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

Comparison of the urban domestic garden flora along a socio-economic gradient in the Tlokwe City Municipality

Catherina Susanna Lubbe

B.Sc.

Dissertation submitted in partial fulfilment of the requirements for the degree *Master of Environmental Sciences* at the North-West University, Potchefstroom Campus

Supervisor: Prof. S.J. Siebert

Co-supervisor: Prof. S.S. Cilliers

May 2011

Abstract

Urbanisation has increased tremendously over the last 60 years so that more than 50 percent of the world population now live in cities. This is especially true for in developed countries, but it is expected that developing countries will take the lead in future urban population growth. This increasing trend of urbanisation has severe consequences for the environment, as it fragments and changes natural areas and alter environmental conditions. This has compelled scientists from many different disciplines to focus on the inclusion of humans into ecology as a driving force of change to create a better understanding of urban ecosystems.

The diversity of fauna and flora in the urban environment provides a myriad of ecosystem goods (such as food and fuel) and services (e.g. cleaning the air and reducing noise levels). Apart from these tangible benefits, urban green space also provides recreational, educational and social benefits to urban inhabitants. A surprisingly substantial proportion (21–36 %) of the total urban green space that produces these ecosystem goods and services is located in private yards. This portrays the importance of the flora of this land-use type, but very little is known about garden flora and its potential for conservation. The determinants of diversity and species richness in gardens were found to be different than for semi-natural ecosystems, because of the high anthropogenic influence. One of these is the socio-economic status of the inhabitants. People with higher socio-economic status were found to harbour more diverse species assemblages in their gardens than those of lower socio-economic status. This phenomenon was termed the “luxury concept”.

In the Tlokwe City Municipality (TCM), the legacy effects of apartheid created a steep socio-economic gradient as a result of the inequitable distribution of economic, natural and social resources. The aims of this study were to gain information on the flora that is present in the domestic gardens of the TCM and to determine if socio-economic status (SES), a management index (MI) and demographic factors influences the distribution of plant species between these gardens. A total of 835 plant species were recorded from 100 domestic gardens and the majority were of alien origin. This large number of species included some Red Data species, invasive alien species and also many utilitarian species. This portrays gardens as important *ex situ* conservation habitats, but simultaneously it could also threaten the integrity of our natural ecosystems through the distribution of alien invasive species.

The gamma, alpha and beta diversity were determined across five SES classes to describe the patterns of domestic garden plant species diversity in the TCM. In accordance with other studies, correlations showed that the SES of the inhabitants affected the plant species distribution in the study area. This was especially true for the distribution of alien species that are cultivated for their ornamental value. More

species were found in areas of high SES than those of lower SES. The other aspect that influenced the distribution of plant species in these gardens were the MI, although this was to a lesser extent than the effect of SES. The confirmation of differences along the SES gradient could be utilised by urban planners and policy makers to correct this imbalance through the provision of urban green spaces where it is needed most.

Opsomming

Verstedeliking het geweldig toegeneem gedurende die afgelope 60 jaar, sodat meer as 50 % van die wêreldbevolking tans in stedelike omgewings leef. Die meeste verstedeliking het voorheen in ontwikkelde lande plaasgevind, maar daar word voorspel dat ontwikkelende lande in die toekoms die voortou sal neem met die bevolkingsgroei in stede. Hierdie toename in verstedeliking het ernstige gevolge vir die omgewing, aangesien dit die natuurlike areas fragmenteer en omvorm en ook die omgewingstoestande in stede verander. Dit het wetenskaplikes vanuit verskeie dissiplines genoop om die mens as dryfkrag van verandering in te sluit by ekologiese studies en sodoende die stedelike omgewing beter te verstaan.

Die dier- en plantdiversiteit in the stedelike omgewing lewer 'n menigte van ekosisteemgoedere (soos kos en brandstof) en –dienste (bv. lugsuiwering en verlaging van klankintensiteit). Bo-en-behalwe hierdie tasbare voordele voorsien die stedelike groen areas ook ontspanningsvoordele, opvoedingsgeleenthede en sosiale voordele aan stedelinge. 'n Verrassende deel (21–36 %) van die groen areas in stede word bygedra deur die plantegroei wat tuine voorkom. Dit beeld die belangrikheid van hierdie land-tipe uit, maar daar is min kennis oor dié plantegroei en die potensiaal daarvan vir bewaring. Daar is gevind dat die faktore wat die diversiteit en spesierykheid van tuine beïnvloed, verskil van dié van semi-natuurlike gebiede as gevolg van die menslike invloed. Sosio-ekonomiese status (SES) van inwoners is een van die faktore wat tuinplantegroei beïnvloed. Mense met 'n hoër SES het meer diverse spesieversamelinge in hulle tuine gehad as dié met 'n laer SES. Hierdie verskynsel staan bekend as die "luuksheidsbeginsel".

Die nalatenskap van apartheid het 'n steil sosio-ekonomiese gradient geskep in die Tlokwe Stadsmunisipaliteit weens die ongelyke verspreiding van ekonomiese, natuurlike en sosiale hulpbronne. Die doel van hierdie studie was om inligting in te win rakende die flora wat in huistuine in die Tlokwe Stadsmunisipaliteit voorkom. Verder was dit ook ten doel om te bepaal of SES, 'n bestuursindeks en demografiese faktore die verspreiding van plantspesies in die tuine beïnvloed. Daar is in total 835 plantspesies in 100 huistuine aangetref, waarvan die meerderheid uitheems was.Ingesluit in hierdie groep was Rooidata spesies, indringerspesies en ook heelwat spesies met gebruikswaarde. Die teenwoordigheid van die bogenoemde spesies beeld die belangrikheid van huistuine as ex situ bewaringsgebiede uit, maar dit kan ook terselfdertyd die integriteit van ons natuulike ekosisteme bedreig deur die verspreiding van indringerspesies.

Die gamma-, alfa- en betadiversiteit is bepaal vir elk van die vyf SES-klasse om sodoende die patrone van plantegroei van huistuine in die Tlokwe Stadsmunisipaliteit te beskryf. In ooreenstemming met ander studies het die korrelasies getoon dat die SES van inwoners die plantegroeiverspreiding in die studiegebied beïnvloed. Dit was veral die geval vir die verspreiding van uitheemse spesies wat aangeplant word ter wille van hulle ornamentele waarde.Gebiede met ‘n hoër SES het ‘n groter aantal spesies gehad as dié met ‘n laer SES. Die ander faktor wat die verspreiding van plantspesies in die huistuine beïnvloed het, was die bestuursindeks; alhoewel in ‘n mindere mate as SES. Die bevestiging van verskille langs die SES-gradiënt voorsien nuttige inligting aan beplanners en beleidskrywers om die wanbalans in stedelike groen ruimtes tussen verskillende SES klasse reg te stel waar dit die nodigste is.

Acknowledgements

First, I give all honour to my Almighty Father, who is the sole provider of all that I am and have.

I would like to thank the following people for their contribution to this dissertation:

- My supervisors, Prof. Stefan Siebert and Prof. Sarel Cilliers for all the time they invested and their valuable input
- Elandrie Davoren, Esmé Kruger, Marguerite Westcott, Mari la Grange, Marié Minnaar, Marlie van Staden and Yolandi Els for assistance with field work and data entering
- Marié du Toit for technical assistance with all maps
- Dr. Suria Ellis from Statistical Consultation Services, North-West University
- The National Research Foundation and North-West University for financial assistance
- All my fellow students and the office personnel for their continuous support
- My husband and my parents for their unconditional love, patience and the sacrifices they made to enable me to complete this project.

Table of contents

List of Figures

List of Tables

List of Abbreviations

CA – Correspondence Analysis

DCA – Detrended Correspondence Analysis

GPS – Global Positioning System

HOV – Homogeneity of Variance

IDW – Inverse Distance Weighting

MI – Management index

PCA – Principle Component Analysis

SA – South Africa

SES – Socio-economic status

TCM – Tlokwe City Municipality

UK – United Kingdom

USA –United States of America

Chapter 1

Introduction

1.1 Introduction

The term urbanisation is used to describe the movement of people from rural areas to towns and cities and it is regarded as one of the most significant demographic trends of all times (Pickett *et al.*, 2001) due to the devastating impact it has on the environment (Wu *et al.*, 2003). The increase in population density of urban areas results in infrastructure development and the transformation of natural areas (Pickett *et al.*, 2001). Such significant changes in biological and spatial composition affect the structure of natural ecosystems, which further influence the processes underlying these ecosystems, for example nutrient cycles, water relations and climate systems (Wu *et al.*, 2003). Urban ecology is the study of these phenomena in the urban environment, but it goes further than traditional ecology in that it includes humans as the primary driving force (Alberti *et al*., 2003). Despite the immigration of humans into cities providing the ecologist with more than enough reason to study the ecology of urbanised areas, it remains poorly understood (Wu *et al.*, 2003). There has, however, been an increase in urban ecological studies in recent years (e.g. Smith *et al.*, 2006a) as scientists realise that the future of human existence and the well-being of the environment lies in sustainable urban planning (Wu, 2008).

The field of urban ecology evolved from simply studying the nature *in* cities to an integrative approach where different disciplines and sectors collaborate to facilitate the best possible understanding of urban ecosystems (Wu, 2008). Urban ecology provides the opportunity to incorporate humans as part of the ecological system (Hope *et al.*, 2003) and to create a better understanding of the environment in which the majority of our society lives in today. Humans are not merely a disturbing force, but we shape the environment in which we live through our actions and should rightly be included in ecological theory (Wu & Hobbs, 2002). In developing countries, however, urban environmental issues are often overshadowed by health and wealth issues of more pressing nature (Cilliers *et al*., 2004) and there is still a lot of progress to be made in this regard.

Today humans are still just as dependant on the environment and "green space" as when we were hunters and gatherers (Chivian & Bernstein, 2008). Cities rely on ecosystems beyond its boundaries for provision of food, energy sources and waste disposal and the area of land that a city requires to sustain its needs is called its ecological footprint (Rees & Wackernagel, 1996). Numerous benefits are included in the keeping of green spaces within urban areas as it can reduce the ecological footprint of a city. Costanza *et al.* (1997) recorded 17 ecosystem goods and services that are provided by green environments. These range from tangible benefits such as the production of fresh air, food and raw materials for building and fuel, to intangible services such as recreational opportunities and promoting social and cultural interaction. To ensure that the urban environment is kept favourable for life to persist within, knowledge on urban ecosystems that provide these services is indispensable.

The extent of domestic gardens as a natural resource in the urban environment has been underestimated in the past, but recent research has shown that gardens constitute between 21–36 % of the green space in cities (Gaston *et al.*, 2005b; Loram *et al.*, 2007; Mathieu *et al.*, 2007). Furthermore, domestic gardens are the only type of green space in cities that are interconnected to form a larger patch, in contrast with other ecosystems that are isolated as a result of fragmentation (Colding, 2007). These high proportions and connectedness emphasise the significance of having domestic gardens included in urban ecological studies. Another important reason to study domestic gardens is that they are the main source of alien species that colonise our natural habitats (Sax & Gaines, 2003) and can cause extinctions of native species (Smith *et al.*, 2006a). Knowledge on the distribution of such species in domestic gardens and also the ways in which their dispersal are aided by anthropogenic influences, such as garden waste disposal (Siebert *et al.*, 2010), will be of great importance in the control of invasive species. Nemudzudzanyi *et al.* (2010) and Molebatsi *et al.* (2010) further emphasised how useful domestic garden plants are important sources of food, medicine and structural materials, especially for the rural poor that do not have the resources of urbanites.

1.2 Objectives

Domestic gardens were excluded from ecological studies in cities until recently mainly because of restricted access (Grimm *et al.*, 2000). Also in Potchefstroom has the garden flora deliberately been excluded from ecological studies (Cilliers, 1998) and the total composition of the local urban flora remains incomplete. The general aim of this study was to increase our knowledge of the domestic garden flora in the Tlokwe Municipal area with a floristic analysis and to determine the patterns and underlying processes (drivers) within this land-use type. It will contribute towards the international community's understanding of floristic trends and patterns within urban ecosystems and add valuable knowledge on the situation from a developing country's perspective.

Amongst several other drivers, an urban-rural gradient implies a gradient determined by socio-economic status (SES) of the residents, because available resources can either limit or enable inhabitants to change their environment to be as they desire (Kinzig *et al.*, 2005). Several studies from the USA concluded that the SES of urban inhabitants has an influence on floristic diversity (Pickett *et al.*, 2001; Hope *et al.*, 2003; Martin *et al.*, 2004; Kinzig *et al.*, 2005), with species diversity being greater where residents of higher income groups reside – termed the “luxury concept”. This study will consider the effect of SES on the patterns of plant species diversity within domestic gardens. The SES is a combination of the following parameters: percentage unemployment, household size, number of rooms in a dwelling, access to basic services and schooling status (refer to section 3.4 for more detail).

The SES gradient is especially pronounced in South Africa, which creates the perfect opportunity to study biodiversity gradients in urban areas. In all of South Africa’s urban areas, the heritage of the apartheid era is still very much visible (Christopher, 1997). Segregation of different racial groups was enforced by strict laws: first by the Natives (Urban Areas) Act no. 21 of 1923 and later by the Group Areas Act of 1950. The first distinguished between urban and rural areas and the regulated movement of only black males were allowed between the two. The second act extensively enforced *apartheid* (separateness) in that people of colour were relocated within urban areas to reside in the areas designated for their specific race. Place of residence was not the only prescription made by these laws, but education and employment restrictions, as well as low wages caused very high poverty and unemployment levels in the black population group (McDonald, 1998). Thus, for a period of 40 years (1950–1990), segregation was forced onto the structure of urban development and social character of South African cities. Since the end of apartheid, urbanisation in South Africa increased rapidly (McConnachie & Shackleton, 2010) and even more than a decade later, many of the so-called “previously disadvantaged people” (Oberholzer, 2005) were still too poor to move away from the townships into the predominantly white, middle-upper class suburbs of cities (Christopher, 2001). Economic constraints are one of the most important barriers to overcome in the desegregation period, along with demographic, social and cultural issues (Lemon, 2003). This legacy effect of the segregation process is expected to influence the plant diversity patterns because of the steep socio-economic gradient that was created.

Specific objectives of this study were to:

- portray the species richness and diversity of domestic gardens;
- determine the structure of the garden vegetation in terms of frequent taxa and dominant growth forms;
- assess how species richness and diversity of domestic garden vegetation compare to that of other urban open spaces in the study area (β diversity);
- assess the presence of alien and naturalised species in domestic gardens;
- determine to what extent domestic gardens provide a refuge for threatened and other indigenous species;
- assess if the legacy effect of apartheid in South Africa had influenced the plant diversity of domestic gardens;

- determine the extent to which utilitarian plants are harboured by different SES classes;
- visually depict the patterns of species richness and diversity of domestic gardens along the SES gradient;
- determine the influence of socio-economic factors on the floristic patterns within domestic gardens;
- establish whether management practices in domestic gardens affect the spatial variation of plant species therein.

1.3 Hypotheses

Hypothesis 1: Plant species richness in domestic gardens will be greater than that of other land-use types and thus will contribute greatly to urban green space diversity.
Hypothesis 2: The political legacy of apartheid in South Africa will influence the plant diversity in domestic gardens through socio-economic means.
Hypothesis 3: Inhabitants with lower socio-economic status will cultivate and harbour more species with utilitarian value.
Hypothesis 4: A higher plant diversity and species richness is expected where residents from higher socio-economic status groups reside.
Hypothesis 5: Management actions will affect plant species richness and diversity in all socio-economic status classes, regardless of financial means and culture.

1.4 Format of study

This dissertation conforms to the guidelines set for a standard dissertation at the North-West University[1]. It encompasses seven chapters, of which three were also prepared as manuscripts for submission to scientific journals (Chapters 4−6). The structure of these chapters implies that a certain amount of duplication was unavoidable, especially regarding literature, methods and results. References sited in these chapters were included in the list of references at the end of the dissertation.

<u>Chapter 2: Literature review</u>
An in-depth examination of the existing literature is provided in this chapter. It reasons on the necessity of ecological knowledge of the urban environment as a whole and the inclusion of private green spaces such as domestic gardens. The importance of interdisciplinary research is also stressed as this study attempted to include socio-economic variables in the explanation of vegetation patterns.

[1]See section 2.1 of the Manual for Post Graduate Studies (www.nwu.ac.za/library/documents/manualpostgrad.pdf)

Chapter 3: Methods

The general methodology followed in the study is described. This includes a description of the study area, project planning and experimental design. Specific methods of importance for other chapters (e.g. statistical analyses) are not covered here, but described thoroughly in the relevant chapters to avoid excessive duplication.

Chapter 4: A floristic analysis of domestic gardens in the Tlokwe City Municipality, South Africa

The floristic analysis was undertaken to determine the importance of domestic garden flora as a contributor to urban green infrastructure. Information on the extent of urban agriculture and invasive species also provided valuable insight into socio-economic and ecological concerns of the urban population today. This chapter has been accepted for publication in *Bothalia* (South African National Biodiversity Institute) (Lubbe *et al.*, 2011).

Chapter 5: Political legacy of South Africa affects the plant diversity patterns of urban domestic gardens along a socio-economic gradient

As a result of segregation laws during the era of apartheid, inequalities between the distribution of financial, social and natural resources between different cultures caused the steep socio-economic gradient visible in many South African cities today. This chapter explores the effects of socio-economic and cultural aspects on the plant diversity patterns along such a gradient in the Tlokwe City Municipality, with some focus on the distinctive use of ornamental and utilitarian plants between different cultures. This chapter has been published in *Scientific Research and Essays* (Academic Journals) (Lubbe *et al*., 2010).

Chapter 6: Patterns of domestic garden plant diversity and underlying drivers along a socio-economic gradient in the Tlokwe City Municipality, South Africa

This chapter attends to the statistical description and analysis of the socio-economic gradient in the Tlokwe City Municipality. It also provides a visual representation of the plant species distribution along this gradient with the use of inverse distance weighting maps and aim to explain the socio-economic drivers behind the observed patterns. This chapter has been prepared for submission to *Ecology & Society* (Resilience Alliance).

Chapter 7: Conclusion

This chapter is a synopsis of the critical findings emanating from chapters 4 to 6 and what contribution it makes towards our existing knowledge about domestic gardens and socio-economic gradients. It also presents some shortcomings in this study and recommendations for future reference.

Chapter 2

Literature review

2.1 Evolution of urban ecology

"We cannot confine ourselves to the so-called 'natural' entities and ignore the processes and expressions of vegetation now so abundantly provided by man. Such a course is not scientifically sound, because scientific analysis must penetrate beneath the forms of 'natural' entities, and it is not particularly useful because ecology must be applied to conditions brought about by human activity. The 'natural' entities and the anthropogenic derivatives alike must be analyzed in terms of the most appropriate concepts we can find." **Arthur Tansley, 1935**

Urbanisation and anthropogenic influences have increased dramatically since Tansley (1935) cautiously encouraged the application of ecology to human environments. According to the United Nations Department of Economic and Social Affairs (2008), only 30 % of the world's population lived in cities in 1950. This figure has increased to more than 50 % in 50 years. Furthermore, it is predicted that two-thirds of the human population will reside in cities within the next 40–50 years, with Sub-Saharan Africa taking the lead in urban population growth (United Nations Department of Economic and Social Affairs, 2008). This situation has many implications. Development of housing and infrastructure cannot keep up with the increase in population numbers, which lead to conditions equal to or even worse than what drove the rural inhabitants to the cities in the first place (World Bank, 1984). It also creates many environmental problems such as air pollution (Fenger, 1999), the destruction of natural habitats (Kendle & Forbes, 1997) and native biodiversity loss (Vitousek *et al.*, 1997; Hansen *et al.*, 2005).

In spite of these facts, urban ecology focused mainly on the more natural areas within cities for a long time (Alberti *et al.*, 2003) and did not realise the importance of integrating humans as a persistent driving force of ecological processes within the city boundaries (Pickett & McDonnell, 1993). Only recently has the interest in the urban environment as a whole and its integration into traditional ecological theory been promoted and studied extensively (Grimm *et al.*, 2000; McIntyre *et al.*, 2000; Luck & Wu, 2002; Alberti *et al.*, 2003). Grimm *et al.* (2000) ascribed this upsurge of interest in urban ecology to a greater realisation that people dominate the systems of the earth and have a devastating impact on the environment, as also indicated by Vitousek *et al.* (1997). Scientists realised the importance of gaining knowledge on the effect of increasing urbanisation to enable better and more sustainable planning in urban environments. More relevant ecological models can be created when humans are included and this could empower us to solve environmental problems more efficiently

(Grimm *et al.*, 2000). Since the early twentieth century, the idea to include humans as part of urban ecosystems has been raised (Adams, 1935; Tansley, 1935; Lindeman, 1940). In spite of the interest in urban ecology, historical events such as the world wars and a lack of funding and technology limited its expansion until recently (McIntyre *et al.*, 2000). Rapid increases in the amount of literature over the last 15 years proved that some of these constraints have been lifted (e.g. improved technology, such as remote sensing).

Wu (2008) summed the efforts and different approaches used in urban ecology into five perspectives: ecology *in* cities (1), ecology *of* cities with the main focus on socio-economic features (2), and three perspectives regarding the ecology *of* cities as ecosystems, namely the urban systems perspective (3), the integrative urban ecosystem perspective (4) and the urban landscape ecology perspective (5) (Figure 2.1). In the first of these approaches, a city was not viewed as an ecosystem *per se* and the ecology *in* urban areas consisted of knowledge of the nature within cities, where organisms or specific habitats within cities were examined (Grimm *et al.*, 2000). The second and contrasting ecology *of* cities-approach, implements ecological principals to a system regarded as essentially socio-economic. In the urban systems perspective (3), socio-economics and ecology are viewed as separate systems that influence each other simultaneously, while integration of these different types of systems takes place within the integrative urban ecosystem approach (4). The only approach to integrate different disciplines and consider the scale and patch-heterogeneity (many patches of different land-use types) of urban ecosystems, however, is the urban landscape ecological perspective (5) (Wu, 2008).

The one outstanding characteristic that distinguishes urban environments from more natural ecosystems is the prevailing presence of humans and their activities. This presents an immense challenge to ecologists, because it includes primarily the human ability of choice that impels change in the urban environment (Alberti *et al.*, 2003). It results in countless interactions and all of these, as well as the traditional biogeophysical factors, has to be considered when integrating humans into ecology (Alberti *et al.*, 2003). There have been a number of attempts to facilitate this integration of social and ecological systems with the use of conceptual frameworks, as the urban environment embodies the goals and values of man and are as much formed by the cultural environment as by the physical setting (Whitney & Adams, 1980). Furthermore, humans are not only the cause of so much destruction to natural ecosystems, but the key to creating sustainable landscapes also resides with us. For this reason, interdisciplinary and transdisciplinary approaches in urban ecological studies are suggested in literature (McIntyre *et al.*, 2000; Dow, 2000; Wu & Hobbs, 2002; Alberti *et al.*, 2003; Fry *et al.*, 2007). According to definitions by Fry *et al.* (2007), interdisciplinary projects are administrated between several unrelated academic disciplines researching a common goal. Transdisciplinary, on the other hand, include not only different academic disciplines but also participants from non-academic sectors (e.g. public participants), working towards common research objectives. The interdisciplinary and transdisciplinary nature of integrative frameworks is regarded as its strength, as it creates a platform from where environmental and social problems can be addressed by different disciplines in mutual aid (Cilliers, 2010).

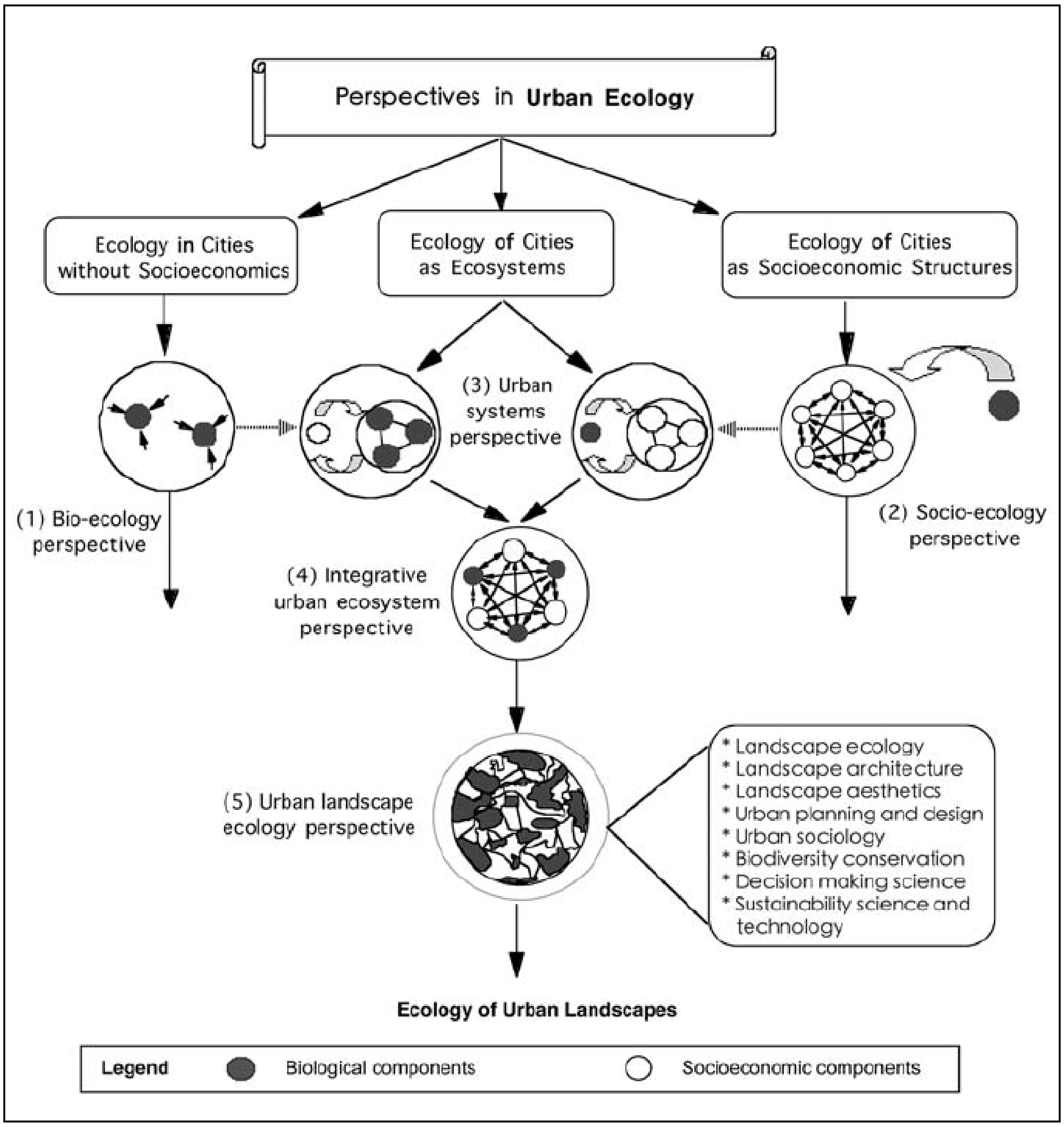


Figure 2.1: A diagram illustrating the development of the five urban ecological perspectives (from Wu, 2008).

Pickett *et al.* (1997) stated that only with the addition of social features, the traditional ecosystem concept can be used to understand urban ecosystems. Ecological studies of the past included features such as primary production, populations, nutrients and disturbance phenomena. However, the knowledge of social scientists was what remained lacking in the integration process between ecological and social sciences (Grimm *et al.*, 2000). Inclusion of other disciplines will lead to the development of new and improved concepts that apply to all ecosystems – including those influenced by anthropogenic factors (Grimm *et al.*, 2000). Some attempts were already made to expand the knowledge within this developing field, such as ecological studies including human preference factors (Acar & Sakici, 2008;

Bixler & Floyd, 1997), socio-economic factors (Dow, 2000; Kinzig *et al.*, 2005; Mennis, 2006) and other demographic trends (Hahs & McDonnell, 2006).

The landscape ecological approach brings together the theoretical knowledge and humanistic aspects in the process of integration between man and science (Wu & Hobbs, 2007) by considering scale, patchiness and dynamics. Alberti (2005) has also stressed the importance of scale in the analysis of any pattern or process, and landscape ecology provides the tools that are needed for integration of ecology, design and management, especially when complex, human-nature interactions are concerned (Wu, 2008).

As is the case with other developing countries, urban ecological research was slow to develop in South Africa in comparison to developed countries (Sukopp, 2002) and it was strongly focused on input from social sciences and urban planners (Poynton & Roberts, 1985). With the increase in urbanisation, scientists realised the value of urban open spaces (Poynton & Roberts, 1985; Roberts, 1993) and the Metropolitan Open Space Systems initiative were established. This initiative promotes urban open space planning and has been applied in cities such as Cape Town (Hennessy, 2000), Durban (eThekwini Municipality Environmental Management Department, 2009), Johannesburg (Strategic Environmental Focus, 2002) and Port Elizabeth (Stewart, 2006). Phytosociological descriptions of urban open spaces in two cities in the North West Province included the hills and ridges (Van Wyk *et al*., 1997), wetlands (Cilliers *et al.*, 1998; Van Wyk *et al.*, 2000), natural grasslands and woodlands (Cilliers *et al*., 1999), intensively managed parks, pavements and parking areas (Cilliers and Bredenkamp, 1999a), vacant lots (Cilliers and Bredenkamp, 1999b) and road verges (Cilliers and Bredenkamp, 2000), but deliberately excluded private gardens. The scope of public green space of small towns in the Eastern Cape was done by McConnachie *et al.* (2008), but also with the exclusion of garden vegetation. Those studies that were conducted in gardens focused on urban agriculture and agroforestry (Rogerson, 1993; May & Rogerson, 1995; Cilliers *et al.*, 2007; Molebatsi *et al.*, 2010).

2.2 The definition of "urban"

In the ecological spectrum of classifying different types of areas in terms of human influence, one would find natural areas at the one end with urban areas on the other. In between is the varying degree of human impact that makes a site less or more urban. McDonnell (1988) defined a natural area as "ecosystems which persist primarily because of natural processes of plant establishment, water availability, nutrient cycling, and plant-animal interactions with minimal human manipulation". Areas that fit this definition are thus only found in the most secluded regions where anthropogenic impact via localised natural resource use, agriculture and urbanisation are very limited or absent. The rest of the scale from semi-natural to urban includes an increasing amount of human influence, but to define "urban" areas simply as human-dominated is not adequate as McIntyre *et al.* (2000) has indicated. This would mean that even some remote sites that are subject to some degree of human influence can be classified as "urban", which creates a definition too broad to be of much worth.

McIntyre *et al.* (2000) investigated the use of the term "urban" and concluded that most literature in natural sciences did not unambiguously describe their definition. General and indistinct terms were used in the cases that did present a definition. A lack of consistent usage of any term is bound to cause problems, as Mack (1999) has described for the processes of publication and reviews. Furthermore, broad definitions can impede the results of any comparative study using data gathered within such vague borders (McIntyre *et al.*, 2000).

Some recent literature has shown potential with the use of quantification of the urbanisation gradient (Luck & Wu, 2002; Hahs & McDonnell, 2006; refer also to section 2.6.1), but this presented a further problem: quantification of a variable appropriate for one study might not be useful for another, as different research questions are addressed, often at much different scales (McIntyre *et al.*, 2000). It is clear that a single, universal definition of "urban", or where "urban" starts, is not realistic. As a solution to the problem, McIntyre *et al.* (2000) suggested that each study included its own, working definition that contains quantitative information such as socio-economic, cultural, demographic and geographical variables that are applicable to the specific research question. This would facilitate easier comparison between and improve the reproducibility of studies.

