamiaceae	DG												R
*Lavandula latifolia Medik.**	Lamiaceae	DG											P	
*Lavandula stoechas L.**	Lamiaceae	DG											P	R
Ledebouria cooperi (Hook.f.) Jessop	Hyacinthaceae			FN										R
Ledebouria inquinata (C.A.Sm.) Jessop	Hyacinthaceae	DG				NA			W	T	G			
Ledebouria macowanii (Baker) S.Venter	Hyacinthaceae					NA				T				
Ledebouria ovatifolia (Baker) Jessop	Hyacinthaceae	DG		FN		NA						I		R
Ledebouria petiolata J.C.Manning & Goldblatt	Hyacinthaceae	DG								T	G	I	P	R
Ledebouria revoluta (L.f.) Jessop	Hyacinthaceae			FN	IG	NA	RV	S				I	P	R
Ledebouria socialis (Baker) Jessop	Hyacinthaceae	DG										I	P	
Leonotis leonurus (L.) R.Br	Lamiaceae	DG				NA								R
Leonotis ocymifolia (Burm.f.) Iwarsson	Lamiaceae	DG												R
Lepidium africanum (Burm.f.) DC.	Brassicaceae	DG					RV	S		T		I	P	
*Lepidium bonariense L.**	Brassicaceae	DG	FF	FN	IG	NA	RV	S		T	G	I	P	R
*Leptospermum laevigatum (Gaertn.) F.Muell.**	Myrtaceae	DG												R
*Leptospermum scoparium J.R.Forst & G. Forst.**	Myrtaceae	DG										I	P	R
Lessertia pauciflora Harv. var. pauciflora	Fabaceae					NA					G			
*Leucaena leucocephala (Lam.) de Wit**	Fabaceae	DG								T				
Leucas capensis (Benth.) Engl.	Lamiaceae	DG	FF	FN		NA			W	T	G	I		
Leucas martinicensis (Jacq.) R.Br.	Lamiaceae					NA								R
*Leucojum aestivum L.**	Amaryllidaceae	DG												R

Leucosidea sericea Eckl. & Zeyh.	Rosaceae	DG				RV						R
Leucospermum cordifolium (Salisb. ex Knight) Fourc.	Proteaceae	DG										R
*Ligularia dentata (A.Grey) Hara**	Asteraceae	DG								I	P	
*Ligustrum ibota Siebold ex Siebold & Zucc.**	Oleaceae	DG							G	I	P	R
*Ligustrum japonicum Thunb. f. rotundifolium (Blume) S.Noshiro**	Oleaceae	DG										R
*Ligustrum japonicum Thunb.**	Oleaceae	DG				RV					P	R
*Ligustrum lucidum W.T.Aiton**	Oleaceae	DG						T	G	I	P	R
*Ligustrum ovalifolium Hassk.**	Oleaceae	DG										R
*Lilium lancifolium Thunb.**	Liliaceae	DG									P	
Limeum fenestratum (Fenzl) Heimerl var. fenestratum	Limeaceae		FF		NA				G			
Limeum sulcatum (Klotzsch) Hutch. var. sulcatum	Limeaceae	DG						T				
Limeum viscosum (J.Gay) Fenzl subsp. viscosum	Limeaceae	DG		FN	NA		W	T	G			R
Limeum viscosum (J.Gay) Fenzl subsp. viscosum var. glomeratum (Eckl. & Zeyh.) Friedrich	Limeaceae	DG							G			
*Limonium minutum (L.) Chaz.**	Plumbaginaceae	DG										R
*Limonium perezii (Stapf) F.T.Hubbard**	Plumbaginaceae	DG										R
*Linaria maroccana Hook.f.**	Scrophulariaceae	DG								I	P	
*Linaria vulgaris Mill.**	Scrophulariaceae					RV						R
Lippia javanica (Burm.f.) Spreng.	Verbenaceae			FN	NA							R
Lippia scaberrima Sond.	Verbenaceae	DG		FN	NA			T	G	I	P	
*Liquidambar styraciflua L.**	Hamamelidaceae	DG									P	R
*Liriodendron tulipifera L.**	Magnoliaceae	DG										R
*Liriope muscari (Decne.) L.H.Bailey**	Convallariaceae	DG									P	R
Lithops hallii de Boer	Mesembryanthemaceae	DG										R
Lithops marmorata (N.E.Br.) N.E.Br.	Mesembryanthemaceae	DG										R
Lithospermum cinereum A.DC.	Boraginaceae				NA				G			

Litogyne gariepina (DC.) Anderb.	Asteraceae								W	T	G			
*Litsea glutinosa (Lour.) C.B.Rob.**	Lauraceae	DG											P	
*Livistona australis (R.Br.) Mart.**	Arecaceae	DG											P	R
Lobelia erinus L.	Lobeliaceae	DG											P	R
*Lobelia laxiflora Kunth**	Lobeliaceae	DG												R
Lobelia thermalis Thunb.	Lobeliaceae				IG	NA		S					P	
*Lobularia maritima (L.) Desv.**	Brassicaceae	DG			IG						G	I	P	R
*Lolium perenne L.**	Poaceae	DG					RV					I	P	R
*Lonicera caprifolium L.**	Caprifoliaceae	DG												R
*Lonicera sempervirens L.**	Caprifoliaceae	DG											P	R
Lophiocarpus polystachyus Turcz.	Penaeaceae					NA						I		
*Lophocereus schottii (Engelm.) Britton & Rose.**	Cactaceae	DG											P	
Lopholaena coriifolia (Sond.) E.Phillips & C.A.Sm.	Asteraceae	DG		FN		NA								R
*Loropetalum chinense (R.Br.) Oliv.**	Hamamelidaceae	DG												R
Lotononis calycina (E.Mey.) Benth.	Fabaceae	DG	FF	FN		NA				T	G			R
Lotononis foliosa Bolus	Fabaceae					NA						I		
Lotononis listii Polhill	Fabaceae	DG		FN		NA	RV	S	W	T	G	I	P	R
Lotononis lotononoides (Scott–Elliot) B.–E.van Wyk	Fabaceae	DG												R
*Lotus subbiflorus Lag. subsp. subbiflorus**	Fabaceae			FN							G			
Loudetia simplex (Nees) C.E.Hubb.	Poaceae			FN		NA						I		R
Lycium cinereum Thunb.	Solanaceae	DG				NA			W	T	G			
Lycium horridum Thunb.	Solanaceae	DG		FN		NA					G			
*Lycopersicon esculentum Mill. var. cerasiforme Hort.**	Solanaceae	DG								T	G	I	P	R
*Lycopersicon esculentum Mill. var. esculentum**	Solanaceae	DG								T	G	I	P	R
*Lysimachia nummularia L.**	Primulaceae	DG											P	R
Mackaya bella Harv.	Acanthaceae	DG												R

Macledium zeyheri (Sond.) S.Ortíz subsp. Zeyheri	Asteraceae			FN		NA						I	P	R
*Magnolia grandiflora L.**	Magnoliaceae	DG											P	R
*Magnolia x soulangeana Soul.–Bod.**	Magnoliaceae	DG											P	R
*Mahonia aquifolium (Pursh) Nutt.**	Berberidaceae	DG											P	
*Mahonia lomariifolia Takeda**	Berberidaceae	DG											P	R
Malephora crocea (Jacq.) Schwantes	Mesembryanthemaceae	DG								T				R
*Malus spectabilis (Aiton) Borkh.**	Rosaceae	DG											P	
*Malus sylvestris (L.) Mill.**	Rosaceae	DG								T	G		P	R
*Malus x domestica Borkh.**	Rosaceae	DG								T		I	P	R
*Malva neglecta Wallr.**	Malvaceae	DG											P	R
*Malva parviflora L. var. parviflora**	Malvaceae	DG					RV	S			G	I	P	R
*Malva sylvestris L.**	Malvaceae	DG								T				R
*Malva verticillata L. var. verticillata**	Malvaceae	DG									G	I		
*Malvastrum coromandelianum (L.) Garcke**	Malvaceae	DG		FN			RV	S				I	P	R
*Malvaviscus arboreus Cav.**	Malvaceae	DG												R
*Mammillaria bocasana Poselg.**	Cactaceae	DG												R
*Mammillaria bombycina Quehl**	Cactaceae	DG											P	
*Mammillaria boolii G.E.Linds.**	Cactaceae	DG												R
*Mammillaria camptotricha Dams**	Cactaceae	DG												R
*Mammillaria elegans DC.**	Cactaceae	DG								T		I	P	R
*Mammillaria elongata DC.**	Cactaceae	DG											P	R
*Mammillaria gracilis Pfeiff.**	Cactaceae	DG												R
*Mammillaria magnimamma Haw.**	Cactaceae	DG												R
*Mammillaria melanocentra Poselg.**	Cactaceae	DG												R
*Mammillaria polythele Mart.**	Cactaceae	DG												R
*Mammillaria spinosissima Lem.**	Cactaceae	DG								T	G	I	P	R

*Manihot esculenta Crantz**	Euphorbiaceae	DG										I	P	R
Manulea parviflora Benth. var. parviflora	Scrophulariaceae					NA								R
*Maranta leuconeura E.Morren**	Marantaceae	DG											P	
Marsilea capensis A.Braun	Marsileaceae						RV						P	
*Medicago laciniata (L.) Mill.**	Fabaceae	DG	FF	FN	IG	NA	RV	S	W	T		I	P	R
*Medicago lupulina L.**	Fabaceae						RV						P	
*Medicago polymorpha L.**	Fabaceae						RV							R
*Medicago sativa L.**	Fabaceae	DG	FF	FN	IG		RV	S		T			P	R
*Melaleuca armillaris (Sol. ex Gaertn.) Sm.**	Myrtaceae	DG											P	R
*Melaleuca bracteata F.Muell.**	Myrtaceae	DG												R
*Melaleuca huegelii Endl.**	Myrtaceae	DG												R
*Melaleuca linariifolia Sm.**	Myrtaceae	DG									G		P	R
*Melaleuca stypheloides Sm.**	Myrtaceae	DG												R
*Melastoma sanguineum Sims**	Melastomataceae	DG												R
Melhania acuminata Mast. var. acuminata	Sterculiaceae					NA				T	G			
*Melia azedarach L.**	Meliaceae	DG		FN	IG	NA	RV	S		T	G	I	P	R
Melianthus elongatus Wijnands	Melianthaceae	DG											P	
Melianthus major L.	Melianthaceae	DG												R
*Melilotis alba Desr.**	Fabaceae	DG	FF	FN		NA	RV	S	W		G	I	P	R
Melinis nerviglumis (Franch.) Zizka	Poaceae			FN		NA	RV					I		R
Melinis repens (Willd.) Zizka subsp. repens	Poaceae	DG	FF	FN		NA	RV	S	W	T	G	I	P	R
Melissa officinalis L.	Lamiaceae	DG												R
Melolobium calycinum Benth.	Fabaceae	DG	FF			NA				T	G			
Menodora africana Hook.	Oleaceae			FN		NA			W	T	G	I	P	
*Mentha pulegium L.**	Lamiaceae	DG											P	R
*Mentha spicata L.**	Lamiaceae	DG								T	G	I	P	R

Merremia kentrocaulos (C.B.Clarke) Rendle	Convolvulaceae	DG									G			
Merremia verecunda Rendle	Convolvulaceae	DG	FF	FN		NA					G			
Microchloa caffra Nees	Poaceae			FN		NA					G	I		R
Mimetes cucullatus (L.) R.Br.	Proteaceae	DG												R
Mimulus gracilis R.Br.	Scrophulariaceae			FN										R
*Mirabilis jalapa L.**	Nyctaginaceae	DG								T	G	I	P	R
*Miscanthus sinensis var. zebrina Beal**	Poaceae	DG												R
*Modiola caroliniana (L.) G.Don**	Malvaceae	DG	FF	FN	IG	NA	RV	S				I	P	R
Mollugo cerviana (L.) Ser. ex DC. var. cerviana	Molluginaceae	DG			IG					T	G			
Momordica balsamina L.	Cucurbitaceae	DG				NA	RV			T	G			
Monadenium lugardiae N.E.Br.	Euphorbiaceae	DG												R
Monocymbium ceresiiforme (Nees) Stapf	Poaceae			FN		NA								R
Monsonia angustifolia E.Mey. ex A.Rich.	Geraniaceae	DG	FF	FN	IG	NA	RV		W	T	G	I	P	R
*Monstera deliciosa Liebm.**	Araceae	DG									G	I	P	R
Moraea stricta Baker	Iridaceae		FF	FN	IG	NA	RV	S					P	R
*Morus alba L. var. alba**	Moraceae	DG			IG					T	G	I	P	R
*Morus nigra L.**	Moraceae			FN			RV	S				I	P	R
*Muehlenbeckia platyclada (F.Muell.) Meisn.**	Polygonaceae	DG												R
Mundulea sericea (Willd.) A.Chev.	Fabaceae	DG									G			R
*Musa x paradisiaca L.**	Musaceae	DG								T	G	I	P	
*Myoporum laetum G.Forst.**	Scrophulariaceae	DG												R
*Myrtus communis L. var. communis**	Myrtaceae	DG									G		P	R
*Nandina domestica Thunb.**	Berberidaceae	DG			IG			S			G	I	P	R
*Narcissus cultivar**	Amaryllidaceae	DG												R
*Narcissus pseudonarcissus L.**	Amaryllidaceae	DG										I		R
Nemesia fruticans (Thunb.) Benth.	Scrophulariaceae					NA								R

Nemesia ligulata E.Mey. ex Benth.	Scrophulariaceae	DG												R
Nemesia strumosa (Herb. Banks. ex. Benth.) Benth.	Scrophulariaceae	DG											P	R
*Neoregelia carolinae (Beer) L.B.Sm.**	Bromeliaceae	DG												R
*Nepeta cataria L.**	Lamiaceae	DG										I		R
*Nephrolepis exaltata (L.) Schott**	Nephrolepidaceae	DG									G	I	P	R
Nerine bowdenii Watson	Amaryllidaceae	DG												R
Nerine filifolia Baker.	Amaryllidaceae	DG					RV							R
Nerine laticoma (Ker Gawl.) T.Durand & Schinz	Amaryllidaceae	DG											P	
*Nerium oleander L.**	Apocynaceae	DG			IG					T	G	I	P	R
*Nicandra physalodes (L.) Gaertn.**	Solanaceae						RV	S					P	
*Nicotiana glauca Graham**	Solanaceae	DG								T	G			
*Nicotiana tabacum L.**	Solanaceae	DG								T				
Nidorella anomala Steetz	Asteraceae			FN		NA						I		R
Nidorella hottentotica DC.	Asteraceae			FN		NA	RV	S				I		R
Nidorella resedifolia DC. subsp. resedifolia	Asteraceae	DG	FF	FN		NA	RV		W	T	G	I		
*Nierembergia linariifolia Graham var. glabriuscula (Dunal) Cocucci & Hunz.**	Solanaceae	DG								T		I		
Nolletia ciliaris (DC.) Steetz	Asteraceae					NA				T		I		
Nolletia rarifolia (Turcz.) Steetz	Asteraceae			FN		NA						I	P	R
*Nothoscordum borbonicum Kunth**	Alliaceae	DG										I	P	R
Nymphaea nouchali Burm.f.	Nymphaeaceae	DG											P	R
Ochna pretoriensis E.Phillips	Ochnaceae	DG												R
Ochna serrulata (Hochst.) Walp.	Ochnaceae	DG												R
Ocimum angustifolium Benth.	Lamiaceae	DG				NA					G	I		
*Ocimum basilicum L.**	Lamiaceae	DG											P	R
Ocimum labiatum (N.E.Br.) A.J.Paton	Lamiaceae	DG											P	

Ocimum obovatum E.Mey. ex Benth. subsp. obovatum	Lamiaceae					NA						I		
Ocimum serratum (Schltr.) A.J.Paton	Lamiaceae	DG											P	
*Oenothera indecora Cambess. subsp. indecora**	Onagraceae					NA		S					P	
*Oenothera lindheimeri (Engelm. & A.Gray) W.L.Wagner & Hoch**	Onagraceae	DG										I	P	R
*Oenothera rosea L'Hér. ex. Aiton**	Onagraceae	DG	FF	FN		NA	RV			T		I	P	R
*Oenothera speciosa Nutt**	Onagraceae	DG								T			P	
*Oenothera tetraptera Cav.**	Onagraceae		FF	FN		NA	RV	S				I	P	R
Oldenlandia herbacea (L.) Roxb. var. herbacea	Rubiaceae	DG		FN										R
Olea capensis L.	Oleaceae	DG												R
Olea europaea L. subsp. africana (Mill.) P.S.Green	Oleaceae	DG									G	I	P	R
Ophioglossum costatum R.Br.	Ophioglossaceae	DG				NA				T	G			
Ophioglossum polyphyllum A.Braun	Ophioglossaceae			FN										R
*Ophiopogon jaburan (Siebold) Lodd.**	Convallariaceae	DG			IG						G	I	P	R
*Ophiopogon japonicus (L.f.) Ker Gawl.**	Convallariaceae	DG			IG					T	G	I	P	R
*Ophiopogon planiscapus Nakai**	Convallariaceae	DG												R
*Opuntia exaltata A.Berger**	Cactaceae	DG										I	P	R
*Opuntia ficus–indica (L.) Mill.**	Cactaceae	DG				NA			W	T	G	I	P	R
*Opuntia humifusa (Raf.) Raf.**	Cactaceae	DG									G			
*Opuntia microdasys (Lehm.) Pfeiff.**	Cactaceae	DG												R
*Opuntia spinulifera Salm–Dyck**	Cactaceae	DG								T	G			
*Opuntia verschaffeltii Cels.**	Cactaceae	DG											P	
Orbea lutea (N.E.Br.) Bruyns subsp. lutea	Apocynaceae	DG				NA				T	G			R
Orbea variegata (L.) Haw.	Apocynaceae	DG											P	R
*Oreocereus trollii (Kupper) Kupper**	Cactaceae	DG												R
*Origanum majorana L.**	Lamiaceae	DG											P	R
*Origanum vulgare L.**	Lamiaceae	DG											P	R