2.3 Importance of urban nature

The human presence in urban environments creates diverse and drastic environmental conditions that are very different from natural conditions (Alberti *et al.*, 2003). As a result of the changes in the environment, different combinations of species are also encountered in urban areas (Kendle & Forbes, 1997). McDonnell & Pickett (1990) described these conditions as a "series of experimental manipulations" at a scale and magnitude that cannot be simulated in the laboratory. This presents ecologists with a magnificent opportunity to gain knowledge on completely novel and unique environments and integrate humans into ecological study (McDonnell & Pickett, 1990). Ecologists also recognised the importance of information on the impact of urbanisation on ecological systems, with an increasing emphasis in the future.

The diversity of fauna and flora in urban environments play a significant by providing ecosystem goods and services. Costanza *et al.* (1997) defined this as "the benefits human populations derive, directly or indirectly, from ecosystem functions". Ecosystem goods include foods, pharmaceutical and industrial products, fuels and fibre (for clothing and building materials), while services consist, among others, of air filtering, erosion and rainwater control, reduction of noise, and recreational and educational opportunities (Millennium Ecosystem Assessment, 2003). Bolund & Hunhammar (1999) chose six ecosystem services of relevance to the city of Stockholm and attempted to quantify the significance of each of these. For instance, the planting of trees could reduce the cost of temperature regulation by US$50–90 per private residence unit each year in Stockholm. Together with reducing temperatures in the summer, the trees would simultaneously play a role in air filtering and carbon sequestration (Bolund & Hunhammar, 1999). Considering this and the collective effects of all other ecosystem services, it could account for an enormous amount of money either saved or wasted in the long run by choosing to utilise these services or not. A negative consequence of the flora in urban areas is that some plants, specifically trees and shrubs, release biogenic volatile organic compounds (BVOC's) that have the potential to produce ozone when it reacts with the nitrogen oxides resultant of anthropogenic activities (Benjamin & Winer, 1998). The extent of release of BVOC's is species-specific and, while attempting to improve air quality with the use of vegetation, some species could do more harm than good. In extensive tree planting efforts, care should thus be taken to use the right species. Paoletti (2009) has highlighted popular urban tree species, such as *Quercus robur*, as presenting high BVOC risk and *Acer platanoides* presenting low risk in forests in Italy. Both Paoletti (2009) and Benjamin and Winer (1998) warned, however, that the methodology of determining a tree's ozone-forming potential has its limitations in the urban environment where numerous other stresses and pollutants are present. Much additional research is still needed on this subject. Managing ecosystem services in a sustainable and economically sensible manner within the urban environment thus require the use of ecological knowledge to inform city planners, managers and decision makers. This will ensure that cities are sustainable now and for future generations (Pickett *et al.*, 2001).

The fauna and flora within urban boundaries often represent the only contact that urban residents have with nature (Kinzig *et al.*, 2005). This includes ruderal, street side and garden vegetation as well as public neighbourhood parks. It is well-known that nature influences the well-being and quality of life of citizens. According to Chiesura (2004), green space in cities are used for the following reasons: relaxation, escape from the busy city life, to experience positive feelings and to connect with nature. This experience has numerous physical, psychological and social consequences, as proved by several independent studies. Research done by Ulrich (1981) showed that patients who were exposed to nature during the recovery phase of their illness were more positive and recovered in a shorter time than patients exposed to built-up environments. Social interaction amongst urbanites is increased by the availability of green space, which is used more often than spaces lacking nature (Coley *et al.*, 1997). According to Kuo & Sullivan (2001), aggressive and violent behaviour was reduced by the presence of green space in a neighbourhood in the USA, while crime rates were significantly lower in highly vegetated areas. There are also therapeutic benefits in gardening and having a private garden, such as stress relief, creating an own identity and deal with emotional losses (Gross & Lane, 2007). The magnitude of the positive effects supplied by nature can also be altered, according to Fuller *et al.* (2007). They claimed that those green spaces with increased species richness (mainly that of plants, but also to a lesser extent that of birds and butterflies) can exert an even more positive influence on a person's well-being.

On the other hand, some people also experience a fear of nature or simply describe it as uncomfortable and dirty. The fear of snakes, spiders and insects can be nurtured from early childhood and the resultant desire for modern comforts and indoor recreation prevent them from enjoying wildlife and unkept nature sites (Bixler & Floyd, 1997). These negative connotations of some members of the urban public are, however, simply overshadowed by the positive properties of an experience with nature (Chiesura, 2004).

Many rural people moved to urban environments to improve their living conditions through better job opportunities. In reality however, for 25–50 % of new-comer citizens, life in the city is even worse than before (World Commission on Environment and Development, 1987). In this regard, urban agriculture can fulfil a substantial role. Currently, about one seventh of our planet's food supply is produced through urban agriculture, which includes backyard and front yard gardening (Olivier, 1999). Vegetable and herb gardens, as well as fruit trees or orchards, may be found within domestic gardens in urban areas. This is especially true for the poorer communities in developing countries, such as South Africa, where it serves as a valuable resource of food or provides additional income (May & Rogerson, 1995; Olivier, 1999; Shackleton *et al*., 2008). For instance, community upliftment projects have been launched in the poorer communities of Ikageng, Potchefstroom (Cilliers *et al.*, 2007) and the aim of this project was to introduce economic and sustainable ways of producing crops on a small scale, such as the eco-circle approach (Trowbridge, 1998). With an increasing amount of mouths to feed in every city, urban agriculture may provide an answer to poverty, famine and community upliftment on a local scale. It can further contribute to an increase in green space in urban areas (World Commission on Environment and Development, 1987) and the protection of our natural ecosystems (Olivier, 1999).

A better understanding of urban ecology, as the study of all of these interactions and processes in the urban environment that serves the urban society, and the application of ecological principles in urban planning will improve living conditions for inhabitants (Mennis, 2006; Cilliers & Siebert, 2010). It will also facilitate increased compassion for nature in the lives of those who can make the greatest difference towards sustainability – the urban public (McKinney, 2002; Fuller *et al.*, 2007). Along with the fact that the urban population is steadily growing, the above information highlights the importance of urban ecology.

2.4 Biodiversity in urban environments

2.4.1 The influence of urbanisation on vegetation

Biodiversity can be defined in very broad terms as the total scope of life in all its variety – from genetic level to communities (Savard *et al.*, 2000). The urbanisation process strongly influences biodiversity, in some ways for better and some for worse. Humans are in turn physically, psychologically and socially dependant on the biodiversity of our surroundings, as was already explained (section 2.3).

According to McKinney (2006) and Williams *et al.* (2009) the species that are present in urban areas originated from three different sources: (1) natives that were present in the landscape before development, (2) native species that did not occur locally, but are adapted to urban environmental conditions, and (3) the alien species introduced through human activities. Not all species from these sources establish in these altered landscapes. A conceptual framework proposed by Williams *et al.* (2009) recognise four filtering selection pressures that are at work in urban landscapes that determine which species can persist. Each filter may cause reductions and/or gains to the urban flora, but identifying a single driving force behind specific gains or losses is difficult, as filters operate concurrently. The design, functions and constrictions within city limits around the world are fairly similar, but it is important to take into account the effects of the surrounding environmental conditions and naturally occurring species, which will also influence changes in vegetation during urbanisation (Savard *et al.*, 2000; Williams *et al.,* 2009). The different filters are described in more detail in the following paragraphs.

The first of these filters is **habitat transformation**. Because the natural area of occurrence of many native species is severely reduced by urban development, many are not able to survive in the urban landscape (species-area relationship). This filter was predicted to cause a net loss of species, although its effect may be less pronounced if the transformed area was formerly cultivated. Agricultural practices would already have removed the most sensitive species from the original pristine landscape (Williams *et al.,* 2009). Hope *et al.* (2006) also found the native urban vegetation to be reduced by a history of agriculture. Their survey in the Arizona-Phoenix metropolis had shown an average number of four genera at sites that were previously cultivated, while sites that were never cultivated before, had on average nine genera (Hope *et al.*, 2006).

Many species need larger surface areas of habitat than those provided in urbanised areas and the fragmented land may also lack corridors connecting separate source and sink habitats for the survival of metapopulations. This is why **habitat fragmentation** can cause a net loss of species (Savard *et al.*, 2000). Only those species that are able to persevere in spite of small population size were expected to be fed through this filter (Williams *et al.,* 2009).

Novel environmental conditions and habitats are created in urban landscapes as a result of development and human activity. It ranges from higher mean temperatures (Kendle & Forbes, 1997), highly heterogeneous and dynamic habitat types (Pickett *et al.*, 2001; McIntyre *et al.*, 2001), altered biogeochemical cycles (Grimm *et al.*, 2000) and soil and substrate types (Rebele, 1994; Craul, 1985) to higher degrees of pollution, compaction and different disturbance regimes (Rebele, 1994). The advanced flowering time of some plant species caused by elevated temperatures is an example of how these altered environmental conditions affects urban biota (Neil & Wu, 2006). This filter of **altered environmental conditions** will thus select for plant species that are adapted to these urban-specific environmental requirements and constraints (Williams *et al.,* 2009). As the altered conditions are mostly permanent, it does not allow for successional recovery as would happen in non-urban habitats (McKinney, 2006) and the result is that novel plant and animal communities would be assembled through this filter (Alberti *et al.*, 2003).

The fourth and last filter proposed by Williams *et al.* (2009) was **human preference**. Large numbers of plant species are introduced into the urban environment for agroforestry and horticultural purposes (Reichard & White, 2001; Thompson *et al.*, 2003) and although most species are only available in small numbers, those favoured most by humans may exert high enough propagule pressure to expand their range and establish natural populations (Kühn & Klotz, 2006). Choices made by humans in selecting the types of species and management regimes largely determine the success of introduced and spontaneous species. Williams *et al.* (2009) predicted that human preference will result in a net gain of species, simply because of the magnitude of plant species introductions.

Empirical results exist to confirm the discussed effects of urbanisation (McKinney & Lockwood, 1999; Sax & Gaines, 2003; Kühn *et al.*, 2004; Wania *et al.*, 2006; McKinney, 2008). They found that urban areas harbour more species (higher gamma diversity) than the surrounding natural and agricultural areas. McKinney (2006) compared the vegetation of several cities in the United States and concluded that many of the alien species establishing in these cities were the same. Furthermore, he found that the vegetation within cities was more alike than when the vegetation of natural areas was compared to each other (urban areas have lower beta diversity than natural areas). Although local biodiversity is increased by the influx of alien species to urban areas, the native biodiversity is also in part being replaced by these common alien species (Sax & Gaines, 2003) – a process called "biotic homogenisation".

2.4.2 The influence of urbanisation on vegetation in developing countries

In developing countries, the effects of urbanisation are expected to be more extreme, because of much higher population densities in urban areas while available resources are often much less (Pauchard *et al.*, 2006). Conservation and biodiversity are also of less importance in developing countries, because of other pressing concerns such as wealth creation, health improvement and poverty alleviation (Cilliers, 2010). As cities are very often located in areas of high biodiversity (Miller & Hobbs, 2002; Kühn *et al.*, 2004), it is important to understand how urbanisation affects urban biota on a global as well as local scale to enable improved conservation of the natural floras present in such diverse environments (Williams *et al.*, 2009). It was suggested that the efforts towards conservation could be strengthened greatly by connecting it with aspects to improve quality of life for its residents (Miller, 2005, Cilliers, 2010). Diaz *et al.* (2006) described the influence of biodiversity loss on human well-being and stated that the rural poor and subsistence farmers, who are most dependent on the ecosystem services provided by biodiversity, will be affected more severely than others by the loss of biodiversity brought about by anthropogenic influences.

2.5 Urban domestic gardens

2.5.1 History of gardening

The horticultural growing of plants has been practiced from as early as 3000 BC, but for purely utilitarian purposes. Only affluent cultures such as the Romans later had the privilege to use plants to create spaces solely as aesthetically pleasing environments. Ornamental gardening as we know it today originated during the twelfth and thirteenth centuries (Owen, 1991). Reichard & White (2001) explained how the discovery of new plants from different parts of the world eventually grew into the global trade that supports ornamental gardening today.

Archaeological records and historical documentation of European and Portuguese explorers dating from the sixteenth century has shown that the southern part of the African continent has only been cultivated since around 300 AD. This was in the form of small-scale agricultural practices to produce food. In 1652, European settlers established the first garden, called the "Kompanjiestuin", to grow fresh produce for the crews of their ships on its way from Europe to Asia (Gilomee & Mbenga, 2007). It was not until 1850 however, that ornamental flora became the priority group of introduced plants, in contrast to the introduction of mostly utility plant species prior to this date (Henderson, 2006). Gardening was strongly under European influence in South Africa as well as other countries in the southern hemisphere, as most cities were founded by Europeans who tried to create a piece of "homeland" in their new surroundings (Faggi & Ignatieva, 2009). This influence led to globalisation of the world's urban flora, but according to Faggi & Ignatieva (2009) there is an increasing realisation of the importance of protecting local heritage, natural and cultural, to create cities that are unique.

In the most recent history of South Africa lies the apartheid era which also strongly influenced the way that gardening is practiced today. Some parts of the community were in a disadvantaged position during this time. This not only led to segregation of the residences of different racial groups, but also to distinctions in schooling and job opportunities (Christopher, 2001). Today, the consequences of this segregation can still be seen in domestic gardens. In the Tlokwe Municipal area of North West, for instance, different racial groups still live mostly in separate locations. Although job and schooling inequalities have been addressed since the end of apartheid, the lag effect from previous disadvantage and segregation, as well as other complex social issues, are still present (Christopher, 2001). Gardens in white neighbourhoods strongly reflect the ostentatious European culture, while black people grow more utilitarian plants in their gardens (May & Rogerson, 1995; refer to chapter 5).

2.5.2 The contributions of garden vegetation to green space

Estimates of urban green space normally excluded the part constituted by domestic gardens (Rapoport, 1993) because it is mostly private property and therefore not under the direct management of local authorities (Gaston *et al.*, 2005a). Although each garden only represents a small space, the total contribution of gardens to a city's green space can be substantial – in the UK it is estimated to be almost a quarter of five major cities (Gaston *et al.*, 2005b; Loram *et al.*, 2007). In a New Zealand city, Mathieu *et al.*, (2007) has shown that gardens make up 46 % of the residential area (more or less 36 % of the entire city region), while 90 % of the total canopy cover in Baltimore, Maryland, are located on private lands (Troy *et al.*, 2007). Most gardens contain many more plant species than any other land-use type in urban environments (Rapoport, 1993; Thompson *et al.*, 2003) and its ability to provide ecosystem goods and services, wildlife habitat and corridors between semi-natural areas (Savard *et al.,* 2000; Davies *et al.*, 2009) should not be neglected. From a financial point of view, this fraction of the city engulfs large sums of money in the form of management costs (Gaston *et al.*, 2005a). This implies that the horticultural industry can generously contribute to biodiversity enhancement in urban areas, if resources are applied correctly and mindsets changed.

The reasons why domestic gardens have such high species richness are, according to Thompson *et al.* (2003), twofold. The first is the incredibly large variety of plants that are available to the home gardener. A list of plants containing more than 70 000 species that are available in UK nurseries was compiled by Macaulay *et al.* (2009), while Isaacson (2004) presented a list that consisted of 90 000 plant species available for sale in the United States. Glen (2002) published a book on the cultivated plants of southern Africa that contains more or less 37 000 species (not claimed to be a fully comprehensive list), compared with the almost 22 000 species of natural flora in South Africa (Germishuizen *et al.*, 2006). So with all these species available and new introductions on a regular basis, the species pool for gardening is very extensive. Within this large pool of plant species is a considerable amount of alien species: 70 % in Mexico City (Díaz-Betancourt *et al.*, 1987), and 67-70 % in Sheffield gardens (Thompson *et al.*, 2003; Smith *et al.*, 2006a). This influx of alien species may put some pressure on the natural vegetation, as some species can naturalise and form self-sustainable populations in the wild. The second factor that helps to maintain the high species richness of domestic gardens is management and maintenance practices. Thompson *et al.* (2003) argued that these practices grant garden plants the “unnatural ability to persist at remarkably low population sizes”.

Conservationists’ focus is sometimes strongly directed towards native species, which has its merits, but in urban areas with the great ratio of alien species such an approach is difficult to implement. Kendle & Forbes (1997) compared the benefits between these two groups in the UK and explained that the contributions of alien species in the urban ecosystem are substantial. Some alien species support more insect fauna than natives and they are, in many circumstances, more tolerant to the urban environmental conditions than most natives. From a conservation point of view, it is more important to encourage a mere interest in nature rather than conservation purism (Kendle & Forbes, 1997). However, such an approach can only be followed in societies where systems are in place to protect natural areas from potential threat of invasive alien species.

2.5.3 Garden vegetation as a means of conservation

Owen (1991) made observations in her home garden over a period of fifteen years and reported a total of 2204 species, which included plants, insects, amphibians, mammals and birds. The reason for this high biodiversity count was the result of gardening practices (Owen, 1991). Gardens in general were also proven to be rich in plant species (Smith *et al.*, 2006a; Thompson *et al.*, 2003; refer to chapter 4). The protection of garden flora is extremely important as plants provide food and habitat prospects for other taxa (Kendle & Forbes, 1997). The high species richness, as well as the extent of private gardens in cities, provides many opportunities for conservation by the general public.

In the public eye, however, the few native species that can survive under urban conditions are widespread generalists not in need of protection, and therefore it is believed to focus conservation efforts on more natural areas (Miller & Hobbs, 2002). Some urban species are even regarded as a nuisance, such as rats and pigeons (Kendle & Forbes, 1997). Aside from the public opinion about conservation, there are other impediments that hinder conservation efforts in urban areas. All properties in urban areas are not under sole jurisdiction of the local government and funding for conservation is dedicated mainly for natural areas (although there are some instances where this has changed; Miller & Hobbs, 2002). It is therefore a challenge to involve the public in urban nature conservation and protect the native fauna and flora worldwide.

Kendle & Forbes (1997) and Miller (2005) stated that the most important motivation behind conservation efforts is for humans to value nature, but this phenomenon is diminishing in younger urban generations (Kahn, 2002). "Environmental generational amnesia" is the process where each generation cares less about the environment than the previous because of less and less exposure to nature in this urbanisation era (Kahn, 2002). They never learn to value and appreciate the benefits of nature and will, therefore, not be prepared to devote resources towards its protection (Miller, 2005). Cilliers *et al.* (2004) discussed this lack of urban nature conservation efforts and proposed an integrated approach that involves economic, social, cultural and ecological contributions. Different values and perceptions of people in each city are often the cause of friction that prevents, amongst others, the implementation of efficient conservation efforts (McDonnell, 2007). The focus of conservation in urban environments should therefore emphasize the improvement of quality of life for its inhabitants rather than on conservation as such. This can be achieved through various methods: engaging children in conservation efforts (Miller, 2005), presenting ecological data in a way that decision makers and planners can understand (Cilliers *et al.*, 2004; Miller, 2005), employ members of the public in conservation initiatives to improve ecological knowledge (Miller & Hobbs, 2002) and facilitate a better understanding of biodiversity and conservation with the use of transdisciplinary research (Cilliers *et al.*, 2004). Because of the vast amounts of resources (financial and political) available to them, a suburban population that is properly informed on ecological matters could bring about a vast change in conservation (McKinney, 2002) – an important motivation to ensure proper public participation.

2.6 Patterns in urban areas

2.6.1 The gradient approach

According to McDonnell & Pickett (1990) a gradient can exist because of the orderly manner by which variation and change occur in the environment. These patterns then determine the way that ecological systems are structured and how they function. For example, in a city there are areas that are completely built or paved and others that still resembles natural habitat (called semi-natural components) (McDonnell & Pickett, 1990). These two can be seen as the extremes of an urbanisation gradient with varying components in between and are representative of the levels of disturbance, for instance.

The gradient approach enables us to study the response and changes of plant populations and communities to gradual changes in the environment (Gosz, 1992), and relate the spatial organisation as a result of urbanisation to ecological processes (Luck & Wu, 2002). The urban-rural gradient method (sometimes also called land-use, wildland-suburban or urban to exurban gradients (McDonnell & Hahs, 2008)), has been successfully used in numerous studies concerning urban vegetation (McDonnell *et al.*, 1997; Pausas & Austin, 2001; Luck & Wu, 2002; Hahs & McDonnell, 2006; McDonnell & Hahs, 2008).

Gradients can be either complex (indirect) or linear. Complex gradients are most common and consist of more than one contrasting variable. Christopher (1997) described the lag effect from the apartheid era in South African cities as the way they are still mostly segregated into different racial and income groups. People with similar income are thus situated in the same suburban neighbourhood. This makes the application of a simple transect approach unfeasible and other approaches must be employed. The solution is quantification of the variables that a gradient comprise of, and the subsequent arrangement or construction of these variables into an indirect gradient (McIntyre *et al.*, 2000).

Apart from the applicability of a quantified gradient in the highly heterogeneous urban environment, the process of quantification is also a means of standardising the gradient approach. Quantifying the gradient will greatly reduce subjectivity within the results (Hahs & McDonnell, 2006) and also make it possible to compare gradients from cities all over the world. Separate studies use different types and lengths of unquantified gradients, which may lead to variation in the data (Pausas & Austin, 2001). Quantification of gradients is the only way to enable comparison (McIntyre *et al.*, 2000), but according to Du Toit & Cilliers (2011), quantification of a gradient requires the same scale and spatial resolution of satellite images for comparison between cities, and then only for cities in similar ecosystem types.

2.6.2 Socio-economic patterns

According to Dow (2000), the use of the gradient approach provides a link between social and ecological sciences. The importance of including social aspects into ecological studies was stated earlier (refer to section 2.1) and it has already been embraced in several recent studies. With the addition of quantified social features, the traditional gradient approach can be greatly strengthened (Collins *et al.*, 2000).

Furthermore, the inclusion of social variables will increase the predictive ability of the results on urban biodiversity patterns (Kinzig *et al.*, 2005).

Plant diversity in urban areas are much different from those in natural areas, as it is not only subjected to ecological constraints such as the availability of nutrients and moisture, but also to social, economic and cultural influences (Hope *et al.*, 2003). For instance, the socio-economic status (SES) of urban inhabitants are expected to influence the vegetation patterns of some areas because their available resources can either limit or enable them to change their environment (Martin *et al.*, 2004; Kinzig *et al.*, 2005; Niinemets & Peñuelas, 2008). Several studies proved that the SES of the citizens has an influence on the floristic diversity (Hope *et al.*, 2003; Martin *et al.*, 2004; Kinzig *et al.*, 2005). In all of these studies, the results were unanimous: residents in the higher income groups occupy urban areas where the species richness is greater than that of areas where the people from the lower income groups reside. This phenomenon is termed the "luxury concept" (Hope *et al.*, 2003). In some cases it was thought that, instead of influencing the vegetation as suggested, the rich simply acquire the high species richness by choosing naturally species rich areas (such as hills and ridges) to settle (Hope *et al.*, 2006). However, most of the species that are represented in gardens are from alien origin (Thompson *et al.*, 2003; refer also to section 4.3.3) and brought to gardens via anthropogenic activities across the globe.

There are, nevertheless, limits to the extent that the socio-economic status of urbanites influences plant diversity in cities. In some areas, such as public parks, top-down constraints implemented by the local municipality means that the public have very little or no influence in design or management thereof. On the other hand, residents can exert bottom-up influences in their neighbourhoods in the form of preferences, spending regimes, etc. The effects of socio-economic status are much more pronounced in such areas (Kinzig *et al.*, 2005). Application of a socio-economic gradient approach would provide results that will undeniably increase our understanding of fundamental ecological principles. It will also equip ecologists, planners and decision makers with information to improve the design and management of urban ecosystems in an ecologically sustainable manner (McDonnell & Pickett, 1990).

2.7 Plant species invasions

It is a well-known fact that some cultivated plants "escape" from gardens and establish self-sustaining populations in the wild. Sullivan *et al.* (2005) conducted research in patches of native coastal forests in New Zealand and have shown that the number of alien species increased proportionately with decreasing distance to the settlements. Of the alien species encountered in the forest patches, almost 70 % were found in nearby settlements as well. The dumping of garden waste proved to be one of the principal causes of these "escapes". In South Africa, the palm *Livistona chinensis* became seminaturalised 100 years after its introduction and it is also ascribed to human-aided dispersal in the form of garden waste (Siebert *et al.*, 2010).

The quest for describing characteristics of alien invasive plants is an ongoing process that began over forty years ago (Baker, 1965; Baker, 1974). Baker (1974) compiled a list of attributes that he thought all typical weeds possessed. This included features such as high seed production under favourable conditions, rapid progression through vegetative life stage to reach its reproductive phase, and a high dispersal capacity. Not much success has been achieved with this set of traits, but more recently research in invasion biology has gained momentum driven by increased human activity and the resultant dispersal of other organisms worldwide (Richardson *et al.*, 2005). Considering the amount of plant species introduced throughout the world (see section 2.5.2), the main objective in this field is to discover what distinguishes invasive species from the other, non-invasive introduced species (Muth & Pigliucci, 2006). Another equally important question asked by invasion biologists concerns the characteristics of vulnerable ecosystems that are prone to invasion (Pyšek *et al.*, 1995).

There are a few reasons why general characterisation of invasiveness has yet to be successfully accomplished, as summarised by Muth & Pigliucci (2006). The first is the problem that invasiveness is a continuous rather than categorically variable. Secondly, temporal changes in invasiveness are well-recorded and these changes make prediction of trends more difficult. Lastly, a lack of information on the frequency and regions of introduction complicates most cases of invasions by hindering the assessment of the rate of spread (Muth & Pigliucci, 2006). Being able to predict potential invasiveness of introduced species holds many advantages. Invasive species have detrimental effects on native vegetation and ecosystems (Schwartz, 1997), which includes changes in soil nutrient levels, excessive water consumption and allelopathic competition. If these potential invaders can be identified before becoming problematic, it could reduce the costs of eradication practices and protect natural ecosystems in advance (Moles *et al.*, 2008).

Different views exist among scientists regarding the feasibility of gathering a set of traits: some consider it promising while others deem it a futile effort (Muth & Pigliucci, 2006). Seeing that the numerous attempts to compile a list of general characters peculiar to invasive species have not been successful, new and altered approaches were suggested in recent literature. Moles *et al.* (2008) presented a new, holistic framework that aims to include the traits of not only invasive species, but also of native vegetation and information on the prevailing environmental conditions. The reasoning behind this is that native plants are well-adapted to local environmental conditions and that invasive species will only be able to establish in case of severe disturbance (changes in environmental conditions) or if it can occupy a niche that were previously unoccupied by native species. They compare the sole investigation of traits without considering the changes in environmental conditions to the taking of an analgesic for controlling headaches caused by a tumour. Muth & Pigliucci (2006) and Pyšek *et al.* (1995) proposed that a middle ground can be found if generalisations were put aside and researchers were to concentrate on specified groups and situations.

With the increasing amount of human action, especially in the biodiversity hotspots of the world, invasion by alien species is predicted to increase in the future (Myers *et al.*, 2000). Especially in species-rich countries such as South Africa, that already has many problems with invasive species (Richardson *et al.*, 2005), it is of critical importance to investigate the options provided in the field of invasion biology and to strive towards protecting our native ecosystems.

2.8 Summary

This short review of selected aspects in the field of urban ecology stated the importance, as well as the need for urban ecology, in an era of increasing urbanisation. The significance of including anthropogenic influences to ensure sustainable development and management of urban ecosystems was also stressed. It further highlighted the influences of the process of urbanisation on the biodiversity present in these human-dominated ecosystems and how the biodiversity in turn affects urban inhabitants. Contributions of vegetation in general, and specifically garden vegetation, towards the urban ecosystem were discussed, including ways to enhance the efforts of conservation to protect this valuable resource. Cities have proven to harbour many more species than the surrounding areas, due to the influx of alien species, and holds true on local as well as regional scale. In contrast, however, the species turnover within and between cities are much lower than that of more natural areas where the floristic composition is variable and not managed by introductions of species. As a result of anthropogenic activity and high global mobility, alien plant introductions are a common phenomenon, and even more so in the future. Research regarding the invasions of some of these introduced species was presented and linked to garden vegetation.

In the chapters to follow, findings regarding different aspects of garden vegetation will be discussed against the backdrop of literature provided here, but additional literature is given in each chapter that focus on its specific theme.

Chapter 3

Material and Methods

3.1 Introduction

Please refer to section 1.4 for a note on the layout of this dissertation. This chapter provides background information on the study area and methods used during the study. Methodology of specific relevance to a certain topic is discussed in the relevant chapters to accommodate the format of this dissertation.

3.2 Study area

This study was conducted in the Tlokwe City Municipality (TCM) in the North West Province. It includes the town of Potchefstroom, the township areas of Ikageng, Promosa and Mohadin, the surrounding smallholdings, and recent informal settlements on the edges of Ikageng. The study area is situated between 26°39′ and 26°44′ latitude and 27°00′ and 27°08′ longitude (Figure 3.1) at an altitude of 1 350 m above sea level. The area has about 140 500 inhabitants (WorkWell, 2004), of which a little over 60 % are employed, mainly in the government and trade sectors (Municipal Demarcation Board, 2006).

3.2.1 History

The city of Potchefstroom was established in 1838 by a Voortrekker group under the leadership of Andries Hendrik Potgieter (Badenhorst, 1939). It was most probably the abundance and availability of water and fertile soil along the Mooi River that influenced their choice to settle there. Potchefstroom was the first settlement of the former Transvaal and also, initially, the capital of the South African Republic (ZAR) (Badenhorst, 1939). Further historic value of this settlement was the fact that the first constitution of the Republic was written here and that it served as centre for church gatherings.

The South African Republic (ZAR) decided in the late 1800's that there should be a "location for coloureds", separate from the main (white) residence, later called Willem Klopperville (Jansen van Rensburg, 2002). In the mid-twentieth century, when the Group Areas Act of 1950 was implemented, black people were relocated from Willem Klopperville to Ikageng. The removal was completed in 1963. Soon after, coloureds and Asians were moved respectively to Promosa and Mohadin (Jansen van Rensburg, 2002). The current town plan of the TCM is based on these racially segregated residential areas, with the industrial zone separating the white from other residential areas (Figure 3.1).

Furthermore, people of similar socio-economic status tend to group together in the urban matrix (Kinzig *et al.*, 2005), even in the absence of such a strong external force.