Ornithogalum abyssinicum (Jacq.) J.C.Manning & Goldblatt	Hyacinthaceae	DG				NA				T	G	I		
Ornithogalum dubium Houtt.	Hyacinthaceae	DG												R
Ornithogalum maximum (Burm.f.) J.C.Manning & Goldblatt	Hyacinthaceae	DG												R
Ornithogalum prasinum Ker Gawl.	Hyacinthaceae	DG				NA				T		I		
Ornithogalum rigidifolium (Baker) J.C.Manning & Goldblatt	Hyacinthaceae					NA						I		
Ornithogalum saundersiae Baker	Hyacinthaceae	DG												R
Ornithogalum setosum (Jacq.) J.C. Manning & Goldblatt	Hyacinthaceae	DG	FF	FN	IG	NA	RV	S				I	P	R
Ornithogalum tenuifolium F.Delaroche subsp. tenuifolium	Hyacinthaceae	DG				NA				T	G		P	R
Ornithogalum thyrsoides Jacq.	Hyacinthaceae	DG											P	R
Ornithoglossum dinteri K.Krause	Colchicaceae	DG	FF	FN		NA				T	G	I	P	R
Oscularia deltoides (L.) Schwantes	Mesembryanthemaceae	DG												R
Osteospermum ecklonis (DC.) Norl.	Asteraceae	DG												R
Osteospermum fruticosum (L.) Norl.	Asteraceae	DG												R
Osteospermum jucundum (Phillips) Norl.	Asteraceae	DG											P	R
Osteospermum muricatum E.Mey. ex DC. subsp. muricatum	Asteraceae	DG	FF			NA			W	T	G		P	R
Osteospermum x hybrida	Asteraceae	DG												R
Othonna dentata L.	Asteraceae	DG												R
*Oxalis articulata Savigny**	Oxalidaceae	DG										I	P	
*Oxalis corniculata L.**	Oxalidaceae	DG	FF	FN	IG	NA	RV	S	W	T	G	I	P	R
Oxalis lanata L.f.	Oxalidaceae	DG											P	
*Oxalis latifolia Knuth**	Oxalidaceae	DG		FN				S			G	I	P	R
Oxalis obliquifolia Steud. ex Rich.	Oxalidaceae			FN		NA	RV	S						R
Oxalis purpurea L.	Oxalidaceae	DG					RV						P	
Oxygonum dregeanum Meisn. subsp. canescens (Sond.) Germish.	Polygonaceae					NA	RV				G	I		
Ozoroa paniculosa (Sond.) R.Fern. & A.Fern.	Anacardiaceae					NA								R

*Pachira aquatica Aublet**	Bombacaceae	DG												R
Pachycarpus schinzianus (Schltr.) N.E.Br.	Apocynaceae					NA						I	P	
*Pachycereus marginatus (DC.) Britton & Rose**	Cactaceae	DG											P	R
*Pachyphytum oviferum J.A. Purpus**	Crassulaceae	DG												R
*Pachypodium baronii Costantin & Bois**	Apocynaceae	DG										I		
*Pachypodium lamerei Drake**	Apocynaceae	DG												R
Pachystigma pygmaeum (Schltr.) Robyns	Rubiaceae					NA						I		
*Pandorea jasminoides (Lindl.) K.Schum.**	Bignoniaceae	DG												R
Panicum coloratum L. var. coloratum	Poaceae	DG	FF	FN		NA	RV	S	W	T	G	I	P	R
Panicum maximum Jacq.	Poaceae	DG				NA	RV	S		T		I	P	R
Panicum natalense Hochst.	Poaceae			FN		NA								R
Panicum schinzii Hack.	Poaceae					NA						I		
Papaver aculeatum Thunb.	Papaveraceae			FN										R
*Papaver nudicaule L.**	Papaveraceae	DG												R
*Papaver somniferum L.**	Papaveraceae	DG												R
Pappea capensis Eckl. & Zeyh.	Sapindaceae			FN		NA						I		R
*Parkinsonia aculeata L.**	Fabaceae	DG								T	G		P	R
*Parodia concinna (Monv.) N.P.Taylor**	Cactaceae	DG												R
*Parodia magnifica L.**	Cactaceae	DG												R
*Parthenium integrifolium L.**	Asteraceae	DG											P	
*Parthenocissus quinquefolia (L.) Planch.**	Vitaceae	DG									G		P	R
*Parthenocissus tricuspidata Planch.**	Vitaceae	DG											P	R
*Parthenocissus vitacea (Knerr) Hitchc.**	Vitaceae	DG											P	
*Paspalum dilatatum Poir.**	Poaceae	DG	FF	FN	IG	NA	RV	S	W	T		I	P	R
Paspalum distichum L.	Poaceae						RV		W	T			P	
*Paspalum notatum Flüggé**	Poaceae			FN			RV	S						R

Paspalum scrobiculatum L.	Poaceae	DG											P	
*Paspalum urvillei Steud.**	Poaceae			FN			RV						P	R
*Passiflora aculeata Hort. ex Mast.**	Passifloraceae	DG											P	
*Passiflora edulis Sims**	Passifloraceae	DG												R
Pavonia burchelii (DC.) R.A.Dyer	Malvaceae	DG	FF			NA			W	T	G	I	P	R
Pearsonia cajanifolia (Harv.) Polhill subsp. cajanifolia	Fabaceae			FN		NA						I		R
Pearsonia sessilifolia (Harv.) Dummer subsp. Sessilifolia	Fabaceae			FN		NA								R
Pearsonia uniflora (Kensit) Polhill	Fabaceae	DG				NA						I		R
*Pedilanthus tithymaloides (L.) Poit**	Euphorbiaceae	DG												R
Pelargonium citronellum J.J.A.van der Walt	Geraniaceae	DG												R
Pelargonium crispum (P.J.Bergius) L'Hér.	Geraniaceae	DG											P	R
Pelargonium echinatum Curtis	Geraniaceae	DG												R
Pelargonium graveolens L'Her.	Geraniaceae	DG												R
Pelargonium multicaule Jacq.	Geraniaceae					NA								R
Pelargonium peltatum (L.) L'Her.	Geraniaceae	DG										I	P	R
Pelargonium reniforme Curtis	Geraniaceae	DG											P	R
*Pelargonium x domesticum L.H.Bailey**	Geraniaceae	DG										I	P	R
Pelargonium x hortorum L.H.Bailey	Geraniaceae	DG								T	G	I	P	R
Pelargonium zonale (L.) L'Hér.	Geraniaceae	DG												R
Pellaea calomelanos (Sw.) Link var. calomelanos	Pteridaceae	DG	FF	FN		NA						I	P	R
Peltophorum africanum Sond.	Fabaceae	DG												R
*Pennisetum clandestinum Hochst. ex Chiov.**	Poaceae	DG	FF	FN	IG	NA	RV	S		T	G	I	P	R
*Pennisetum setaceum (Forssk.) Chiov.**	Poaceae	DG								T	G		P	R
*Pennisetum villosum R.Br. ex Fresen.**	Poaceae	DG									G			R
Pentanisia angustifolia (Hochst.) Hochst.	Rubiaceae			FN		NA						I		R
Pentarrhinum insipidum E.Mey.	Apocynaceae	DG		FN		NA	RV					I	P	R

*Pentas lanceolata (Forssk.) Deflers**	Rubiaceae	DG												R
Pentzia calcarea Kies	Asteraceae	DG		FN	IG	NA	RV		W	T	G			
Pentzia globosa Less.	Asteraceae	DG		FN		NA			W	T	G	I	P	
*Peperomia marmorata Hook.f.**	Piperaceae	DG											P	
Pergularia daemia (Forssk.) Chiov.	Apocynaceae					NA	RV		W	T	G			
Perotis patens Gand.	Poaceae					NA					G			
*Persea americana L.**	Lauraceae	DG								T	G	I		R
*Persicaria lapathifolia (L.) Gray**	Polygonaceae						RV						P	
*Petrea volubilis L.**	Verbenaceae	DG											P	R
*Petroselinum crispum (Mill.) A.W.Hill**	Apiaceae	DG										I	P	R
*Petunia x hybrida E.Vilm.**	Solanaceae	DG			IG						G	I	P	R
*Phalaris arundinacea var. picta L.**	Poaceae	DG												R
*Phaseolus vulgaris L.**	Fabaceae	DG								T		I	P	R
*Philadelphus coronarius L.**	Hydrangeaceae	DG												R
*Philodendron selloum K.Koch.**	Araceae	DG									G	I	P	R
*Phlox drummondii Hook.**	Polemoniaceae	DG												R
*Phoenix canariensis Hort. ex Chabaud**	Arecaceae	DG								T	G	I	P	R
*Phoenix dactylifera L.**	Arecaceae	DG								T	G		P	R
Phoenix reclinata Jacq.	Arecaceae	DG												R
*Phoenix roebelenii O'Brien**	Arecaceae	DG								T				R
*Phormium colensoi Hook.f.**	Phormiaceae	DG											P	
*Phormium tenax J.R.Forst. & G.Forst**	Phormiaceae	DG											P	R
*Photinia glabra (Thunb.) Maxim.**	Rosaceae	DG											P	R
*Photinia serrulata Franch. & Sav.**	Rosaceae	DG										I	P	R
Phygelius capensis E.Mey. ex Benth.	Scrophulariaceae	DG								T			P	R
*Phyla nodiflora (L.) Greene var. nudiflora**	Verbenaceae	DG											P	

Phylica plumosa L.	Rhamnaceae	DG											R
Phyllanthus maderaspatensis L.	Phyllanthaceae	DG	FF			NA			T	G	I		
Phyllanthus parvulus Sond.	Phyllanthaceae	DG		FN		NA			T	G	I	P	R
Phymaspermum athanasioides (S.Moore) Källersjö	Asteraceae			FN		NA							R
*Physalis angulata L.**	Solanaceae	DG	FF	FN	IG	NA	RV	S		G	I	P	R
*Physalis peruviana L.**	Solanaceae	DG											R
*Physalis viscosa L.**	Solanaceae	DG		FN		NA	RV			G	I	P	R
*Phytolacca dioica L.**	Phytolaccaceae	DG								G		P	R
*Phytolacca octandra L.**	Phytolaccaceae	DG					RV						R
*Picris echioides L.**	Asteraceae	DG	FF				RV					P	R
*Pinus elliottii Engelm. var. elliottii**	Pinaceae	DG								G			
*Pinus halepensis Mill.**	Pinaceae	DG			IG					G		P	R
*Pinus mugo Turra**	Pinaceae	DG										P	
*Pinus patula Schltdl. & Cham.**	Pinaceae	DG		FN			RV						R
*Pinus roxburghii Sarg.**	Pinaceae	DG										P	
*Pittosporum crassifolium A.Cunn.**	Pittosporaceae	DG											R
Pittosporum eugenioides A.Cunn.	Pittosporaceae	DG											R
*Pittosporum tenuifolium Gaertn.**	Pittosporaceae	DG											R
*Pittosporum undulatum Vent.**	Pittosporaceae	DG											R
Pittosporum viridiflorum Sims.	Pittosporaceae	DG											R
Plantago lanceolata L.	Plantaginaceae	DG	FF	FN	IG	NA	RV	S			I	P	R
Plantago major L.	Plantaginaceae	DG				NA						P	
*Platanus occidentalis L.**	Platanaceae	DG										P	
*Platanus x acerifolia (Aiton) Willd.**	Platanaceae	DG		FN			RV	S				P	R
*Platycladus orientalis (L.) Franco**	Cupressaceae	DG										P	R
*Plectranthus barbatus Andrews**	Lamiaceae	DG										P	R

Plectranthus ciliatus E.Mey. ex. Benth	Lamiaceae	DG											P	R
Plectranthus ecklonii Benth.	Lamiaceae	DG												R
Plectranthus fruticosus L'Hér.	Lamiaceae	DG				NA								R
Plectranthus hereroensis Engl.	Lamiaceae					NA								R
Plectranthus hilliardiae Codd	Lamiaceae	DG											P	R
Plectranthus madagascariensis (Pers.) Benth.	Lamiaceae	DG								T	G		P	R
Plectranthus neochilus Schltr.	Lamiaceae	DG								T	G		P	R
Plectranthus pentheri (Gürke) Van Jaarsv. & T.J.Edwards	Lamiaceae	DG								T	G			
Plectranthus praetermissus Codd.	Lamiaceae	DG												R
Plectranthus saccatus Benth. var. saccatus	Lamiaceae	DG								T	G		P	R
*Plectranthus scutellarioides (L.) R.Br.**	Lamiaceae	DG										I	P	R
*Plectranthus thyrsoideus (Baker) B.Mathew**	Lamiaceae	DG									G	I		R
*Pleioblastus pygmaeus (Miq.) Nakai**	Poaceae	DG											P	R
*Pleioblastus variegatus (Siebold. ex Miq.) Makino**	Poaceae	DG											P	R
Plumbago auriculata Lam.	Plumbaginaceae	DG						S		T	G	I	P	R
*Plumeria rubra L.**	Apocynaceae	DG										I	P	R
*Poa annua L.**	Poaceae	DG			IG		RV	S		T	G	I	P	R
*Poa pratensis L.**	Poaceae	DG											P	
Podocarpus falcatus (Thunb.) R.Br. ex. Mirb.	Podocarpaceae	DG											P	R
Podocarpus henkelii Stapf ex Dallim. & Jacks.	Podocarpaceae	DG										I	P	R
Podocarpus latifolius (Thunb.) R.Br. ex Mirb.	Podocarpaceae	DG											P	
Podranea ricasoliana (Tanf.) Sprague	Bignoniaceae	DG											P	R
Pogonarthria squarrosa (Roem. & Schult.) Pilg.	Poaceae		FF	FN		NA					G	I		R
Pollichia campestris Aiton	Caryophyllaceae	DG	FF	FN		NA	RV		W	T	G	I	P	R
Polygala amatymbica Eckl. & Zeyh.	Polygalaceae			FN		NA	RV	S				I	P	R
Polygala hottentotta C.Presl	Polygalaceae		FF	FN		NA	RV				G	I	P	R

Polygala leptophylla Burch.	Polygalaceae	DG				NA				T			P	
Polygala myrtifolia L.	Polygalaceae	DG											P	R
Polygala myrtifolia L. var. myrtifolia	Polygalaceae	DG						S						R
Polygala uncinata E.Mey. ex Meisn.	Polygalaceae			FN		NA	RV							R
*Polygonum capitatum Buch.–Ham. ex D.Don**	Polygonaceae	DG									G			R
*Polypodium aureum L.**	Polypodiaceae	DG												R
*Polystichum proliferum (R.Br.) C.Presl**	Dryopteridaceae	DG										I	P	R
Polystichum wilsonii H.Christ	Dryopteridaceae	DG											P	
*Pontederia cordata L.**	Pontederiaceae	DG												R
*Populus deltoides W.Bartram ex Marshall**	Salicaceae	DG		FN							G		P	R
*Populus nigra L. var. italica Du Roi.**	Salicaceae	DG								T	G			
*Populus simonii Carrière**	Salicaceae	DG								T		I	P	
*Populus x canescens (Aiton) Sm.**	Salicaceae			FN									P	
Portulaca grandiflora Hook.	Portulacaceae	DG		FN		NA				T	G	I	P	R
Portulaca kermesina N.E.Br.	Portulacaceae	DG	FF	FN		NA			W	T	G	I	P	R
*Portulaca oleracea L.**	Portulacaceae	DG		FN	IG	NA	RV	S		T	G	I	P	R
Portulaca quadrifida L.	Portulacaceae	DG	FF	FN	IG	NA	RV	S	W	T	G	I	P	R
Portulacaria afra Jacq.	Portulacaceae	DG								T			P	R
*Primula obconica Hance**	Primulaceae	DG										I	P	
*Primula vulgaris Huds.**	Primulaceae	DG												R
*Primula x polyantha Mill.**	Primulaceae	DG											P	R
*Prosopis glandulosa Torr. var. torreyana (Benson) Johnst.**	Fabaceae	DG							W	T	G		P	
Protea caffra Meisn. subsp. caffra	Proteaceae	DG		FN		NA								R
Protea compacta R.Br.	Proteaceae	DG												R
Protea cynaroides (L.) L.	Proteaceae	DG												R
Protea eximia (Salisb. ex Knight) Fourc.	Proteaceae	DG												R

Protea longifolia Andrews	Proteaceae	DG												R
Protea repens (L.) L.	Proteaceae	DG												R
Protea welwitschii Engl.	Proteaceae			FN										R
*Prunus armeniaca L.**	Rosaceae	DG								T	G	I	P	R
*Prunus avium L.**	Rosaceae	DG												R
*Prunus cerasifera Ehrh.**	Rosaceae	DG											P	R
*Prunus domestica L.**	Rosaceae	DG		FN			RV					I	P	R
*Prunus laurocerasus L.**	Rosaceae	DG											P	R
*Prunus nigra Aiton**	Rosaceae	DG										I	P	R
*Prunus persica (L.) Batsch**	Rosaceae	DG								T	G	I	P	R
*Prunus salicifolia Kunth**	Rosaceae	DG					RV							R
*Prunus serrulata Lindl.**	Rosaceae	DG												R
Pseudogaltonia clavata (Mast.) E.Phillips	Hyacinthaceae	DG	FF	FN		NA	RV				G			
Pseudognaphalium luteo–album (L.) Hilliard & B.L.Burtt	Asteraceae	DG	FF	FN	IG	NA	RV	S				I	P	R
Pseudognaphalium oligandrum (DC.) Hilliard & B.L.Burtt	Asteraceae	DG				NA			W	T	G			
Ptaeroxylon obliquum (Thunb.) Radlk.	Rutaceae	DG												R
Ptycholobium contortum (N.E.Br.) Brummitt	Fabaceae	DG				NA				T		I	P	
*Punica granatum L.**	Punicaceae	DG								T	G	I	P	R
Pupalia lappacea (L.) A.Juss. var. lappacea	Amaranthaceae	DG				NA	RV				G		P	
Pycreus macranthus (Boeck.) C.B.Clarke	Cyperaceae			FN		NA							P	
Pygmaeothamnus zeyheri (Sond.) Robyns var. zeyheri	Rubiaceae			FN		NA	RV					I		R
*Pyracantha angustifolia (Franch.) C.K.Schneid.**	Rosaceae	DG		FN							G		P	R
*Pyracantha coccinea M.Roem.**	Rosaceae	DG											P	R
*Pyracantha crenulata (D.Don) M.Roem.**	Rosaceae	DG											P	
*Pyrostegia venusta Miers**	Bignoniaceae	DG												R
*Pyrus communis L.**	Rosaceae	DG					RV						P	R

*Quercus ilex L.**	Fagaceae	DG												R
*Quercus palustris Du Roi.**	Fagaceae	DG												R
*Quercus robur L.**	Fagaceae	DG					RV						P	R
*Quercus suber L.**	Fagaceae	DG				NA	RV						P	
Racosperma baileyanum (F.Muell.) Pedley	Fabaceae	DG											P	
*Racosperma cultriforme (G.Don) Pedley**	Fabaceae	DG												R
*Racosperma salignum (Labill.) Pedley**	Fabaceae	DG												R
*Ranunculus asiaticus L.**	Ranunculaceae	DG												R
Ranunculus multifidus Forssk.	Ranunculaceae	DG	FF	FN	IG	NA	RV	S					P	R
Rapanea melanophloeos (L.) Mez.	Myrsinaceae	DG												R
*Raphanus raphanistrum L.**	Brassicaceae	DG					RV						P	R
Raphionacme galpinii Schltr.	Apocynaceae			FN		NA						I	P	R
Raphionacme hirsuta (E.Mey.) R.A.Dyer ex E.Phillips	Apocynaceae					NA						I		
Rhamnus prinoides L'Hér.	Rhamnaceae	DG												R
*Rhaphiolepis indica (L.) Lindl.**	Rosaceae	DG										I	P	R
*Rheum rhabarbarum L.**	Polygonaceae	DG												R
Rhigozum brevispinosum Kuntze	Bignoniaceae	DG				NA				T			P	
*Rhododendron indicum (L.) Sweet**	Ericaceae	DG										I	P	R
*Rhododendron japonicum (Blume.) Schneid.**	Ericaceae	DG												R
*Rhododendron pulchrum Sweet**	Ericaceae	DG												R
Rhoicissus rhomboidea (E.Mey. ex Harv.) Planch.	Vitaceae	DG											P	
Rhoicissus tomentosa (Lam.) Wild & R.B.Drumm.	Vitaceae	DG										I	P	R
*Rhus chinensis Mill.**	Anacardiaceae	DG										I	P	
*Rhus succedanea L.**	Anacardiaceae	DG												R
Rhynchosia caribaea (Jacq.) DC.	Fabaceae					NA						I		
Rhynchosia confusa Burtt Davy	Fabaceae		FF	FN		NA	RV			T	G		P	

Rhynchosia minima (L.) DC. var. minima	Fabaceae		FF		IG		RV	S				P	R
Rhynchosia monophylla Schltr.	Fabaceae					NA					I		
Rhynchosia nitens Benth.	Fabaceae					NA					I	P	
Rhynchosia totta (Thunb.) DC. var. totta	Fabaceae	DG		FN		NA	RV	S			I	P	R
*Richardia brasiliensis Gomes**	Rubiaceae	DG		FN			RV	S			I	P	R
*Ricinus communis L.**	Euphorbiaceae	DG										P	R
*Robinia pseudoacacia L.**	Fabaceae	DG		FN			RV		T	G	I	P	R
*Rosa banksiae R.Br.**	Rosaceae	DG			IG					G	I	P	R
*Rosa canina L.**	Rosaceae	DG											R
*Rosa chinensis Jacq.**	Rosaceae	DG			IG				T	G	I	P	R
*Rosa rubiginosa L.**	Rosaceae	DG							T	G	I	P	R
*Rosa x rehderiana Blackb.**	Rosaceae	DG							T		I	P	R
*Rosmarinus officinalis L.**	Lamiaceae	DG					RV				I	P	R
*Rosularia chrysantha (Boiss. & Heldr. ex Boiss) Takht.**	Crassulaceae	DG										P	R
Rotheca myricoides (Hochst.) Steane & Mabb.	Lamiaceae	DG											R
*Roystonea regia (Kunth) O.F.Cook**	Arecaceae	DG											R
Rubia horrida (Thunb.) Puff	Rubiaceae					NA					I		
Rubus idaeus L.	Rosaceae	DG											R
Rubus rigidus Sm.	Rosaceae						RV						R
Ruellia cordata Thunb.	Acanthaceae			FN		NA		S					R
*Rumex crispus L.**	Polygonaceae	DG				NA	RV	S			I	P	R
Rumex sagittatus Thunb.	Polygonaceae					NA	RV						R
Rumohra adiantiformis (G.Forst.) Ching	Dryopteridaceae	DG											R
Ruschia canonotata (L.Bolus) Schwantes	Mesembryanthemaceae	DG				NA			T	G			
Ruschia caroli (L. Bolus) Schwantes	Mesembryanthemaceae	DG											R
Ruschia maxima (Haw.) L.Bolus	Mesembryanthemaceae	DG											R

Ruschia perfoliata (Mill.) Schwantes	Mesembryanthemaceae	DG								T	G			
Ruschia ruralis (N.E.Br.) Schwantes	Mesembryanthemaceae	DG				NA				T				
Ruschia species [LYM56]	Mesembryanthemaceae	DG								T				
*Ruscus aculeatus L.**	Ruscaceae	DG											P	R
Ruspolia hypocrateriformis (Vahl) Milne–Redh. var. australis	Acanthaceae	DG												R
*Russelia equisetiformis Schltdl. & Cham.**	Scrophulariaceae	DG												R
*Ruta graveolens L.**	Rutaceae	DG								T	G	I		R
Ruttya ovata Harv.	Acanthaceae	DG												R
*Saccharum officinarum L.**	Poaceae	DG								T	G	I	P	
*Saintpaulia ionantha H.Wendl.**	Gesneriaceae	DG												R
*Salix babylonica L.**	Salicaceae	DG								T		I	P	R
*Salix fragilis L. var. fragilis**	Salicaceae	DG										I		
Salix mucronata Thunb. subsp. mucronata	Salicaceae	DG											P	
*Salvia elegans Vahl**	Lamiaceae	DG										I	P	R
*Salvia farinacea Benth.**	Lamiaceae	DG											P	R
*Salvia greggii A.Gray**	Lamiaceae	DG											P	R
*Salvia leucantha Cav.**	Lamiaceae	DG									G	I	P	R
*Salvia microphylla Kunth**	Lamiaceae	DG										I	P	R
*Salvia officinalis L.**	Lamiaceae	DG												R
*Salvia reflexa Hornem.**	Lamiaceae	DG	FF			NA	RV					I	P	R
Salvia repens Burch. ex Benth.	Lamiaceae	DG											P	R
Salvia runcinata L.f.	Lamiaceae	DG		FN		NA	RV		W	T	G	I	P	R
*Salvia splendens Sellow ex Roem. & Schult.**	Lamiaceae	DG											P	R
*Sambucus nigra L.**	Caprifoliaceae	DG								T	G	I	P	R
Sansevieria aethiopica Thunb.	Dracaenaceae	DG	FF			NA				T	G			
*Sansevieria trifasciata Prain**	Dracaenaceae	DG								T	G	I	P	R

*Saponaria ocymoides L.**	Caryophyllaceae	DG										I	P	
*Saponaria officinalis L.**	Caryophyllaceae	DG						S		T	G	I	P	R
Scabiosa africana L.	Dipsacaceae	DG											P	
Scabiosa columbaria L.	Dipsacaceae			FN		NA						I	P	R
Scadoxus puniceus (L.) Friis & Nordal	Amaryllidaceae	DG											P	
*Schefflera actinophylla (Endl.) Harms**	Araliaceae	DG											P	R
*Schefflera arboricola (Hayata) Merr.**	Araliaceae	DG											P	R
*Schinus molle L.**	Anacardiaceae	DG	FF					S		T	G	I	P	R
*Schinus terebinthifolius Raddi**	Anacardiaceae	DG											P	R
Schistostephium crataegifolium (DC.) Fenzl ex Harv.	Asteraceae			FN		NA								R
Schizachyrium sanguineum (Retz.) Alston	Poaceae	DG		FN		NA						I		R
Schizocarphus nervosus (Burch.) Van der Merwe	Hyacinthaceae	DG									G			
*Schkuhria pinnata (Lam.) Cabrera**	Asteraceae	DG	FF	FN	IG	NA	RV	S	W	T	G	I	P	R
*Schlumbergera bridgesii (Lem) Loefgr.**	Cactaceae	DG												R
*Schlumbergera truncata (Haw.) Moran**	Cactaceae	DG												R
*Schlumbergera x buckleyi (T.Moore) D.R.Hunt**	Cactaceae	DG											P	R
Schmidtia pappophoroides Steud. ex J.A.Schmidt	Poaceae	DG	FF	FN		NA	RV		W	T	G			
Schoenoplectus corymbosus (Roem. & Schult.) J.Raynal	Cyperaceae	DG							W		G		P	R
Schotia afra (L.) Thunb. var. afra	Fabaceae	DG												R
Schotia brachypetala Sond.	Fabaceae	DG												R
*Sciadopitys verticillata (Thunb.) Siebold & Zucc.**	Sciadopityaceae	DG											P	
*Scrophularia nodosa L.**	Scrophulariaceae	DG										I	P	
*Scutellaria racemosa Pers.**	Lamiaceae	DG											P	
Searsia chirindensis (Baker f.) Moffett	Anacardiaceae	DG												R
Searsia dentata (Thunb.) F.A. Barkley	Anacardiaceae	DG		FN		NA								R
Searsia discolor (E.Mey. ex Sond.) Moffett	Anacardiaceae					NA								R

Searsia lancea (L.f.) F.A. Barkley	Anacardiaceae	DG		FN		NA	RV	S		T	G	I	P	R
Searsia leptodictya (Diels) T.S.Yi, A.J.Mill. & J.Wen	Anacardiaceae	DG		FN		NA				T		I	P	R
Searsia magalismontana (Sond.) Moffett subsp. magalismontana	Anacardiaceae	DG		FN		NA	RV					I		R
Searsia pallens (Eckl. & Zeyh.) Moffett	Anacardiaceae							S						R
Searsia pendulina (Jacq.) Moffett	Anacardiaceae	DG			IG		RV	S		T	G	I	P	R
Searsia pyroides (Burch.) Moffett	Anacardiaceae	DG				NA	RV					I	P	R
Searsia rigida (Mill.) F.A.Barkley	Anacardiaceae					NA						I		R
Sebaea grandis (E.Mey.) Steud.	Gentianaceae	DG	FF	FN		NA					G	I	P	R
*Sechium edule (Jacq.) Sw.**	Cucurbitaceae	DG												R
Seddera suffruticosa (Schinz) Hallier f.	Convolvulaceae					NA	RV					I	P	
*Sedum mexicanum Britton**	Crassulaceae	DG										I		
*Sedum morganianum E.Walther**	Crassulaceae	DG									G		P	R
Sedum nussbaumerianum Bitter	Crassulaceae	DG												R
*Sedum pachyphyllum Rose**	Crassulaceae	DG											P	R
*Sedum palmeri S.Watson**	Crassulaceae	DG												R
*Sedum praealtum A.DC.**	Crassulaceae	DG												R
*Sedum rubrotinctum R.T.Clausen**	Crassulaceae	DG						S				I	P	R
*Sedum sieboldii Hort. ex G.Don.**	Crassulaceae	DG											P	
*Sedum treleasei Rose**	Crassulaceae	DG												R
Selaginella dregei (C.Presl) Hieron.	Selaginellaceae					NA								R
Selaginella kraussiana (Kunze) A.Braun	Selaginellaceae	DG												R
Selago densiflora Rolfe	Scrophulariaceae	DG		FN		NA	RV	S	W		G	I	P	R
Selago mixta Hilliard	Scrophulariaceae	DG	FF	FN		NA	RV		W	T	G			
Selago welwitschii Rolfe var. holubii (Rolfe) Brenan	Scrophulariaceae	DG	FF			NA			W	T		I		
*Sempervivum arachnoideum L.**	Crassulaceae	DG												R
*Sempervivum tectorum L.**	Crassulaceae	DG												R

Senecio affinis DC.	Asteraceae					NA						I		R
Senecio articulatus (L.) Sch.Bip.	Asteraceae	DG								T			P	R
Senecio barbertonicus Klatt	Asteraceae	DG					RV			T	G	I	P	R
Senecio consanguineus DC.	Asteraceae	DG		FN	IG	NA	RV	S		T	G		P	R
Senecio coronatus (Thunb.) Harv.	Asteraceae			FN		NA						I		R
Senecio elegans L.	Asteraceae	DG												R
Senecio erubescens Aiton var. crepidifolius DC.	Asteraceae			FN	IG	NA	RV	S					P	R
Senecio harveianus MacOwan	Asteraceae						RV							R
Senecio inornatus DC.	Asteraceae		FF			NA	RV					I	P	R
Senecio latifolius DC.	Asteraceae	DG												R
Senecio macrocephalus DC.	Asteraceae	DG												R
Senecio macroglossus DC.	Asteraceae	DG												R
Senecio othonniflorus DC.	Asteraceae			FN		NA						I		R
Senecio oxyriifolius DC. subsp. oxyriifolius	Asteraceae	DG		FN		NA				T	G	I		R
Senecio rowleyanus H.Jacobsen	Asteraceae	DG											P	R
Senecio scaposus DC. var. scaposus	Asteraceae	DG								T	G	I	P	R
Senecio tamoides DC.	Asteraceae	DG								T	G	I	P	R
Senecio venosus Harv.	Asteraceae	DG		FN		NA						I		R
Senegalia ataxacantha (DC.) Kyal. & Boatwr.	Fabaceae	DG											P	
Senegalia burkei (Benth.) Kyal. & Boatwr.	Fabaceae	DG												R
Senegalia caffra (Thunb.) P.J.H.Hurter & Mabb.	Fabaceae	DG				NA		S				I	P	R
Senegalia galpinii (Burtt Davy) Seigler & Ebinger	Fabaceae	DG			IG					T	G		P	R
Senegalia mellifera (Benth.) Seigler & Ebinger	Fabaceae	DG	FF			NA				T	G			R
*Senna corymbosa (Lam.) Irwin & Barneby**	Fabaceae	DG								T	G	I	P	R
Senna italica Mill. subsp. arachoides (Burch.) Lock	Fabaceae	DG	FF	FN		NA	RV		W	T	G			R
*Senna occidentalis (L.) Link**	Fabaceae	DG									G			

Sericorema sericea (Schinz) Lopr.	Amaranthaceae					NA						I		
Seriphium plumosum L.	Asteraceae		FF	FN		NA	RV					I	P	R
Sesamum alatum Thonn.	Pedaliaceae	DG	FF	FN		NA				T	G			
Sesamum capense Burm.f.	Pedaliaceae	DG								T				
Sesamum triphyllum Welw. ex Asch. var. triphyllum	Pedaliaceae	DG	FF			NA	RV			T	G		P	
Sesbania transvaalensis J.B.Gillett	Fabaceae					NA	RV						P	
Setaria incrassata (Hochst.) Hack.	Poaceae		FF	FN		NA						I	P	R
Setaria lindenbergiana (Nees) Stapf	Poaceae	DG				NA							P	R
Setaria nigrirostris (Nees) T.Durand & Schinz	Poaceae					NA						I	P	
Setaria pumila (Poir.) Roem. & Schult.	Poaceae			FN		NA	RV		W		G	I	P	R
Setaria sphacelata (Schumach.) Moss var. sericea (Stapf) Clayton	Poaceae					NA						I		
Setaria sphacelata (Schumach.) Moss var. sphacelata	Poaceae	DG		FN		NA	RV				G	I	P	R
Setaria sphacelata (Schumach.) Moss var. torta (Stapf) Clayton	Poaceae	DG				NA						I		
Setaria verticillata (L.) P.Beauv.	Poaceae	DG		FN		NA			W		G	I	P	R
Sida alba L.	Malvaceae	DG								T				R
Sida chrysantha Ulbr.	Malvaceae	DG	FF	FN		NA			W	T	G	I		
Sida cordifolia L.	Malvaceae	DG	FF	FN	IG	NA	RV	S	W	T	G	I	P	R
Sida dregei Burtt Davy	Malvaceae	DG		FN		NA	RV	S				I		R
Sida rhombifolia L. subsp. rhombifolia	Malvaceae	DG	FF	FN	IG	NA	RV	S				I	P	R
Sida spinosa L. var. spinosa	Malvaceae	DG	FF	FN		NA	RV	S	W	T	G	I	P	R
*Silene armeria L.**	Caryophyllaceae	DG												R
Silene coeli-rosa (L.) Godr.	Caryophyllaceae	DG												R
*Sisymbrium orientale L.**	Brassicaceae	DG		FN		NA	RV	S	W	T		I	P	R
Sisymbrium thellungii O.E.Schulz	Brassicaceae		FF	FN	IG	NA	RV	S				I	P	R
*Solanum capsicastrum Schauer**	Solanaceae	DG										I		

*Solanum elaeagnifolium Cav.**	Solanaceae	DG	FF	FN		NA	RV	S		T	G	I	P	R
Solanum lichtensteinii Willd.	Solanaceae	DG	FF	FN		NA				T	G	I	P	
*Solanum mauritianum Scop.**	Solanaceae	DG		FN		NA	RV						P	R
*Solanum melongena L.**	Solanaceae	DG										I	P	
*Solanum nigrum L.**	Solanaceae	DG		FN			RV	S	W	T	G	I	P	R
Solanum panduriforme E.Mey.	Solanaceae	DG		FN		NA	RV				G	I	P	R
*Solanum pseudocapsicum L.**	Solanaceae	DG											P	R
*Solanum rantonnetii Carriere**	Solanaceae	DG									G	I	P	R
Solanum retroflexum Dunal	Solanaceae					NA					G			
Solanum rigescens Jacq.	Solanaceae	DG		FN		NA					G	I		
*Solanum sisymbriifolium Lam.**	Solanaceae	DG										I	P	R
Solanum supinum Dunal var. supinum	Solanaceae	DG	FF			NA			W	T	G	I		
*Solanum tuberosum L.**	Solanaceae	DG								T	G	I	P	R
*Solanum wendlandii Hook.f**	Solanaceae	DG												R
*Solanum wrightii Benth.**	Solanaceae	DG											P	
*Soleirolia soleirolii (Req.) Dandy**	Urticaceae	DG												R
*Solidago canadensis L.**	Asteraceae	DG									G	I	P	
*Solidago virgaurea L.**	Asteraceae	DG										I	P	
*Sonchus asper (L.) Hill subsp. asper**	Asteraceae	DG	FF	FN	IG	NA	RV	S			G	I	P	R
Sonchus dregeanus DC.	Asteraceae	DG	FF	FN	IG	NA	RV	S				I	P	R
Sonchus nanus Sond. ex Harv.	Asteraceae			FN		NA	RV	S						R
*Sonchus oleraceus L.**	Asteraceae	DG		FN			RV	S			G	I	P	R
Sonchus wilmsii R.E.Fr.	Asteraceae			FN		NA		S					P	R
*Sophora japonica L.**	Fabaceae	DG										I		
Sorghum bicolor (L.) Moench subsp. arundinaceum (Desv.) de Wet & Harlan	Poaceae	DG									G	I	P	