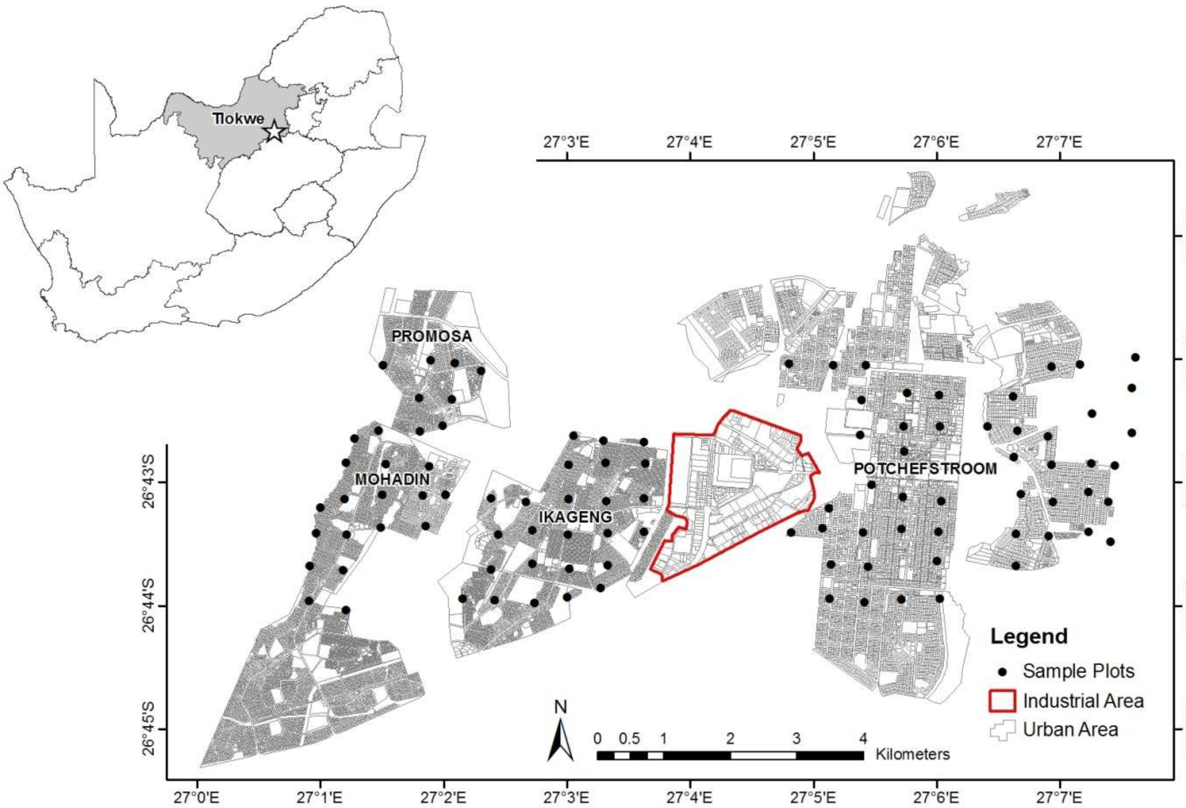


Figure 3.1: Locality of the study area (Tlokwe City Municipality) in South Africa and the layout of the grid system and the 100 sample plots (black dots) in the Tlokwe City Municipality. The industrial zone (in red) separates the previously white occupied neighbourhoods in the east from the western neighbourhoods occupied by people of colour.

3.2.2 Vegetation and topography

The study area forms part of the Grassland biome (Mucina & Rutherford, 2006) at the confluence of the Carletonville Dolomite Grassland, Andesite Mountain Bushveld and the Rand Highveld Grassland vegetation units. The Carletonville Dolomite Grassland consists of undulating plains, interrupted with chert ridges, while the Rand Highveld Grassland has highly variable topography from undulating plains to series of ridges and sloping plains. Many dominant species occur that include grasses such as *Eragrostis chloromelas*, *Heteropogon contortus* and *Themeda triandra.* The Andesite Mountain Bushveld is characterised by hill slopes and valleys. Thorny bushveld as well as a grass-layer is present in this vegetation unit with species such as *Acacia caffra*, *Euclea crispa* and *Hyparrhenia hirta* (Mucina & Rutherford, 2006). Conservation of the natural vegetation does not exceed seven percent in any of these vegetation units (Mucina & Rutherford, 2006) and one of the greatest threats to the natural vegetation is the transformation of natural land by agriculture, urbanisation and mining in the area (Mangold *et al*. 2002) threats that are common in areas containing high biodiversity (Kühn *et al.* 2004; Jha & Bawa 2006).

Information on the vegetation of some urban open spaces in Potchefstroom was compiled in a series of studies by Cilliers (1998). Vegetation of railway reserves, vacant lots, managed open spaces, wetlands, roadside verges, natural and semi-natural areas were described with phytosociological methods. The exclusion of large areas of Ikageng, Promosa, Mohadin and also the vegetation of domestic gardens in Potchefstroom provided the opportunity for further research.

3.2.3 Geology and land types

The TCM's major rock types form part of the Malmani subgroup of the Transvaal Supergroup which includes mostly Mispah, Glenrosa and Hutton soil forms (Mucina & Rutherford, 2006) from Fa and Bc land types. Arcadia and Rensburg soil forms occur in the drainage depressions with alluvium along the Mooi River. Historic soil data does not translate well into descriptions of old and well established gardens, because the soil composition may have very little relationship to the underlying geology (Gilbert, 1989). Other areas of the study site, such as Ikageng, have been recently developed and these soils may still very much resemble the parent material and geology.

3.2.4 Climate

The area is at an altitude of 1 350 m above sea level. Based on climatic data gathered over 21 years by the South African Weather Service (McBride, 2008), the Potchefstroom area receives a mean rainfall of 593 mm, mainly in the summer months, but with dry winters. The mean monthly maximum temperature during summer months is 30.7 °C that drops to a mean monthly minimum of 0.3 °C in winter months. Frequent frost in winter is a common phenomenon (Mucina & Rutherford, 2006).

3.3 Vegetation sampling

3.3.1 Sampling design and process

ArcView (Environmental Systems Research Institute, 2006) was used to overlay a 4 km wide grid of 500 x 500 m squares onto a topographic map of the study area. Coordinates were determined for grid intersects and the exact position of each point was located in the field with a Global Positioning System

(GPS). Stratified sampling was applied by ensuring a representative number of sample sites within each of five socio-economic classes (refer to section 3.4). The closest garden within a radius of 100 m of the sampling coordinates was chosen. If access to the chosen site was denied (which happened on two occasions) an adjacent garden was sampled. On the original map, there were a total of 151 possible sample plots, but only 100 sites were available for sampling (shown in Figure 3.1) as the 51 plots that were oust were either in natural areas or institutional and business properties. Institutional / corporate gardens, apartment buildings and student housing were not included in this study as the management and economic input differ widely from that of domestic gardens, which would have resulted in difficulty constructing a socio-economic gradient.

In literature, different terms are used to describe private gardens, for example "urban domestic gardens" (Smith *et al.*, 2006a) and "homegardens" (Das & Das, 2005). According to Vogl *et al.* (2004), these terms refer to different types of gardens, e.g. urban ornamental versus rural agroforestry gardens. For the purpose of this dissertation, the term "domestic gardens" will be used to refer to the fenced yard of privately-owned or rented dwellings, excluding institutional gardens and apartment buildings with communal gardens. All gardens in the study area contained one or more of the following micro-gardens: ornamental plantings, lawn, hedge, vegetable garden, orchard, and medicinal or herb garden.

Sample plots of 20 x 20 m were laid out to include a variety of different micro-gardens. Within each sample plot, a point survey of 100 points was carried out – preferably in five transects of 20 points each, with transects spaced 4 m apart (Figure 3.2). If the garden area was not large enough to accommodate such layout, the distances between transects were altered, but no point was sampled within 1 m radius of the next or previous points. This closer arrangement of transects were inevitable in most of the gardens in Ikageng and Promosa where the sizes of yards range between 200–900 m^2, compared to 900–14 600 m^2 in Potchefstroom (Van Rooyen: Tlokwe City Council, pers. comm.). At each point, the nearest woody, forb and grass species were identified and added to a frequency table. If no plants in either category were found within 30 cm of the point, it was noted as bare ground. This data set will be referred to as sample plot data. A second set of data were collected by noting all plant species in the entire yard, thus providing presence-absence data that will be referred to as yard data. The reason for collecting two data sets was to have data for quantitative analyses and qualitative assessment of the total species composition of gardens in the study area.

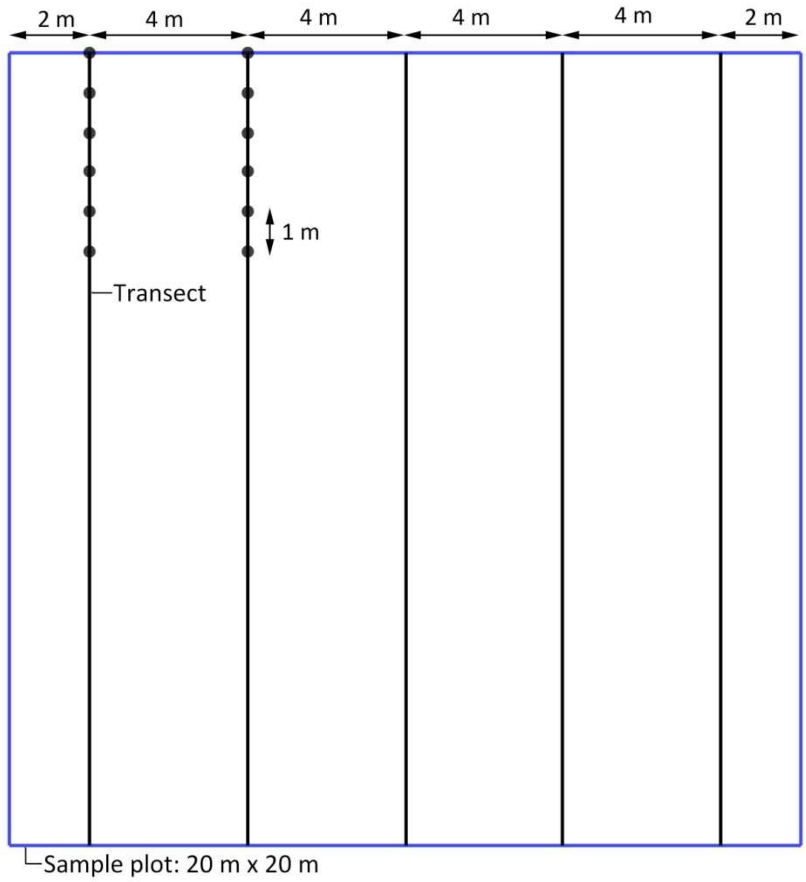


Figure 3.2: A schematic representation of the layout of the 20 x 20 m sample plots.

3.3.2 Plant species identification

To minimise the effect of limited initial knowledge of cultivated species by the surveyors, identification was done to the species level, excluding infraspecific variation. The identification of horticultural plant species was complicated as these taxa are not well-represented in herbaria. Collections of the herbaria were sufficient for the identification of indigenous and alien weedy species that are commonly found. Literature on garden plants (Pienaar, 1994; Pienaar, 2000; Glen, 2002; Smith & Van Wyk, 2008), indigenous plants (Venter & Venter, 2002; Joffe, 2007), wild flowers (Van Wyk & Malan, 1997), grasses (Van Oudtshoorn, 1999) and weeds (Bromilow, 1996; Henderson, 2001) aided in the identification process. The species list was also augmented with additional information on the classification of a species as indigenous, indigenous cultivated, alien or naturalised (Germishuizen *et al.*, 2006). Garden hybrid species were considered as alien cultivated.

For the purpose of this dissertation, the following definitions regarding the classification of species groups were used:

- Indigenous – naturally occurring within the study area (North West Province), usually not cultivated.

- Indigenous cultivated – indigenous to South Africa and not occurring naturally within the study area, but cultivated in gardens.
- Naturalised – not indigenous to South Africa, but occurs in the study area where it sustains self-replacing populations outside of cultivation without direct intervention by people (includes invasive aliens).
- Alien cultivated – not indigenous to South Africa and not naturalised in the study area, but cultivated in gardens and including garden hybrid species.

Many other studies excluded annual species from their analysis so as to exclude seasonal variation. In this study, however, these species were included because they form such an integral part of gardening and are believed to make a substantial contribution to the total garden flora and ecosystem services in urban areas.

3.4 Socio-economic status (SES) determination

Data from the 2001 Census Survey (Municipal Demarcation Board, 2006) were used to determine the socio-economic status (SES) of all the wards in the Tlokwe Municipal area (Figure 3.3), which were then divided into the five classes (class 1 had the lowest SES and class 5 the highest SES) (Table 3.1) that make up the indirect socio-economic gradient. The information in the Census Survey was given in percentages for each ward. More recent data from the WorkWell Social Survey were also available (WorkWell, 2004), but most of the information was presented as categorical variables, which makes it difficult to integrate and compare different parameters. For this reason, the Census Survey data were preferred over the Social Survey data.

Five different parameters were used to determine the five SES classes. For all categories, the number of individuals was calculated as a percentage of the total in its category. A higher percentage indicates a lower SES for all of the parameters.

1. **Percentage unemployment** is the percentage of unemployed people, excluding economically non-active persons.
2. **Household size** is the percentage of households with five (5) or more people.
3. **Number of rooms** is the percentage of households with two (2) or less rooms.
4. **Access to basic services** is the percentage of households with pipe water more than 200 m away and including those with no access to pipe water.
5. **Schooling status** is the percentage of people with no schooling (from the grouped education category).

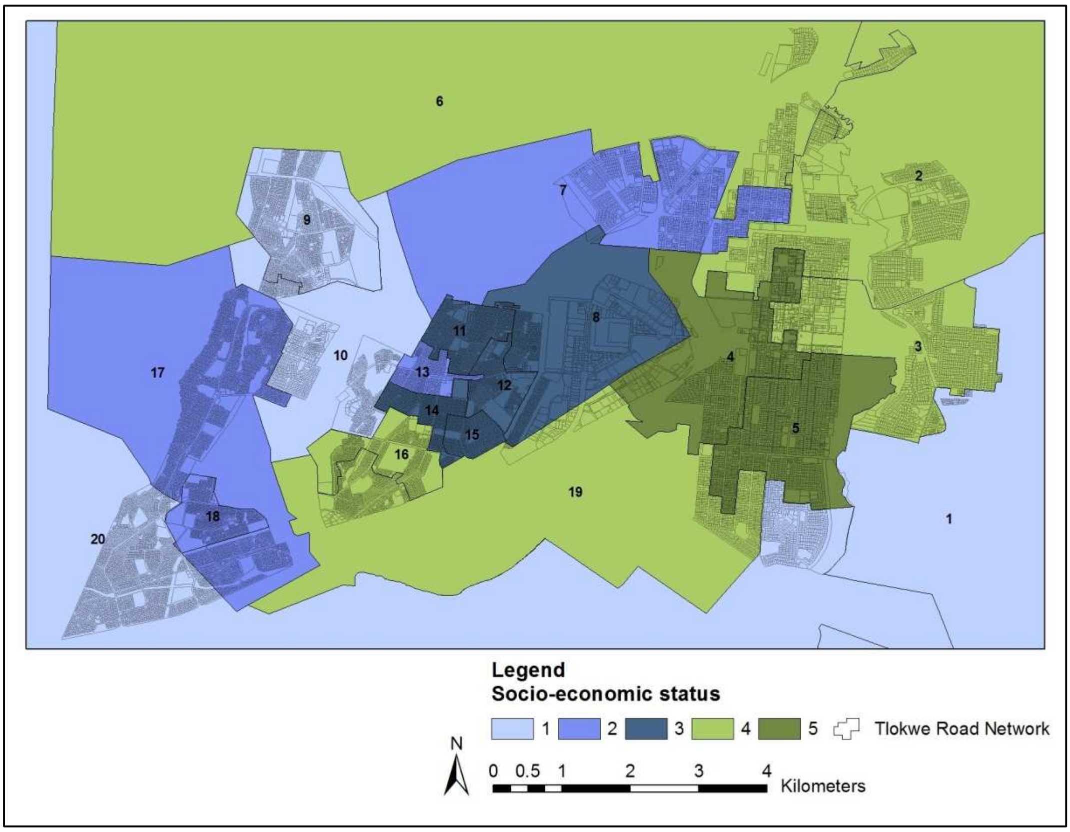


Figure 3.3: The ward delineation in the TCM, divided into the five socio-economic status classes.

Table 3.1: Comparison of five parameters to determine five socio-economic status (SES) classes within the TCM (1 – lowest SES, 5 – highest SES).

SES (class)	Unemployment[1]	Household size[2]	Number of rooms[3]	Access to basic services[4]	Schooling status[5]
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

[1] % unemployment of individuals

[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

Table 3.2 presents the scoring system that was used to determine the validity of the SES classes as chosen in Table 3.1. For every parameter in Table 3.1, the SES class that had the highest percentage scored a point of 1 and the lowest a point of 5. The highest total score indicated the class with the highest SES (earning > USD 3 000 per month) while the class with the lowest score was the most economically stressed (< USD 100 per month).

Table 3.2: Scoring system applied to test the validity of the five socio-economic status classes chosen for the TCM. The class that had the highest percentage in Table 3.1 scored a point of 1 and the lowest a point of 5, with the highest score reflecting the least economically stressed class. Class 1 – economically stressed household (< USD 100 per month); class 5 – economically affluent household (> USD 3 000 per month).

Parameters	SES class scores				
	1	**2**	**3**	**4**	**5**
Unemployment[1]	1	2	3	4	5
Household size[2]	2	3	1	4	5
Number of rooms[3]	1	2	3	4	5
Access to basic service[4]	2	1	3	4	5
Schooling status[5]	2	1	4	3	5
Score	**8**	**9**	**14**	**19**	**25**

For the purpose of this study, we subjectively moved 18 sample plots to the SES class that the adjacent wards belong to (Table 3.3) to better represent its actual SES. The electoral ward delineation in the TCM collectively grouped areas from different actual SES (areas of predominantly white neighbourhoods together with areas of black inhabited, informal settlements), possibly for political reasons (Christopher, 1997) (see ward 19 in Figure 3.3). Some of the sample plots were thus classified into a SES class that does not reflect its true SES, which is similar to that of the neighbourhood surrounding it.

Table 3.3: Original and new SES classes of 18 designated sample plots (1 – lowest socio-economic status, 5 – highest socio-economic status).

Sample plot number	Original SES class	New SES class
18	1	4
19	1	4
20	1	4
40	1	4
59	1	4
68	2	3
69	2	3
77	1	4
78	1	4
95	1	4
108	2	4
109	2	4
122	4	1
123	4	1
124	4	1
125	4	3
126	4	3
141	4	3

3.5 Management and maintenance questionnaire

A two-part questionnaire was compiled to collect data on the management of gardens and information of the house owners / tenants (Appendix A). The first section included categorical questions of the maintenance regimes in gardens (the use of herbicides and pesticides, irrigation methods, etc.) as well as a few open-ended questions on their choice of plant species. In the second section, social information was gathered (period of time the dwelling has been inhabited by current owner / tenants, etc.). To ensure consistency, all questionnaires were filled out by one person while asking participants the questions.

3.6 Data analysis

Data consolidation was done in a spreadsheet. All the other statistical and analysis methods are described in the following chapters:

1. Chapter 4 further describes the sources of information consulted to identify Red Data species, invasive species, and the distribution and origin of plant species.
2. Chapter 5 specifically provides a description of the method for the Detrended Correspondence Analysis (DCA) ordination.
3. In Chapter 6, more in-depth statistical analyses were done to describe the patterns of plant diversity and determine some drivers thereof. The methods include one-way ANOVA, Inverse Distance Weighting, diversity indices and correlations.

Chapter 4

A floristic analysis of domestic gardens in the Tlokwe City Municipality, South Africa

4.1 Introduction

Urbanisation is one of the most significant demographic trends of all times (Pickett *et al.*, 2001) because of its devastating impact on the environment (Wu *et al.*, 2003). The increase in population density of urban areas (Pickett *et al.*, 2001) results in infrastructure development and the subsequent transformation of natural areas. Significant changes in biological and spatial composition alter the structure of ecosystems, which in turn influence the processes underlying such ecosystems, for example nutrient cycles, water relations and climate systems (Wu *et al.* 2003). Plants play an important role in sustaining urban ecosystems (Colding, 2007; Savard *et al.*, 2000). Urban green spaces provide both physical ecosystem services such as temperature and flood control, removal of carbon from the atmosphere and social ecosystem services such as the increase of aesthetical values and community well-being (Bolund & Hunhammar, 1999; Alberti, 2005; Hope *et al.*, 2006). Knowledge of urban vascular plant floras, as key contributors to the ecosystem, is therefore indispensible to ensure that the urban environment is kept favourable for life to persist within.

Globally, the urban vascular plant floras have higher diversity than that of the surrounding countryside. This trend was noted in California, United States of America (USA) (Williams *et al*., 2005), Brussels, Belgium (Godefroid & Koedam, 2007), several cities in Germany (Kühn *et al.*, 2004), and Phoenix, Arizona, USA (Hope *et al.*, 2003). In Sheffield, England, the gamma diversity recorded in a relatively small number of domestic gardens equalled that of the native flora in the area, and was expected to become much higher with increasing sample size (Smith *et al.*, 2006a). The comparatively higher gamma diversity of urban vegetation and also garden floras is mainly the result of the high spatiotemporal heterogeneity in urban environments (Rebele, 1994) and an increasing dispersal of alien plant species via global transportation and other human actions (McKinney, 2008).

The richness of garden floras is related to the size of the species pool available to gardeners (Thompson *et al.*, 2003). A list containing more than 70 000 plant species that are available from United Kingdom nurseries was compiled by Macaulay *et al.* (2009), while Isaacson (2004) presented a list that consisted of 90 000 plant species available for sale in the USA. Glen (2002) published a book on the cultivated plants of southern Africa that contains approximately 37 000 species, compared with the little over 21 800 species of natural flora in southern Africa (Germishuizen *et al.*, 2006).

The aim of this chapter is to provide a first total floristic survey of the domestic gardens of a typical, medium-sized, southern African city. Objectives were to analyse and describe the plant diversity found in domestic gardens by determining and exploring the dominant families, genera and species, origin of species under cultivation, endemic and threatened plant species, useful plant species, invasive species and growth forms. The analysis provides baseline information with which to compare garden flora of other cities and countries and will contribute to the establishment of a broader understanding of the management and conservation potential of this specific type of land use. Additionally, the comparison of the garden flora with the flora of other urban open spaces (other land-use types) in the Tlokwe Municipal area (Cilliers, 1998) will shed light on the contribution that domestic gardens make towards urban plant diversity in the study area.

4.2 Methods

Cross-referencing was done between our checklist and the South African Red Data List of plants (Raimondo *et al.*, 2009) to determine which threatened species occurred in the domestic gardens of the TCM. Alien invader species was identified from a list of invader species compiled by Henderson (2001), which is based on national legislation (South Africa, 1983; Conservation of Agricultural Resources Act), amended in 2001). The distribution of indigenous and naturalised species of South Africa was compiled from Germishuizen *et al.* (2006). Distribution patterns could be discerned by grouping provinces on account of their general floristic composition and rainfall data to produce the chosen geographic regions of origin. The origin of cultivated alien species as well as the uses of cultivated species was determined from the literature (Van Wyk & Gericke, 2000; Glen, 2002; United States Department of Agriculture, 2009; Aluka, 2010; Hawaiian Ecosystems at Risk, 2010).

The species grown in the domestic gardens of the TCM were sorted into seven categories of relevance to gardening and cultivation: ornamental, weed, food, medicinal, shade, hedge and windbreak. A category for fuel was not included, as any flammable biomass (e.g. firewood, dung, charcoal) serves the purpose for many poor households in the absence of electricity (Millenium Ecosystem Assessment, 2003) and therefore no plants were found to be specifically cultivated for this purpose.

The land-use types compared with domestic gardens were natural and semi-natural areas, wetlands, managed areas (parks, pavements and parking areas), roadside verges, vacant lots and railway reserves. In the case of domestic gardens, indigenous (135) and indigenous cultivated species (119) were grouped as indigenous, while alien cultivated (390) and naturalised species (191) were grouped together as alien species, as the data from the previous survey (Cilliers, 1998) did not distinguish between these groups.

4.3 Results

4.3.1 Best represented families

A total of 145 plant families were recorded for the domestic gardens of the TCM. This high number of families is surprising, but consistent with other studies, as 56 families (39 %) are represented by only a single species in the study area. The 20 most diverse families represent 54 % (455 species) of the total number of species recorded (Table 4.1). Diversity, as indicated here, was determined by the number of species recorded for a given family, regardless of the frequency of occurrence of each species.

Ten of the 20 most diverse garden families in the TCM are also on the list of the most species-rich South African families (Table 4.1) (Snyman, 2009). Asteraceae, Fabaceae and Iridaceae are of the most species-rich South African families and are amongst the top five for the study area. The third and fifth most species-rich South African families (Mesembryanthemaceae and Ericaceae, respectively) were not amongst the frequent garden families. The best represented families of the study area contain many garden families and genera that are extensively cultivated throughout the world (e.g. Lamiaceae: *Ocimum* spp., *Lavandula* spp., *Plectranthus* spp.; Rosaceae: *Cotoneaster* spp., *Rosa* spp., *Prunus* spp.; Crassulaceae: *Sedum* spp., *Echeveria* spp., *Kalanchoe* spp.) and many naturalised species (e.g. Fabaceae: *Prosopis glandulosa*, *Robinia pseudoacacia*, *Medicago laciniata*; Solanaceae: *Solanum sisymbrifolium*, *Cestrum elegans*; Agavaceae: *Agave americana*).

Twenty-six families (18 % of all plant families recorded for the TCM) could be classified as exclusively alien as none of their constituent species are indigenous to South Africa (Table 4.2). These alien families generally comprise less than ten species, with the exception of Agavaceae with 12 species, which is ranked fifteenth of the twenty most frequent families in the TCM (Table 4.1).

Table 4.1: Twenty most diverse plant families of domestic gardens in the TCM. Superscript enumerators indicate a family's position on the South African list of most diverse families (Snyman, 2009).

Position	Plant family	No. spp.	% total no. spp.
1	Asteraceae[1]	75	9.0
2	Poaceae[16]	52	6.2
3	Lamiaceae	38	4.5
4	Fabaceae[2]	36	4.3
5	Rosaceae	33	3.9
6	Solanaceae	29	3.5
7	Crassulaceae[17]	21	2.5
8	Asphodelaceae[9]	17	2.0
9	Cactaceae	17	2.0
10	Amaryllidaceae	15	1.8
11	Malvaceae[16]	15	1.8
12	Scrophulariaceae[7]	14	1.7
13	Apocynaceae[8]	13	1.6
14	Araceae	13	1.6
15	Agavaceae	12	1.4
16	Brassicaceae	11	1.3
17	Euphorbiaceae[14]	11	1.3
18	Iridaceae[4]	11	1.3
19	Oleaceae	11	1.3
20	Verbenaceae	11	1.3

Table 4.2: Exclusively alien plant families recorded for the domestic gardens of the TCM and the number of species representing each family.

Alien families	No. spp.	Alien families	No. spp.
Agavaceae	12	Platanaceae	2
Caprifoliaceae	8	Cannabaceae	1
Liliaceae *sensu stricto*	7	Capparidaceae	1
Berberidaceae	5	Casuarinaceae	1
Pinaceae	5	Cycadaceae	1
Aceraceae	3	Elaeagnaceae	1
Alstroemeriaceae	3	Ginkgoaceae	1
Bromeliaceae	3	Juglandaceae	1
Saxifragaceae	3	Punicaceae	1
Cannaceae	2	Saururaceae	1
Fagaceae	2	Simaroubaceae	1
Magnoliaceae	2	Theaceae	1
Marantaceae	2	Tropaeolaceae	1

4.3.2 Dominant genera

In total, 501 plant genera were recorded in the TCM. Of these, two-thirds were represented by only a single species in the TCM. The ten most diverse genera represented nine percent of the total number of recorded species (Table 4.3). Only three of the most diverse genera (*Asparagus*, *Cyperus* and *Tradescantia*) belong to families not included amongst the 20 most diverse for the study area (Asparagaceae, Cyperaceae and Commelinaceae, respectively). Thirty-four of the 78 species (44 %) represented by the ten most diverse genera of urban domestic gardens in the TCM are alien to South Africa.

Table 4.3: The most diverse genera of the domestic gardens in the TCM and the number of species representing each.

Genera	Family	No. spp.
Solanum	Solanaceae	12
Aloe	Asphodelaceae	10
Eragrostis	Poaceae	9
Salvia	Lamiaceae	9
Asparagus	Asparagaceae	8
Acacia	Fabaceae	7
Cyperus	Cyperaceae	6
Plectranthus	Lamiaceae	6
Prunus	Rosaceae	6
Tradescantia	Commelinaceae	6

4.3.3 Dominant species

A total of 835 species were recorded from the domestic gardens of the TCM, of which 235 were recorded only once and most of them were alien (70 %). The species accumulation curve for these 100 sample plots has reached an asymptote (Figure 4.1), indicating that a sufficient number of sample sites were included in the survey to capture a representative number of species for this land-use type.

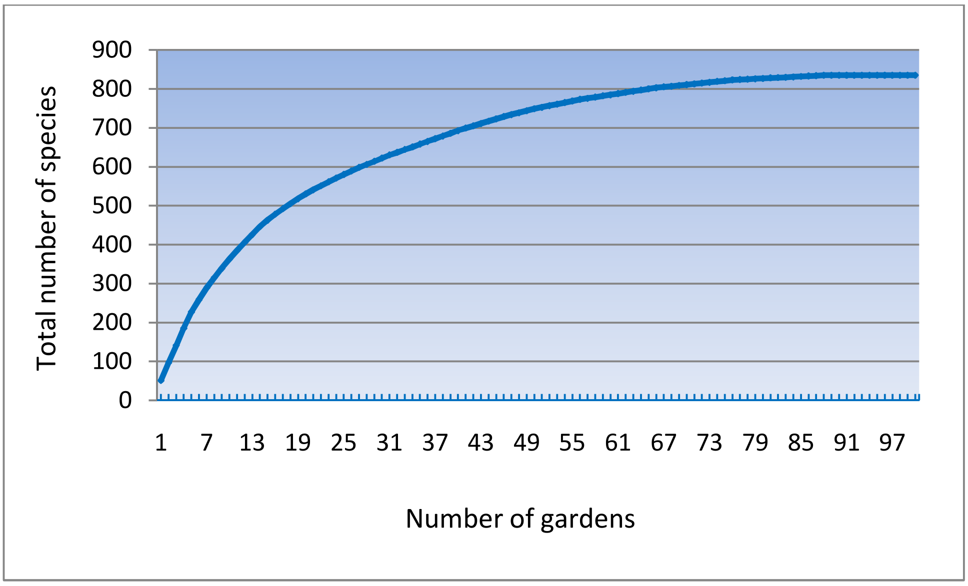


Figure 4.1: Species accumulation curve for the survey of 100 domestic gardens in the TCM.

The twenty plant species that occurred most frequently were all present in more than half of the sampled gardens (Table 4.4). *Pennisetum clandestinum*, as the most favoured lawn grass, was the highest ranked species as it occurred in all but one of the gardens (99 %). Another grass species, *Cynodon dactylon*, had the second highest frequency. Three herbaceous species (*Euphorbia prostrata, Conyza bonariensis* and *Guilleminea densa*), which are commonly considered as naturalised garden weeds, made up the rest of the top five. *Cynodon dactylon* is the only indigenous species amongst the top five most frequent species, but it is regarded as a weedy species (Henderson, 2001). Half of the recorded twenty most frequent species are naturalised in South Africa (ten), compared to the seven cultivated (indigenous and alien) and three naturally occurring indigenous species. The best represented families among the twenty most frequent species were the Poaceae (five species) and Asteraceae (three species).

4.3.4 Endemic species

A list of South African endemic species was recorded for the domestic gardens of the TCM (Table 4.5). It serves as confirmation of the contribution that domestic gardens make towards the conservation of unique plant species. In total, 61 endemic species were recorded, all of which are commonly cultivated, except for three species that are normally only found naturally as weeds in gardens (Pienaar, 1994; Pienaar, 2000; Germishuizen *et al*., 2006). *Tulbaghia violacea* was the most commonly cultivated South African endemic species as it occurred in 30 % of the sampled gardens. *Portulaca grandiflora* and *Sida spinosa* were both also commonly cultivated (27 %). Nine other endemic species were present in ten percent or more of the sample plots. In contrast, 49 endemic species occurred in less than ten percent of the plots, with 19 found only once.

Table 4.4: Twenty most frequently recorded species from the domestic gardens of the TCM. Alien species are marked with an asterisk (*).

Species	Families	Origin	% plots
*Pennisetum clandestinum**	Poaceae	Cultivated A	99
Cynodon dactylon	Poaceae	Cultivated I	84
*Euphorbia prostrata**	Euphorbiaceae	Naturalised	79
*Conyza bonariensis**	Asteraceae	Naturalised	76
*Guilleminea densa**	Amaranthaceae	Naturalised	72
*Portulaca oleracea**	Portulacaceae	Naturalised	69
*Dichondra micrantha**	Convolvulaceae	Cultivated A	66
Urochloa panicoides	Poaceae	Indigenous	66
Cynodon hirsutus	Poaceae	Indigenous	65
*Ligustrum lucidum**	Oleaceae	Cultivated A	63
*Oxalis corniculata**	Oxalidaceae	Naturalised	62
*Rosa chinensis**	Rosaceae	Cultivated A	61
*Alternanthera pungens**	Amaranthaceae	Naturalised	59
*Euphorbia hirta**	Euphorbiaceae	Naturalised	59
*Sonchus oleraceus**	Asteraceae	Naturalised	59
*Bidens bipinnata**	Asteraceae	Naturalised	56
Chlorophytum comosum	Anthericaceae	Cultivated I	56
*Prunus persica**	Rosaceae	Cultivated A	56
*Amaranthus viridis**	Amaranthaceae	Naturalised	55
Eragrostis lehmanniana	Poaceae	Indigenous	52

Cultivated A – cultivated alien, Cultivated I – cultivated indigenous.

4.3.5 Endangered and protected species

Eighteen species regarded as having a threat status, according to the South African National Red Data List (Raimondo *et al.*, 2009) were recorded from domestic gardens in the TCM (Table 4.6), which includes species listed as endangered (4), vulnerable (4), near threatened (3), rare (2) and declining (5). The most common of these threatened species were *Clivia miniata* (Vulnerable) and *Dietes bicolor* (Rare), which occurred in more than ten percent of the sampled gardens. The occurrence of the remaining 16 species was much lower (Table 4.6).

4.3.6 Useful plants

The utilisation of plants as food, natural healing remedies, construction material and for other benefits is as old as humanity itself and an important part of South Africa's cultural heritage (Van Wyk *et al.*, 1997; Van Wyk & Gericke, 2000). The majority of plant species (61 %) was cultivated in domestic gardens for the sole purpose of ornamental decoration (Figure 4.2). Frequent species in this group included *Pennisetum clandestinum* and *Rosa chinensis*. The second most diverse group was the weeds (16 %), with *Cynodon dactylon* and *Euphorbia prostrata* as most frequent species. A further 9 % of the species were classified as food plants on account of their edible leaves, tubers, fruits or seeds. Medicinal plants accounted for seven percent of all the species, while five percent were regarded as shade trees. Hedges and windbreaks did not make a considerable contribution.

Table 4.5: South African endemic species that were recorded from domestic gardens of the TCM.

Species	Origin	% plots	Species	Origin	% plots
Tulbaghia violacea	Cultivated	30	*Anisodontea elegans*	Cultivated	2
Portulaca grandiflora	Cultivated	27	*Crassula capitella*	Cultivated	2
Sida spinosa	Natural	27	*Crassula tetragona*	Cultivated	2
Tulbaghia simmleri	Cultivated	22	*Cussonia paniculata*	Cultivated	2
Crassula ovata	Cultivated	19	*Encephalartos natalensis*	Cultivated	2
Euryops chrysanthemoides	Cultivated	16	*Felicia amelloides*	Cultivated	2
Strelitzia alba	Cultivated	12	*Haworthia cymbiformis*	Cultivated	2
Aptenia cordifolia	Cultivated	11	*Lampranthus glaucus*	Cultivated	2
Cyperus textilis	Cultivated	11	*Nemesia strumosa*	Cultivated	2
Dietes bicolor	Cultivated	11	*Podocarpus henkelii*	Cultivated	2
Lampranthus roseus	Cultivated	10	*Podranea ricasoliana*	Cultivated	2
Ledebouria socialis	Cultivated	10	*Aloe brevifolia*	Cultivated	1
Chondropetalum tectorum	Cultivated	9	*Aloe tenuior*	Cultivated	1
Strelitzia reginae	Cultivated	9	*Carpobrotus edulis*	Cultivated	1
Dimorphotheca ecklonis	Cultivated	8	*Crassula multicava*	Cultivated	1
Pelargonium peltatum	Cultivated	8	*Cyrtanthus elatus*	Cultivated	1
Agapanthus africanus	Cultivated	7	*Encephalartos horridus*	Cultivated	1
Haworthia fasciata	Cultivated	7	*Geranium incanum*	Cultivated	1
Dietes grandiflora	Cultivated	5	*Haemanthus albiflos*	Cultivated	1
Species	**Origin**	**% of plots**	**Species**	**Origin**	**% of plots**

Gasteria bicolor	Cultivated	5	*Haworthia reinwardtii*	Cultivated	1
Gnaphalium nelsonii	Natural	5	*Lampranthus glaucoides*	Cultivated	1
Ornithogalum thyrsoides	Cultivated	5	*Melianthus elongatus*	Cultivated	1
Zantedeschia pentlandii	Cultivated	5	*Oxalis lanata*	Cultivated	1
Lampranthus blandus	Cultivated	4	*Pelargonium reniforme*	Cultivated	1
Begonia homonyma	Cultivated	3	*Plectranthus saccatus*	Cultivated	1
Coleonema pulchellum	Cultivated	3	*Scabiosa africana*	Cultivated	1
Ehretia rigida	Natural	3	*Senecio articulatus*	Cultivated	1
Lampranthus aureus	Cultivated	3	*Senecio rowleyanus*	Cultivated	1
Ocimum serratum	Cultivated	3	*Senecio scaposus*	Cultivated	1
Plectranthus hilliardiae	Cultivated	3	*Ursinia chrysanthemoides*	Cultivated	1
Aloe striatula	Cultivated	2			

Table 4.6: Species encountered in the domestic gardens of the TCM that are listed on the South African National Red Data List (Raimondo *et al*. 2009).

Species	National status	No. plots
Begonia homonyma	Endangered	3
Lampranthus aureus	Endangered	3
Encephalartos horridus	Endangered	1
Encephalartos lebomboensis	Endangered	1
Clivia miniata	Vulnerable	27
Crinum moorei	Vulnerable	5
Zantedeschia pentlandii	Vulnerable	5
Lampranthus glaucus	Vulnerable	2
Haworthia fasciata	Near threatened	7
Encephalartos natalensis	Near threatened	2
Nemesia strumosa	Near threatened	2
Dietes bicolor	Rare	11
Freylinia tropica	Rare	2
Crinum bulbispermum	Declining	6
Eucomis autumnalis	Declining	6
Crinum macowanii	Declining	2
Hypoxis hemerocallidea	Declining	2
Acacia erioloba	Declining	1

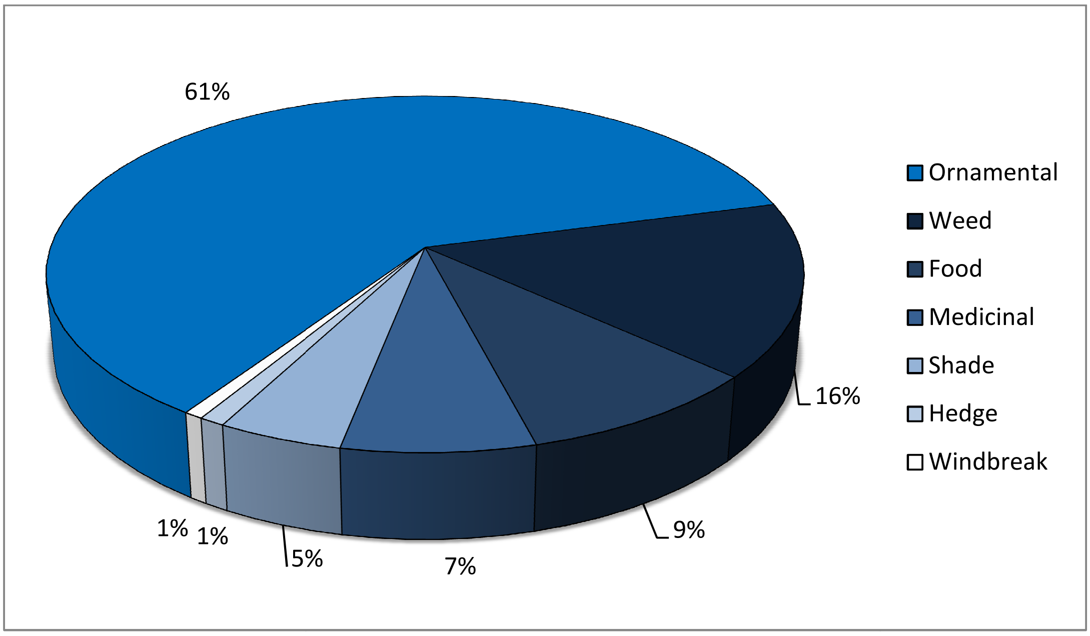


Figure 4.2: Contribution of the urban flora towards useful plant categories of domestic gardens in the TCM (seven categories of use were identified as relevant to gardening and cultivation).

4.3.7 Origin of cultivated indigenous species

Most of the species found in the domestic gardens of the TCM do not occur naturally in South Africa (72.2 % of the garden flora). The remaining 27.8 % of the recorded garden flora consisted of 232 indigenous and indigenous cultivated species (Germishuizen *et al.*, 2006). The number of indigenous cultivated species in each of six geographical groups in South Africa is shown in Figure 4.3. Widespread species, that have fewer specific environmental preferences, contributed greatly towards the garden flora, with 122 species that occurred in more than eight of the 13 regions specified in Germishuizen *et al.* (2006). Thereafter, most of the cultivated species (69) were contributed by the flora of the Eastern Cape and KwaZulu-Natal (southeastern provinces). The other four regions all made a smaller contribution to the domestic garden flora of the TCM than the south-eastern provinces.

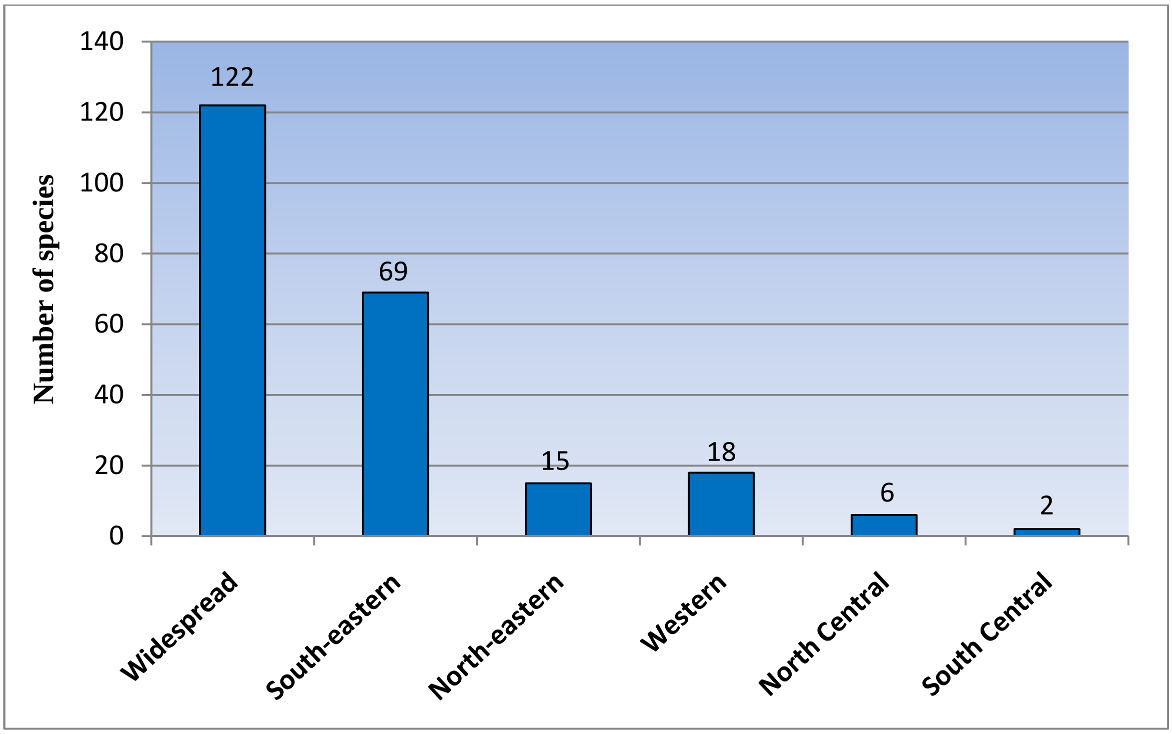


Figure 4.3: Main geographical origin of the indigenous cultivated species that were recorded for domestic gardens in the TCM. South Central (Free State; Lesotho), North Central (North West Province; Limpopo; Botswana), Western (Western Cape; Northern Cape; Namibia), North-eastern (Mpumalanga; Gauteng; Swaziland), South-eastern (KwaZulu Natal; Eastern Cape). Widespread species were defined as occurring naturally in eight or more regions.

4.3.8 Origin of naturalised and cultivated alien species

For 65 of the naturalised and cultivated alien species, no information was available regarding their origin, while 31 species occurred originally in more than one region. The remaining 484 naturalised and cultivated alien species were grouped according to regions of common origin (Figure 4.4). More than a third (36.4 %) of the alien horticultural plant species found in the domestic gardens of the TCM was originally introduced from the Americas (North, Central and/or South America). Asia was the second largest contributor to the alien horticultural flora, as 23.3 % of the species originate from there. Hybrids that originated in gardens also made a significant contribution of 9.5 %.

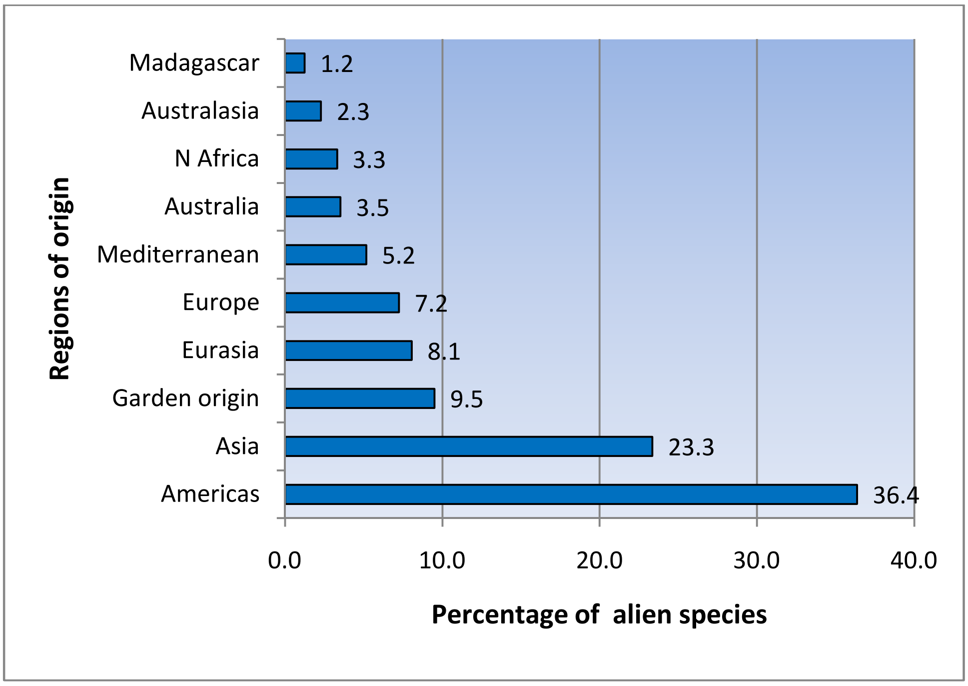


Figure 4.4: Ten regions of origin of alien cultivated and naturalised alien species recorded for domestic gardens in the TCM.

4.3.9 Invasive species

Apart from the substantial utilisation, maintenance and conservation of biodiversity taking place in gardens, there are some unforeseen consequences, such as the occurrence of invasive alien species. In the domestic gardens of the TCM, 88 declared invader and weed species were found (Table 4.7) (Henderson, 2001). There were 32 species in Category 1 declared weeds, which contain the most severe type of invasive species. *Canna* x *generalis* formed part of this group and it occurred in 43 % of gardens. *Pennisetum clandestinum* and *Cynodon dactylon*, which have shown the highest occurrences of all, were some of the species classified as Category 2 declared invaders. Category 3 declared invaders had the highest number of species (36) and included, amongst others, *Ligustrum lucidum* in more than 60 % of the surveyed gardens. *Celtis sinensis* (38 %), from the list of proposed invaders, was found to be the most frequent species.

Table 4.7: The four categories of invasiveness and the three most dominant invasive species for each. The number of species that were found for each category in domestic gardens in the TCM is shown in brackets.

Category 1: declared weeds (32)	No. of occurrences
Canna* x *generalis	43
Araujia sericifera	23
Nerium oleander	17
Category 2: declared invaders (12)	
Pennisetum clandestinum	99
Cynodon dactylon	84
Robinia pseudoacacia	15
Category 3: declared invaders (36)	
Ligustrum lucidum	63
Ipomoea purpurea	35
Nephrolepis exaltata	32
Proposed invaders (8)	
Celtis sinensis	38
Celtis australis	9
Duranta erecta	5

C1 – prohibited in South Africa, must be eradicated where possible; C2 – planting only allowed under controlled conditions in demarcated areas, trading only with permits; C3 – no further plantings and no trade allowed (Henderson, 2001).

4.3.10 Growth forms

The majority of species (341) found in the domestic gardens of the TCM were forbs (Figure 4.5). *Euphorbia prostrata* and *Guilleminea densa* were the most frequent herbaceous species occurring respectively in 79 % and 72 % of sample plots. The second most diverse growth form was shrubs (173 species) with frequent species such as *Rosa chinensis* and *Ficus carica*, followed by trees (131 species), of which the most frequent representative was the popular hedge species, *Ligustrum lucidum*. *Prunus persica* was found to be the second most frequent tree, as it is commonly cultivated for its edible fruit. Succulents, geophytes and graminoids were all represented by a relatively similar number of species with ferns being the smallest represented group.

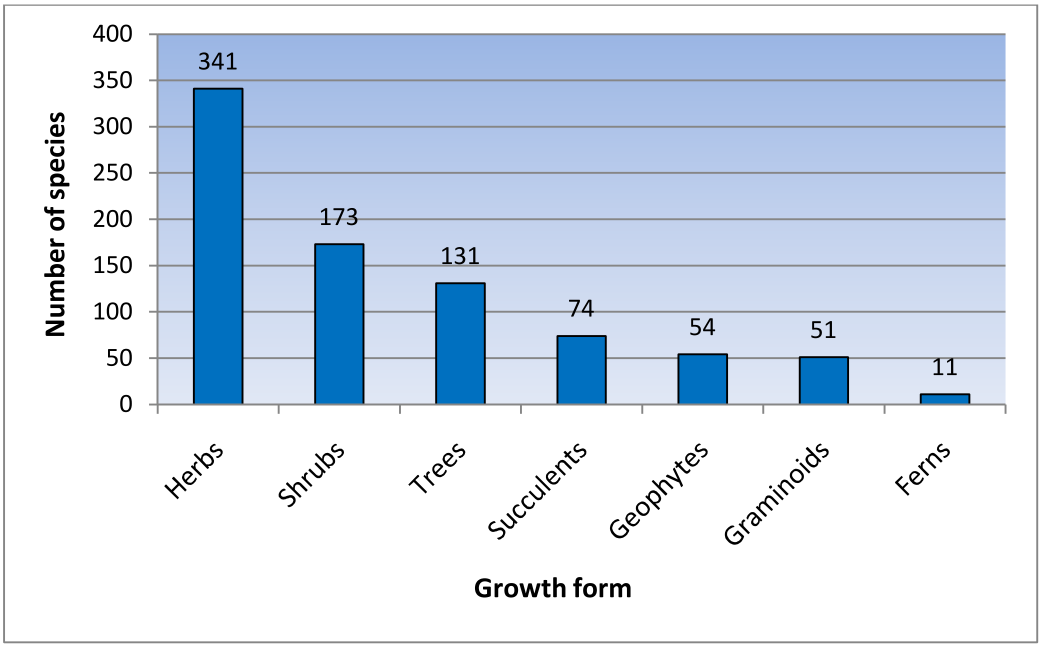


Figure 4.5: Diversity within growth forms in the flora of domestic gardens in the TCM.

4.3.11 Total species diversity

The total number of species and the numbers of indigenous and alien species of different land-use types were compared (Figure 4.6). Two distinct floristic differences are evident between domestic gardens and the other land-use types. The first is the substantially higher total number of species (or gamma diversity) of domestic gardens when compared to the other land-use types. The other difference is the inverted relationship of indigenous and alien species in domestic gardens when compared to the other land-use types. Domestic gardens contained almost twice as many alien as indigenous species.

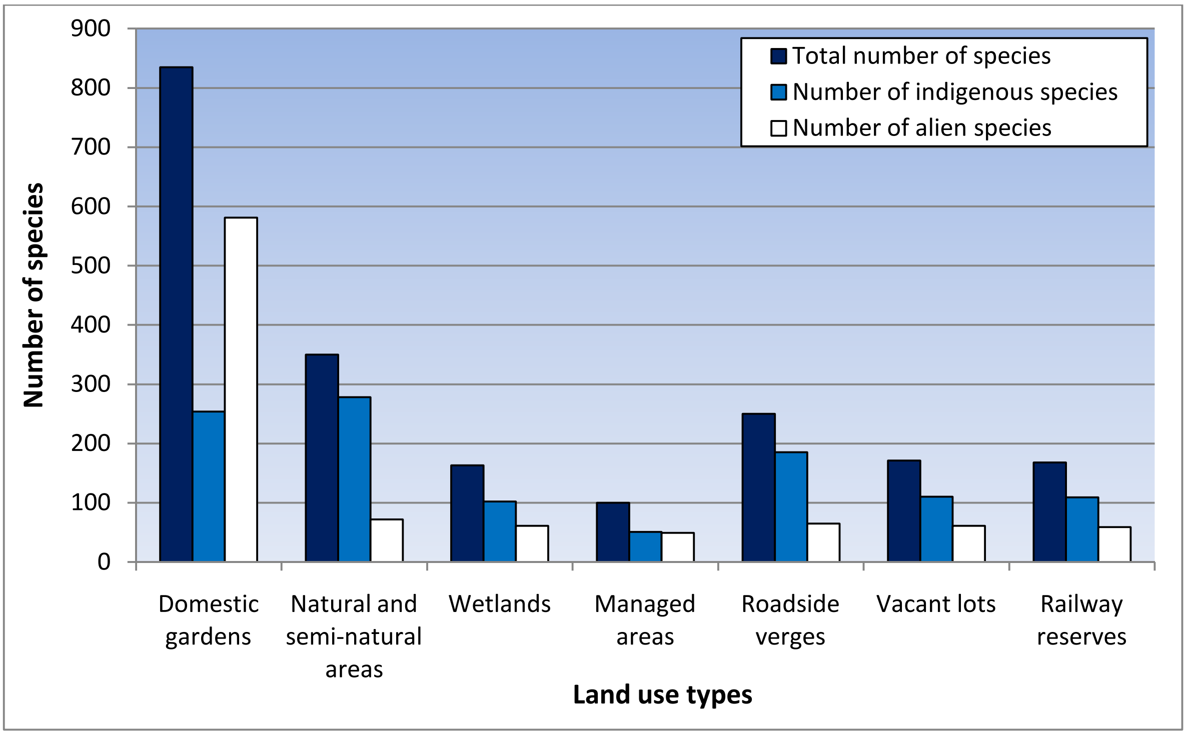


Figure 4.6: Comparison of total species, indigenous species (including cultivated indigenous species) and alien species (including naturalised species) for the different land-use types of the TCM (gamma diversity).

4.4 Discussion

4.4.1 Dominant taxa

Urban areas are characterised as a heterogeneous and highly dynamic environment (Rebele 1994), a phenomenon that is also observed within domestic gardens of residential areas (Mathieu *et al.*, 2007). The gamma diversity of plant species encountered in the 100 sampled domestic gardens of the TCM (835 species belonging to 145 families) is in accordance with results from other studies (e.g. 973 species in Lauris, France, from 120 gardens – Marco *et al*., 2008; 1 166 species in Sheffield, United Kingdom, from 61 gardens – Smith *et al.*, 2006a). The fact that 235 species were recorded only once is indicative of the high species turnover between gardens, and is consistent with the findings in gardens of Sheffield (Thompson *et al.*, 2003).

All the well-represented garden genera contain many species in the South African natural flora, except for *Prunus* and *Tradescantia* (Germishuizen *et al.*, 2006). Many species from the most frequent genera (such as *Solanum*, *Aloe* and *Salvia*) are popular ornamental species and some are declared weeds, which may explain to a certain extent the frequent occurrence of these genera in gardens. Despite the high number of species from the dominant genera that are alien to South Africa (44 %), none of the dominant genera were from alien families. This means that the alien species share a close affinity with South African indigenous species at family level (Germishuizen *et al.*, 2006). Of the 20 most frequent species, most were naturalised weeds rather than cultivated species. These naturalised species may originally have been horticultural subjects that escaped from gardens into the natural surroundings (Siebert *et al.*, 2010; Hodkinson & Thompson, 1997) Species belonging to alien plant families are cultivated mostly for their high ornamental value, e.g. *Cordyline australis*, *Abelia* x *grandiflora*, *Aspidistra elatior* and *Nandina domestica*.

4.4.2 Endemic and endangered species

Endemic and endangered species represent only a small portion of the garden flora, but however small the contribution of a few gardens may seem to be towards the protection of such species, its collective effort across an entire urban ecosystem and also globally holds tremendous potential (Savard *et al.*, 2000; Gaston *et al.*, 2005b). However, the cultivation of these species takes place for their utilitarian value and not necessarily with conservation in mind. As perceptions of what is considered useful or aesthetic can change over time, these plant species of conservation concern may be replaced with something new (Hope *et al.*, 2006). The presence of these rare and endangered species in domestic gardens highlights the role that such land-use types can fulfil in the conservation of indigenous biodiversity, albeit a somewhat vulnerable niche. Other problems regarding the cultivation of such endangered species in domestic gardens relate to the difficulty of propagation and cultivation, a lack of aesthetic qualities of some species (Winter & Botha, 1994) and possible threats to the genetic integrity of natural populations (Whelan *et al.*, 2006) all which makes the feasibility of large-scale conservation through gardening somewhat slim. Through interaction of gardens with each other and other types of green space in close vicinity within the urban environment, better support of biodiversity is possible – a concept described by Colding (2007) as 'ecological land-use complementation'. This means that more indigenous species can be supported in terms of nutrition, space and water resources by the combined patches of the entire urban green infrastructure, which stresses the importance of proper planning of urban development. Furthermore, the conservation resources that already exist can be utilised better in protecting not only endangered, but also abundant indigenous species (Hamilton, 1999).

4.4.3 Useful plants

Despite the high proportion of species originating from Asia and the Americas, the culture of gardening in Potchefstroom is European (Cilliers, 2010) and it has influenced local cultures and resulted in the high occurrence of ornamental plant species in most gardens of the city. Inhabitants of Ganyesa, a small, rural village in the North West Province (Cilliers, 2010), and Ga-Rankuwa, a black township in the City of

Tshwane (Coetzee *et al.*, 2010), were also noted to use many ornamental species for cultivation – an indication that even poorer, more traditional communities regard aesthetics as important. In a study by Clayton (2007) that investigated the reasons for gardening, most of the respondents indicated that the aim of their gardening is a "colourful appearance", confirming the importance of the aesthetic value of garden plants. Weeds, the second most diverse group, are not favoured by gardeners because of their occurrence in unwanted locations (Henderson, 2001). However, these plants are almost always present in gardens and contribute towards the ecological environment within the garden. Food plants did not contribute as significantly to the diversity of the total flora (9 %) of the TCM gardens as would be expected. For instance, in Ganyesa almost 28 % of plant species were classified as food plants (Cilliers, 2010). Molebatsi *et al*. (2010) indicated that the more rural of a series of Batswana communities harboured a greater number of useful, indigenous species than more urban communities. This is an indication of the dependence of poorer communities on utility gardens for their livelihoods. The other categories (medicinal, shade, hedge and windbreak species) all made very small contributions to the diversity of garden flora. Some of the hedge species, however, occurred in many gardens (*Ligustrum lucidum*, 63 %; *Rosa banksiae*, 19 %), indicating that low diversity in a plant use category may underestimate their importance.

4.4.4 Species distribution

Species that are widespread throughout South Africa were the most common indigenous and indigenous cultivated species in gardens, such as the tree *Acacia karroo*, and grasses *Cynodon dactylon* and *Eragrostis lehmanniana*. Species originating from the south-eastern provinces were also commonly cultivated. These two provinces are among those with the highest annual rainfall for South Africa (Mucina & Rutherford, 2006). It was expected that species adapted to high water availability would do well in horticulture, since such conditions are common in gardens due to irrigation with municipal water services. Fewer species were contributed by the drier regions of South Africa, despite these species probably being the best adapted to the climate of the study area and would be much more water wise (Joffe, 2007). The fact that indigenous species are present as part of cultivation practices, is partly ascribed to nurseries promoting such plantings in gardens. All three of the major nurseries in Potchefstroom keep 20–30 % of indigenous stock for cultivation and recommend these above alien horticultural species (Du Toit, 2010; Grobler, 2010; Scheepers, 2010). In many cases, however, customers rather purchase the more colourful or hardy alien horticultural species, of which there is normally a greater variety available.

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. Commonalities between the climate of the country of origin of cultivated alien species and the South African Highveld climate could be the reason why more alien plants are available for cultivation. The Americas and Asia were the largest contributors to the alien horticultural flora in gardens of the TCM, indicating that plant species from these regions may be best-suited for the local climatic conditions (you have not shown this causality and there could be many other reasons, unrelated to climate, that could explain why plants from these regions were used) and even hardier than most indigenous cultivated species. Apart from hardiness and suitability for cultivation, these cultivated alien species also share another important characteristic – ornamental or food value – that makes them popular for cultivation. The garden hybrid species also made a substantial contribution to diversity, suggesting that these taxa are already adapted to the environmental conditions in domestic gardens.

4.4.5 Invasive species

South Africa is regarded as a country threatened by invasive alien plants with 1 226 alien taxa occurring naturally within its borders (Richardson *et al*., 2005). Many of these alien species possess the potential to escape from cultivation in gardens to form self-sustaining natural populations (Sullivan *et al.*, 2005). This may have detrimental effects on the survival and existence of indigenous vegetation and biodiversity (Pimentel *et al.*, 2000; Richardson & Van Wilgen, 2004). The high number of alien invasive species found in domestic gardens of the TCM (88) confirmed that this problem has its origin in ecosystems created by man, where sources of alien invasive species are maintained. Most of the invasive species found in domestic gardens either were cultivated extensively in the past (although they may not be commercially available anymore, e.g. *Ligustrum lucidum*) or are still cultivated and available today (*Canna* x *generalis*, *Celtis sinensis* and *Pennisetum clandestinum*). The fact that these species are still cultivated could be an indication that they may become even more problematic in the future and that more cultivated species have the potential to spread into the natural environment (Siebert *et al*., 2010). However, due to the low occurrences of most of the cultivated invasive species in gardens, it is less likely that these species will spread outside of cultivation. This information on the presence and abundance of invasive species in domestic gardens can be incorporated into preventative measures and eradication plans in the future.