Sorghum bicolor (L.) Moench subsp. bicolor	Poaceae	DG								T	G			R
*Sorghum halepense (L.) Pers.**	Poaceae		FF	FN		NA	RV					I	P	R
*Spartium junceum L.**	Fabaceae	DG											P	R
*Spathiphyllum x hybridum N.E.Br.**	Araceae	DG											P	R
*Sphagneticola trilobata (L.) Pruski**	Asteraceae	DG									G			R
Sphenostylis angustifolia Sond.	Fabaceae			FN		NA						I		R
*Spinacea oleracea L.**	Chenopodiaceae	DG										I	P	R
*Spiraea cantoniensis Lour.**	Rosaceae	DG										I	P	R
Spiraea japonica L.f.	Rosaceae	DG												R
*Spiraea x arguta Zabel**	Rosaceae	DG											P	R
Sporobolus africanus (Poir.) A.Robyns & Tournay	Poaceae	DG		FN	IG		RV	S	W		G	I	P	R
Sporobolus fimbriatus (Trin.) Nees	Poaceae	DG	FF			NA			W	T	G	I	P	
Sporobolus pectinatus Hack.	Poaceae			FN		NA								R
Sporobolus stapfianus Gand.	Poaceae					NA								R
*Sprekelia formosissima (L.) Herb.**	Amaryllidaceae	DG								T		I	P	R
*Stachys byzantina K.Koch.**	Lamiaceae	DG											P	R
Stachys hyssopoides Burch. ex Benth.	Lamiaceae					NA						I		
Stachys linearis Burch. ex Benth.	Lamiaceae	DG									G			
Stachys spathulata Burch. ex Benth.	Lamiaceae	DG				NA	RV		W	T	G		P	
Stangeria eriopus (Kunze) Baill.	Stangeriaceae	DG												R
Stapelia gigantea N.E.Br.	Apocynaceae	DG								T	G			R
Stapelia grandiflora Masson	Apocynaceae	DG												R
Stapelia leendertziae N.E.Br.	Apocynaceae	DG											P	R
*Stellaria media (L.) Vill.**	Caryophyllaceae	DG										I	P	R
*Stenocactus multicostatus A.Berger**	Cactaceae	DG												R
Stenotaphrum secundatum (Walter) Kuntze	Poaceae						RV	S						R

*Stephanotis floribunda Brongn.**	Apocynaceae	DG												R
Stipagrostis uniplumis (Licht.) De Winter	Poaceae					NA				T				
Stomatostemma monteiroae (Oliv.) N.E.Br.	Apocynaceae					NA				T				
Strelitzia alba (L.f.) Skeels	Strelitziaceae	DG											P	R
Strelitzia nicolai Regel & Körn	Strelitziaceae	DG											P	R
Strelitzia reginae Aiton	Strelitziaceae	DG											P	R
Striga asiatica (L.) Kuntze	Orobanchaceae			FN		NA						I		R
Striga bilabiata (Thunb.) Kuntze subsp. Bilabiata	Orobanchaceae					NA						I		
Striga elegans Benth.	Orobanchaceae			FN		NA								R
Striga gesnerioides (Willd.) Vatke ex Engl.	Orobanchaceae			FN		NA								R
*Strongylodon macrobotrys A.Gray**	Fabaceae	DG												R
*Styphnolobium japonicum (L.) Schott**	Fabaceae	DG								T	G		P	
Sutera caerulea (L.f.) Hiern	Scrophulariaceae			FN		NA								R
Sutera levis Hiern	Scrophulariaceae					NA								R
*Syagrus romanzoffiana (Cham.) Glassman**	Arecaceae	DG												R
*Symphytum officinale L.**	Boraginaceae	DG											P	R
*Syngonium podophyllum Schott**	Araceae	DG								T	G	I	P	
Syzygium cordatum Hochst. ex C.Krauss	Myrtaceae	DG												R
*Syzygium eugenioides (Merr. & L.M. Perry) Biffin & Craven**	Myrtaceae	DG												R
*Syzygium luehmannii (F.Muell.) L.A.S.Johnson**	Myrtaceae	DG												R
*Syzygium paniculatum Gaertn.**	Myrtaceae	DG											P	R
*Syzygium smithii (Poir.) Nied**	Myrtaceae	DG												R
*Tagetes erecta L.**	Asteraceae	DG		FN						T	G	I	P	R
*Tagetes minuta L.**	Asteraceae	DG	FF	FN		NA	RV	S	W		G	I	P	R
*Tagetes patula L.**	Asteraceae	DG								T	G	I	P	R
Talinum arnotii Hook.f.	Portulacaceae	DG	FF			NA					G	I		

Talinum caffrum (Thunb.) Eckl. & Zeyh.	Portulacaceae	DG	FF	FN		NA	RV	S	W	T		I	P	R
Talinum crispatulum Dinter ex Poelln.	Portulacaceae	DG	FF			NA				T	G			
*Talinum portulacifolium (Forssk.) Asch. ex Schweinf.**	Portulacaceae	DG											P	R
*Tamarix ramosissima Ledeb.**	Tamaricaceae	DG									G		P	R
*Tanacetum parthenium (L.) Sch.Bip.**	Asteraceae	DG											P	
*Taraxacum officinale Weber**	Asteraceae	DG		FN	IG	NA	RV	S				I	P	R
Tarchonanthus camphoratus L.	Asteraceae	DG	FF	FN		NA			W	T	G			
Tecoma capensis (Thunb.) Lindl.	Bignoniaceae	DG									G		P	R
*Tecoma stans (L.) Juss. ex Kunth**	Bignoniaceae	DG								T				R
*Tephrocactus articulatus (Otto) Backeb.**	Cactaceae	DG												R
Tephrosia burchellii Burtt Davy	Fabaceae	DG	FF	FN		NA			W	T	G			
Tephrosia elongata E.Mey. var. elongata	Fabaceae					NA						I		R
Tephrosia longipes Meisn. subsp. longipes var. longipes	Fabaceae			FN		NA		S				I	P	R
Tephrosia lupinifolia DC.	Fabaceae	DG	FF	FN							G			R
Tephrosia purpurea (L.) Pers. subsp. leptostachya (DC.) Brummitt	Fabaceae		FF	FN		NA						I	P	R
Terminalia sericea Burch. ex DC.	Combretaceae	DG				NA				T	G			
Tetradenia brevispicata (N.E.Br.) Codd	Lamiaceae						RV						P	
Tetradenia riparia (Hochst.) Codd	Lamiaceae	DG												R
*Teucrium botrys L.**	Lamiaceae	DG								T				
Teucrium trifidum Retz.	Lamiaceae	DG				NA			W		G	I		
Thamnochortus pellucidus Pillans	Restionaceae	DG												R
Themeda triandra Forssk.	Poaceae		FF	FN	IG	NA	RV	S			G	I	P	R
Thesium utile A.W.Hill	Santalaceae		FF	FN		NA	RV				G	I	P	R
*Thomasia macrocarpa Endl.**	Malvaceae	DG												R
*Thryptomene saxicola (A.Cunn. ex Hook.) Schauer.**	Myrtaceae	DG												R
*Thuja occidentalis L.**	Cupressaceae	DG											P	R

Thunbergia alata Sims	Acanthaceae	DG											P	R
*Thymus vulgaris L.**	Lamiaceae	DG											P	R
*Thymus x citriodorus (Pers.) Schreb.**	Lamiaceae	DG												R
*Tigridia pavonia (L.f.) DC.**	Iridaceae	DG												R
*Tillandsia cyanea Linden ex K. Koch**	Bromeliaceae	DG												R
*Tillandsia tenuifolia L.**	Bromeliaceae	DG											P	R
*Tillandsia usneoides (L.) L.**	Bromeliaceae	DG												R
*Tipuana tipu (Benth.) Kuntze**	Fabaceae	DG					RV				G		P	R
Titanopsis calcarea (Marloth) Schwantes	Mesembryanthemaceae	DG												R
Tolpis capensis (L.) Sch.Bip.	Asteraceae			FN									P	
*Toona ciliata M.Roem.**	Meliaceae	DG												R
*Trachelospermum jasminoides Lam.**	Apocynaceae	DG										I	P	R
Trachyandra burkei (Baker) Oberm.	Asphodelaceae	DG									G			
Trachyandra laxa (N.E.Br.) Oberm.	Asphodelaceae		FF	FN		NA					G			
Trachyandra saltii (Baker) Oberm.	Asphodelaceae			FN		NA						I	P	
*Trachycarpus fortunei (Hook.) H.Wendl.**	Arecaceae	DG									G	I	P	R
Trachypogon spicatus (L.f.) Kuntze	Poaceae			FN		NA						I		R
*Tradescantia cerinthoides Kunth**	Commelinaceae	DG										I	P	R
*Tradescantia fluminensis Vell.**	Commelinaceae	DG										I	P	R
*Tradescantia pallida (Rose) D.R.Hunt**	Commelinaceae	DG								T	G	I	P	R
*Tradescantia sillamontana Matuda**	Commelinaceae	DG										I	P	R
*Tradescantia spathacea Sw.**	Commelinaceae	DG											P	
*Tradescantia virginiana L.**	Commelinaceae	DG											P	
*Tradescantia zebrina Bosse**	Commelinaceae	DG								T				R
Tragia rupestris Sond.	Euphorbiaceae					NA						I		
*Tragopogon dubius Scop.**	Asteraceae	DG	FF	FN		NA	RV					I	P	R

Tragus berteronianus Schult.	Poaceae	DG	FF	FN		NA	RV	S			G	I	P	
Tragus koelerioides Asch.	Poaceae	DG			IG	NA			W	T	G			
Tragus racemosus (L.) All.	Poaceae	DG	FF	FN		NA			W	T	G			
Tribulus terrestris L.	Zygophyllaceae	DG		FN	IG	NA	RV	S	W	T	G	I	P	R
Trichilia emetica Vahl subsp. emetica	Meliaceae	DG												R
Trichoneura grandiglumis (Nees) Ekman	Poaceae		FF			NA					G	I	P	R
*Tridax procumbens L.**	Asteraceae	DG												R
Trifolium africanum Ser.	Fabaceae				IG								P	
*Trifolium repens L.**	Fabaceae	DG		FN	IG	NA	RV	S				I	P	R
Tripteris aghillana DC. var. aghillana	Asteraceae	DG	FF	FN		NA	RV				G	I	P	R
Triraphis andropogonoides (Steud.) E.Phillips	Poaceae	DG				NA						I		R
Tristachya leucothrix Nees	Poaceae			FN										R
Tristachya rehmannii Hack.	Poaceae			FN		NA								R
Triumfetta sonderi Ficalho & Hiern	Tiliaceae					NA						I		
Trochomeria species [LYM11]	Cucurbitaceae					NA				T				
*Tropaeolum majus L.**	Tropaeolaceae	DG									G	I	P	R
Tulbaghia acutiloba Harv.	Alliaceae	DG										I		
Tulbaghia natalensis Baker	Alliaceae	DG								T				
Tulbaghia simmleri P.Beauv.	Alliaceae	DG								T	G	I	P	R
Tulbaghia violacea Harv.	Alliaceae	DG								T		I	P	R
Typha capensis (Rohrb.) N.E.Br.	Typhaceae	DG					RV						P	R
*Ulmus parvifolia Jacq.**	Ulmaceae	DG		FN			RV	S				I	P	R
*Ulmus procera Salisb.**	Ulmaceae	DG											P	
Urelytrum agropyroides (Hack.) Hack.	Poaceae			FN		NA								R
Urochloa brachyura (Hack.) Stapf	Poaceae			FN		NA	RV	S				I		R
Urochloa mosambicensis (Hack.) Dandy	Poaceae	DG	FF	FN	IG	NA	RV	S	W	T	G	I	P	R

Urochloa panicoides P. Beauv.	Poaceae	DG	FF	FN	IG	NA	RV	S	W	T	G	I	P	R
Ursinia chrysanthemoides (Less.) Harv.	Asteraceae	DG											P	
Ursinia nana DC. subsp. nana	Asteraceae					NA								R
*Urtica urens L.**	Urticaceae	DG										I	P	R
Vachellia erioloba (E.Mey.) Seigler & Ebinger	Fabaceae	DG	FF	FN		NA	RV			T	G		P	R
Vachellia grandicornuta (Gerstner) Seigler & Ebinger	Fabaceae	DG												R
Vachellia hebeclada (DC.) Kyal. & Boatwr. subsp. hebeclada	Fabaceae	DG	FF	FN		NA	RV		W	T	G	I		
Vachellia karroo (Hayne) Banfi & Galasso	Fabaceae	DG	FF	FN	IG	NA	RV	S	W	T	G	I	P	R
Vachellia robusta (Burch.) Kyal. & Boatwr.	Fabaceae	DG				NA				T		I		R
Vachellia sieberiana (DC.) Ali	Fabaceae	DG		FN										R
Vachellia tortilis (Forssk.) Galasso & Banfi	Fabaceae	DG		FN		NA			W	T	G			
Vachellia xanthophloea (Benth.) P.J.H.Hurter	Fabaceae	DG												R
Vahlia capensis (L.f.) Thunb.	Vahliaceae	DG		FN		NA			W	T	G			R
Vangueria infausta Burch. subsp. Infausta	Rubiaceae					NA								R
Vangueria parvifolia Sond.	Rubiaceae	DG												R
Veltheimia bracteata Harv. ex Baker	Hyacinthaceae	DG												R
*Verbascum thapsus L.**	Scrophulariaceae	DG											P	
*Verbena aristigera S.Moore**	Verbenaceae	DG	FF	FN		NA	RV	S		T	G	I	P	R
*Verbena bonariensis L.**	Verbenaceae	DG	FF	FN		NA	RV	S	W		G	I	P	R
*Verbena brasiliensis Vell.**	Verbenaceae						RV		W	T				R
*Verbena canadensis Britton**	Verbenaceae	DG												R
*Verbena hybrida Groenland & Rümpler**	Verbenaceae	DG								T	G		P	R
*Verbena officinalis L.**	Verbenaceae		FF	FN	IG	NA	RV	S				I	P	R
*Verbena peruviana (L.) Britton**	Verbenaceae	DG												R
*Verbesina encelioides (Cav.) Benth. & Hook. var. encelioides**	Asteraceae	DG	FF	FN	IG	NA			W	T	G		P	
Vernonia galpinii Klatt	Asteraceae			FN		NA						I		R

Vernonia natalensis Oliv. & Hiern	Asteraceae			FN		NA								R
Vernonia oligocephala (DC.) Sch.Bip. ex Walp.	Asteraceae			FN		NA						I	P	R
Vernonia poskeana Vatke & Hildebr. subsp. botswanica G.V.Pope	Asteraceae	DG	FF	FN		NA				T	G			R
*Veronica persica Desf. ex Poir.**	Scrophulariaceae	DG											P	R
*Viburnum odoratissimum Ker Gawl.**	Adoxaceae	DG						S				I	P	R
Viburnum opulus L.	Adoxaceae	DG												R
*Viburnum suspensum Lindl.**	Adoxaceae	DG											P	R
*Viburnum tinus L.**	Adoxaceae	DG										I	P	R
*Vigna caracalla (L.) Verdc.**	Fabaceae	DG												R
Vigna unguiculata (L.) Walp.	Fabaceae	DG								T	G		P	
Vigna vexillata (L.) A.Rich. var. vexillata	Fabaceae						RV							R
*Villadia batesii (Hemsl.) Baehni & Macbride**	Crassulaceae	DG												R
*Vinca major L.**	Apocynaceae	DG									G	I	P	R
*Vinca minor L.**	Apocynaceae	DG												R
*Viola hederacea Labill.**	Violaceae	DG												R
*Viola odorata L.**	Violaceae	DG						S			G	I	P	R
*Viola tricolor L.**	Violaceae	DG										I	P	R
*Viola x wittrockiana Gams ex Nauenb. & Buttler**	Violaceae	DG										I	P	R
Virgilia oroboides (P.J.Bergius) T.M.Salter subsp. oroboides	Fabaceae	DG												R
*Vitex agnus–castus L.**	Lamiaceae	DG		FN									P	R
*Vitex trifolia L.**	Lamiaceae	DG								T				R
*Vitis vinifera L.**	Vitaceae	DG								T	G	I	P	R
Wahlenbergia banksiana A.DC.	Campanulaceae		FF			NA			W		G			
Wahlenbergia undulata (L.f.) A.DC.	Campanulaceae	DG	FF	FN		NA	RV		W	T		I	P	R
Waltheria indica L.	Sterculiaceae					NA					G			

*Washingtonia filifera (Linden. ex André) H.Wendl.**	Arecaceae	DG									I	P	R
Watsonia angusta Ker Gawl.	Iridaceae	DG											R
*Watsonia x hybrida**	Iridaceae	DG											R
*Weigela florida (Bunge.) A.DC.**	Caprifoliaceae	DG										P	R
*Wisteria floribunda (Willd.) DC.**	Fabaceae	DG										P	
*Wisteria sinensis (Sims) DC.**	Fabaceae	DG							T	G		P	R
Withania somnifera (L.) Dunal	Solanaceae					NA							R
*x Fatshedera lizei (hort. ex Cochet) Guillaumin**	Araliaceae	DG										P	R
x Ruttyruspolia A. Meeuse & de Wet	Acanthaceae	DG											R
*Xanthium spinosum L.**	Asteraceae	DG			IG		RV	W	T	G	I	P	
*Xanthium strumarium L.**	Asteraceae	DG	FF	FN	IG	NA	RV	W	T	G		P	R
Xenostegia tridentata (L.) D.F.Austin & Staples subsp. angustifolia (Jacq.) Lejoly & Lisowski	Convolvulaceae					NA					I	P	
Xerophyta retinervis Baker	Tecophilaeaceae					NA							R
Xysmalobium undulatum (L.) Aiton f.	Apocynaceae					NA					I		
*Yucca aloifolia L.**	Agavaceae	DG							T		I	P	R
*Yucca elephantipes Regel ex Trel.**	Agavaceae	DG											R
*Yucca filamentosa L.**	Agavaceae	DG										P	R
*Yucca gloriosa L.**	Agavaceae	DG					RV			G		P	R
Zaleya pentandra (L.) C.Jeffrey	Aizoaceae	DG								G			
Zantedeschia aethiopica (L.) Spreng.	Araceae	DG								G	I	P	R
Zantedeschia elliottiana (W.Watson) Engl.	Araceae	DG										P	R
Zantedeschia pentlandii (R.Whyte ex W.Watson) Wittm.	Araceae	DG									I	P	R
Zanthoxylum capense (Thunb.) Harv.	Rutaceae	DG				NA					I		R
*Zea mays L.**	Poaceae	DG							T	G	I	P	R
*Zelkova serrata (Thunb.) Makino**	Ulmaceae	DG										P	

*Zephyranthes grandiflora Lindl.**	Amaryllidaceae	DG								T	G	I	P	R
*Zingiber officinale Rosc.**	Zingiberaceae	DG												R
*Zinnia elegans Jacq.**	Asteraceae	DG								T	G	I	P	R
*Zinnia peruviana (L.) L.**	Asteraceae	DG		FN		NA			W	T	G	I	P	R
Ziziphus mucronata Willd. subsp. mucronata	Rhamnaceae	DG		FN		NA	RV		W	T	G			R
Ziziphus rivularis Codd	Rhamnaceae	DG												R
Ziziphus zeyheriana Sond.	Rhamnaceae	DG		FN		NA	RV		W	T	G	I	P	R
Zornia linearis E.Mey.	Fabaceae	DG	FF	FN		NA					G	I		R
Zornia milneana Mohlenbr.	Fabaceae	DG	FF	FN		NA	RV			T	G	I		R

Annexure B – SIMPER results

Results of the SIMPER analyses as discussed in Chapter 4.

Table B.1: Results for SIMPER analyses indicating the top twenty species responsible for groupings of the domestic gardens and natural areas in the NMS graph (Figure 4.3).

Species	**Type**	**Ave. diss.**	**% Contrib.**	**Cumul. %**	**Ave. abund.: NA**	**Ave. abund.: DG**
Pennisetum clandestinum	Grass	5.56	5.82	5.82	0.01	21.4
Cynodon dactylon	Grass	4.2	4.39	10.21	10.31	12.39
Schmidtia pappophoroides	Grass	3.53	3.7	13.91	12.89	0.13
Themeda triandra	Grass	2.02	2.11	16.02	7.97	0
Felicia muricata **subsp**. *muricata*	Forb	1.95	2.04	18.06	7.07	1.16
Dichondra micrantha	Forb	1.88	1.96	20.03	0	7.6
Eragrostis lehmanniana **var**. *lehmanniana*	Grass	1.81	1.9	21.92	4.89	3.88
Vachellia hebeclada **subsp**. *hebeclada*	Shrub	1.58	1.66	23.58	5.86	0.23
Aristida diffusa **subsp**. *burkei*	Grass	1.58	1.65	25.23	5.69	0.05
Aristida congesta **subsp**. *congesta*	Grass	1.49	1.56	26.79	5.51	0.34
Eragrostis trichophora	Grass	1.3	1.36	28.15	4.59	0.74
Tragus koelerioides	Grass	1.25	1.3	29.46	4.38	0.26
Digitaria eriantha	Grass	1.14	1.19	30.64	4.17	0.1
Elephantorrhiza elephantine	Shrub	1.08	1.13	31.77	4.19	0.01
Aloe greatheadii **var**. *davyana*	Succul ent	1.06	1.11	32.88	4.12	0.06
Bulbine abyssinica	Geoph yte	0.98	1.03	33.9	3.34	0.5
Guilleminea densa	Forb	0.92	0.96	34.86	0.61	3.32
Schkuhria pinnata	Forb	0.83	0.87	35.74	1.51	1.93
Ziziphus zeyheriana	Tree	0.8	0.84	36.58	3.28	0
Diospyros lycioides **subsp**. *lycioides*	Shrub	0.76	0.79	37.37	3.03	0.05

Key to column headings: Ave. dis: Average dissimilarity; % Contrib.: Percentage contribution of each species to the average dissimilarity; Cumul. %: Cumulative contribution percentage; Abund.: mean abundance per sample plot; NA: Natural area; DG: Domestic garden.

Table B.2: Results for SIMPER analyses indicating the top ten species responsible for the groupings of the different settlements, based on the sample plot data of the domestic gardens, in the NMS graph (Figure 4.9).

Species	**Type**	**Ave. dis.**	**% Contrib.**	**Cumul. %**	**Ave. abund.: T**	**Ave. abund.: G**
Cynodon dactylon	Grass	2.49	3.16	3.16	4.61	3.4
Portulaca quadrifida	Succulent	1.65	2.09	5.25	1.98	0.85
Eragrostis lehmanniana **var**. *lehmanniana*	Grass	1.59	2.01	7.26	2.04	1.67
Schkuhria pinnata	Forb	1.48	1.88	9.14	1.64	1.45
Dodonaea viscosa **var**. *angustifolia*	Tree	1.46	1.85	10.99	1.64	0
Zea mays	Grass	1.38	1.75	12.74	1.45	0.49
Mollugo cerviana **var**. *cerviana*	Forb	1.34	1.69	14.44	1.02	1.76
Guilleminea densa	Forb	1.28	1.62	16.05	2.11	1.37
Felicia muricata **subsp**. *muricata*	Forb	1.19	1.51	17.57	1.38	0.91
Portulaca oleracea	Succulent	1.13	1.43	19	1.26	0.46
	Type	**Ave. dis.**	**% Contrib.**	**Cumul. %**	**Ave. abund.: T**	**Ave. abund.: I**
Pennisetum clandestinum	Grass	5.02	5.7	5.7	0.22	5.84
Cynodon dactylon	Grass	2.51	2.85	8.54	4.61	2.38
Portulaca quadrifida	Succulent	1.79	2.03	10.57	1.98	0
Eragrostis lehmanniana **var**. *lehmanniana*	Grass	1.52	1.72	12.29	2.04	1.84
Schkuhria pinnata	Forb	1.46	1.65	13.95	1.64	0
Guilleminea densa	Forb	1.43	1.62	15.57	2.11	1.75
Dodonaea viscosa **var**. *angustifolia*	Tree	1.43	1.62	17.19	1.64	0
Zea mays	Grass	1.23	1.39	18.58	1.45	0.02
Felicia muricata **subsp**. *muricata*	Forb	1.21	1.38	19.96	1.38	0.04
Cynodon hirsutus	Grass	1.21	1.38	21.33	0	1.39
	Type	**Ave. dis.**	**% Contrib.**	**Cumul. %**	**Ave. abund.: G**	**Ave. abund.: I**
Pennisetum clandestinum	Grass	6.57	7.52	7.52	0.63	5.84
Cynodon dactylon	Grass	3.05	3.49	11.02	3.4	2.38
Eragrostis lehmanniana **var**. *lehmanniana*	Grass	2.23	2.55	13.57	1.67	1.84
Mollugo cerviana **var**.	Forb	2.17	2.48	16.05	1.76	0

cerviana						
Guilleminea densa	Forb	1.94	2.22	18.27	1.37	1.75
Cynodon hirsutus	Grass	1.87	2.14	20.42	0.68	1.39
Euphorbia prostrata	Forb	1.71	1.95	22.37	0.51	1.37
Schkuhria pinnata	Forb	1.61	1.84	24.21	1.45	0
Portulaca kermesina	Succulent	1.55	1.78	25.99	0.41	1.22
Urochloa panicoides	Grass	1.5	1.72	27.71	0.25	1.29
	Type	**Ave. dis.**	**% Contrib.**	**Cumul. %**	**Ave. abund.: T**	**Ave. abund.: P**
Pennisetum clandestinum	Grass	4.66	4.98	4.98	0.22	5.99
Dichondra micrantha	Forb	3.96	4.23	9.22	0	4.93
Cynodon dactylon	Grass	2.4	2.57	11.79	4.61	2.15
Poa annua	Grass	1.67	1.79	13.58	0.02	2.06
Oxalis corniculata	Forb	1.64	1.76	15.33	0	2.05
Portulaca quadrifida	Succulent	1.62	1.73	17.07	1.98	0
Eragrostis lehmanniana **var**. *lehmanniana*	Grass	1.6	1.71	18.78	2.04	0.32
Guilleminea densa	Forb	1.51	1.62	20.39	2.11	0.66
Schkuhria pinnata	Forb	1.32	1.41	21.81	1.64	0
Dodonaea viscosa **var**. *angustifolia*	Tree	1.3	1.39	23.19	1.64	0
	Type	**Ave. dis.**	**% Contrib.**	**Cumul. %**	**Ave. abund.: G**	**Ave. abund.: P**
Pennisetum clandestinum	Grass	5.86	6.33	6.33	0.63	5.99
Dichondra micrantha	Forb	5.27	5.7	12.04	0	4.93
Cynodon dactylon	Grass	2.72	2.95	14.98	3.4	2.15
Poa annua	Grass	2.24	2.42	17.4	0.1	2.06
Oxalis corniculata	Forb	2.09	2.26	19.67	0.14	2.05
Mollugo cerviana **var**. *cerviana*	Forb	1.89	2.04	21.71	1.76	0
Eragrostis lehmanniana **var**. *lehmanniana*	Grass	1.69	1.83	23.53	1.67	0.32
Cynodon hirsutus	Grass	1.54	1.66	25.19	0.68	1.25
Guilleminea densa	Forb	1.43	1.54	26.74	1.37	0.66
Schkuhria pinnata	Forb	1.42	1.53	28.27	1.45	0
	Type	**Ave. dis.**	**% Contrib.**	**Cumul. %**	**Ave. abund.: I**	**Ave. abund.: P**
Dichondra micrantha	Forb	4.6	6.07	6.07	0.58	4.93
Poa annua	Grass	2.17	2.87	8.94	0.02	2.06
Pennisetum clandestinum	Grass	2.11	2.78	11.72	5.84	5.99
Cynodon dactylon	Grass	2.07	2.73	14.45	2.38	2.15

Oxalis corniculata	Forb	1.98	2.62	17.07	0.33	2.05
Eragrostis lehmanniana **var**. *lehmanniana*	Grass	1.86	2.45	19.52	1.84	0.32
Guilleminea densa	Forb	1.77	2.34	21.86	1.75	0.66
Cynodon hirsutus	Grass	1.72	2.27	24.13	1.39	1.25
Urochloa panicoides	Grass	1.44	1.9	26.03	1.29	0.82
Euphorbia prostrata	Forb	1.37	1.81	27.84	1.37	1.06
	Type	**Ave. dis.**	**% Contrib.**	**Cumul. %**	**Ave. abund.: T**	**Ave. abund.: R**
Pennisetum clandestinum	Grass	3.34	3.51	3.51	0.22	5.2
Cynodon dactylon	Grass	2.23	2.35	5.86	4.61	1.39
Dichondra micrantha	Forb	1.78	1.87	7.73	0	2.67
Eragrostis lehmanniana **var**. *lehmanniana*	Grass	1.36	1.43	9.16	2.04	0
Guilleminea densa	Forb	1.34	1.4	10.57	2.11	0.16
Portulaca quadrifida	Succulent	1.33	1.4	11.97	1.98	0
Agapanthus praecox **subsp**. *orientalis*	Geophyte	1.26	1.32	13.29	0.02	1.91
Chlorophytum comosum	Forb	1.18	1.24	14.53	0.08	1.83
Oxalis corniculata	Forb	1.13	1.19	15.72	0	1.68
Schkuhria pinnata	Forb	1.09	1.14	16.86	1.64	0
	Type	**Ave. dis.**	**% Contrib.**	**Cumul. %**	**Ave. abund.: G**	**Ave. abund.: R**
Pennisetum clandestinum	Grass	3.98	4.16	4.16	0.63	5.2
Dichondra micrantha	Forb	2.25	2.35	6.5	0	2.67
Cynodon dactylon	Grass	2.14	2.23	8.73	3.4	1.39
Agapanthus praecox **subsp**. *orientalis*	Geophyte	1.59	1.66	10.39	0	1.91
Chlorophytum comosum	Forb	1.51	1.58	11.97	0	1.83
Mollugo cerviana **var**. *cerviana*	Forb	1.47	1.53	13.5	1.76	0
Oxalis corniculata	Forb	1.36	1.42	14.92	0.14	1.68
Eragrostis lehmanniana **var**. *lehmanniana*	Grass	1.3	1.36	16.28	1.67	0
Schkuhria pinnata	Forb	1.13	1.18	17.46	1.45	0
Guilleminea densa	Forb	1.06	1.11	18.57	1.37	0.16
	Type	**Ave. dis.**	**% Contrib.**	**Cumul. %**	**Ave. abund.: I**	**Ave. abund.: R**
Dichondra micrantha	Forb	2.05	2.36	2.36	0.58	2.67
Pennisetum clandestinum	Grass	1.55	1.79	4.14	5.84	5.2
Agapanthus praecox **subsp**.	Geophyte	1.5	1.73	5.87	0.14	1.91

orientalis						
Cynodon dactylon	Grass	1.47	1.69	7.56	2.38	1.39
Eragrostis lehmanniana **var**. *lehmanniana*	Grass	1.46	1.68	9.24	1.84	0
Chlorophytum comosum	Forb	1.41	1.62	10.87	0.3	1.83
Guilleminea densa	Forb	1.37	1.57	12.44	1.75	0.16
Oxalis corniculata	Forb	1.31	1.51	13.95	0.33	1.68
Euphorbia prostrata	Forb	1.12	1.29	15.24	1.37	0.02
Cynodon hirsutus	Grass	1.12	1.29	16.53	1.39	0
	Type	**Ave. dis.**	**% Contrib.**	**Cumul. %**	**Ave. abund.: P**	**Ave. abund.: R**
Dichondra micrantha	Forb	2.05	2.64	2.64	4.93	2.67
Pennisetum clandestinum	Grass	1.49	1.93	4.57	5.99	5.2
Poa annua	Grass	1.31	1.69	6.26	2.06	1.06
Cynodon dactylon	Grass	1.31	1.69	7.95	2.15	1.39
Chlorophytum comosum	Forb	1.24	1.61	9.56	1.21	1.83
Agapanthus praecox **subsp**. *orientalis*	Geophyte	1.17	1.5	11.06	0.84	1.91
Oxalis corniculata	Forb	1.04	1.34	12.4	2.05	1.68
Cynodon hirsutus	Grass	0.91	1.17	13.58	1.25	0
Hedera helix	Climber	0.9	1.16	14.73	0.49	1.12
Rosa chinensis	Shrub	0.88	1.13	15.86	0	1.19

Key to column headings: Ave. dis: Average dissimilarity; % Contrib.: Percentage contribution of each species to the average dissimilarity; Cumul. %: Cumulative contribution percentage; Abund.: mean abundance per sample plot; T: Tlhakgameng; G: Ganyesa; I: Ikageng; P: Potchefstroom; R: Roodepoort.

Annexure C – One-way ANOVA's and Tukey test results

Additional results of the One-way ANOVA's and Tukey tests as described in Chapter 4.

Table C.1: Tukey's HSD test for unequal sample size results of the Margalef's species richness values for all the studied LUT (domestic gardens (DG), fallow fields (FF), fragmented natural areas (FN), institutional gardens (IG), natural areas (NA), road verges (RV), sidewalks (S) and wetlands (W)). Marked differences (bold) are significant at $p < 0.05$.

	DG	FF	FN	IG	NA	RV	S
FF	**0.000366**						
FN	0.999940	**0.001720**					
IG	**0.000162**	0.771655	**0.000461**				
NA	0.581155	**0.000035**	0.888617	**0.000037**			
RV	0.246965	0.629458	0.459978	0.083877	**0.025240**		
S	**0.000051**	1.000000	**0.000538**	0.814789	**0.000032**	0.554728	
W	0.278409	0.974199	0.452343	0.209847	0.051999	0.999892	0.959313

Table C.2: Tukey's HSD test for unequal sample size results of the Pielou's evenness values for all the studied LUT (see Table C.1 for list of abbreviations). Marked differences (bold) are significant at $p < 0.05$.

	DG	FF	FN	IG	NA	RV	S
FF	**0.002046**						
FN	0.950726	0.080706					
IG	**0.000032**	**0.019808**	**0.000035**				
NA	0.224970	**0.000039**	0.260641	**0.000032**			
RV	**0.010478**	0.999996	0.205846	**0.010369**	**0.000117**		
S	**0.000083**	0.999968	**0.018707**	**0.042561**	**0.000032**	0.998875	
W	0.448109	0.979420	0.925800	**0.000735**	0.062349	0.995282	0.922316

Table C.3: Tukey's HSD test for unequal sample size results of the Shannon's diversity index values for all the studied LUT (see Table C.1 for list of abbreviations). Marked differences (bold) are significant at $p < 0.05$.

	DG	FF	FN	IG	NA	RV	S
FF	**0.000767**						
FN	1.000000	**0.000454**					
IG	**0.000032**	**0.039969**	**0.000032**				
NA	**0.000136**	**0.000032**	0.349453	**0.000032**			
RV	0.191153	0.809813	0.145317	**0.000780**	**0.000114**		
S	**0.000037**	0.999663	**0.000045**	0.104673	**0.000032**	0.498671	
W	0.623775	0.857225	0.557673	**0.000357**	**0.010723**	0.999999	0.631644

Table C.4: Tukey's HSD test for unequal sample size results of the Simpson's diversity index values for all the studied LUT (see Table C.1 for list of abbreviations). Marked differences (bold) are significant at p < 0.05.

	DG	FF	FN	IG	NA	RV	S
FF	0.183592						
FN	0.999361	**0.046233**					
IG	**0.000032**	**0.000062**	**0.000032**				
NA	**0.000043**	**0.000048**	0.481552	**0.000032**			
RV	0.665892	0.997332	0.327929	**0.000034**	**0.001184**		
S	**0.005288**	0.992074	**0.001419**	**0.000493**	**0.000032**	0.822246	
W	0.998255	0.903904	0.966987	**0.000032**	0.188558	0.995827	0.541637

Table C.5: One-way ANOVA results between the four diversity indices and the LUT sampled in Tlhakgameng (see Table C.1 for list of abbreviations). Marked differences (bold) are significant at p < 0.05.

	One way ANOVA		Post hoc Tukey Unequal N HSD
Margalef's species richness	$F_{(3,114)} = 50.55$	$p < 0.0001$	DG differs from FF, NA & W
Pielou's evenness	$F_{(3,114)} = 34.84$	$p < 0.0001$	DG differs from FF, NA & W FF differs from NA
Shannon's	$F_{(3,114)} = 60.02$	$p < 0.0001$	DG differs from FF, NA & W FF differs from NA
Simpson's index	$F_{(3,114)} = 34.76$	$p < 0.0001$	DG differs from FF, NA & W FF differs from DG, NA & W

Table C.6: One-way ANOVA results between the four diversity indices and the LUT sampled in Ganyesa (see Table C.1 for list of abbreviations). Marked differences (bold) are significant at p < 0.05.

	One way ANOVA		Post hoc Tukey Unequal N HSD
Margalef's species richness	$F_{(6,134)} = 14.99$	$p < 0.0001$	IG differs from FN, NA & W NA differs from DG, IG & FF
Pielou's evenness	$F_{(6,134)} = 4.36$	$p < 0.0001$	IG differs from NA
Shannon's	$F_{(6,134)} = 15.76$	$p < 0.0001$	DG differs from NA IG differs from DG, FF, FN, NA & W
Simpson's index	$F_{(6,134)} = 7.96$	$p < 0.0001$	DG differs from NA IG differs from DG, FF, FN, NA & W

Table C.7: One-way ANOVA results between the four diversity indices and the LUT sampled in Ikageng (see Table C.1 for list of abbreviations). Marked differences (bold) are significant at p < 0.05.

	One way ANOVA		Post hoc Tukey Unequal N HSD
Margalef's species richness	$F_{(2,93)} = 69.70$	$p < 0.0001$	NA differs from DG; NA differs from S
Pielou's evenness	$F_{(2,93)} = 15.07$	$p < 0.0001$	DG differs from NA
Shannon's	$F_{(2,93)} = 64.93$	$p < 0.0001$	NA differs from DG; NA differs from S
Simpson's index	$F_{(2,93)} = 27.39$	$p < 0.0001$	NA differs from DG; NA differs from S

Table C.8: One-way ANOVA results between the four diversity indices and the LUT sampled in Potchefstroom (see Table C.1 for list of abbreviations). Marked differences (bold) are significant at p < 0.05.