4.4.6 Species diversity

The higher gamma diversity of domestic gardens when compared to other land-use types is further proof of the heterogeneous nature of urban areas and gardens. In the Phoenix-Arizona metropolis, Hope *et al*. (2003) found that the city had much higher gamma diversity than the surrounding desert as a result of the introduced alien vegetation that has replaced the indigenous species. The high gamma diversity of urban domestic gardens is the result of the diverse species pool that gardeners can choose from for cultivation purposes in a variety of habitat types. Plant diversity is generally viewed as an indication and determinant of overall biodiversity, influencing all related biota (Matson *et al.*, 1997) and the green space, in urban areas are thus of critical importance for all that is living in these environments.

More alien than indigenous species are cultivated in domestic gardens because cultivation practices promote the planting of hardy and aesthetic alien species that can be imported from all over the world (Thompson *et al*., 2003; Kühn *et al.*, 2004), simultaneously contributing to high species diversity. Gardens are continually supplied with nutrients and water, thus diminishing the constraints of survival associated with natural areas and thereby increasing the number of species that can exist in a limited environment (Hope *et al.*, 2003; Niinemets & Peñuelas, 2008). Species that would otherwise not be able to survive in native habitats and climates are thus able to survive.

4.5 Summary

The data presented here is a snapshot of the garden flora of a city – a moment in time of a very dynamic and complex system – the garden flora of an entire southern African city. Nevertheless, it provides a broad picture of the state of the garden flora. As there is very little such descriptive data available, especially for developing countries, this chapter contributes to the pool of knowledge necessary to understand urban biodiversity, and urban ecosystems as a whole, more effectively.

Domestic gardens contribute to the plant diversity of urban ecosystems, which forms the basis of the provision of several ecosystem goods and services. Furthermore, gardens have enormous potential to maintain indigenous diversity and threatened species, albeit on a small scale in every garden. On the other hand, with the majority of species cultivated in gardens being alien, it holds the potential to produce even more invasive species that could harm our natural ecosystems and indigenous vegetation. Considering both the benefits of garden vegetation and the possible threat that it poses towards our natural heritage, much more knowledge on the ecological functioning of gardens is necessary to fully understand their features. In addition, socio-economic surveys are required to allow cities to manage the urban green environment sensibly and to optimise their potential for sustainability, an aspect that will be elaborated on in the following two chapters.

Chapter 5

Political legacy of South Africa affects the plant diversity patterns of urban domestic gardens along a socio-economic gradient

5.1 Introduction

Anthropogenic influences are one of the most dominant and persistent driving forces of species richness within urban areas. This makes the inclusion of social, economic and cultural aspects an imperative necessity in urban ecology and biodiversity conservation (Alberti *et al*., 2003; Goddard *et al.*, 2009). However, most studies have been undertaken in developed, northern-hemisphere countries (Hahs and McDonnell, 2007), with very little urban ecological research conducted in developing countries (Altay *et al.*, 2010). Cilliers (2010) discussed the importance of ecological studies of the more informal and multifunctional green areas in cities of developing countries (e.g. gardens) by mentioning the social, ecological and economic benefits of these areas, which may also contribute to the increase of liveability, equity and sustainability in cities. The application of urban ecological theories developed in Western countries can, however, not always hold true for Eastern or African countries with their different climates, cultures and floras (Cilliers *et al.*, 2009). South Africa, with its political legacy of cultural segregation, and economic empowerment of the minority (McDonald, 1998), has therefore created steep socio-economic gradients in the urban environment (refer to section 1.2) where changes in plant diversity patterns of domestic gardens can be analysed.

Collectively, the domestic gardens of an urban environment constitute an enormous part of a city. In Sheffield (UK) gardens are estimated to cover almost a quarter (25 %) of the entire city (Gaston *et al*., 2005), while 36 % of a New Zealand city (Dunedin) is made up of gardens (Mathieu *et al*., 2007). The contribution of urban domestic gardens as a resource for wildlife and provider of ecosystem services (Savard *et al*., 2000) can thus not be neglected. In terms of planning and management of urban open spaces, gardens should be regarded as part of the larger urban green infrastructure, for example in application of the concept of ecological land-use complementation (Colding, 2007). This approach builds on the idea that "land uses in urban green areas could synergistically interact to support biodiversity when clustered together in different combinations". Ecological research of private gardens were, however, quite rare due to access problems created by multiple ownership, the dynamic nature of gardens and the fact that they are unregulated habitats with no recommended planning and management criteria (Gaston *et al*., 2005a, Mathieu *et al*., 2007; Goddard *et al.*, 2009). A good example of the realisation of the importance of home garden research is the Biodiversity of Urban Gardens (BUGS) projects in England which aimed to describe gardens as a resource for biodiversity and ecosystem functioning (Gaston *et al.*, 2005a; Smith *et al.*, 2006a). However, understanding all the factors contributing to the complex nature of ecosystem services in urban areas also requires more studies of the species richness of domestic gardens. Additionally, it is important to promote ecological landscaping in gardens and all other urban landscape parcels (Byrne, 2008; Byrne and Grewal, 2008). This could only be realised once the interrelationships between biophysical and socio-cultural variables are understood (Byrne and Grewal, 2008) and specific ecological principles are taken into consideration (Cadenasso and Pickett, 2008). Most previous studies on domestic gardens in developing countries did, however, not focus on integration between ecological and socio-economic principles (Cilliers, 2010), but emphasised urban agriculture and agroforestry in Africa, Asia, Latin America and Amazonia and also include homegardens in rural areas (Rugalema *et al.*, 1994; Altieri *et al.*, 1999; Winklerprins, 2002; Pandey *et al.*, 2007).

The gradient approach, proposed by McDonell and Pickett (1990) to be useful to study the ecology of cities and towns, allows us to study the response of plant communities and populations to gradual changes in the environment (Gosz, 1992). Gradients in urban areas (anthropogenic gradients) are indirect and non-linear, as they serve as surrogates for a variety of social, economical and even environmental variables. Their complex character thus prevents us from studying it with the traditional transect-method (McDonnell and Hahs, 2008). With the use of the gradient approach, ecological and social science information can be amalgamated (Theobald, 2004) and patterns of biodiversity can easily be discerned, which has the potential to be applied to aid ecologically sensible management and planning in the urban environment (Grimm *et al*., 2000). Quantification of a gradient is a further refinement of the traditional gradient approach, because subjectivity can be greatly reduced, reproducibility ensured and different urban areas can be compared with each other (McIntyre *et al.,* 2000). The differences in plant species composition and richness between urban areas occupied by groups with different socio-economic status have been documented for urban and residential areas in general (Hope *et al.*, 2003; Pedlowski *et al.*, 2003; McConnachie *et al.*, 2008), and specifically for domestic gardens (Kirkpatrick *et al*., 2007), and then in areas containing a single cultural group. In South Africa it has been shown that the layout and species composition of gardens of a single cultural group changes in cities that are also inhabited by other cultures (Molebatsi *et al.*, 2010; Nemudzudzanyi *et al.*, 2010).

The aim of this chapter was to assess the possibility of the influence on the plant species diversity in the Tlokwe City Municipality (TCM) by the legacy effect of apartheid through socio-economic means. This is a unique study as it is conducted in a city with a history of cultural segregation, comprised of three different cultural groups. Differences in the number and types of utilitarian plant species will also be investigated, as this is expected to differ between cultural groups. A comparison between the species richness of domestic gardens with that of other land-use types will also be shown.

5.2 Methods

Alpha diversity was measured as the richness within a particular sample plot, namely the number of species per sample plot, while gamma diversity constitutes the total number of species of all sample plots in a land-use type or SES class (Shaw, 2003). Data consolidation and processing of beta diversity were performed with an indirect ordination (DCA) in CANOCO (Ter Braak & Smilauer, 2002) to elucidate species turnover (spatial floristic change) of gardens across a socio-economic gradient. This multivariate analyses technique gives us the opportunity to represent a complex data matrix (sample and species relationship) in a low, visual dimensional space, making the interpretation of the data much easier. This technique allows us to make the assumption that plots clustered together resemble similar floristic composition (or lower beta diversity). Two outlier sample plots were removed for a better resolution on the final DCA scatter diagram. These plots were outliers as the sampled gardens were on business premises and not managed despite the high SES of the garden owner.

5.3 Results and discussion

5.3.1 Species richness of different land-use types

Urban environments are highly heterogeneous because humans desire many different land uses which results in a variety of land covers (Rebele, 1994). Each of these land-uses has a different number and composition of indigenous and alien species (Figure 5.1), which is a result of a plethora of biotic, abiotic and anthropogenic factors (Cilliers, 1998; Kirkpatrick *et al.*, 2007). Domestic gardens had more than double the gamma diversity than any of the other land-use types, including natural and semi-natural areas (Figure 5.1).

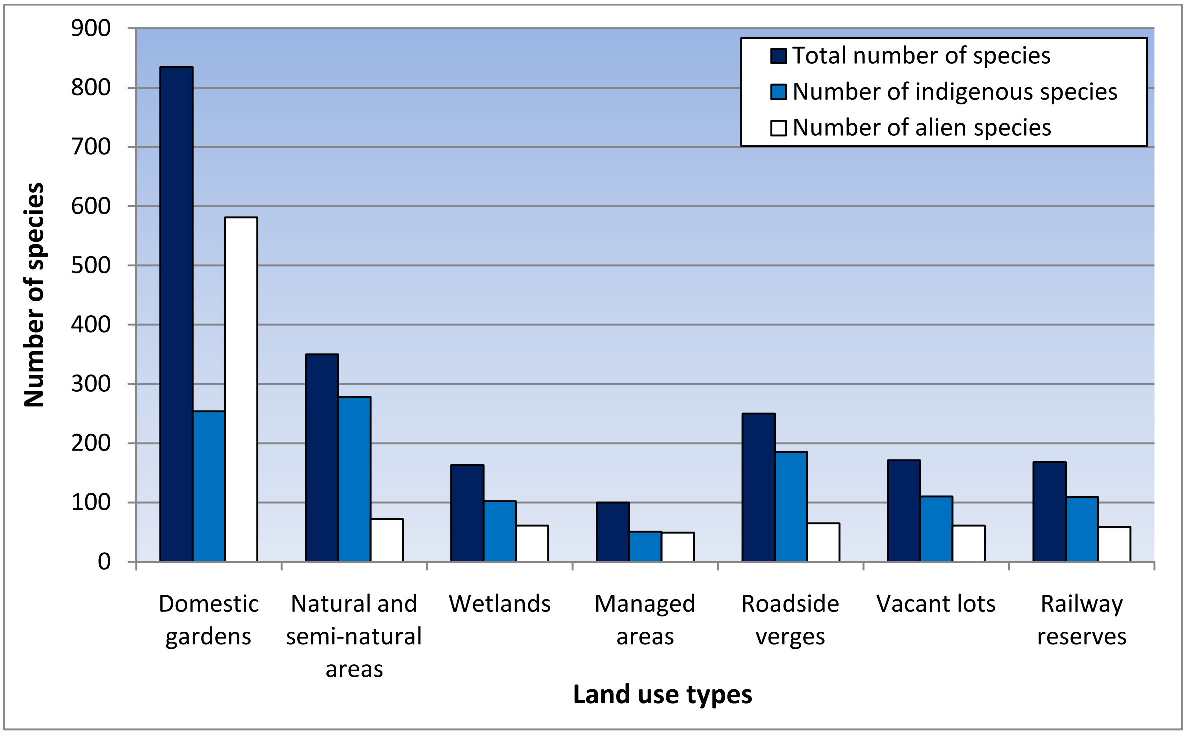


Figure 5.1: Comparison of total species, indigenous species (including cultivated indigenous species) and alien species (including naturalised species) for the different land-use types of the TCM (gamma diversity).

The reason is twofold: firstly, the species pool available to domestic gardens in a city provides a wide choice, and secondly, the management and maintenance practices of cultivation eliminate many environmental stress factors. Another striking difference between domestic gardens and the other land-use types was the much higher proportion of alien species found in gardens. Gardeners choose the hardier alien species for cultivation purposes (Appendix B, refer also to the high occurrence of alien species in Table 5.1). Technological improvements are increasing anthropogenic mobility on a global scale and, whether purposefully or by accident, this facilitates a global distribution of alien species of which many come to be sold in nurseries. This selection for hardy aliens is a problematic outcome of domestic gardens, since these urban adaptable species tend to become more widespread and abundant due to human activities (McKinney, 2006).

Table 5.1: Food (fruit and vegetables) and medicinal plants recorded from domestic gardens of the TCM. Alien species indicated by an asterisk (*).

Vegetables	Fruits	Medicinals
*Allium cepa**	*Acca sellowiana**	*Acacia karroo*
*Allium porrum**	*Carya illinoinensis**	*Aloe arborescens*
*Alocasia macrorrhiza**	*Ceratonia siliqua**	*Aloe ferox*
*Amaranthus deflexus**	*Citrus aurantifolia**	*Ammocharis coranica*
*Amaranthus hybridus**	*Citrus calamandin**	*Apium graveolens**
*Amaranthus spinosus**	*Citrus limon**	*Aptenia cordifolia*
*Amaranthus viridis**	*Citrus reticulata**	*Argemone ochroleuca**
*Armoracia rusticana**	*Citrus sinensis**	*Artemisia afra*
*Beta vulgaris**	*Cydonia oblonga**	*Berula erecta*
*Bidens bipinnata**	*Dovyalis caffra*	*Buddleja salviifolia*
*Bidens pilosa**	*Eriobotrya japonica**	*Bulbine frutescens*
*Boerhavia erecta**	*Ficus carica**	*Cannabis sativa**
*Brassica oleracea**	*Fortunella japonica**	*Catharanthus roseus**
*Capsicum annuum**	*Fortunella margarita**	*Centaurea cyanus**
*Capsicum frutescens**	*Fragaria ananassa**	*Chamaemelum nobile**
Carpobrotus dimidiatus	*Grewia flava*	*Coriandrum sativum**
Carpobrotus edulis	*Grewia occidentalis*	*Cotyledon orbiculata*
Citrillus lanatus	*Helianthus annuus**	*Cymbopogon nardus**
Cucumis myriocarpus	*Malus domestica**	*Datura inoxia**
*Cucurbita pepo**	*Malus sylvestris**	*Eucomis autumnalis*
*Daucus carota**	*Morus alba**	*Foeniculum vulgare**
Digitaria eriantha	*Musa paradisiacal**	*Ginkgo biloba**
Eleusine coracana	*Musa* x *sapientium**	*Hypoxis hemerocallidea*
Enneapogon scoparius	*Opuntia ficus-indica**	*Laurus nobilis**
*Ipomoea batatas**	*Persea americana**	*Lavandula latifolia**
*Lactuca sativa**	*Phoenix dactylifera**	*Mentha pulegium**
*Lycopersicon esculentum**	*Physalis angulata**	*Ocimum basilicum**
*Manihot esculenta**	*Physalis viscosa**	*Olea europaea*
*Medicago sativa**	*Prunus armeniaca**	*Origanum vulgare**
Pentarrhinum inspidum	*Prunus laurocerasus**	*Ornithogalum tenuifolium*
*Phaseolus vulgaris**	*Prunus persica**	*Plumbago auriculata*
*Portulaca oleracea**	*Prunus* x *domestica**	*Ranunculus multifidus*
*Solanum capsicastrum**	*Punica granatum**	*Rosmarinus officinalis**
*Solanum melongena**	*Pyrus communis**	*Rumex crispus**
*Solanum nigrum**	*Solanum nigrum**	*Ruta graveolens**
*Solanum tuberosum**	*Vitis vinifera**	*Salvia leucantha**
Sorghum bicolor		*Sambucus nigra**
*Spinacia oleracea**		*Solidago canadensis**
*Tropaeolum majus**		*Tagetes minuta**
Urochloa panicoides		*Tecoma capensis*
Vigna unguiculata		*Tulbaghia violacea*
*Zea mays**		*Zantedeschia aethiopica*

5.3.2 Species richness of different socio-economic status groups

Along the indirect SES gradient, a clear indication of the effect of SES on the plant species distribution patterns in urban domestic gardens was evident (Figure 5.2). Species gamma diversity of groups with a higher SES (classes 4 and 5) were more than double than that of the first three groups with lower SES. This phenomenon is termed the "luxury concept" (Hope *et al*., 2003). Resources, financial or labour, can enable people to change their environment, while resource shortages can limit such changes. The species richness of class 4 was significantly higher than that of class 5, since this group included smallholdings of up to 8 ha with more permanent labour resources than the sample plots in class 5.

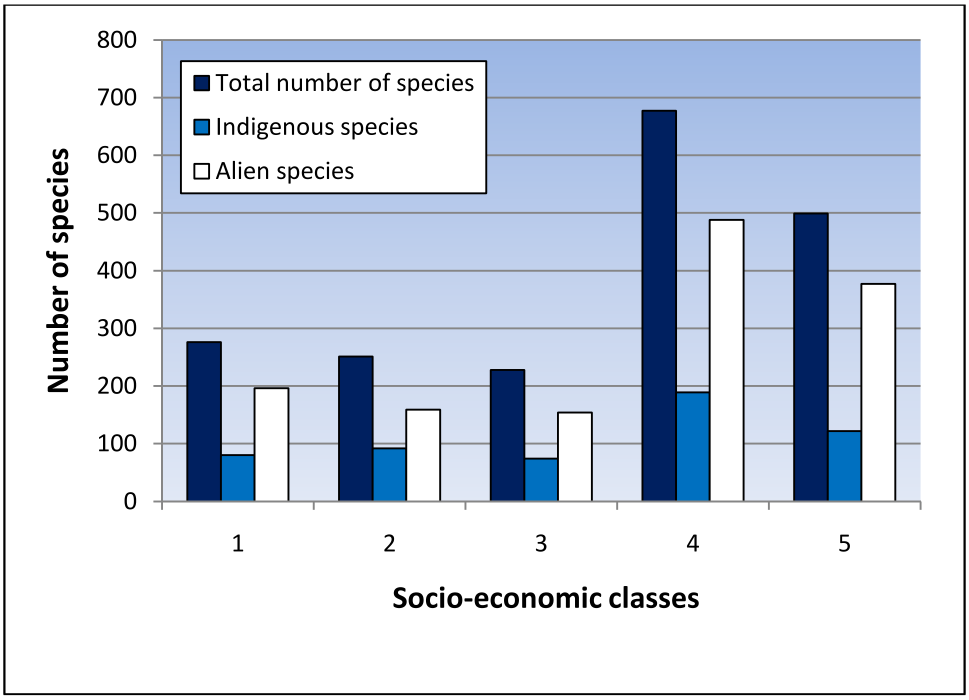


Figure 5.2: Gamma diversity, namely the total number of species recorded for all gardens in each socio-economic class, and differentiating between indigenous and alien species, for the TCM.

Another aspect that needs to be considered is cultural influences. Classes 4 and 5 constitute the areas where people mainly from European origin reside, on land that was part of the original settlement of white people in this area in 1838 – which was chosen for the fertile soil along the Mooi River. Settlement of other racial groups was, due to the segregation policy, further away from this fertile area in the hills and ridges, with the industrial area forming a buffer zone between the white and non-white areas (refer to Figure 3.1) (Christopher, 1997). These non-fertile areas include mostly SES classes 1 to 3, while the people are primarily from native African origin, namely Batswana. According to Batswana beliefs the area around the house should be devoid of vegetation to reflect the tidiness of the household (Cilliers *et al*., 2009) ("lebala" concept, see Figure 5.3A).

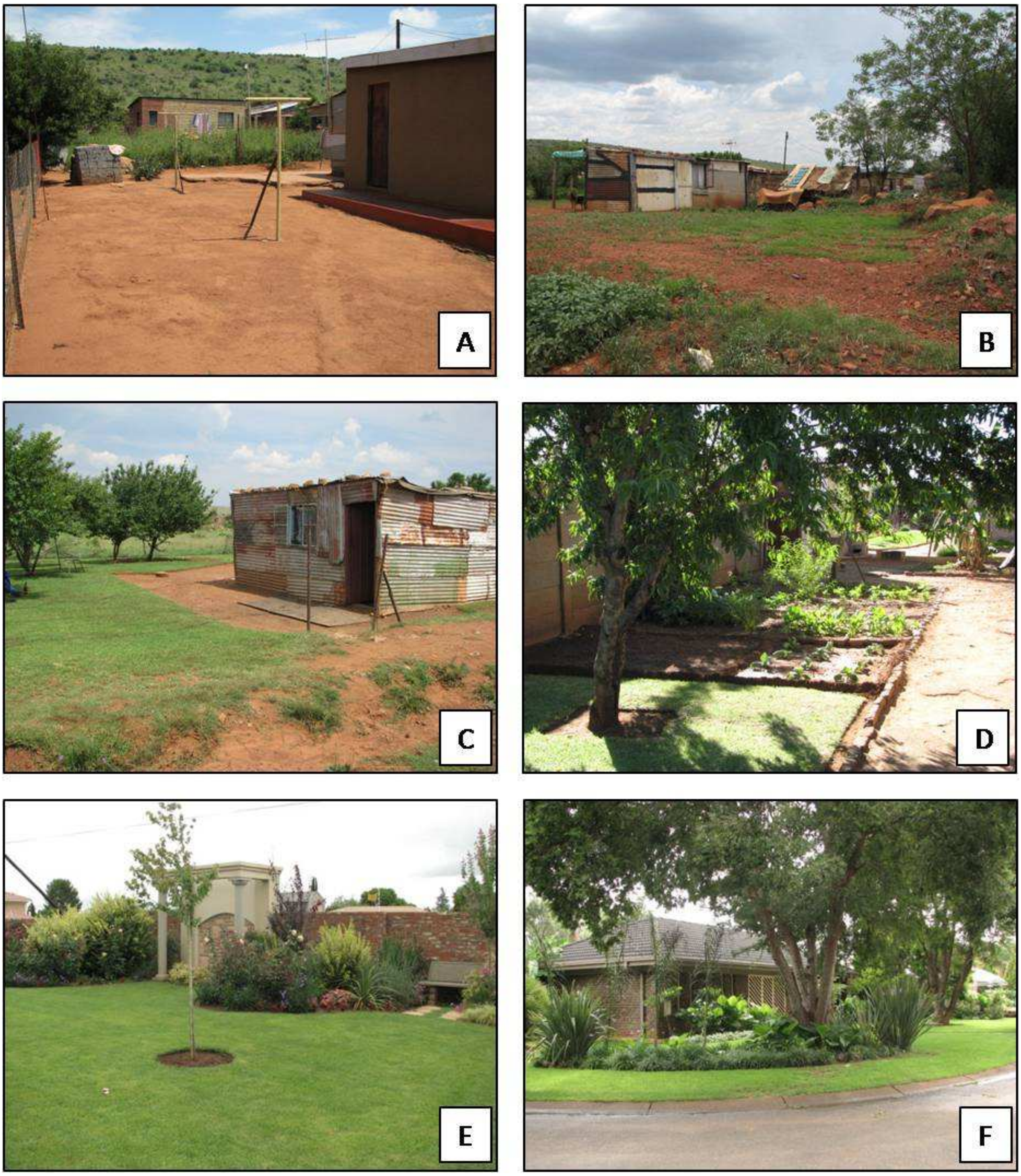


Figure 5.3: Visual representation of the change in domestic garden species composition along a socio-economic gradient in the TCM, with (B) representing the lowest class, and (F) progressively represents the highest class. The ‘lebala’ concept is depicted by (A).

5.3.3 Species diversity

The differences in alpha diversity between different SES groups (Figure 5.4) provided a similar result to gamma diversity (Figure 5.2) – SES classes 1 to 3 had more or less similar alpha and gamma diversity, but these three classes had considerably lower values than classes 4 and 5. This is attributable to the historic cultural preferences and amount of available resources that enabled wealthier, white people to create an intensively managed vegetated environment (refer to section 6.3.4 for statistical validation). These inequities are well known for South African cities (Christopher, 1997) with white, affluent suburbs that have large plots and poor, black suburbs with high housing densities. This trend could therefore also be ascribed to housing density as was shown in a study on gardens in France (Marco *et al*., 2010).

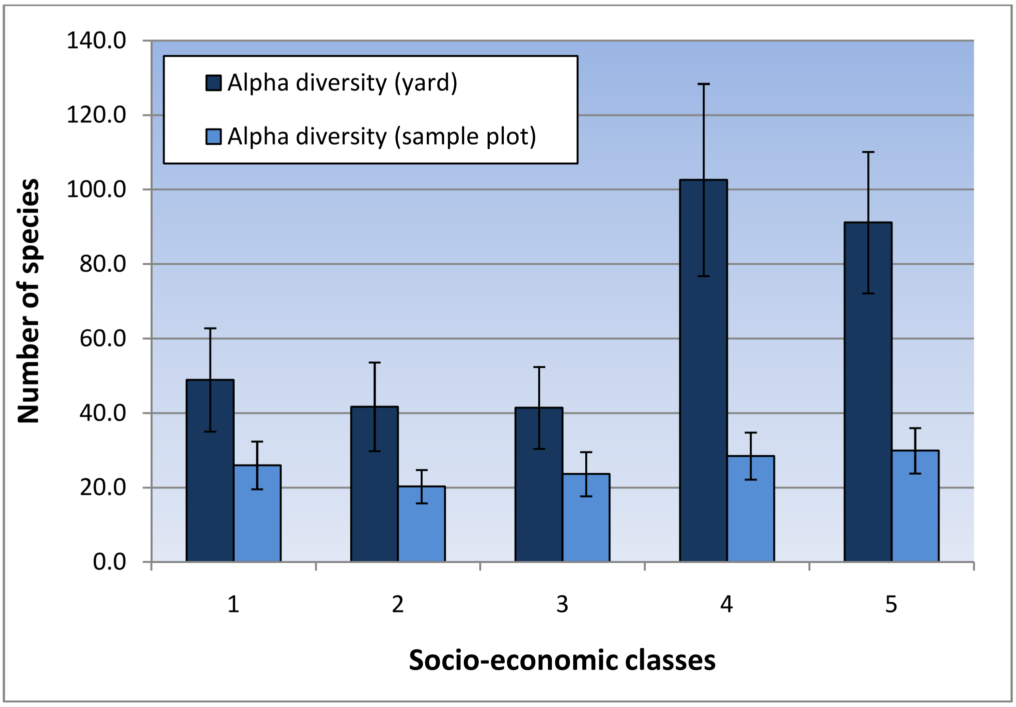


Figure 5.4: Alpha diversity for each of the five socio-economic classes in the TCM. Richness data was sampled in 20 x 20 m plots (sample plot) and the whole garden (yard, which varied in size).

Similarity between the species composition of different sample plots revealed two distinct assemblages (Figure 5.5). In this ordination, representing beta diversity (species turnover), the plots of SES classes 4 and 5 shared a similar floristic composition, while SES classes 1, 2 and 3 were floristically more similar. This is in accordance with the findings of Marco *et al*. (2010) that indicated how gardens associated with the same housing density showed similar species composition. The scatter diagram indicates the steep SES gradient in the near separation of these assemblages, which is determined by cultural preferences and financial means to acquire plants and manage the garden.

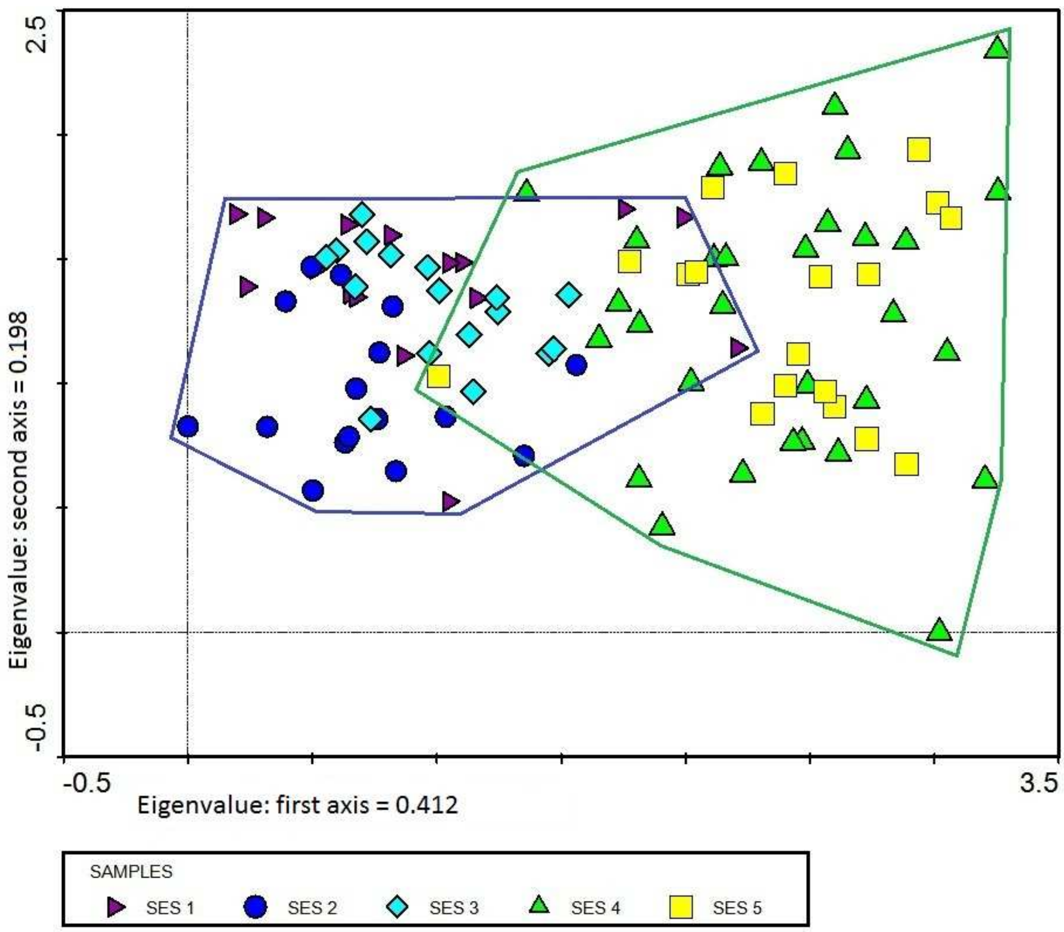


Figure 5.4: Scatter diagram of an indirect ordination (DCA) of species turnover in sample plots of gardens from low SES (left) to high SES (right) in the TCM; samples grouped closer together share a more similar species composition.

Axis	Eigenvalues	Lengths of gradients	Percentage variance
1	0.414	3.255	4.4
2	0.198	2.339	6.5

5.3.4 Utilitarian plants

The utilitarian value of plants also has an effect on the plant diversity of gardens. When a useful plant forms part of a specifically planted micro-garden containing a group of plants with similar uses then it has obvious value. This makes micro-gardens ideal surrogates to draw apart the effects of cultural preference and financial means, as people from European origin rarely include utilitarian plants in their garden (Kirkpatrick *et al*., 2007). A pattern was evident along the SES gradient regarding the cultivation of useful plants when the presence of micro-gardens of different groups of useful plants (vegetable gardens, fruit trees and herb/medicinal gardens) (Table 5.1) was plotted against each SES class (Figure 5.6). A relatively strong negative relationship exist for fruit trees and SES (R^2 = -0.65), suggesting that poorer households grow more fruit trees. Although trees are slow to mature and expensive, poor communities rather invest in these trees as job insecurity prevents people from becoming dependant on market products. Vegetable gardens and herb/medicinal gardens did not show statistically significant correlations with SES (respectively R^2 = 0.098; R^2 = 0.001). When utilarian plants were grouped together the relationship with SES remained moderately negative (R^2 = 0.5), indicating that people from poorer communities more readily cultivate and make use of utilitarian plants as a means of additional income or simply to improve livelihoods. This confirms what was found in a study of tropical homegardens, where plant diversity is regarded as important only in terms of providing subsistence and income to the households (Pandey *et al*., 2007). Another study by Molebatsi *et al.* (2010) showed that less-westernised communities in rural areas depend more strongly on their utility gardens for livelihoods than do those communities exposed to the European culture of ornamental gardening (refer also to section 6.4.3).

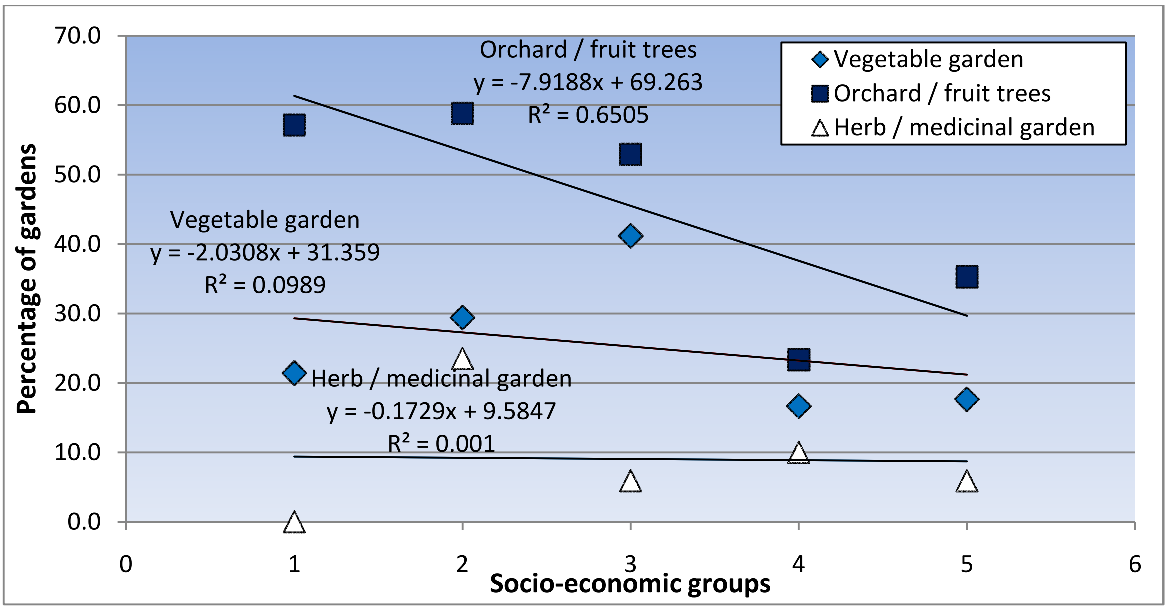


Figure 5.6: Regression analysis of the percentage of gardens containing micro-gardens with specific utilitarian plants across a socio-economic gradient in the TCM.

5.4 Summary

This study provides evidence of the effects that socio-economic factors, other than ecological factors which are traditionally investigated, have on vegetation patterns. SES and cultural influences were identified as some of the driving forces of plant species richness patterns observed within the study area, showing higher species richness in the more affluent, white-dominated suburbs. Thus, the legacy effect of apartheid does influence the patterns of plant species diversity as a result of the skewed distribution of financial resources. Much of the increased diversity of gardens, in comparison with other land-use types, is made up of alien species that contributes to biotic homogenisation of urban environments and urban domestic gardens have a higher alpha, beta and gamma diversity than other land-use types on a local scale. On a regional scale, however, the opposite should be true for beta and gamma diversity, as urban domestic garden floras collectively are homogeneous, meaning that the garden floras of different cities would be similar due to a shared species pool, but the natural areas of different cities would differ in species pools due to largely varying, natural environmental conditions and less anthropogenic influence. This study, as well as others focusing on the integration between social, cultural and ecological aspects in urban areas which are ecologically, culturally and socially as heterogeneous as the city of Tlokwe, will contribute to our knowledge of the functioning of urban ecosystems (Cilliers *et al.*, 2009).

The relationship between SES and plant species diversity that were observed in the TCM will be further explored in Chapter 6, with the addition of other factors (management intensity and demographic aspects). This is an attempt to explain the patterns of plant species diversity, which will also be described.

Chapter 6

Patterns of domestic garden plant diversity and underlying drivers along a socio-economic gradient

6.1 Introduction

Urbanisation is transforming landscapes at unprecedented rates (United Nations Department of Economic and Social Affairs, 2008), creating complex and dynamic ecosystems (Pickett *et al.*, 2000; Alberti, 2005). The effects of urbanisation can be summed as four so-called filters that act on vegetation and, ultimately, also on other taxa during development and expansion of urban areas (refer also to section 2.4.1) – habitat transformation, habitat fragmentation, altered environmental conditions and human preference (Williams *et al.,* 2009). All these filters act simultaneously to create patchiness, which simply means that spatial units differ from surrounding units in terms of its appearance or its nature (e.g. size, shape and composition).

These differences are however subjected to scale: the patch may be a whole continent when using a broader scale or a fallen log in a forest when taking a closer look (Wu *et al.*, 2003), and a city with all its patches could simply be another patch in a larger landscape (Collins *et al.*, 2000). A "nested hierarchy" is thus formed when considering patches at different scales. It can also be seen as a complex system that is composed of interconnected subsystems which, when examined closer, are made up of their own subsystems (Wu & Loucks, 1995). Complexity of any system can thus be reduced by applying the hierarchical patch dynamics approach and the understanding and prediction probabilities in such ecosystem studies will be increased (Wu *et al.*, 2003). In summary, this approach attempts to explain the effects of the patterns on the ecosystem dynamics (processes) and *vice versa* at different spatial scales (Wu *et al.*, 2003).

Patterns of plant species distribution in urban areas have shown that more species are harboured in cities than in the surrounding landscapes (Thompson *et al.*, 2003; Kühn *et al.*, 2004; Wania *et al.*, 2006; McKinney, 2008) and it is often dominated by alien species (Pyšek, 1998; Clement & Moore, 2003; McConnachie *et al.*, 2008), although some examples exist of urban species richness that is lower than its natural surroundings (Jim & Chen, 2009). The increased species richness can be ascribed to three possible reasons: a higher occurrence of alien species introduced through horticulture and commonly occurring indigenous species (Kühn & Klotz, 2006), the high heterogeneity of the urban environment and also the degradation of natural habitats surrounding cities by agricultural activities (Wania *et al*., 2006). However, the process of urbanisation destroys the habitat of indigenous plants and cause extinction of unique, local species. Simultaneously, it creates an environment suited for urban-adapted species that establish in cities all over the world, thus causing homogenisation of urban floras (McKinney, 2002; Olden & Poff, 2003). The increased presence of alien horticultural species in the urban environment thus cause local biodiversity to be higher, but on a global scale, urbanisation leads to impoverishment of the available species pool (McKinney, 2006).

Garden plant diversity has been excluded from urban ecological studies for a long time, but in recent years, its value as part of the urban green space (Loram *et al.*, 2007) and a source of alien and invasive plant species (Reichard & White, 2001) has been recognised (refer to section 2.5.2). However, the focus of research on gardens in developed countries is very different from that of developing countries. The latter focus more on urban agriculture and agroforestry to increase the livelihoods of urbanites (e.g. Trinh *et al*., 2003; Wezel and Bender, 2003; Blanckaert *et al.*, 2004), whereas developed countries conduct research in gardens with its potential for biodiversity conservation and ecosystem services in mind (Cilliers *et al.*, *in press* a). A major study on gardens was conducted in Sheffield, UK, called the Biodiversity in Urban Gardens in Sheffield (BUGS) project. This study analysed the composition of garden flora (vascular plants – Smith *et al.*, 2006a; lawns – Thompson *et al.*, 2004) and invertebrate richness (Smith *et al.*, 2006b), as well as the scope and contribution of gardens in the city (Thompson *et al.*, 2003; Smith *et al.*, 2006a). Some other garden studies focused on floral diversity (Das & Das, 2005; Marco *et al*., 2008), the potential resource provision of domestic gardens for biodiversity (Davies *et al.*, 2009), garden types (Daniels & Kirkpatrick, 2006; Kirkpatrick *et al*., 2007) and predictors of vegetation cover on private properties (Martin *et al.*, 2004; Mennis, 2006; Troy *et al.*, 2007).

According to Wu (2008), the ultimate goal of urban ecology is to understand how the patterns of urbanisation and its effects are related to the underlying ecological processes. The integration of ecological knowledge into the design and management of the urban environment is challenging and a main concern of applying the landscape ecology approach in urban areas (Wu & Hobbs, 2002), which has the aim of creating more sustainable cities (Musacchio & Wu, 2004). Currently, most or all of our cities are in a state where it cannot sustain itself, as is signified by the numerous environmental problems experienced as a result of urbanisation (McGranahan & Satterthwaite, 2003). Wu (2008) states that human and environmental health will be affected more and more by the level of sustainability of our cities. Aiming to improve sustainability (instead of bringing an end to urbanisation) is thus ultimately advantageous for the well-being of humanity (Cilliers & Siebert, 2010).

Gradient analysis is often used to study ecological patterns in general (Gosz, 1992) and specifically urban vegetation patterns along urban-rural gradients (McDonnell & Hahs, 2008; Du Toit & Cilliers, 2011). The one characteristic that separates urban areas from its more natural counterparts is the dominant presence of humans (Alberti *et al.*, 2003). Hope *et al.* (2003) recognised the need for the addition of another type of gradient in search of patterns in the flora of the urban environment – the socio-economic gradient. The preference of individuals regarding the surrounding vegetation is often shaped by their cultural upbringing and social background. Preference combined with financial means, with which people can alter their surroundings, creates such a socio-economic gradient (Kinzig *et al.*, 2005). Investigating this gradient is of particular importance because of the definite association between the quality of life and socio-economic status (SES) of the urban residents. Urban stresses such as crime and housing problems can be avoided to some extent by citizens with better financial resources, leaving the poorer segment of the urban population vulnerable to social and psychological distress (Nelson *et al.*, 1998). Chiesura (2004) discussed how green space can improve the conditions in urban areas by creating a relaxing, peaceful environment, not to mention the physical benefits such as clean air and temperature reduction, among others (Bolund & Hunhammar, 1999). There are also studies indicating a positive relationship between urban plant diversity and wealth (Hope *et al*., 2003; Kinzig *et al.*, 2005; Hope *et al.*, 2006) and specifically residential urban plant diversity (Martin *et al.*, 2004; Mennis, 2006). This relationship is termed the luxury concept (refer to section 2.6.2; Hope *et al.*, 2003). In the aftermath of apartheid, neither financial nor environmental resources are yet equally distributed amongst the urban population of South Africa (Christopher, 1997; Lubbe *et al.*, 2010), as would be the ideal. Access to environmental services, such as those provided by domestic gardens, has the potential to increase quality of life for urbanites (Bolund & Hunhammar, 1999), but with inequity of access the poorer segment of society is less able to utilise these benefits and, consequently, experience a lower quality of life (Pedlowski *et al.*, 2002). In Rio de Janeiro, Brazil, a higher personal involvement of residents to increase green space has been noted amongst wealthier citizens (Pedlowski *et al.*, 2002). This behaviour reinforces the existing segregation.

Gardens are the ideal landscape to examine the effect of socio-economic and cultural differences, because the vegetation of this land-use type is controlled according to individual preferences and financial means (Parsons & Daniel, 2002; Martin *et al.*, 2004). Most areas of urban vegetation in public areas are structured to some collective social norm by local management authorities, but the design of domestic gardens is subject to wealth, personal preferences and spending regimes of residents. This is in turn influenced by education, trends and advice that combine to create a more diverse floral composition that reflects the socio-economic heterogeneity of a city (Martin *et al.*, 2004; Hope *et al.*, 2006; Smith *et al.*, 2006), especially in SA with its incredibly high cultural heterogeneity and unequal distribution of resources, which produces a steep SES gradient (Lubbe *et al.*, 2010).

Instead of an urban-to-rural gradient, this study was conducted on the foundation of a socio-economic gradient to allow for an indirect gradient analysis. The social characteristics were incorporated into the gradient approach by quantification of wards into SES classes (refer to section 3.4). In the previous chapter (Lubbe *et al.*, 2010), the existence of a steep socio-economic gradient and cultural segregation in the study area was illustrated. This chapter aims to portray the patterns of plant diversity and richness in domestic gardens of the Tlokwe City Municipality (TCM) and also to determine some of the socio-economic drivers of garden plant diversity.

The specific objectives of this chapter are to:

- describe alpha diversity;
- describe beta diversity;
- portray the gamma diversity through species numbers and determine differences between SES classes;
- determine whether changes in diversity can be ascribed to drivers such as yard size, population density, socio-economic status and a self-designed management index.

6.2 Methods

6.2.1 Vegetation sampling

The vegetation surveys at each study site included a 100 point-sampling method in a 20 x 20 m sample plot (sample plot data, Figure 3.2) as well as a notation of all the plant species present in each yard (yard data). For more detail on these methods, refer to section 3.3.

6.2.2 Diversity indices

Diversity on different spatial scales in the ecological context can be divided into three groups, namely alpha, beta and gamma diversity (Shaw, 2003). Gamma diversity is the total number of species or overall diversity for a specific landscape or land-use type, as described in section 4.3.11 and 6.3.3, while beta diversity represents the change between different landscapes or samples (refer to section 6.2.3). The species richness within a fixed area is called alpha diversity and the indices discussed here are primarily used to describe this kind of diversity (Shaw, 2003). Sample plot data was used to calculate the diversity indices for all sample plots with the statistical package, Primer 5 (Clarke & Gorley, 2001).

The first and most straightforward measure of alpha diversity is the number of species present in a sample plot (Shaw, 2003), but simply using species richness characteristics are often inadequate because it omits important information on the contribution (number of individuals or biomass) of each species to the sample (Magurran, 1988). Diversity indices include both the number of species and the abundance of all the species in a sample in a single number, indicating if there are common and rare species present or if the species are all equally represented in the sample (Magurran, 1988). Comparing the diversity of multiple samples is possible with the use of such diversity indices (Shaw, 2003). Magurran (1988) identified three different types of diversity indices, of which we shall use the following two: (1) species richness indices and (2) proportional abundance indices.

Species richness indices, for example Margalef's or Menhinick's indices, are a measure of species richness that also includes the sum of individuals recorded for all the species in a specific sample plot (Magurran, 1988). These indices are easy to calculate and provide results that are directly comprehensible. For this study, **Margalef's species richness index** (d) was used:

$$d = \frac{(S-1)}{\ln N} \quad \textbf{(Eq.1)}$$

with S = number of species

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

Proportional abundance indices go a step further than species richness indices by including both the species richness and the relative contribution (or abundance) of each species (Magurran, 1988). Indices of this type can either stress the importance of species richness by weighting towards rare species (Shannon's index) or emphasize dominance by regarding abundant species as more important (Simpson's index).

Shannon's index (*H'*) is calculated as follows:

$$H' = -\sum p_i \ln p_i \quad \textbf{(Eq.2)}$$

with p_i = the proportion of the *i*th species in the sample

Although Shannon's index includes the equitability of abundance of species in a sample, a separate measure of evenness can be calculated with **Pielou's evenness** (J'):

$$J' = \frac{H'}{\ln(S)} \quad \textbf{(Eq.3)}$$

with H' = Shannon's index

S = number of species

Simpson's diversity index (*D*) is used to determine the probability of two consecutive samples having different species composition and is calculated as follows:

$$\boldsymbol{D = 1 - \sum (p_i \times p_i)} \qquad \textbf{(Eq.4)}$$

with p_i = the proportion of the *i*th species in the sample

A one-way ANOVA was used to test for significant differences between the SES classes of all diversity indices except Simpson's, for which a Kruskal-Wallis test was conducted because its data did not comply to the assumptions of a one-way ANOVA (refer to section 6.2.6 for more detail).

6.2.3 Inverse distance weighting

Several techniques exist to model spatial patterns in a given area. Inverse distance weighting (IDW) is one such technique often used in ecological studies (Fortin & Dale, 2005). Discrete sample point values (be it rainfall, species abundance or other variables) are used to estimate the values of unsampled locations to produce a continuous map (Isaaks & Srivastava, 1989). An improvement of IDW over other spatial interpolation techniques is that the complexity of spatial patterns is preserved by the selective weighting of sample points (Fortin & Dale, 2005), which produces highly visual results. This does not mean, however, that it gives an accurate representation of the actual conditions on the ground; it merely represents the general patterns (Fortin & Dale, 2005), which are still informative.

To explore the patterns of different groups of plants (indigenous, naturalised, etc.) along the SES gradient in the TCM, maps were generated with IDW in ArcMap, ArcView 9.2 (ESRI, 2006). In this case, the IDW patterns of the five species groups (total number of species, indigenous cultivated, alien cultivated, naturalised and indigenous species) were projected on the street map of the TCM. The yard data were used, as this provides a better representation of the patterns observed in the gardens of the TCM than the sample plot data (see also Figure 5.4). Sample plot data is often very localised sample points in homogeneous plant assemblages (e.g. lawns or maize) and is not representative of the total yard flora. The SES of the inhabitants of each sample plot is indicated on the map, with 1 being the lowest SES and 5 the highest. For a detailed description of the determination of SES classes, refer to section 3.4 and Tables 3.1 and 3.2.

6.2.4 Beta diversity measure

The formal definition of beta (β) diversity, as defined by Whittaker (1960), is the "extent of species replacement or biotic change along environmental gradients" and the higher the beta diversity, the more dissimilar the tested localities are (Koleff *et al.*, 2003). Whittaker was a pioneer in the study of ecological diversity (Whittaker, 1960; 1972; 1977), but many similar and adapted versions of beta diversity measures has seen the light since his proposal (β_W, see Equation 5) (Wilson & Shmida, 1984; Koleff *et al.*, 2003). The great variety of available measures, applied in many different ways, sometimes obstructs comparison between the results of different studies, although β_W is one of the most frequently applied measures (Koleff *et al.*, 2003). It is also the measure of choice in gradient studies where the samples cannot be arranged along a single gradient (Wilson & Shmida, 1984), as is the case in urban environments which are complex and influenced simultaneously by multiple factors (Alberti *et al.*, 2003). For these reasons, β_W was used to determine the beta diversity of the five SES classes. Whittaker's measure (β_W) is calculated as follows:

$$\boldsymbol{\beta_{W=}\left(\frac{S}{\bar{\alpha}}\right)-1} \qquad \textbf{(Eq.5)}$$

with S = total number of species recorded in the study system (gamma diversity)
$\bar{\alpha}$ = average number of species found within the community samples

This measure is dependent on the sample area, because species richness is an increasing function of sample area (Lawton, 1999; Crawley & Harral, 2001; Smith *et al.*, 2006a). Therefore, only sample plot data were used in the analysis of beta diversity. A lot of information is lost in the process of calculating a single index to describe all plot-to-plot variation, such as the species composition (Veech & Crist, 2010), but no perfect measure exists and the least inadequate measure must be used to answer each individual research question (Ricotta, 2010). Ordinations and dissimilarity matrices augment beta diversity values because it retains information that illuminates the underlying gradients that give rise to beta diversity (Veech & Crist, 2010).

6.2.5 Ordinations

Ordinations are mathematical instruments used to investigate the variation of communities along a gradient, often associated with environmental conditions such as soil moisture level or nutrient contents (Lepš & Šmilauer, 2003). Samples are evaluated on account of their species composition and the closer the arrangement on the ordination axes, the more similar they are (Kent & Coker, 1994). Ordination methods can be classified as either direct or indirect. The latter do not incorporate environmental data or other explanatory factors (such as SES) into the analysis as is done with direct ordinations, but such data is used for interpretation of the results (Kent & Coker, 1994). Principle component analysis (PCA), correspondence analysis (CA), detrended correspondence analysis (DCA) and non-metric multidimensional scaling (NMDS) are some of the most widely-used indirect gradient analysis methods available (Lepš & Šmilauer, 2003).

For this study, a DCA was chosen to compare the floristic composition of sample plots in all five SES classes, because of the complexity of the indirect SES gradient (Lepš & Šmilauer, 2003). As with the IDW maps, the procedure was run for alien cultivated, indigenous cultivated, naturalised and indigenous species groups individually to determine if the effect of SES varies for these different groups of species. For the total species group as well as the other four species groups (alien cultivated, indigenous cultivated, naturalised and indigenous species), ordinations were done with sample plot data. An ordination of the total species group (yard data) was already presented in section 5.3.3 to indicate the high species turnover between domestic gardens in the TCM. In the sample plot ordinations of some species groups, sample plots that contained no species were regarded as empty and left out of the analyses. Alien cultivated species had four empty plots, indigenous cultivated had 30, naturalised had none and indigenous species had three empty plots.

6.2.6 One-way ANOVA and Kruskal-Wallis test

Analysis of variance (ANOVA) is a statistical technique applied to data to determine if there is a significant difference between the means of two or more samples (Tabachnick & Fidell, 2001). 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 & Keough, 2002).

The result of a one-way ANOVA simply informs on the possibility of significant differences, but does not indicate which groups differ from each other. To determine this, *post hoc* testing is required (Tabachnick & Fidell, 2001). In this case, Tukey's honestly significant difference (HSD) test was used to compare the sample means pair wise with that of every other sample (SES classes) and indicate which samples are significantly different (Quinn & Keough, 2002). Other tests accompanying the ANOVA are the Levene and Brown Forsythe tests for homogeneity of variances (HOV), which indicates if the data comply with the assumptions of HOV for the ANOVA. The other assumption made by ANOVA is normal distribution of data (Statsoft, 2010). In the case that assumptions are not met, another similar method, the non-parametric Kruskal-Wallis test, can be carried out. This test is more robust and does not make the same assumptions than a one-way ANOVA (Quinn & Keough, 2002).

The software package STATISTICA 9.0 (Statsoft, 2009) was used to perform a one-way ANOVA to determine significant differences between the five SES classes on account of the mean number of species, followed by Tukey's HSD test for unequal sample size as *post-hoc* test.

6.2.7 Correlations

Correlations are used to describe the relationships between two or more continuous variables (Quinn & Keough, 2002). If the changes in one variable are related to the changes of another, these two variables are considered to be correlated (Hair *et al.*, 1998). Normal distribution is a prerequisite of the commonly used Pearson's correlation method (Quinn & Keough, 2002), therefore Box-Cox transformations were performed to alter the distribution of the data before applying correlation techniques (Statsoft, 2010) (Appendix C). All transformed variables are indicated with †.

Pearson's correlation coefficient (*r*) is calculated as follows:

$$\boldsymbol{r = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2\sum(y-\bar{y})^2}}} \qquad \textbf{(Eq.6)}$$

Two surrogate variables were chosen (SES† and a self-constructed management index (MI†)), after determining correlations between variables (SES†, MI†, population density† and yard size†). SES† and MI† were chosen to test the effect of socio-economic variables on the spatial variation of species numbers in different species groups (e.g. alien cultivated). Correlation procedures could not be performed for the indigenous cultivated species group, as a result of too many "empty" plots in yard and sample plot data.

SES is composed of five parameters (refer to section 3.4): (1) percentage unemployment, (2) household size, (3) number of rooms, (4) access to basic services and (5) schooling status. The management index was constructed by extracting data from the questionnaire (Appendix D) concerning management actions that take place in each garden (Table 6.1). According to the intensity of management actions, a score was assigned to each (Table D.1 and D.2), for example mowing the lawn once a week would receive a higher score than mowing it once a month. Specific actions that could be regarded as "higher management" were then weighted to highlight the effect of interest and investment in gardening. Then the scores across all actions were summed for each garden to produce the MI (Table D.3).

Table 6.1: Management actions used to compile the management index (MI), weighted actions are marked with a *.

Management actions		
Watering	Sweeping	*Top soiling lawn
*Fertilising	Pruning	Spiking lawn
*Chemical weeding	Removing dead material	*Mowing lawn
Mechanical weeding	Raking lawn	*Type of irrigation system

6.3 Results

6.3.1 Gamma diversity

The total number of species for each of the five SES classes is presented in Figure 6.1. This figure includes the gamma diversity for both the sample plot and total yard data sets, similar to the alpha diversity shown in Figure 5.4. The same trend as for the alpha diversity is visible here, with the higher SES classes containing almost twice the number of species than the lower SES classes (yard data). The sample plot data portrays the same relationship, but with less pronounced differences.

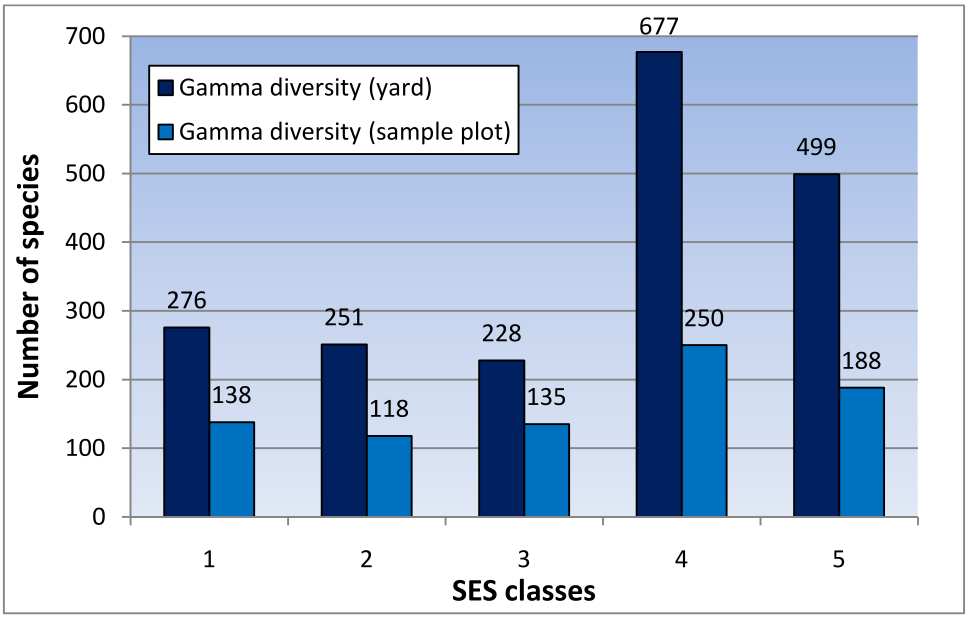


Figure 6.1: Gamma diversity of each of the five socio-economic classes in the TCM. Richness data was sampled in 20 x 20 m plots (sample plot) and the entire yard (yard).

SES groups

A one-way ANOVA was performed to determine if the five SES classes differ from each other on account of the mean number of species per garden in the TCM (yard data), which could also be seen as a measure of gamma diversity. Results of an ANOVA are given as a p-value, which is significant if $p<0.05$.

The p-value for this analysis is much smaller than 0.05 (Table 6.2), indicating that at least some of the socio-economic groups are significantly different with regard to the mean number of species.

Table 6.2: Results of the one-way ANOVA, as determined for the mean number of species per garden in each SES class in the TCM.

Source	SS	df	MS	F	p
SES	76385.48	4	19096.37	54.42598	**0.0000000**
Residual	33332.52	95	350.8686		
Total	109718	99			

Tukey's HSD test for unequal sample size were used to determine which classes are significantly different from one another and the results of this test are presented in Table 6.3, where significant differences are indicated in bold. The test indicated that there are two distinct SES groups, made up of SES classes 1–3 and 4–5. SES classes one to three are not significantly different from each other, but they are different from SES classes four and five, which represent a second group. Figure 6.11 presents the mean number of species for every SES class, providing visual confirmation of the result of the Tukey's HSD test.

Table 6.3: Results of the Tukey's HSD test for unequal sample size when comparing the mean number of species per garden of each SES class in the TCM. Significant differences are indicated in bold (p < 0.05).

	1 (M=48.938)	**2 (M=41.722)**	**3 (M=41.412)**	**4 (M=102.61)**
1				
2	0.811593			
3	0.786908	0.999999		
4	**0.000117**	**0.000117**	**0.000117**	
5 (M=91.167)	**0.000117**	**0.000117**	**0.000117**	0.360940

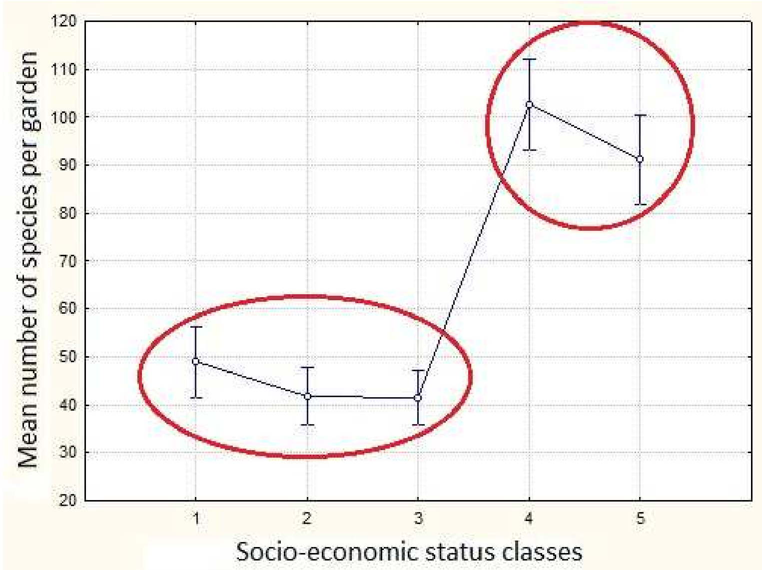


Figure 6.2: Plot of means and confidence intervals of the number of species per garden for each SES class in the TCM.

Both the Levene and Brown-Forsythe tests indicated with significantly small p-values that the data does not have homogeneity of variance (Levene test: p = 0.0003; Brown-Forsythe test: p = 0.0005). For this reason, a Kruskal-Wallis test was carried out. This rank-order test does not make any assumptions regarding the distribution of the data (Quinn & Keough, 2002). The results of the Kruskal-Wallis test (Table 6.4) indicate the exact same configuration of SES classes: classes 1–3 are not significantly different from one another, but individually they are different from classes 4–5. The Kruskal-Wallis *H*-statistic equals 72.26 for the 100 sample plots, exceeding the critical value (Chi-square = 9.488) at a 0.05 significance level with 4 degrees of freedom. The significance (p-value) for the Kruskal-Wallis test is smaller than 0.05.

Table 6.4: Results of the non-parametric Kruskal-Wallis test, comparing the mean ranks of the number of species for the five SES classes in the TCM. H (4, N = 100) = 72.26, p = 0.0000.

	1 **R:33.688**	**2** **R:24.194**	**3** **R:22.618**	**4** **R:77.516**
1				
2	0.952342			
3	1.095467	0.160706		
4	**4.907719**	**6.202301**	**6.270107**	
5 **R:71.556**	**3.798916**	**4.897485**	**4.987720**	0.693325

6.3.2 Alpha diversity

Margalef's species richness index (Figure 6.3 A) presented values between four and six for all five SES classes. The species richness of SES class two differed significantly from that of classes four and five, with the p-value of 0.0007, well below the significance level of 0.05. Figure 6.3 (B) indicates the values of Shannon's index across the five SES classes. In this case, SES class two was significantly lower than all the other SES classes (p = 0.0006). The values of Shannon's diversity index (2–2.5) indicated moderate diversity for the domestic gardens in the TCM. Pielou's evenness index (Figure 6.3 C) is constrained between zero and one, where a value of one indicates equal abundance of all species. In this case, the values of evenness for all five SES classes were 0.7–0.8, pointing out that the number of individuals is distributed evenly per garden in all five SES classes. There was only a marginally significant difference between SES classes two and three (p = 0.05). The last index is Simpson's (Figure 6.3 D), which also significantly differed between SES classes two and five. Furthermore, the values of Simpson's index for all the SES classes were high (0.76–0.86), indicating high heterogeneity.