	One way ANOVA		Post hoc Tukey Unequal N HSD
Margalef's species richness	$F_{(6,112)}$ **= 7.82**	***p < 0.0001***	IG differs from DG, FF, FN, NA, RV & S
Pielou's evenness	$F_{(6,112)}$ **= 6.38**	***p < 0.0001***	IG differs from DG, FF, FN, NA, RV & S
Shannon's	$F_{(6,112)}$ **= 10.16**	***p < 0.0001***	IG differs from DG, FF, FN, NA, RV & S
Simpson's index	$F_{(6,112)}$ **= 8.17**	***p < 0.0001***	IG differs from DG, FF, FN, NA, RV & S

Table C.9: One-way ANOVA results between the four diversity indices and the LUT sampled in Roodepoort (see Table C.1 for list of abbreviations). Marked differences (bold) are significant at p < 0.05.

	One way ANOVA		Post hoc Tukey Unequal N HSD
Margalef's species richness	$F_{(4,119)}$ **= 50.32**	***p < 0.0001***	R differs from DG, FN & NA S differs from DG, FN & NA
Pielou's evenness	$F_{(4,119)}$ **= 31.04**	***p < 0.0001***	FN differs from NA R differs from DG, FN & NA S differs from DG, FN & NA
Shannon's	$F_{(4,119)}$ **= 53.59**	***p < 0.0001***	FN differs from NA R differs from DG, FN & NA S differs from DG, FN & NA
Simpson's index	$F_{(4,119)}$ **= 36.62**	***p < 0.0001***	R differs from DG, FN & NA S differs from DG, FN & NA

Annexure D – Questionnaire: Ganyesa

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
POTCHEFSTROOM CAMPUS

Q Nr: ____________

GPS: ____________

PLANT DIVERSITY and SES SURVEY:
GANEYSA (Bophirima District, North West Province)

IMPORTANT NOTES TO FIELDWORKERS

- Please **introduce yourself** to the respondent;
- Tell the respondent that you are **doing research** in this area;
- and then ask the respondent if you can ask him/her some questions about their garden/yard (patlelo) and their socio-economic status.

THEN…

- ***Please thank the respondent for his/her participation****;*
- *tell him/her that there are* ***no right or wrong answers*** *to the questions;*
- *and that you are* ***going to write down all the answers*** *to the questions on this questionnaire (remember to write the answer as close as possible to the respondents own wording****, in English****).*

Before starting the interview ***please thank the respondent for his/her participation****; tell him/her that there are* ***no right or wrong answers****; and that you are* ***going to write down all the answers*** *to the questions on this questionnaire (remember to write the answer as close as possible to the respondents own wording****, in English****).*

1. What is a garden the way you understand it?

2. Do you think that it is important to have a garden? (Ask them to please tell you why).

3. Please tell me more about your garden/yard (***Patlelo***)?

4. What is the occupation (work/job), age and gender of the main gardener?

5. Who helps (works) in the garden / yard (***Patlelo***); and list what does each person/s do?

6. What is the age/s and gender of the persons helping in the garden / yard (***Patlelo***)?

7. Why do you grow ornamental flowers (*plants you can't eat or use in any other way*)?

____

____

8. Which of the following activities takes place in your garden / yard (***Patlelo***)?

	√	How often?
Water the garden		
Fertilise the garden		
Weed the garden		
Sweep the garden		
Prune your hedges / trees		
Remove any dead material		
Any method of pest control		

Key to terminology:

- **Watering** the garden refers to watering specific plants with a hosepipe, bucket or any other container that contains a water base fluid;
- **Fertilising** refers to the use of compost (decomposed plant material such as leaves) or manure (the dung of livestock, such as cattle, sheep or chickens) or chemicals and/or granules;
- **Weeding** refers to removing unwanted (alien or problem) plants;
- **Sweeping the garden** refers to sweeping an area around the house that are cleared of vegetation (plants);
- **Pruning** refers to the cutting off unwanted branches, twigs, etc. so that the plant has a distinctive shape;
- **Pest control** refers to applying some action to remove or prevent unwanted insects from destroying vegetation (plants) that are considered a part of the garden.

9. Would young people/children like to learn more about gardening?

(1) Yes	(2) No

10. Would you like to learn more about gardening?

(1) Yes	(2) No

11. How long have you lived on this plot?

(1) 0-2 years	(2) Between 2 and 5 years	(3) 5-10 years	(4) More than 10 years

12. How many people live here on a permanent basis?

____

____

13. How many of the people living here on a permanent basis are males and how many are females, and what are their ages?

Males		**Females**	
How many	Age	How many	Age

14. How many of these people generate an income through part-time work or permanent jobs/work?

____

____

15. Are there persons in your household that are of income earning age (between the ages of 18-60, who can work), but that can't find any work/jobs?

____

____

16. In what type of structure do you live?

Informal house (Zinc structure)	1
Traditional house (Mud structure)	2
Formal house	3

17. How many rooms does your house have?

____

18. Do you own or rent this house?

Rent	1
Own	2

19. Do you have a toilet or sanitation (a place to wash yourself) facility available and where is it?

None	0
Outside your home	1
Inside your home	2

20. Which of the following energy resources do you use to help you to see at night?

Wood fire	1
Candles	2
Paraffin (lamps)	3
Electricity	4
Other	

Please specify other?

____

21. Which of the following energy resources do you use to stay warm when it is cold?

Wood fire	1
Paraffin (heater)	2
Electricity (electrical heater)	3
Other	

Please specify other?

____

22. Which of the following energy resources do you use to cook your food on?

Wood fire	1
Paraffin (stove)	2
Electricity (stove)	3
Other	

Please specify other?

____

23. Where do you get your water from, specifically the water for your own use to drink and to cook your food?

Natural source (River/Stream or Dam/Pan)	1
Communal water tap	2
Water tap in your yard	3
Water tap in your home	4

24. Where do you get the water that you use in your garden?

Natural source (River/Stream or Dam/Pan)	1
Rainwater	2
Communal water tap	3
Borehole/well on property	4
Water tap in your yard	5
Water tap in your home	6

25. How far away is your water source, that you use in your garden?

More than 1 km	1
500m – 1 km	2
100 – 500m	3
Less than 100m	4

26. How do you transport the water you use in your garden if you don't have a tap in your yard?

Carry in buckets	1
Wheelbarrow	2
Donkey car	3
Other	

Please specify other

____

27. Do you buy food or do you produce your own fruit/vegetables?

Produce/grow	1

Buy and grow	2
Buy	3

28. For what reason do you grow your own fruit/vegetables?

For own consumption	1
For own consumption and to sell	2
To sell	3

29. If you grow vegetables, where do you get your vegetables seeds/seedlings from?

Buy	1
Produce	2
Get for free	3

30. Do you use any plants from the veldt (**naga**)?

(1) Yes	(2) No

31. If yes, what do you use these plants for?

____

____

32. Which of the following animals do you own/

Chicken/Geese/Ducks/Turkey	1
Pig	2
Goats/Sheep	3
Donkey	4
Cattle	5

33. What is the highest level of education in your household? Please fill in the number of household members with a specific level of qualification ***(People living here permanently).***

Level of education	Male	Female
(1) None		
(2) Primary school		

(3) Secondary school (excluding Grade 12)		
(4) Grade 12		
(5) A tertiary qualification		

34. How do you earn your money / how do you get your money?

Support from others/family members	1
Piece work/odd jobs (skrop werk)	2
Government grant	3
Informal business	4
Own business	5
Permanent job	6
Other	

Please specify other

____

35. Does any member of your household have access to any of the following modes of transport?

Bicycle	1
Donkey car	2
Own motor car	3

36. What is the combined total monthly income of all the working household members?

R o – 500	1
R 500 – 1000	2
R 1000 – 2000	3
R 2000 – 5000	4
More than R 5000	5

37. On what do you spend <u>most</u> of your money? Please rank in order of expenditure.

(1) Food	
(2) Housing	

(3) Medical expenses	
(4) Transport	
(5) Clothing	
(6) School	
(7) Insurance	
(8) Remittances/support to others elsewhere	
(9) Other	

In case of "other" please specify ____

38. Satisfaction of life scale

Statement	Yes	No
Are you satisfied with your life?		
Are you satisfied with your living conditions?		
Do you have the basic resources needed for you to make a living?		
Do the people in your community support each other and work together?		
My health and the health of my family is good?		

39. How often do you feel happy, calm and peaceful?

Always	Sometimes	Never

40. Do you have someone to turn to in times of stress?

Always	Sometimes	Never

Annexure E – Questionnaire: Tlhakgameng

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
POTCHEFSTROOM CAMPUS

Questionnaire No: ____________

GPS: _______________________

PLANT DIVERSITY, SOCIO-ECONOMIC STATUS AND INDIGENOUS KNOWLEDGE SYSTEM SURVEY:

Tlhakgameng (Bophirima Region, North West Province)

NOTES FOR FIELDWORKERS

The purpose of the study: To gather information about useful plants in home gardens and communal land.

IMPORTANT NOTES TO FIELDWORKERS

- Please **introduce yourself** to the respondent;
- Tell the respondent that you are **involved in research** in the area;
- Inform the respondent about the **purpose of the study**;
- Explain that results from this research will **benefit the community** by helping them to create their own home gardens to sustain their livelihood;
- Obtain permission from the respondent to ask them questions about their garden (*tshimo*) and socio-economic status;
- Assure the respondent that you have **permission** from the traditional leader;
- Tell the respondent that there are **no right or wrong answers** to the questions, and they are not forced to answer any question if they feel offended (they can withdraw at any stage);
- Please **fill in all the answers** (answers must be in English);
- **Thank the respondent** for his/her participation, and ask if another visit in the future would be acceptable.

For inquiries please contact: Lerato Molebatsi
Tel number: 018-299 2505
Cell number: 073 264 6663 / 072 945 9897

1. What do you understand by the term ‘garden’ (*tshimo*)?

2. In your opinion, do you think it‘s important to have a garden/*tshimo*?

3. Do you grow useful* plants in your garden? If so, for what purpose do you use them?

*Food (fruit, grain), medicine, firewood, building material, tools, spiritual, etc.

4. What is the age and gender of the main gardener?

5. List all garden activities that family members take part in relating to gender and age.

Activity	**Gender (male/female)**	**Age**

6. Do you grow ornamental* flowers?

(1) Yes	(2) No

* Ornamental- is a plant grown for its beauty.

7. If yes, why?

____

____

____

____

8. Which of the following activities takes place in your garden/yard (***tshimo***)?

Activity	Mark with X	How often?
Water the garden		
Fertilise the garden		
Weed the garden		
Sweep the garden		
Prune hedges/trees		
Remove dead material		
Pest control		

Key to terminology:

- **Watering** the garden refers to watering specific plants with a hosepipe, bucket or any other container that contains a water base fluid;
- **Fertilising** refers to the use of compost (decomposed plant material such as leaves) or manure (the dung of livestock, such as cattle, sheep or chickens) or chemicals and/or granules;
- **Weeding** refers to removing unwanted (alien or problem) plants;
- **Sweeping the garden** refers to sweeping an area around the house that are cleared of vegetation (plants);
- **Pruning** refers to the cutting off unwanted branches, twigs, etc. so that the plant has a distinctive shape;
- **Pest control** refers to applying some action to remove or prevent unwanted insects from destroying vegetation (plants) that are considered as part of the garden.

9. Where did you learn about gardening?

Parents	1
Grandparents	2
Elsewhere (specify)	3

10. Do you use information provided by your parents or grandparents to manage the garden?

(1) Yes	(2) No

11. If yes, please specify?

____

____

____

12. In your opinion, do you think it is necessary to use traditional knowledge that has been transferred over generations and explain why?

____

____

____

13. Do you think that the knowledge gained from past generations is being lost?

(1) Yes	(2) No

14. If yes, what are factors influencing to the disappearance of this knowledge?

____

____

____

____

15. What can be done to protect traditional knowledge which is passed from one generation to another?

____

____

____

____

16. Do you know persons under the age of 21 with an interest in gardening?

(1) Yes	(2) No

17. If yes, would they like to learn more about gardening?

(1) Yes	(2) No

18. How long have you lived in this house (*ntlo*)?

(1) 0-2 years	(2) Between 2 and 5 years	(3) 5-10 years	(4) More than 10 years

19. How many people live in this house (*ntlo*) on a permanent basis?

____

20. Please indicate the ages of people living in this house on a permanent basis with regard to gender?

Males		**Females**	
Age	Number	Age	Number
< 10		< 10	
11-20		11-20	
21-35		21-35	
36-50		36-50	
>51		>51	

21. Indicate the number of people in your house who are generating an income (earn money).

	Male	**Female**
Permanent job		
Temporary job		

22. Do you house unemployed persons between the ages of 18-60 who can't find a job?

(1) No	(2) Yes

23. Age and gender of unemployed people living with you?

Gender	**Age**

24. In what type of a house (*ntlo*) do you live?

Informal house (Zinc structure)	1
Traditional house (Mud or wood structure)	2
Formal house (Brick structure)	3

25. How many rooms does your house (*ntlo*) have?

___

26. Do you own/ rent this house (*ntlo*)?

Rent	1
Own	2

27. Do you have a toilet (*ntlwana*)?

(1) No	(2) Yes

28. If yes, where is it situated?

(1) Outside the house	(2) Inside the house

29. What type of light do you use at night?

Fire (burn wood)	1
Candles	2
Paraffin (lamps)	3
Electricity	4
Other	

Please specify "other"?

___

30. To stay warm during cold weather, what do you use?

Wood fire	1
Paraffin (heater)	2
Electricity (electrical heater)	3
Other	

Please specify "other"?

____

31. What type of energy source do you use to cook?

Wood fire	1
Paraffin stove	2
Gas stove	3
Electricity stove	4
Other	

Please specify "other"?

____

32. Where do you fetch water for domestic use?

Natural source (river/stream or dam/pan)	1
Communal tap water	2
Tap water (in your yard/'*patlelo*')	3
Tap water (inside your house/'*ntlo*')	4

33. Where do you get the water that you use in your garden (*tshimo*)?

Natural source (river/stream or dam/pan)	1
Rainwater	2
Communal water tap	3
Borehole/well on property	4
Water tap in your yard	5

34. How far is the water source that you use to water your garden?

More than 1 km	1
500m – 1 km	2
100 – 500m	3
Less than 100m	4

35. What mode of transport do you use to fetch water for the garden?

Carry in buckets	1
Wheelbarrow	2
Donkey cart	3
Other	

Please specify "other"

____

____

____

36. Do you buy or produce your own food (e.g. vegetables)?

Produce/grow	1
Buy and grow	2
Buy	3
None	

37. Why do you grow fruits/vegetables?

For own consumption	1
For own consumption and to sell	2
To sell	3

38. If you grow vegetables, where do you get your seeds?

Get for free	1
Produce	2
Buy	3

39. Do you use any plants from the veldt (*naga*)?

(1) Yes	(2) No

40. If yes, what do you use them for?

____

____

____

____

41. Which of the following animals do you have?

Chicken/Geese/Ducks/Turkey	1
Pig	2
Goats/Sheep	3
Donkey	4
Cattle	5

42. Please indicate the highest level of education of your family members living in your house?

Level of education	Number of males (M)	Number of females (F)
(1) None		
(2) Primary school		
(3) Secondary school (excluding Grade 12)		
(4) Grade 12		
(5) A tertiary qualification		

43. Where do you get your main source of income (money) for living?

Family/Neighbour support	1
Temporary job	2
Government grant	3
Informal business	4
Own business	5
Permanent job	6
Other	

Please specify "other"

____

44. Please indicate the mode of transport that you use most often?

None	
Bicycle	1
Donkey car	2
Own motor car	3
Other	

45. What is the combined monthly income of all working members in the household?

R 0 – 500	1
R 500 – 1000	2
R 1000 – 1500	3
R 1500– 2000	4
More than R 5000	5

46. Please indicate from the highest to the lowest with relation to your monthly expenditure? (Use the number system 1-9 to indicate the expenditure)

Items	**Numbers**
Food	
Housing	
Medical expenses	
Transport	
Clothing	
School	
Insurance	
Remittances/support to others elsewhere	
Other	

In case of "other" please specify

____

Annexure F – Questionnaire: Ikageng and Potchefstroom

Urban ecological survey
School of Environmental Sciences and Development
North West University
Potchefstroom Campus

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT

Name : ______________________ **Q no.** : ______________________

Address: ______________________ **Date** : ______________________

______________________ **GPS** : ____________________ /

______________________ ______________________

Phone no. : ______________________

<u>Section 1: Management and maintenance</u>

1. Which of the following activities takes places in your garden?

Activity	**Yes**	**No**
Water the garden		
Fertilise the garden		
Weed the garden – chemically		
Weed the garden – mechanically		
Sweep the garden		
Prune the hedges / trees		
Remove dead plant material		

2. What type of irrigation system do you use?

Fixed irrigation with timer	4
Fixed irrigation without timer	3
Non-fixed irrigation	2
None	1

3. Which of the following fertilisers are used in your flower beds?

			How often?				
Fertiliser	**Yes**	**No**	**Once a year**	**Once a month**	**Once a fortnight**	**Once a week**	**> once a week**

Chemical fertiliser							
Kraal manure							
Own compost							
Commercial compost							
None							

4. Which method(s) of pest control take(s) place in your flower beds?

			How often?				
Method	**Yes**	**No**	**Once a year**	**Once a month**	**Once a fortnight**	**Once a week**	**> once a week**
Chemical pest control							
Companion planting							
None							

5. Which of the following activities takes place on your lawn?

Activity	**Yes**	**No**
Water		
Fertilising		
Weed – chemically		
Weed – mechanically		
Rake		
Topsoil		
Spike		
Mow		
Graze		

6. Which of the following fertilisers are used on your lawn?

			How often?				
Fertiliser	**Yes**	**No**	**Once a year**	**Once a month**	**Once a fortnight**	**Once a week**	**> once a week**
Chemical							
Kraal manure							
Own compost							
Commercial compost							
None							

7. Who/what determines which species are planted in your garden?

You are a collector of specific plants	6
You have a bird/butterfly garden	5
Advice from gardening services	4
Gardening shows/magazine articles	3
What friends/neighbours have in their gardens	2
Availability at the nursery	1
Other (please specify)	0

8. Do you have any of the following?

	Yes	**No**
Vegetable garden		
Herb garden		
Fruit trees / orchard		
Medicinal garden / plants		

9. If any of the above (Question 8) is present, which of the following activities takes place in it?

			How often?				
Activity	**Yes**	**No**	**Once a year**	**Once a month**	**Once a fortnight**	**Once a week**	**> once a week**
Water the garden							
Fertilise the garden							
Weed the garden							
Sweep the garden							
Remove dead material							

10. Which of the following fertilisers are used in your vegetable/herb garden and/or orchard?

Fertiliser	**Yes**	**No**
Chemical fertiliser		
Kraal manure		
Own compost		
Commercial compost		
None		