IDW patterns

IDW provide a highly visual map, in this case by projecting the total species numbers (alpha diversity) sampled at each site onto a street map of the study area (Figures 6.4–6.6). In the following maps, blue indicate areas with the lowest alpha diversity, while red areas have the highest alpha diversity and the other colours present intermediate diversity values. Important to notice is that the range of numbers assigned to each colour (number of species) are not constant for all the maps. Total number of plant species, the number of alien cultivated and indigenous cultivated species for every sample plot shows similar trends and are therefore presented together in Figure 6.4 A–C. The patterns for indigenous (Figure 6.5) and naturalised (Figure 6.6) species are presented as separate maps.

Two SES groups (classes 1–3 and 4–5; refer to Figure 6.2) are separated by the industrial zone in the TCM, typical of many South African cities (McDonald, 1998; Figure 3.1). As there are no residences in the industrial zone, no sample plots were placed in this area and the indicated patterns are a result of the estimation by the IDW method between the lower and higher species richness areas. The low to moderate species richness indicated for the industrial zone is thus not necessarily a true representation and more sampling (of ruderal vegetation, etc.) is needed to inform on the actual species richness within this area, but this is not within the scope of this study.

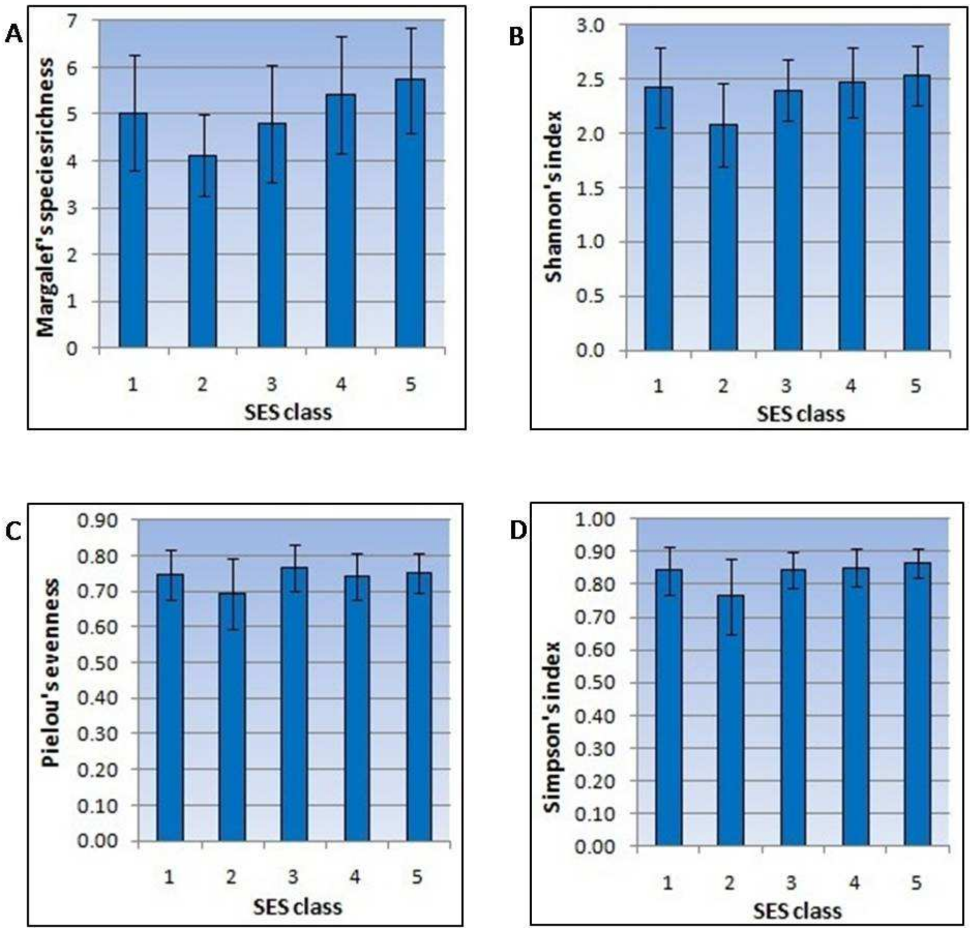


Figure 6.3: Diversity indices and standard deviation for the five SES classes in the TCM: (A) Margalef's species richness index, (B) Shannon's index, (C) Pielou's evenness index and (D) Simpson's index. Significance values and classes that were found to be significantly different, as determined with a one-way ANOVA for (A–C) and Kruskal-Wallis for (D), are shown in the table below.

Index	p-value	SES classes with significant differences
A: Margalef	0.0007	(2)(4,5)
B: Shannon	0.0006	(2)(1,3,4,5)
C: Pielou	0.0500	(2)(3)
D: Simpson	0.0168	(2)(5)

In Figure 6.4 (A), there is a marked distinction between the two parts of the TCM separated by the industrial zone. In the west, the alpha diversity is much lower (23–77 species per sample plot) than in the east (92–173 species per sample plot). This corresponds with the SES of the inhabitants, with lower SES concentrated in the west (SES classes 1–3) and higher SES in the east (SES classes 4–5). The patterns of cultivated species, both alien and indigenous (Figures 6.4 B and C, respectively), portray to a large extent that of the total number of species, because cultivated species made the greatest contribution to the species recorded in these domestic gardens (refer to Chapter 4, also Appendix B). An important difference between the indigenous cultivated and alien cultivated species patterns, however, is the number of plant species in these two groups. There were many more alien cultivated than indigenous cultivated species, as was also indicated in the floristic analysis (section 4.3.11). Alien cultivated species counts reached up to 67–83 in the higher SES classes, while the recorded indigenous cultivated species were one third of that (19–26) for the same classes. Only two gardeners in the study area indicated in the questionnaire (section 3.5 and Appendix A) that they aim to plant only indigenous species (including indigenous and indigenous cultivated species, as defined for this study). These two gardens are indicated with black squares in Figures 6.4. Both these gardens portrayed high indigenous cultivated species richness (Figure 6.4 C). When comparing it with the total species numbers, however, it is obvious that there were many non-indigenous species present that elevated the species count to slightly over 100 species in total.

A different pattern is visible for the distribution of naturally occurring indigenous species in the TCM (Figure 6.5). Sample plots on the outskirts of the TCM, thus closer to the surrounding, more natural areas, contained more naturally occurring indigenous species than sample plots towards the central belt of the TCM. The indigenous species were never encountered in large numbers, as the maximum number of indigenous species encountered in any garden was 22 and the largest proportion of gardens had less than 12 indigenous species. Only one of the marked gardens (see also Figure 6.4) portrayed the aim of the gardener to plant indigenous species, but the species count for this plant species group made only a small contribution to the total number of species recorded in this garden.

The distribution of naturalised species in the TCM (Figure 6.6) also portrays the increase in species richness from west to east, like the total and cultivated species patterns. Additionally, there was a higher occurrence of naturalised species in gardens towards the edge of the study area (28–50 species per garden), in closer proximity to natural vegetation, compared with the 8–27 naturalised species in the central belt. These numbers are considerably higher than those of the indigenous species.

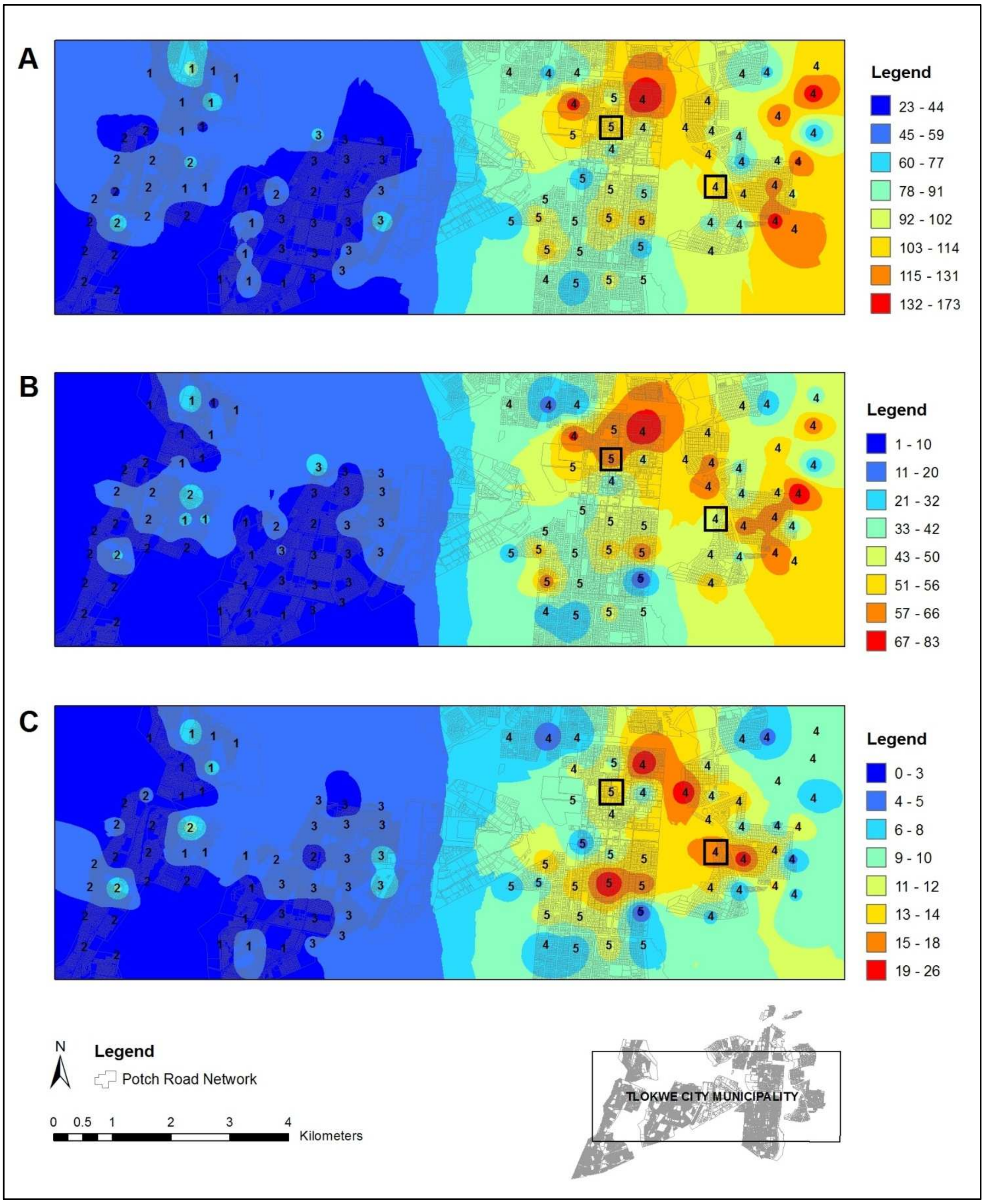


Figure 6.4: Distribution patterns of the total number of species (alpha diversity) for (A), number of alien cultivated species (B) and the number of indigenous cultivated species (C) in the domestic gardens of the TCM. The two study sites indicated by squares were specified by the residents to be planted only with indigenous plant species.

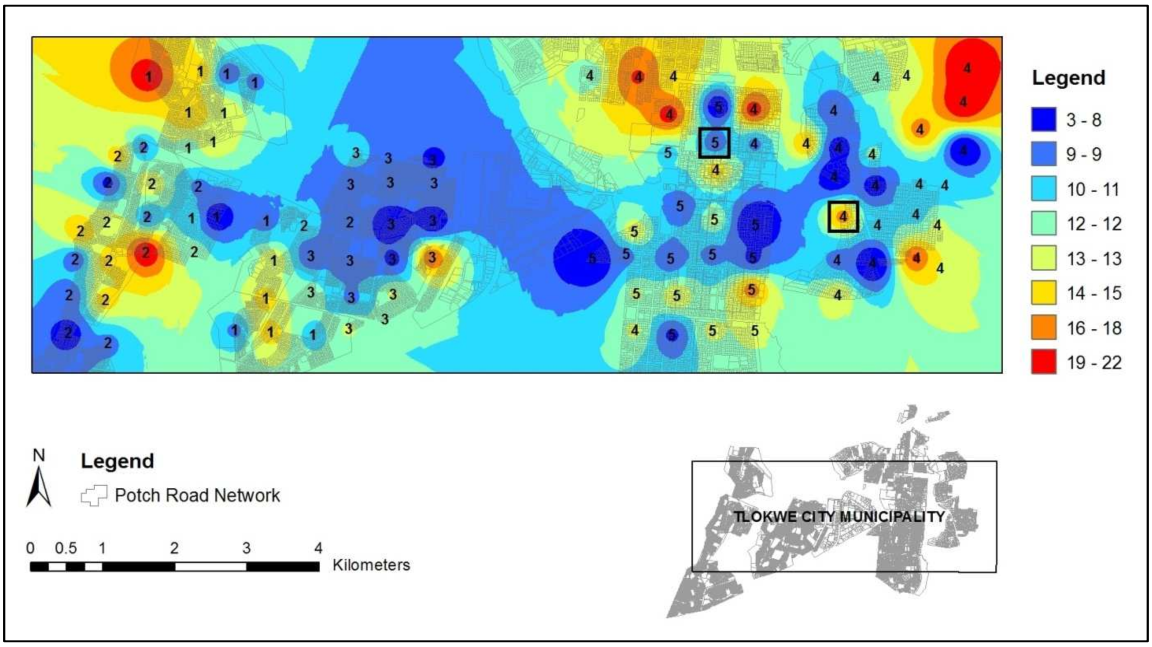


Figure 6.5: Distribution patterns of naturally occurring indigenous species in the domestic gardens of the TCM. The two study sites indicated by squares were specified by the residents to be planted only with indigenous plant species.

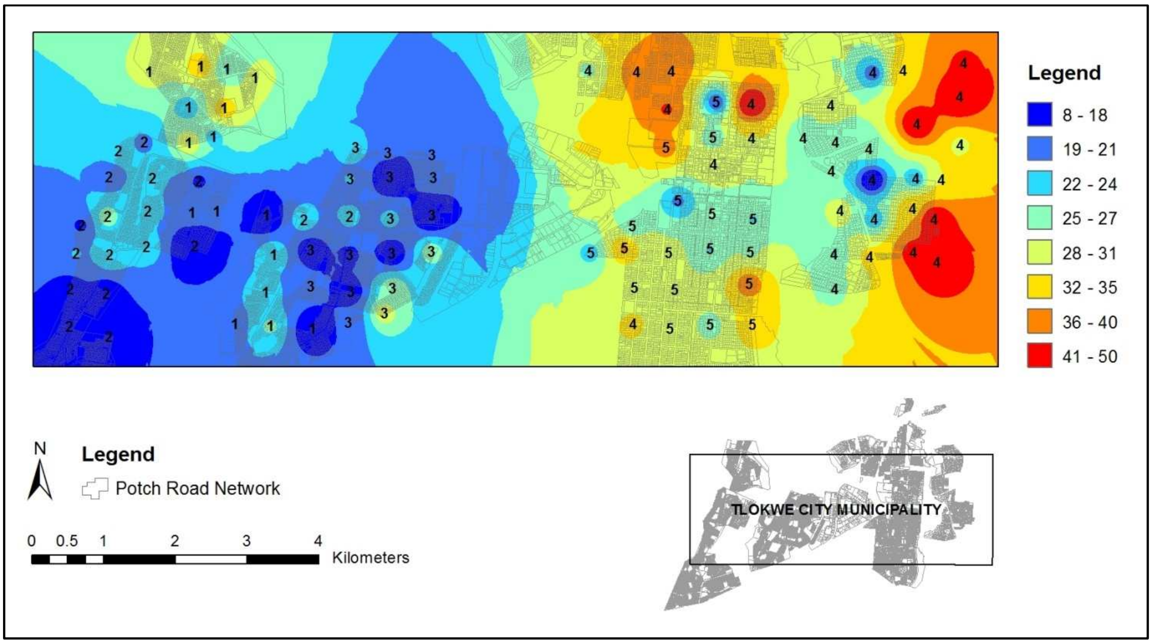


Figure 6.6: Distribution patterns of naturalised species in the domestic gardens of the TCM.

6.3.3 Beta diversity

The beta diversity values (β_W) as determined for each of the five SES classes is presented in Figure 6.7. The β_W -values for the lower SES classes were all relatively similar and ranged between 4.3 and 4.8. SES class 5 had the second highest beta diversity (β_W = 5.3), but it was not that much different from the first three classes. The class with the highest beta diversity was SES class 4 with a β_W of 7.8. For the total gardens in the TCM, however, the β_W was almost double that of the highest SES class.

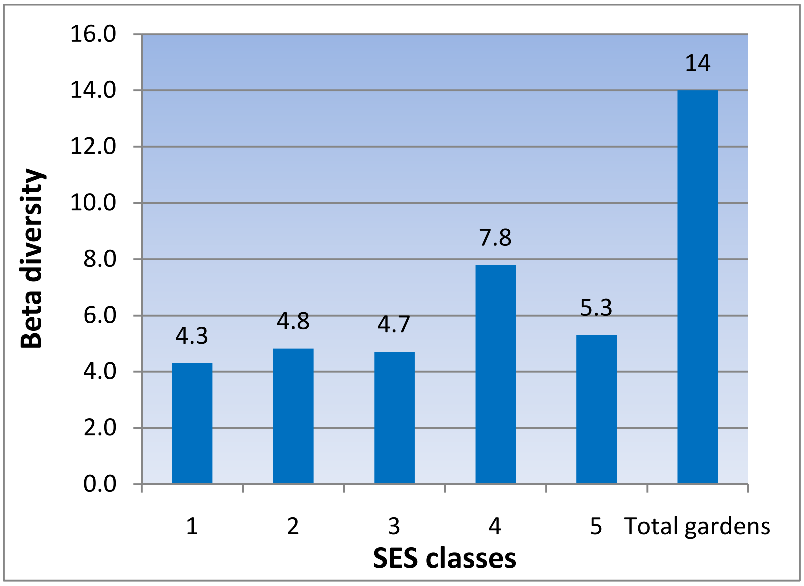


Figure 6.7: Beta diversity for each of the five SES classes as well as for all the gardens sampled in the TCM, as determined with Whittaker's measure.

Ordinations

DCA ordinations (Figures 6.8–6.11) are used to examine the underlying causes of beta diversity along a gradient, in this case a socio-economic gradient. In all the ordinations the sample plots of the lower SES classes (1–3) are delimited in blue and the two higher SES classes (4–5) in green to improve the distinction between the two. Red circles indicate clusters of sample plots.

The first ordination is that of the **total species group** (Figure 6.8). No definite cluster of sample plots can be identified, but there are more sample plots from the lower SES classes towards the left, while the right side is dominated by sample plots of higher SES classes (see also Figure 6.2). This indicates a higher dissimilarity between than within the two SES groups. Sample plots from the two SES groups do segregate to a certain extent along a gradient of SES, as was indicated by the differences in beta diversity values (Figure 6.5). The most frequent species in each SES class were also different, although the greatest difference was between the lowest three classes and the higher two. Dominating the species lists of SES classes one to three were common grass species (*Pennisetum clandestinum* and *Cynodon dactylon*), weeds (*Portulaca oleraceae*, *Bidens bipinnata* and *Euphorbia prostrata*) and the peach tree (*Prunus persica*), while ornamental plant species were dominating the species lists of SES classes four and five (*Dichondra micranta*, *Celtis sinensis*, *Agapanthus praecox* and *Rosa chinensis*), along with the same grass species as mentioned above and the weed *Oxalis corniculata*.

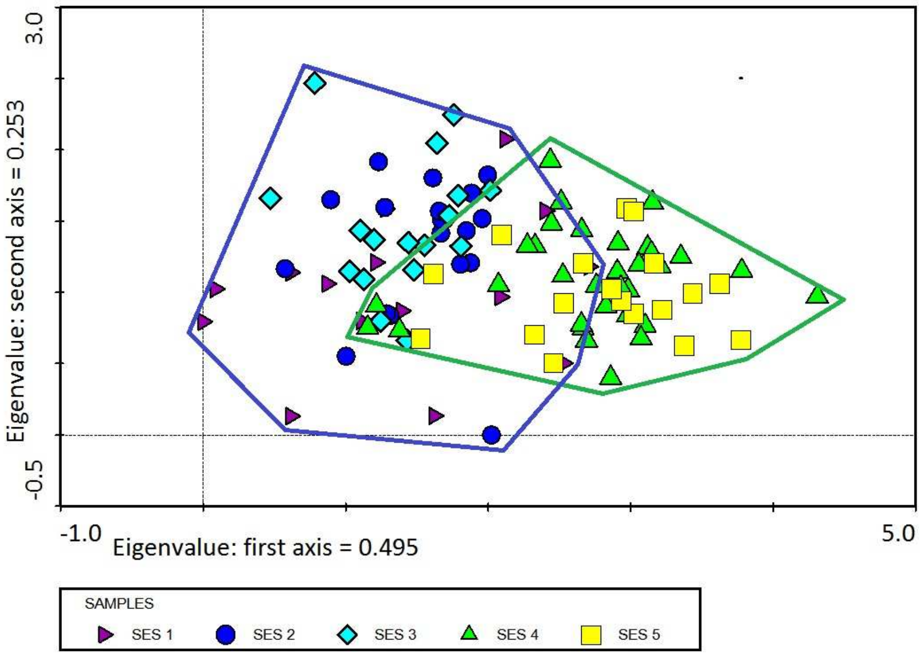


Figure 6.8: A DCA ordination of the total species composition based on sample plot data in the gardens of the TCM, grouped into five SES classes.

Figure 6.9 presents the ordinations for the (A) **alien cultivated** and (B) **indigenous cultivated species groups**. In both these ordinations, a discernable core can be identified that included sample plots from all five SES classes. The higher SES classes (4–5) had less outlier sample plots that were not included in the core than SES classes one to three. The ordination for indigenous cultivated species (B) contained 26 less samples than that of alien cultivated species, mostly from the lower SES classes. The lowest SES class had only seven sample plots that contained indigenous cultivated species, compared to 16 gardens of the same class in (A).

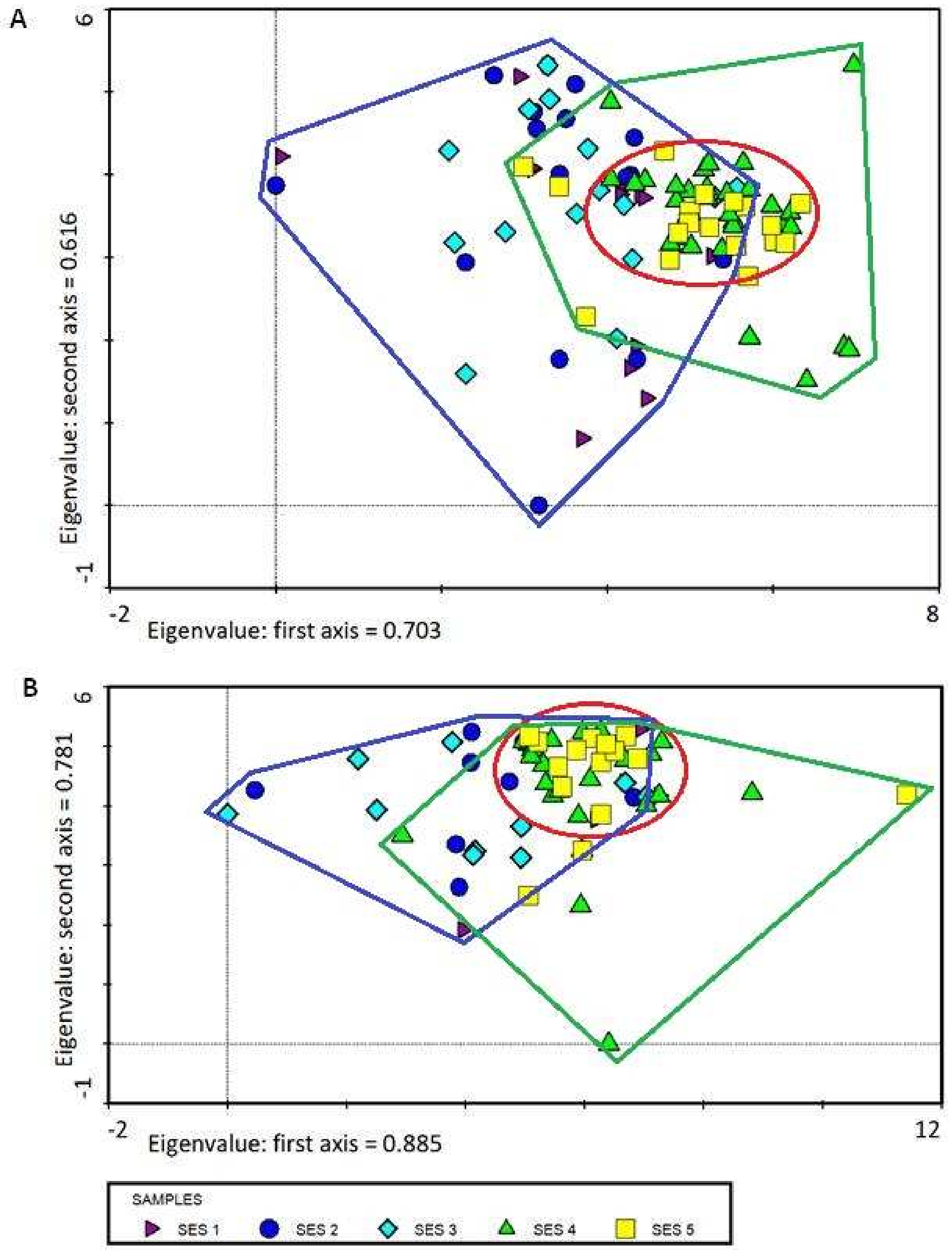


Figure 6.9: DCA ordinations of (A) the alien cultivated and (B) indigenous cultivated species composition based on sample plot data in the gardens of the TCM, grouped into five SES classes.

The **naturalised species group** ordination (Figure 6.10) differed from the previous ordinations in that two clusters of sample plots can be identified: a first made up mainly of lower SES sample plots on the left and a second on the right, containing mostly sample plots from SES classes four and five. Outlier sample plots do seem to segregate to a small extend into lower and higher SES groups, but no definite relationship can be obtained from this. Figure 6.11 is the ordination for **indigenous species composition**. No clusters were formed within the separate SES groups, although a small cluster containing sample plots from all five SES classes were present.

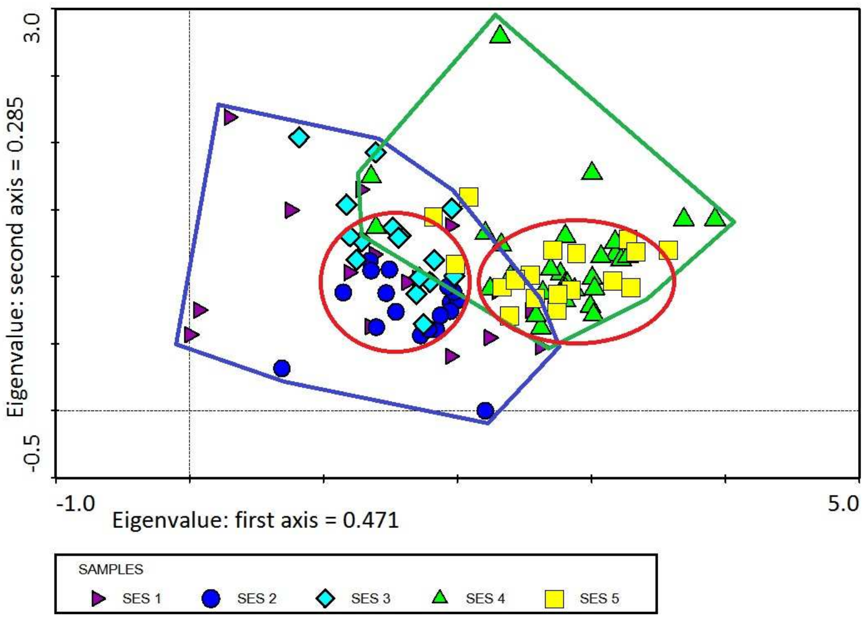


Figure 6.10: DCA ordination of the naturalised species composition based on sample plot data in the gardens of the TCM, grouped into five SES classes.

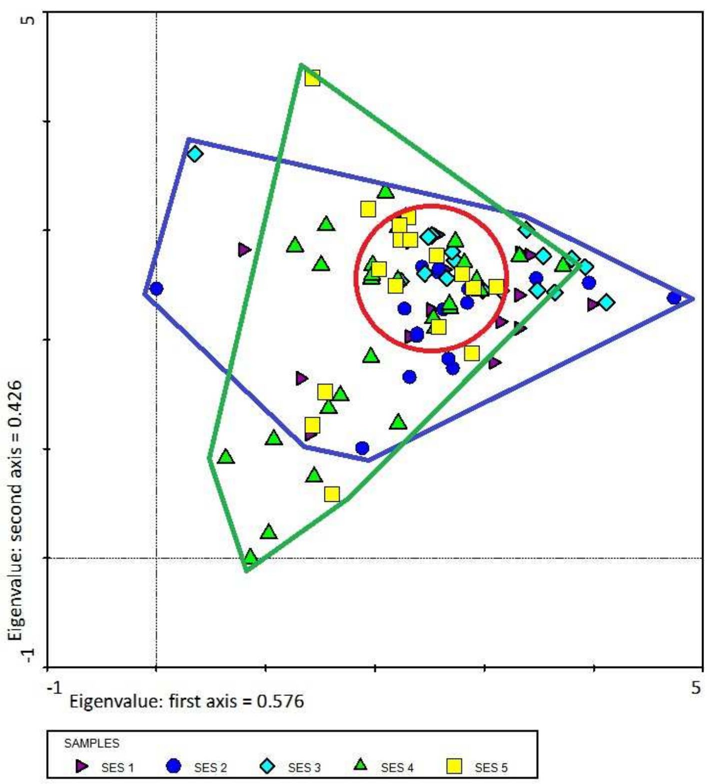


Figure 6.11: DCA ordination of the indigenous species composition based on sample plot data in the gardens of the TCM, grouped into five SES classes.

6.3.4 Drivers of diversity patterns

Before testing for correlations between possible drivers and plant species richness, the drivers were tested for interdependence amongst themselves (Table 6.5). Values of 0.5 and higher ($r \geq 0.5$) indicates a strong, positive correlation (highly significant), while moderate levels of positive correlation (significant) are indicated by values between 0.3 and 0.5 ($0.3 \leq r < 0.5$). Values that are between 0.1 and 0.3 ($0.1 \leq r < 0.3$) suggests a diminishing level of correlation.

Population density (2001 Census Survey data; Municipal Demarcation Board, 2006) and yard size were found to be correlated with SES (respective r = -0.36 and 0.67). It has been proved that an increase in the size of a sampled area leads to a subsequent increase in the number of species (Crawley & Harral, 2001), which is why this moderate relationship required a more in-depth examination. Controlling the SES by testing within each SES class, the effect of yard size on the species numbers was tested with correlations. The increasing yard sizes showed moderate, positive correlations with the number of species in the case of cultivated domestic gardens, as r-values ranged between 0.21 and 0.34 for the five SES classes. There was a moderate, positive correlation between SES and the MI (r = 0.31). Elevation was also strongly correlated with SES (r = -0.78) and yard size (r = -0.69) and moderately with the MI and population density.

Table 6.5: Correlation matrix for testing interdependence of the possible drivers of plant species richness in the TCM. Significant correlations are indicated with * and highly significant with ** ($p < 0.05$).