11. What is the purpose of the fruit/vegetables that you grow?

For own household use/consumption	1
To sell as a source of income	2
Both	3
Medicinal value	4

12. Do you have gardening assistance?

Gardening services	1
Gardeners	2
None	3

13. What is the origin of the plants currently in your garden?

Most plants were already in the garden when you moved in	1
Most plants were planted by you after you have moved in	2
You created an entirely new garden	3

14. Are you aware of any declared weeds and invaders in your garden?

____

____

____

15. Do you plant only indigenous species in your garden?

____

____

____

Section 2: Social aspects

16. How long have you been living in this house?

____

17. Do you know how old this garden is?

____

18. The level of education of house owner/tenant?

No education	1
Primary education completed	2

Secondary education (Grade 12 excluded)	3
Secondary education completed	4
Tertiary education (undergraduate) completed	5
Tertiary education (postgraduate) completed	6

19. Where do you get the water in your garden?

Borehole in your yard	4
Water tap in your yard	3
Communal water tap	2
Natural source (river/stream or dam/pan)	1

20. If not in your yard (Question 19), how far away is the water that you use in your garden?

> 1000 m	1
500 m – 1000 m	2
100 m – 500 m	3
< 100 m	4

21. What is the age of the garden manager/decision maker?

____

22. Would you like feedback on this study? Yes/No

Annexure G – Questionnaire: Roodepoort

Urban Ecological survey
School of Environmental Sciences and Development
North-West University
Potchefstroom Campus

NORTH-WEST UNIVERSITY
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NOORDWES-UNIVERSITEIT
POTCHEFSTROOM CAMPUS

Name : ______________________ Q no. : ______________________

Address: ______________________ Date : ______________________

______________________ GPS : ____________________ /

______________________ ______________________

Phone no. : ______________________

Section 1 : Garden management and maintenance

1. Which of the following activities takes place in your garden?

Activity	**Yes**	**No**
Water the garden		
Fertilise the garden		
Weed the garden (Chemically / Mechanically)		
Prune your hedges / trees		
Remove any dead material		
Any method of pest control		

2. What type of irrigation system do you use?

Fixed irrigation with timer	4
Fixed irrigation without timer	3
Non-fixed irrigation	2
None	1

3. Which of the following fertilisers are used in your flower beds and how often?

Fertiliser	**Yes**	**No**	**How often?**				
			Once a year	**Once a month**	**Once a fortnight**	**Once a week**	**More than once a week**
Chemical fertiliser							

Own compost							
Commercial compost							
None							

4. Which method(s) of pest control take(s) place in your flower beds?

Method	Yes	No	How often?				
			Once a year	**Once a month**	**Once a fortnight**	**Once a week**	**More than once a week**
Chemical pest control							
Companion planting							
None							

5. Which of the following activities takes place on your lawn?

Activity	Yes	No
Watering		
Fertilising		
Weed (Chemically / Mechanically)		
Mow		
Rake		

6. Which of the following fertilisers are used on your lawn and how often?

Fertiliser	Yes	No	How often?				
			Once a year	**Once a month**	**Once a fortnight**	**Once a week**	**More than once a week**
Chemical fertiliser							
Own compost							
Commercial compost							
None							

7. Who / what determines which species are planted in your garden?

You are a collector of specific plants	6
You have a bird / butterfly garden	5
Advice from gardening services	4

Gardening shows / magazine articles	3
What friends / neighbours have in their gardens	2
Availability at the nursery	1
Other (Please specify)	0

8. Do you have any of the following?

	Yes	No
Vegetable garden		
Herb garden		
Fruit trees / orchard		
Medicinal garden / plants		

9. If any of the above (Question 8) is present, which of the following activities takes place?

Activity	Yes	No	How often?				
			Once a year	Once a month	Once a fortnight	Once a week	More than once a week
Water the garden							
Fertilise the garden							
Weed the garden							
Remove dead material							

10. Which of the following fertilisers are used in your vegetable / herb garden and / or orchard?

Fertiliser	Yes	No
Chemical fertiliser		
Own compost		
Commercial compost		
None		

11. What is the purpose of the fruit / vegetables that you grow?

For own household use / consumption	1
To sell as a source of income	2
Both	3
Medicinal value	4

12. Do you have gardening assistance?

Gardening services	1
Gardeners	2
None	3

13. What is the origin of the plants currently in your garden?

Most plants were already in the garden when you moved in	1
Most plants were planted by you after you moved in	2
You created an entirely new garden	3

14. Are you aware of any declared weeds and invaders in your garden?

____

____

15. Do you plant only indigenous species in your garden?

____

____

Section 2 : Social aspects

16. How long have you been living in this house? ____________________

17. Do you know how old this garden is? ____________________

18. What is the highest level of education of the homeowner?

No education	1
Primary education completed	2
Secondary education completed (Grade 12 excluded)	3
Secondary education completed	4
Tertiary education (undergraduate) completed	5
Tertiary education (postgraduate) completed	6

19. Where do you get the water in your garden?

Borehole in your yard	2
Water tap in your yard	1

21. What is the age of the garden manager / decision maker? ____________________

22. Would you like feedback on this study? Yes / No

Annexure H – Tukey's HSD test for unequal sample size results

The Tukey's HSD test for unequal sample size results between the floristic data, garden management activities, management index and all the studied settlements as described in Chapter 6.

Table H.1: Tukey's HSD test for unequal sample size results of the total species richness for all the studied settlements. Marked differences (bold) are significant at $p < 0.05$.

	Tlhakgameng	Ganyesa	Ikageng	Potchefstroom
Ganyesa	0.999904			
Ikageng	0.461570	0.373682		
Potchefstroom	**0.000017**	**0.000017**	**0.000017**	
Roodepoort	**0.000017**	**0.000017**	**0.000017**	0.054532

Table H.2: Tukey's HSD test for unequal sample size results of the alien species richness for all the studied settlements. Marked differences (bold) are significant at $p < 0.05$.

	Tlhakgameng	Ganyesa	Ikageng	Potchefstroom
Ganyesa	0.994295			
Ikageng	0.423310	0.684358		
Potchefstroom	**0.000017**	**0.000017**	**0.000017**	
Roodepoort	**0.000017**	**0.000017**	**0.000017**	0.998795

Table H.3: Tukey's HSD test for unequal sample size results of the indigenous species richness for all the studied settlements. Marked differences (bold) are significant at $p < 0.05$.

	Tlhakgameng	Ganyesa	Ikageng	Potchefstroom
Ganyesa	0.997405			
Ikageng	**0.000017**	**0.000017**		
Potchefstroom	**0.034378**	0.082875	**0.003390**	
Roodepoort	**0.001637**	**0.000439**	**0.000017**	**0.000017**

Table H.4: Tukey's HSD test for unequal sample size results of the tree species richness for all the studied settlements. Marked differences (bold) are significant at $p < 0.05$.

	Tlhakgameng	Ganyesa	Ikageng	Potchefstroom
Ganyesa	0.999985			
Ikageng	**0.004325**	**0.005957**		
Potchefstroom	**0.000017**	**0.000017**	**0.000017**	
Roodepoort	**0.000017**	**0.000017**	**0.000017**	0.318713

Table H.5: Tukey's HSD test for unequal sample size results of the shrub species richness for all the studied settlements. Marked differences (bold) are significant at $p < 0.05$.

	Tlhakgameng	Ganyesa	Ikageng	Potchefstroom
Ganyesa	0.998785			
Ikageng	0.690037	0.842073		
Potchefstroom	**0.000017**	**0.000017**	**0.000017**	
Roodepoort	**0.000017**	**0.000017**	**0.000017**	**0.000350**

Table H.6: Tukey's HSD test for unequal sample size results of the succulent species richness for all the studied settlements. Marked differences (bold) are significant at $p < 0.05$.

	Tlhakgameng	Ganyesa	Ikageng	Potchefstroom
Ganyesa	0.953156			
Ikageng	0.155294	0.527729		
Potchefstroom	0.851133	0.998032	0.743448	
Roodepoort	**0.000025**	**0.000017**	**0.000017**	**0.000017**

Table H.7: Tukey's HSD test for unequal sample size results of the herb species richness for all the studied settlements. Marked differences (bold) are significant at $p < 0.05$.

	Tlhakgameng	Ganyesa	Ikageng	Potchefstroom
Ganyesa	1.000000			
Ikageng	0.992052	0.991325		
Potchefstroom	**0.000017**	**0.000017**	**0.000017**	
Roodepoort	**0.000017**	**0.000017**	**0.000017**	0.336877

Table H.8: Tukey's HSD test for unequal sample size results of the geophyte species richness for all the studied settlements. Marked differences (bold) are significant at $p < 0.05$.

	Tlhakgameng	Ganyesa	Ikageng	Potchefstroom
Ganyesa	0.934476			
Ikageng	0.875285	0.999824		
Potchefstroom	**0.000017**	**0.000017**	**0.000017**	
Roodepoort	**0.000017**	**0.000017**	**0.000017**	0.357939

Table H.9: Tukey's HSD test for unequal sample size results of the fern species richness for all the studied settlements. Marked differences (bold) are significant at $p < 0.05$.

	Tlhakgameng	Ganyesa	Ikageng	Potchefstroom
Ganyesa	0.996478			
Ikageng	0.841191	0.962380		
Potchefstroom	**0.000017**	**0.000017**	**0.000017**	
Roodepoort	**0.000017**	**0.000017**	**0.000017**	**0.000083**

Table H.10: Tukey's HSD test for unequal sample size results of the epiphyte species richness for all the studied settlements. Marked differences (bold) are significant at $p < 0.05$.

	Tlhakgameng	Ganyesa	Ikageng	Potchefstroom
Ganyesa	1.000000			
Ikageng	1.000000	1.000000		
Potchefstroom	0.972232	0.972232	0.972232	
Roodepoort	**0.000026**	**0.000026**	**0.000026**	**0.000240**

Table H.11: Tukey's HSD test for unequal sample size results of the graminoid species richness for all the studied settlements. Marked differences (bold) are significant at $p < 0.05$.

	Tlhakgameng	Ganyesa	Ikageng	Potchefstroom
Ganyesa	**0.000017**			
Ikageng	0.402157	**0.001477**		
Potchefstroom	**0.033348**	0.079472	0.777587	
Roodepoort	0.906271	**0.000017**	0.068670	**0.007153**

Table H.12: Tukey's HSD test for unequal sample size results of the weed species richness for all the studied settlements. Marked differences (bold) are significant at $p < 0.05$.

	Tlhakgameng	Ganyesa	Ikageng	Potchefstroom
Ganyesa	0.692317			
Ikageng	**0.000017**	**0.000017**		
Potchefstroom	**0.000017**	**0.000017**	0.271732	
Roodepoort	**0.000601**	0.051009	**0.006430**	**0.000018**

Table H.13: Tukey's HSD test for unequal sample size results of the C1 weed species richness for all the studied settlements. Marked differences (bold) are significant at $p < 0.05$.

	Tlhakgameng	Ganyesa	Ikageng	Potchefstroom
Ganyesa	0.995887			
Ikageng	**0.001287**	**0.000283**		
Potchefstroom	0.801682	0.946172	**0.000028**	
Roodepoort	0.819627	0.955360	**0.000028**	0.999999

Table H.14: Tukey's HSD test for unequal sample size results of the C2 invader species richness for all the studied settlements. Marked differences (bold) are significant at $p < 0.05$.

	Tlhakgameng	Ganyesa	Ikageng	Potchefstroom
Ganyesa	0.624108			
Ikageng	0.999748	0.504507		
Potchefstroom	0.320993	0.985864	0.231895	
Roodepoort	**0.042151**	0.629222	**0.024774**	0.908582

Table H.15: Tukey's HSD test for unequal sample size results of the C3 invader species richness for all the studied settlements. Marked differences (bold) are significant at $p < 0.05$.

	Tlhakgameng	**Ganyesa**	**Ikageng**	**Potchefstroom**
Ganyesa	0.998208			
Ikageng	0.516142	0.710006		
Potchefstroom	**0.000017**	**0.000017**	**0.000017**	
Roodepoort	**0.000017**	**0.000017**	**0.000017**	0.978467

Table H.16: Tukey's HSD test for unequal sample size results of the food species richness for all the studied settlements. Marked differences (bold) are significant at $p < 0.05$.

	Tlhakgameng	**Ganyesa**	**Ikageng**	**Potchefstroom**
Ganyesa	0.992431			
Ikageng	0.301424	0.567283		
Potchefstroom	0.999999	0.995501	0.347673	
Roodepoort	**0.012399**	**0.046091**	0.703970	**0.015995**

Table H.17: Tukey's HSD test for unequal sample size results of the medicinal species richness for all the studied settlements. Marked differences (bold) are significant at $p < 0.05$.

	Tlhakgameng	**Ganyesa**	**Ikageng**	**Potchefstroom**
Ganyesa	0.997894			
Ikageng	**0.000017**	**0.000017**		
Potchefstroom	**0.000017**	**0.000017**	0.057824	
Roodepoort	**0.000017**	**0.000017**	**0.000066**	0.352373

Table H.18: Tukey's HSD test for unequal sample size results of the ornamental species richness for all the studied settlements. Marked differences (bold) are significant at $p < 0.05$.

	Tlhakgameng	**Ganyesa**	**Ikageng**	**Potchefstroom**
Ganyesa	0.998120			
Ikageng	0.999023	0.999999		
Potchefstroom	**0.000017**	**0.000017**	**0.000017**	
Roodepoort	**0.000017**	**0.000017**	**0.000017**	**0.000017**

Table H.19: Tukey's HSD test for unequal sample size results of the vulnerable species richness for all the studied settlements. Marked differences (bold) are significant at $p < 0.05$.

	Tlhakgameng	**Ganyesa**	**Ikageng**	**Potchefstroom**
Ganyesa	0.656730			
Ikageng	0.895103	0.991560		
Potchefstroom	**0.000032**	**0.004807**	**0.000896**	
Roodepoort	**0.000017**	**0.000017**	**0.000017**	**0.000017**

Table H.20: Tukey's HSD test for unequal sample size results of the declining species richness for all the studied settlements. Marked differences (bold) are significant at $p < 0.05$.

	Tlhakgameng	**Ganyesa**	**Ikageng**	**Potchefstroom**
Ganyesa	0.999944			
Ikageng	0.054083	0.075333		
Potchefstroom	0.227778	0.286400	0.980265	
Roodepoort	0.999983	1.000000	0.074255	0.271043

Table H.21: Tukey's HSD test for unequal sample size results of the rare species richness for all the studied settlements. Marked differences (bold) are significant at $p < 0.05$.

	Tlhakgameng	**Ganyesa**	**Ikageng**	**Potchefstroom**
Ganyesa	**0.013421**			
Ikageng	0.993094	**0.048474**		
Potchefstroom	**0.004529**	0.995584	**0.018536**	
Roodepoort	**0.000017**	**0.007738**	**0.000017**	**0.029103**

Table H.22: Tukey's HSD test for unequal sample size results of the near threatened species richness for all the studied settlements. Marked differences (bold) are significant at $p < 0.05$.

	Tlhakgameng	**Ganyesa**	**Ikageng**	**Potchefstroom**
Ganyesa	**0.003902**			
Ikageng	**0.035371**	0.962087		
Potchefstroom	0.336794	0.503530	0.885372	
Roodepoort	0.481842	**0.000020**	**0.000100**	**0.004714**

Table H.23: Tukey's HSD test for unequal sample size results of the critically rare species richness for all the studied settlements. Marked differences (bold) are significant at $p < 0.05$.

	Tlhakgameng	**Ganyesa**	**Ikageng**	**Potchefstroom**
Ganyesa	1.000000			
Ikageng	1.000000	1.000000		
Potchefstroom	1.000000	1.000000	1.000000	
Roodepoort	**0.001771**	**0.001771**	**0.001771**	**0.002063**

Table H.24: Tukey's HSD test for unequal sample size results of the endangered species richness for all the studied settlements. Marked differences (bold) are significant at $p < 0.05$.

	Tlhakgameng	**Ganyesa**	**Ikageng**	**Potchefstroom**
Ganyesa	0.998358			
Ikageng	1.000000	0.998358		
Potchefstroom	0.483466	0.670788	0.483466	
Roodepoort	**0.000020**	**0.000029**	**0.000020**	**0.004858**

Table H.25: Tukey's HSD test for unequal sample size results of the watering gardening activity for all the studied settlements. Marked differences (bold) are significant at $p < 0.05$.

	Tlhakgameng	Ganyesa	Ikageng	Potchefstroom
Ganyesa	0.999941			
Ikageng	1.000000	0.999941		
Potchefstroom	0.196280	0.250588	0.196280	
Roodepoort	**0.005957**	**0.009201**	**0.005957**	0.742806

Table H.26: Tukey's HSD test for unequal sample size results of the fertiliser application gardening activity for all the studied settlements. Marked differences (bold) are significant at $p < 0.05$.

	Tlhakgameng	Ganyesa	Ikageng	Potchefstroom
Ganyesa	**0.005269**			
Ikageng	0.844896	**0.000093**		
Potchefstroom	0.216665	0.712791	**0.016051**	
Roodepoort	**0.038356**	0.977427	**0.001193**	0.959472

Table H.27: Tukey's HSD test for unequal sample size results of the weeding gardening activity for all the studied settlements. Marked differences (bold) are significant at $p < 0.05$.

	Tlhakgameng	Ganyesa	Ikageng	Potchefstroom
Ganyesa	**0.000036**			
Ikageng	**0.000420**	0.965114		
Potchefstroom	0.843102	**0.002637**	**0.023676**	
Roodepoort	0.996818	**0.000143**	**0.002006**	0.960603

Table H.28: Tukey's HSD test for unequal sample size results of the pruning gardening activity for all the studied settlements. Marked differences (bold) are significant at $p < 0.05$.

	Tlhakgameng	Ganyesa	Ikageng	Potchefstroom
Ganyesa	**0.025187**			
Ikageng	0.126482	0.974284		
Potchefstroom	0.808579	**0.000609**	**0.005885**	
Roodepoort	**0.000017**	**0.000017**	**0.000017**	**0.000017**

Table H.29: Tukey's HSD test for unequal sample size results of the removal of dead plant material gardening activity for all the studied settlements. Marked differences (bold) are significant at $p < 0.05$.

	Tlhakgameng	Ganyesa	Ikageng	Potchefstroom
Ganyesa	**0.023330**			
Ikageng	**0.000017**	**0.000017**		
Potchefstroom	**0.000287**	0.719110	**0.000017**	
Roodepoort	**0.000702**	**0.000017**	**0.000017**	**0.000017**

Table H.30: Tukey's HSD test for unequal sample size results of the management index values for all the studied settlements. Marked differences (bold) are significant at $p < 0.05$.

	Tlhakgameng	Ganyesa	Ikageng	Potchefstroom
Ganyesa	0.943814			
Ikageng	**0.000022**	**0.000211**		
Potchefstroom	0.906409	0.999923	**0.000523**	
Roodepoort	**0.000017**	**0.000017**	**0.000017**	**0.000017**

Annexure I – Values of each of the six parameters used to determine SES classes

Table I.1: The values of each of the six parameters used to determine the five SES classes of all the wards in the surveyed settlements (as described in Chapter 7). Higher % indicates a lower SES for all of the parameters (Lubbe, 2011).

	% Unemployment	Household size	Number of rooms	Access to basic services	Schooling status	Median monthly income
Tlhakgameng Ward 4	19.4%	81%	36.4%	54.5%	30.6%	83.8
Tlhakgameng Ward 5	13.9%	55%	42.5%	47.5%	44.0%	123.3
Ganyesa Ward 6	61.3%	47.6%	33.3%	42.9%	56.4%	126.9
Ganyesa Ward 7	72%	46.9%	15.6%	25%	37.8%	141.6
Ganyesa Ward 8	18%	50%	0%	0%	27.3%	323.7
Ikageng Ward 8	45.5%	36.0%	22.1%	4.6%	7.3%	3 206.3
Ikageng Ward 9	42.4%	37.1%	31.2%	0.4%	8.8%	3 318.8
Ikageng Ward 10	52.5%	31.2%	51.1%	39.8%	16.9%	1 993.5
Ikageng Ward 11	52.5%	31.2%	51.1%	39.8%	16.9%	1 993.5
Ikageng Ward 12	52.8%	37.3%	20.6%	0.8%	6.4%	4 152.9
Ikageng Ward 13	38.3%	33.0%	34.2%	1.5%	11.9%	3 543.3
Ikageng Ward 14	49.6%	42.2%	17.1%	0.0%	10.4%	2 817.9
Ikageng Ward 15	53.9%	43.9%	28.0%	0.3%	5.4%	2 577.6
Ikageng Ward 16	46.3%	40.6%	37.9%	4.1%	19.2%	2 599.4
Ikageng Ward 17	53.8%	25.3%	44.8%	35.6%	35.3%	3 343.2
Ikageng Ward 18	53.3%	35.7%	52.5%	0.4%	19.4%	1 238.0
Potchefstroom Ward 1	13.9%	19.0%	31.2%	7.3%	17.1%	5 930.2
Potchefstroom Ward 2	5.6%	13.3%	23.9%	3.2%	4.6%	12 350.0
Potchefstroom Ward 3	3.9%	8.8%	7.6%	1.5%	1.8%	13 437.0
Potchefstroom Ward 4	7.6%	14.0%	11.0 %	2.3%	2.2%	10 522.0
Potchefstroom Ward 5	7.9%	12.5%	10.0%	2.7%	2.2%	11 516.4
Potchefstroom Ward 7	21.1%	15.3%	32.2%	19.0%	27.5%	8 948.2
Roodepoort Ward 9	12.3%	17.7%	13.7%	4.9%	2.4%	12 877.8
Roodepoort Ward 13	5.9%	12.5%	11.7%	2.3%	1.9%	20 958.2
Roodepoort Ward 14	8.1%	9.6%	12.9%	1.6%	1.2%	18 193.0
Roodepoort Ward 83	8.4%	18.8%	17.4%	6.2%	3.2%	18 184.4
Roodepoort Ward 85	5.1%	13.4%	18.6%	5.0%	3.0%	22 815.1
Roodepoort Ward 97	6.1%	11.3%	22.4%	4.7%	3.4%	21 734.5

Annexure J – Canonical component results

Additional results of the canonical component analyses as described in Chapter 8.

Table J.1: The canonical weight of each of the socio-economic variables (left set) (High positive values are indicated in bold and high negative values are indicated in bold and italics).

Variable	L_Root 3	L_Root 4	L_Root 5	L_Root 6
% Unemployment	***-0.97***	0.47	***-2.73***	-0.42
Household size	0.33	**0.98**	**2.52**	0.17
Number of rooms	***-1.25***	***-0.63***	0.51	0.44
Access to basic services	0.28	-0.18	1.02	***-1.30***
Schooling status	0.38	-0.21	-1.14	**0.80**
Monthly income	***-1.02***	**0.63**	-0.18	0.06

Table J.2: The canonical weight of each of the floristic variables (right set) (High positive values are indicated in bold and high negative values are indicated in bold and italics).

Variable	R_Root 3	R_Root 4	R_Root 5	R_Root 6
Alien	**14.76**	**12.13**	***-5.29***	**7.26**
Indigenous	**7.31**	**7.01**	-2.74	2.13
Tree	***-3.94***	***-3.74***	-0.66	-2.91
Succulent	***-2.86***	***-2.36***	-1.08	-0.31
Herb	***-4.55***	***-3.90***	-0.86	***-3.98***
Geophyte	1.38	2.06	-0.15	-0.42
Fern	0.09	-0.25	-0.67	1.37
Epiphyte	-0.68	0.70	0.01	-0.38
Graminoid	-0.28	-0.60	0.71	-1.60
Weed	-0.43	0.24	1.07	2.07
C1 Weed	-0.14	0.28	2.72	-0.72
C2 Invader	0.19	-0.47	-0.50	0.13
C3 Invader	***-1.75***	-1.88	-2.03	1.39
Food	0.19	0.01	0.14	-0.10
Medicinal	***-1.46***	-1.65	0.64	1.92
Ornamental	***-8.70***	***-8.68***	**10.11**	***-4.39***

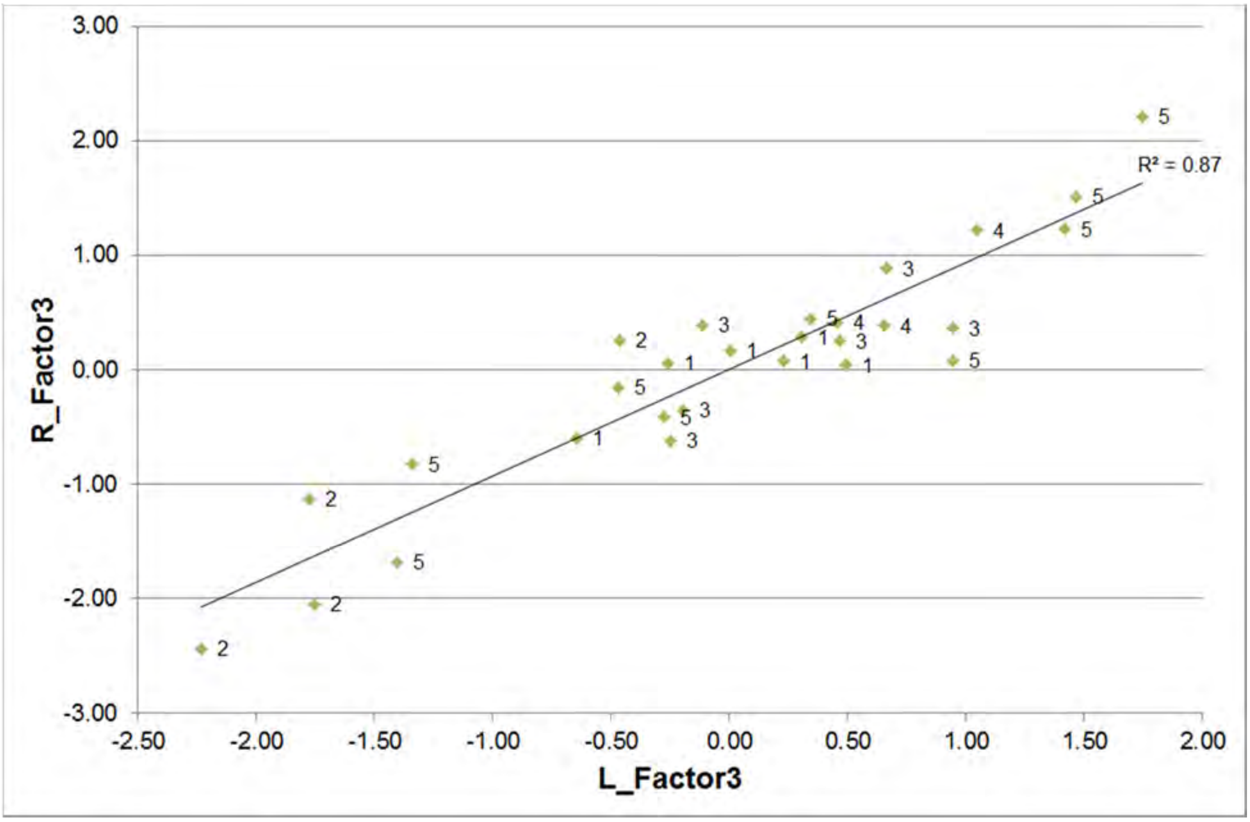

Figure J.1: Scatterplot of the third canonical variates for the socio-economic (Left) and floristic variables (Right).

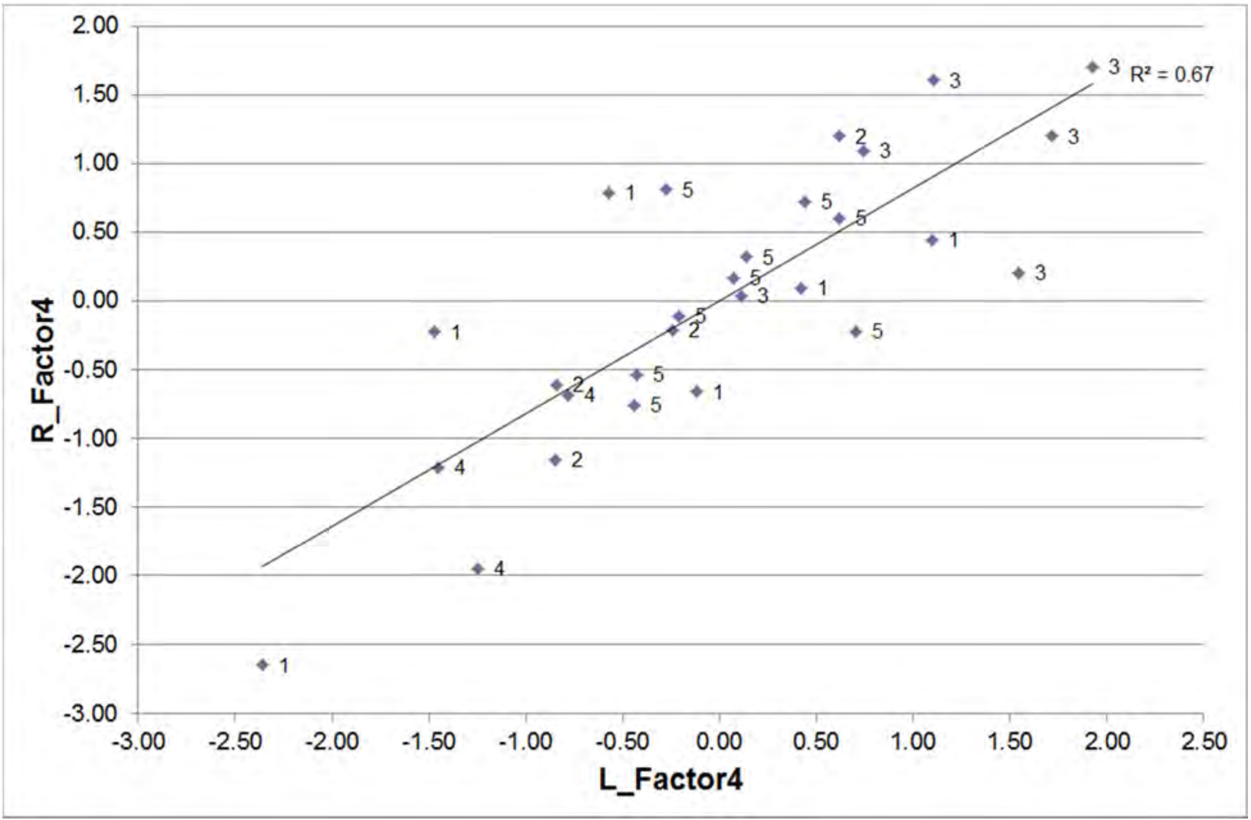

Figure J.2: Scatterplot of the fourth canonical variates for the socio-economic (Left) and floristic variables (Right).

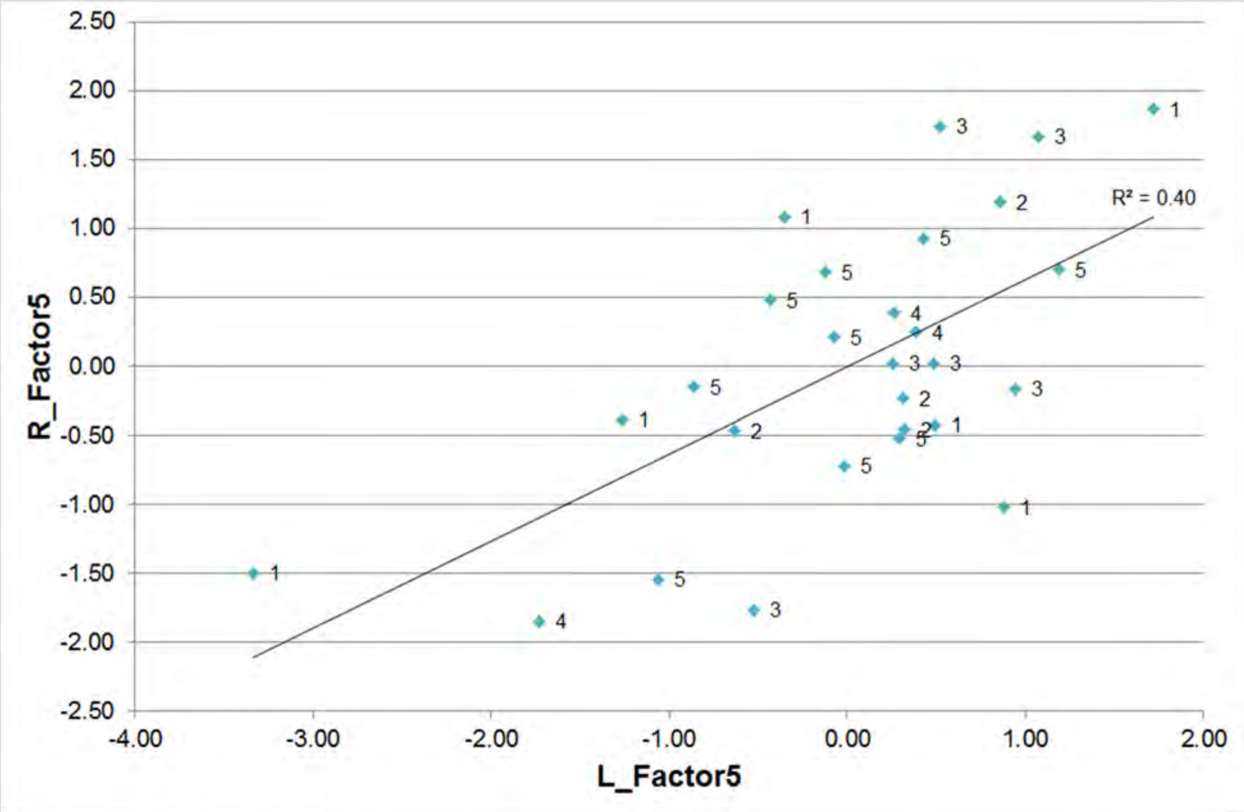

Figure J.3: Scatterplot of the fifth canonical variates for the socio-economic (Left) and floristic variables (Right).

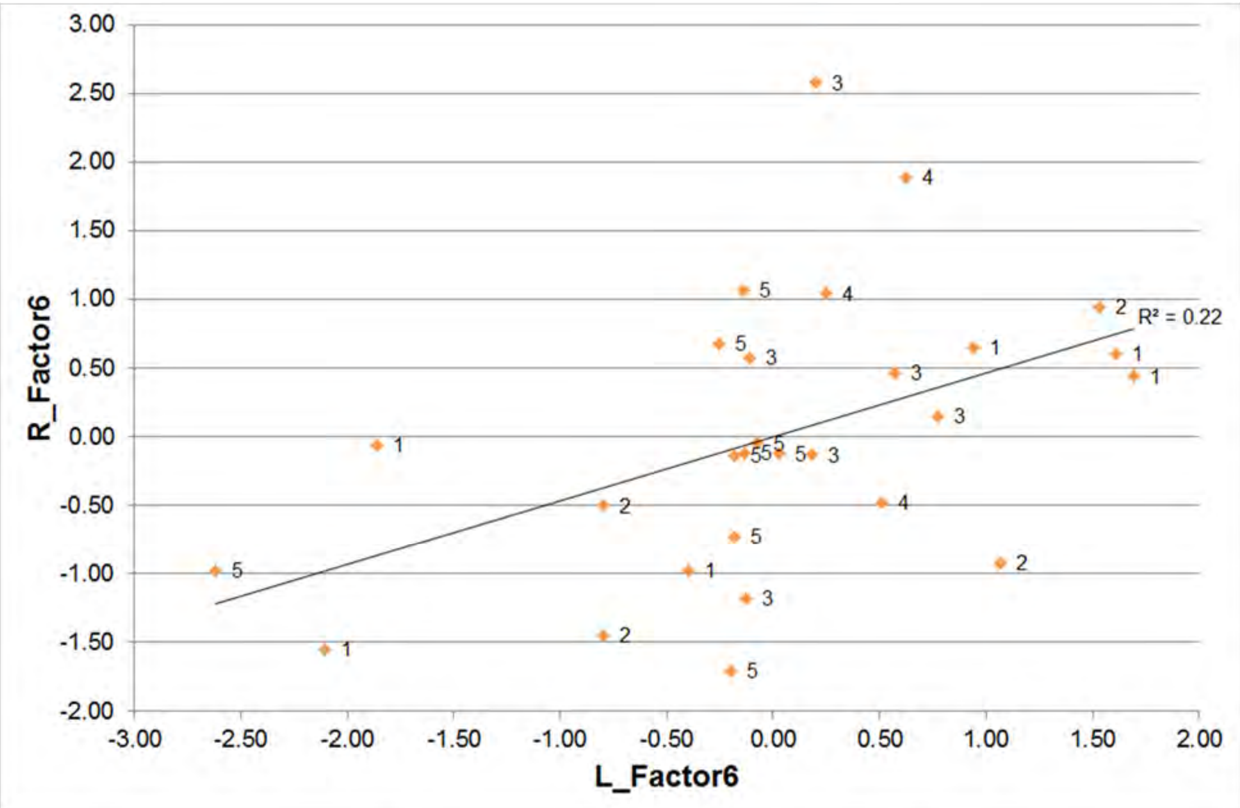

Figure J.4: Scatterplot of the sixth canonical variates for the socio-economic (Left) and floristic variables (Right).