Variables	MI†	SES†	Yard size†	Population density
SES†	**0.31***			
Yard size†	0.29	**0.67****		
Population density†	-0.22	**-0.36***	**-0.61****	
Elevation	**-0.39***	**-0.78****	**-0.69****	**0.34***

†*Transformed variables*

The correlation coefficients of all the tested relationships between possible drivers and plant species richness are shown in Table 6.6. The strongest relationships were detected between SES† and the number of alien cultivated species (r = 0.71) and, as with some of the other results, also between SES† and the total number of species (r = 0.67) because of the relationship between these two species groups. The MI† portrayed a moderate relationship with r-values of 0.42 for the total number of species and 0.49 for the number of alien cultivated species. The reason why the correlation of each variable with both the total number of species and the number of alien cultivated species are more or less the same each time is that alien cultivated species contributed the greatest proportion of the species in the gardens of the TCM (refer to section 4.3.11). SES† was also moderately correlated with the number of naturalised species, but no significant correlation exists between this plant group and the MI†. Neither of the variables showed a significant correlation with the number of indigenous species.

Table 6.6: Pearson's correlation coefficients (r) of the management index† and socio-economic status† with different species groups in the domestic gardens of the TCM, significant relationships are indicated in bold.

Species group	Management Index†	Socio-economic status†
Total number of species	**0.416324**	**0.674711**
Number of alien cultivated species	**0.489331**	**0.714046**
Number of naturalised species	0.195895	**0.396105**
Number of indigenous species	-0.179834	-0.134591

6.4 Discussion

6.4.1 Gamma diversity

SES groups

The statistical separation of the five SES classes into two groups (Figure) indicated that the differences in SES (as determined with data from the Municipal Demarcation Board) were not as pronounced with regard to the number of species as was expected with the high cultural and economic heterogeneity of the South African population in mind. It seems that there were only two major SES groups that affected the number of plant species: the rich and the poor. The effect of SES was also noted in studies in the USA, where increased SES accompanied an increase in the richness of neighbourhood vegetation, although the abundance thereof was influenced by the year of neighbourhood development (Martin *et al.*, 2004).

The two SES groups also coincides with the main cultural groupings in the population of the TCM, therefore cultural differences between the two groups (Chapter 5; Lubbe *et al.*, 2010) could be offered as an additional explanation for the clear separation. However, this was not explicitly tested for. SES classes one, two and three were comprised mainly of the previously disadvantaged part of the population who has not yet had the means or opportunities for changing their circumstances (Lemon, 2003), in spite of the fact that the suppression has officially ended more than fifteen years ago. The two higher SES classes were in the area where white people from European origin reside (although not exclusively white). Furthermore, people with different cultural backgrounds would idealise very different ecological surroundings (Kinzig *et al.*, 2005) and the question could be asked whether someone's cultural heritage would allow them to change their surroundings, even if they had the resources to do so. For example, people from European origin prefer a shady, vegetated environment (Faggi & Ignatieva, 2009) compared to open and devegetated surroundings preferred by traditional Tswana people (Cilliers *et al.*, 2009) and varying levels of financial resources might not necessarily alter such behaviour imprinted by culture.

6.4.2 Alpha diversity

Diversity indices

As a whole, the diversity indices did not indicate much difference between the five SES classes. The only class that has proven to be different was SES class two. The study sites in this second SES class were informal settlements on the edge of the formal development which is also the most recently developed part of the study area. Margalef's species richness index showed that the two higher SES classes had higher species richness than the lower SES classes and specifically SES class two. This corresponds partially with the pattern of gamma diversity (section 6.3.3), but the differences are less pronounced with Margalef's species richness index.

The values of Shannon's index for the gardens of the TCM (2–2.5) were of similar magnitude than that of the garden vegetation of Trabzon City, Turkey (Acar *et al.*, 2007). Values of 2–3.5 were reported for the latter, with an increasing function as housing types changed. The differences in diversity between the formal (SES classes 1, 3, 4 and 5) and informal settlements (SES class 2) in the TCM can be ascribed to the fact that gardens are well-developed in those areas with formal housing, while construction and maintenance of shelter is probably of higher priority in informal settlements. Pielou's evenness index has shown very little difference between the SES classes in terms of the relative abundance among species and, with only a marginally significant p-value, could be regarded as not significant.

The Simpson's index indicated a significant difference between SES classes two and five, with class two being lower than class five. These two classes represent respectively the newest and oldest residential areas in the TCM. The lower diversity of the newly developed area might be due to the clearing of the natural vegetation of a site before construction (Sharpe *et al.*, 1986) with only a few weedy species present and possibly some ornamental species used in the onset of a garden, while older neighbourhoods have well-established gardens with mature flora (Mennis, 2006).

The application of diversity indices to describe the alpha diversity of gardens is not a common approach as only one garden study was found to use it (Acar *et al.*, 2007), and probably with good reason. The diversity indices did not reflect the patterns of alpha diversity observed along the gradient as was expected. A possible explanation for this could be the low frequency values of most species found in gardens (28 % of all the species were encountered in only one garden, refer to section 4.3.3) – a factor that is explicitly considered by diversity indices. To compare the alpha diversity of domestic gardens, it might be more efficient to simply report the mean number of species recorded per garden for each SES class (Figure 5.4).

Comparing the mean number of species in the gardens of the TCM in all five SES classes with that of other studies reveals an interesting pattern. In the past, developing countries have shown a lower rate of urbanisation and developed countries are thus currently more urbanised (United Nations Department of Economic and Social Affairs, 2008). Nemudzudzanyi *et al.* (2010) and Molebatsi *et al.* (2010) have shown that there were an increase in species numbers from deep-rural to peri-urban gardens and a decrease in the percentage of indigenous species. Deep-rural gardens refer to those areas where tribal authority manages the community and the majority of inhabitants are subsistence farmers, while peri-urban gardens are 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 (Molebatsi *et al.*, 2010). Two accounts of species richness of gardens in developed countries can be found in Sheffield, UK (Smith *et al.*, 2006a; 41–264 species, mean species richness of 112, including annuals) and in Phoenix, Arizona (Kinzig *et al.*, 2005; 20–70 perennial plant species). In the TCM, an average of 70 species per garden (ranging between 23–173 species) was recorded, while Das & Das (2005) found as little as 8–39 species in gardens of a village in Dorgakona valley, North East India. Most of the species in Indian gardens were indigenous and planted for utilitarian purposes. Although it does appear that plant species richness in gardens is higher in developed than in developing countries, this trend requires further examination on a global scale.

IDW patterns

The most striking aspect of the patterns of the total number of species and cultivated species (Figure 6.2) was the steep gradient from west to east that accorded with the SES of the inhabitants in the TCM. This represent a visual image of the effect of SES on vegetation patterns in urban areas, as was indicated in other studies (Hope *et al.*, 2003; Kinzig *et al.*, 2005; Mennis, 2006; Lubbe *et al.*, 2010) and also in section 6.3.4. More alien than indigenous species were recorded, as expected. This can be ascribed to the trend of the horticultural trade to import, cultivate and promote hardy and remarkable alien species for cultivation in gardens (Reichard & White, 2001). Two thirds of all the species recorded in the gardens of Sheffield, UK, were also of alien origin (Thompson *et al.,* 2003).

The natural surroundings do not appear to have an influence on cultivated species, but the patterns observed in the case of indigenous and naturalised species suggest that gardens interact with the surrounding vegetation. For example, the surrounding, more natural vegetation (Highveld National Park in the west – Daemane *et al.*, 2010, and wetlands and riparian areas within the developed areas –

Cilliers *et al.*, 1998) acts as a source of these indigenous species, which are usually not cultivated and yet found in gardens. It is interesting to note that gardeners in recently established gardens of new developments also tolerate the presence of remnants of natural vegetation, thus the higher indigenous species richness in gardens. A possible reason for this tolerance is the utilitarian value of these indigenous species as shade, medicine, food (e.g. African leafy vegetables) and fuelwood (Das & Das, 2005; Molebatsi *et al.*, 2010). The fact that the naturalised species occur in higher numbers in gardens on the outskirts of the TCM could be ascribed to recent disturbances associated with new housing development in SES class two and also to the larger yard size in SES class four, which makes management more difficult and could result in a greater presence of spontaneous vegetation. Sullivan *et al.* (2005) found an association between the alien species observed in coastal forest patches and those grown in gardens of nearby settlements, indicating that horticultural species escape from gardens into the surrounding vegetation. In the case of the gardens in SES class four, it is also possible that the remnants of natural vegetation in the larger yards form a refuge for such garden escapees.

6.4.3 Beta diversity

When considering the beta diversity of the **total species group** (Figure 6.5), SES class 4 having the highest beta diversity can be contributed to the presence of smallholdings, which were generally larger in size than the average yard in other SES classes. Furthermore, it also contained more remnant natural vegetation patches and were less isolated from the surrounding semi-natural vegetation than gardens surrounded by other gardens. The lower beta diversity of the three lower SES classes indicated that these gardens shared a more similar species composition within each class and thus a lower species turnover. The gardens of SES classes four and five were less similar in total species composition, as shown by the higher β_W-values. On the scale of the entire study area, the gardens presented a much higher degree of dissimilarity and species turnover, as was also found in other garden studies. Smith *et al.* (2006 a) found that 42 % (490 species) of the entire garden flora in Sheffield (UK) were recorded only once. Another study by Acar *et al.* (2007) reported the majority of woody species in the gardens of Trabzon City (Turkey) to have a frequency of less than 15 %, which is indicative of a high species turnover. The low occurrence of so many species in gardens, especially alien cultivated species, reduces the possibility of these species naturalising and thriving outside of cultivation.

The separation of species into species groups are nothing new, but most studies only distinguish between indigenous (often called native) and alien (exotic) species (Martin *et al.*, 2004; Smith *et al.*, 2006; Marco *et al.*, 2008). The addition of cultivated and naturalised species divisions is unique to this study.

Similarity in species composition of all five SES classes occurred in both the **cultivated species groups** (Figure 6.9 A and B), as indicated by the aggregation of sample plots in a discernable core. The fact that the higher SES classes had less sample plots as outliers from the core groupings than the lower SES classes indicated that the first were more similar with regard to both alien and indigenous cultivated species composition than the latter. Wealthier people from European origin were more likely to plant species that serves only an ornamental function (Faggi & Ignatieva, 2009) which would typically be the species sold in local nurseries to which they have common access. Another possible explanation can be mimicry activities that take place on a neighbourhood scale because people want to belong and fit in and therefore aim to plant species similar to their neighbours (Zmyslony & Gagnon, 1998; Marco *et al.*, 2008; Nassauer *et al.*, 2009) and thus causing the higher similarity in species composition of neighbourhoods. On the other hand, the poorer and predominantly black portion of the community planted more utilitarian species (see also section 5.3.4) and some even maintained vast areas of bare ground around the dwelling (Cilliers *et al.*, 2009) that cause the differences to be more pronounced with regard to cultivated species.

Two distinct clusters were identified on the **naturalised species group** ordination (Figure 6.8 A), indicating that the two SES groups differ from each other on account of the naturalised species composition. Only four common species were found between the ten most frequent naturalised species in both the SES groups (*Pennisetum clandestinum*, *Euphorbia prostrata*, *Conyza bonariensis* and *Guilleminea densa*). Some other naturalised species that were frequently found in the higher SES classes are dependent on a higher water supply (e.g. *Dichondra micrantha* and *Oxalis corniculata*), while *Portulaca oleraceae* and *Alternanthera pungens* were some of the other species found most frequently in gardens of the lower SES classes.

The ordination for the **indigenous species group** (Figure 6.8 B) did portray a slight clustering of sample plots, but there were no distinction between the five SES classes. This indicated that the species composition of some sample plots were more similar to each other, although this was not a result of SES similarities. Other explanatory variables must be explored to identify the drivers behind indigenous species composition in domestic gardens, for example the different habitat types. SES classes one to three are located in the drier, rocky hills and ridges with shallow soil and less occurrence of frost, while the deeper, more fertile soil closer to the river is where SES classes four and five lies.

An indirect gradient analysis does not include the explanatory variables in the calculations, but such information can be used in retrospect to explain the patterns detected with this indirect method (Kent & Coker, 1994). Hope *et al.* (2003) tested for environmental and geographic factors such as the history of agriculture and soil nitrogen concentration in addition to the socio-economic variables and found that the latter play a more significant role in shaping plant distribution in urban areas than do the other geomorphic factors. This means that all variation in change across the TCM cannot necessarily be ascribed to SES without also testing for the other factors, although its influence is still undeniable. Apart from biogeophysical factors, other social aspects can also influence the species composition of domestic garden vegetation. For example, the fashion trends for gardening, advice from gardening societies and clubs (Smith *et al.*, 2006a), property ownership (Gross & Lane, 2007), proximity to nurseries and landscape design practices could all possibly affect the species composition of garden vegetation.

6.4.4 Drivers of diversity patterns

Smith *et al.* (2006a) found that the size of the garden had a greater influence on indigenous than alien plant species, which could be an explanation for the diminished influence of yard size on the alien-dominated garden flora of the TCM. To determine the effects of only SES, the current gradient must be extended to include the deep-rural study sites of poor communities with their larger gardens (Molebatsi *et al.*, 2010), as well as highly urbanised and affluent neighbourhoods that have vast, private residential lots (a doctoral study launched this year). Studying such a gradient will allow the effect of yard size to be down-weighted and the socio-economic and cultural influences to be tested implicitly.

The relationship between SES† and elevation was contradictory to what was expected. In other towns and cities, the rich tend to live at higher altitudes because they can afford to buy stands with a view (Hope *et al*., 2003). Elevation in the TCM showed a negative relationship with SES as a result of the history of the town where the wealthier, white people settled closer to the river in areas with fertile soil (lower elevation) and the black poor were forced to live in the hills and ridges further away from the fresh water (Jansen van Rensburg, 2002).

SES and the MI were regarded as independent variables in spite of the moderate, positive correlation between them. Independence was assumed as the management intensity in any garden is dependent on the interest of the gardener and not necessarily his / her socio-economic status. According to Clayton (2007), gardeners can garden for economic reasons by making the property look attractive and thus keep up or increase its value, but people can also do it to provide a sense of individuality, worth and efficiency. A wealthier person may be able to spend more money on gardening equipment, buying plants and chemicals, but someone with a lower SES could devote the same amount of time and effort towards gardening and utilise other resources, for example obtain plants from friends or to create beautiful and diverse gardens. A quarter of the respondents from the three lower SES classes in this study indicated through the questionnaire (section 3.5) that they receive their plants from other gardeners within the community. Similarly, Troy *et al.* (2007) found that income levels are related to the possible planting area, but the realised planting area were best explained by a suite of lifestyle behaviour variables that included household consumption and expenditure patterns. Smith *et al.* (2006) also commented on the observation that smaller gardens can have a rich variety of plants, while some larger gardens can contain relatively few species simply because of a less enthusiastic gardening attitude.

Even though biogeophysical drivers were not tested for in this study, the magnitude of the correlation between SES and the number of alien cultivated species, as well as confirmation from literature (Hope *et al.*, 2003; Martin *et al.,* 2004; Kinzig *et al.*, 2005), corroborates the fact that SES does have an influence on the patterns of species richness and diversity in urban areas – especially on those species that are cultivated and kept in gardens as a result of human choice. Kinzig *et al.* (2005) found this response to be clearer in privately owned land than public gardens, because of top-down management decisions by local municipalities that shape the gardens rather than the neighbourhood SES. An increase in the number of naturalised species as SES increase could be the result of higher numbers of individuals in the higher SES classes with larger yards, which leads to increased propagule pressure from potentially invasive species. The influence of SES on biodiversity in urban areas as a whole and specifically in domestic gardens holds dire implications for countries, such as South Africa, with environmental inequity issues. As plant diversity influence that of other taxa (Kendle & Forbes, 1997; Martin *et al.*, 2004), the effects of differences in plant diversity will affect the overall biodiversity of any green space. The urban poor already lack public green space (Pedlowski *et al.*, 2002; McConnachie *et al.*, 2008, Du Toit, 2009) and the fact that their financial means are insufficient to create private green space will ultimately affect their quality of life (Cilliers & Siebert, 2010). Using this information in urban planning strategies and greening efforts can ensure that inequity in terms of provision and management of urban green space are corrected.

The influence of management practices, as encapsulated in the MI, is true for gardening and agricultural ecosystems. The seemingly inexhaustible sources of nutrient and water supply, the lack of natural enemies and competition for resources are all part of the environment created in domestic gardens (Niinemets & Peñuelas, 2008). Although the MI did not portray the same strong relationship with these two species groups, it was only marginally smaller than the 0.5 which indicates a strong correlation. This implies that more intense management of a garden, irrespective of the amount of financial resources, can cause higher species richness. Resources other than those acquired with money can be utilised, for example substituting labour for goods or benefitting from municipal or non-profit greening initiatives (Troy *et al.*, 2007). Smith *et al.* (2006) also tested for an index of management intensity, but it did not significantly affect the species numbers. They suggested that the effect of the management intensity may been apparent if a distinction could be made between cultivated and spontaneous flora in gardens, as the management actions are most likely to influence spontaneous flora. Information gathered with the questionnaires in this study proved to be somewhat unreliable, in spite of the presence of a translator where necessary. Respondents were not always entirely truthful, so the management data did not reflect the actual management of each garden.

6.5 Summary

The results of this study were presented on two distinct scales, namely city scale (gamma diversity) and neighbourhood scale (alpha and beta diversity). Additionally, the comparison with results from other studies gave the study a global perspective. These different views of garden vegetation revealed some processes that are localised to the study area, for example the negative relationship between SES and elevation. Other patterns, such as the changes in plant species diversity along the SES gradient are also true for other settlements around the world. The application of the hierarchical patch dynamics paradigm served to simplify the patterns of garden vegetation in the TCM and to elucidate patterns that might have been missed at other scales.

To facilitate a better understanding of human-environment interactions in the study area, a purely descriptive approach is not sufficient and the consideration of socio-economic aspects as possible drivers attempted to explain the patterns of plant species richness and diversity. The objectives explored for this chapter was to describe the patterns of plant diversity along the steep SES gradient in the TCM, divided into alpha, beta and gamma diversity, and also to determine if the SES and management actions of inhabitants caused the changes in species numbers. Consistent with other studies, plant diversity increased along the SES gradient in the TCM. This finding provides useful information for policy makers and urban planners to engage in pro-active development of an improved quality of life-environment for all urbanites through the provision and management of urban green space, especially in areas of low SES that also contain very little public green space. Another important contribution is made to the understanding of domestic garden ecosystems in general, but more specifically those in developing countries. South Africa has an extremely heterogeneous population with regards to culture and wealth distribution, and these differences are clearly portrayed in the domestic gardens of the TCM.

Chapter 7

Conclusion

7.1 Introduction

The study of domestic gardens is gaining increased interest from ecologists around the world, in both developed (Martin *et al.*, 2004; Smith *et al.*, 2006a; Kirkpatrick *et al.*, 2007; Loram *et al.*, 2007) and developing countries (Rapoport, 1993; Blanckaert *et al.*, 2004; Das & Das, 2005; Lubbe *et al.*, 2010). This study of the Tlokwe City Municipality (TCM) is unique in that it is the first in South Africa to examine the flora found within the domestic gardens of an entire city, after that of rural (Davoren, 2009) and deep-rural settlements (Molebatsi *et al.*, 2010) were described. Within the TCM is a steep gradient of social and cultural differences, which made it the ideal environment to test for the influence of cultural and socio-economic factors on the patterns of distribution of plant species in the gardens. In its entirety, this study served the important aim of increasing the knowledge on a part of the urban flora which is often deliberately excluded. This chapter will provide a broad synthesis of the main findings, which will be presented order as indicated below (the hypotheses relevant to each chapter were added for clarity):

- **A floristic analysis** (Chapter 4);
  - Hypothesis 1: Plant species richness in domestic gardens will be greater than that of other land-use types and thus will contribute greatly to urban green space diversity.
- **The influence of the political legacy of apartheid on plant diversity** (Chapter 5);
  - Hypothesis 2: The political legacy of apartheid in South Africa will influence the plant diversity in domestic gardens through socio-economic means.
  - Hypothesis 3: Inhabitants with lower socio-economic status will cultivate and harbour more species with utilitarian value.
- **The description of the patterns of plant diversity and socio-economic processes associated with these patterns** (Chapter 6).
  - Hypothesis 4: A higher plant diversity and species richness is expected where residents from higher socio-economic status groups reside.
  - Hypothesis 5: Management actions will affect plant species richness and diversity in all socio-economic status classes, regardless of financial means and culture.

7.2 A floristic analysis

With a total of 835 plant species of 501 genera in 145 families recorded from 100 domestic gardens, the immense contribution of garden flora towards the urban green infrastructure and species pool in a single city was portrayed in this chapter. In comparison with other land-use types in the study area, domestic gardens had substantially higher total (gamma) diversity, which supports Hypothesis 1 set for this study. Among the large number of recorded species were 61 species endemic to South Africa as well as 18 species listed on the South African National Red Data List. The presence of these species is a clear indication of the *ex situ* conservation potential of domestic gardens. On the other hand, the majority of species that were found in these gardens was of alien origin and this included 88 invasive species, alerting once again the possible threat that garden vegetation holds for our natural ecosystems. Nearly two-thirds of all the species in the TCM were planted for their ornamental value, while edible plants formed only a small group in comparison to more rural settlements (Molebatsi *et al.*, 2010). Objectives of this chapter were successfully met through the floristic description and analysis of the garden vegetation. The importance of the information provided in this chapter lies in the improved understanding of gardens which is no longer a neglected land-use type. The presence of both threatened and invasive species in the garden vegetation of the TCM merits an in-depth look, on a larger scale, into the conservation possibilities as well as potential threat of this land-use type to the integrity of our indigenous ecosystems.

7.3 Political legacy affects plant species diversity patterns

The main objective of this chapter was to explore the possibility that the pronounced socio-economic status and cultural differences in the study area, as a result of segregation policies of the past, will affect the plant species diversity of domestic gardens. In accordance with other studies on neighbourhood vegetation (Martin *et al.,* 2004; Kinzig *et al.*, 2005), the legacy effect of segregation actions through socio-economic means was visible between the plant species diversity of different socio-economic status (SES) classes, confirming Hypothesis 2 and fulfilling the objective of this chapter. Furthermore, the two main SES groups in the TCM were also different with regard to the degree of cultivation and utilisation of plant species for their usefulness. SES classes 1–3 use more utilitarian plants than SES classes 4–5, confirming Hypothesis 3. This situation is unique to South Africa with its heterogeneous demographic profile, although more so on a larger-than-city scale. As nearly 14 % of the world's food is already produced in urban areas (Olivier, 1999), the role of urban agriculture is extended, it could be the answer to improve the quality of life of millions of people.

7.4 Patterns of plant species diversity and drivers

After the preliminary analysis done in Chapter 5, the differences between the plant diversity in domestic gardens of the TCM were further explored in this chapter. First, the patterns of plant diversity across the TCM were described in terms of gamma, alpha and beta diversity. Statistically, and in terms of gamma diversity, the only significant difference between the five SES classes was between the rich (SES classes four and five) and the poor (SES classes one to three). These differences were substantial: the higher SES classes had higher gamma diversity than the lower SES classes, supporting Hypothesis 4. Alpha diversity also verified this finding. The beta diversity among the SES classes indicated that those of lower SES had a lower species turnover and were thus more homogeneous than the gardens of higher SES that had higher beta diversity. These findings support the "luxury concept" described by Hope *et al.* (2003).

The second theme of this chapter was to test different variables against the species richness to establish what drives the domestic garden plant diversity in the TCM. The strongest correlation was found to be between the SES and the number of alien cultivated species, which also serves to confirm Hypothesis 4. The management index (MI) also showed a moderate relationship with the alien cultivated species group, although Smith *et al.* (2006a) suggested that the intensity of management is more likely to influence the spontaneous species in gardens than cultivated species, but that this distinction would be difficult and time-consuming. Therefore, it could not be tested as of yet and, although the effect of management input was visible, it could not be determined whether this was regardless of financial means (Hypothesis 5).

The information that was given in this chapter did not only serve to widen the knowledge-base of urban ecological theory, but it also realised the integration of different disciplines (Grimm *et al*., 2008). The knowledge can now be used to inform the planning and design of urban areas in South Africa and other developing countries that face similar social challenges and heterogeneity amongst their population.

7.5 Recommendations and the way forward

The absence of biogeophysical data (e.g. soil nutrient content and development history) in this study can be seen as a major drawback, as the effect of these variables on the tested variation could not be discerned or excluded. Future studies would greatly benefit from the inclusion of such variables. Also lacking in this study is recent data for the vegetation of other land-use types in the study area, sampled with the same methods than the domestic gardens in order to make the data fully comparable. Expansion of the gradient to include more variation in the SES, such as inclusion of the rural poor and affluent metropolitan citizens, would further clarify the existence of the "luxury concept" (Hope *et al.*, 2003).

As already mentioned, private gardens possess the latent quality to contribute to biodiversity and conservation of indigenous flora. The participation of the general public, as the people investing large quantities of money and time into their gardens (McKinney, 2002), is crucial to develop this potential. This requires a great deal of public education, starting with (but not limited to) children (Miller, 2005) and press exposure on positive, conservation-sensitive gardening practices and initiatives. Integrated, transdisciplinary research would also be valuable (Cilliers *et al*., 2004) to direct the development of public participatory programs and evaluate any contributions made through these efforts.

The global body of information on domestic gardens is growing exponentially and scientists now realise the importance of engaging the different fields of research as well as the non-academic sectors of society (Wu & Hobbs, 2002; Fry *et al.*, 2007). This study provided a view from the perspective of a developing country, where the need for decisive action to improve the living conditions of urbanites is crucial.

References

ACAR, C., ACAR, H. & EROĞLU, E. 2007. Evaluation of ornamental plant resources to urban biodiversity and cultural changing: a case study of residential landscapes in Trabzon City (Turkey). *Building and Environment*, 42:218–229.

ACAR, C. & SAKICI, Ç. 2008. Assessing landscape perception of urban rocky habitats. *Building and Environment*, 43:1153–1170.

ADAMS, C.C. 1935. The relation of general ecology to human ecology. *Ecology*, 16:316–335.

ALBERTI, M. 2005. The effects of urban patterns on ecosystem function. *International Regional Science Review*, 28:168–192.

ALBERTI, M., MARZLUFF, J.M., SHULENBERGER, E., BRADLEY, G., RYAN, C. & ZUMBRUNNEN, C. 2003. Integrating humans into ecology: opportunities and challenges for studying urban ecosystems. *BioScience*, 53:1169–1179.

ALTAY, V., ÖZYIĞIT, İ.İ. & YARCI, C. 2010. Urban flora and ecological characteristics of the Kartal District (Istanbul): A contribution to urban ecology in Turkey. *Scientific Research and Essays*, 5:183–200.

ALTIERI, M.A., COMPANIONI, N., CANIZARES, K., MURPHY, C., ROSSET, P., BOURQUE, M. & NICHOLLS, C.I. 1999. The greening of the "barrios": urban agriculture for food security in Cuba. *Agriculture and Human Values*, 16:131–140.

ALUKA. 2010. African plants. http://www.aluka.org/page/content/plants.jsp. Date of access: 3 Feb. 2010.

BADENHORST, W.J. 1939. Die geskiedenis van Potchefstroom. Potchefstroom : Gedenkboek-komitee. 317 p.

BAKER, H.G. 1965. Characteristics and modes of origin of weeds. (*In* Baker, H.G. & Stebbins, G.L., *eds.* The genetics of colonizing species. New York, NY: Academic Press. p. 147–168.)

BAKER, H.G. 1974. The evolution of weeds. *Review of Ecology and Systematics*, 5:1–24.

BENJAMIN, M.T. & WINER, A.M. 1997. Estimating the ozone-forming potential of urban trees and shrubs. *Atmospheric Environment*, 32(1):53–68.

BIXLER, R.D. & FLOYD, M.F. 1997. Nature is scary, disgusting and uncomfortable. *Environment and Behaviour*, 29:443–467.

BLANCKAERT, I., SWENNEN, R.L., FLORES, M.P., LÓPEZ, R.R. & SAADE, R.L. 2004. Floristic composition, plant uses and management practices in homegardens of San Rafael Coxcatlán, Valley of Tehuacán-Cuicatlán, Mexico. *Journal of Arid Environments*, 57:39–62.

BOLUND, P. & HUNHAMMAR, S. 1999. Ecosystem services in urban areas. *Ecological Economics*, 29:293–310.

BROMILOW, C. 1995. Problem plants of South Africa. Pretoria: Briza. 315 p.

BYRNE, L. 2008. Ecological landscaping: from scientific principles to public practices and policies. *Cities and the Environment*, 1(2):article 2, 3 p. http://escholarship.bc.edu/cate/vol1/iss2/2. Date of access: Sep. 2010.

BYRNE, L. & GREWAL, P. 2008. Introduction to ecological landscaping: a holistic description and framework to guide the study and management of urban landscape parcels. *Cities and the Environment*, 1(2): article 3, 20 p. http://escholarship.bc.edu/cate/vol1/iss2/3. Date of access: Sep. 2010.

CADENASSO, M.L. & PICKETT, S.T.A. 2008. Urban principles for ecological landscape design and maintenance: scientific fundamentals. *Cities and the Environment*, 1(2): article 4, 16 p. http://escholarship.bc.edu/cate/vol1/iss2/4. Date of access: Mar. 2010.

CHIESURA, A. 2004. The role of urban parks for the sustainable city. *Landscape and Urban Planning*, 68:129–138.

CHIVIAN, E. & BERNSTEIN, A. 2008. Sustaining life: how human health depends on biodiversity. New York: Oxford University Press. 568 p.

CHRISTOPHER, A.J. 1997. Racial land zoning in urban South Africa. *Land Use Policy*, 14(4):311–323.

CHRISTOPHER, A.J. 2001. Urban segregation in post-apartheid South Africa. *Urban Studies*, 38:449–466.

CILLIERS, S.S. 1998. Phytosociological studies of urban open spaces in Potchefstroom, North West Province, South Africa. Ph.D. Thesis, PU for CHE, Potchefstroom.

CILLIERS, S.S. 2010. Social aspects of urban biodiversity – an overview. (*In* Müller, N., Werner, P., Kelcey, J., *eds*. Urban biodiversity & design. United Kingdom: Blackwell Publishing, p. 81–100).

CILLIERS, S.S., BOUWMAN, H. & DREWES, E. 2009. Comparative urban ecological research in developing countries. (*In* McDonnell, M.J., Hahs, A.K. & Breuste, J.H., *eds*. Ecology of cities and towns: a comparative approach. Cambridge: Cambridge University Press. p. 90–111.)

CILLIERS, S.S. & BREDENKAMP, G.J. 1999a. Analysis of the spontaneous vegetation of intensively managed urban open spaces in the Potchefstroom municipal area, North West Province, South Africa. *South African Journal of Botany*, 65:59–68.

CILLIERS, S.S. & BREDENKAMP, G.J. 1999b. Ruderal and degraded natural vegetation on vacant lots in the Potchefstroom municipal area, North West Province, South Africa. *South African Journal of Botany,* 65:163–173.

CILLIERS, S.S. & BREDENKAMP, G.J. 2000. Vegetation of road verges on an urbanization gradient in Potchefstroom, South Africa. *Landscape and Urban Planning*, 46:217–239.

CILLIERS, S.S., MATJILA, E.M. & SANDHAM, L. 2007. Urban agriculture utilizing the eco-circle approach in disadvantaged communities in Potchefstroom, South Africa. (*In* Stewart, G., Ignatieva, M., Bowring, J., Egoz, S. & Melnichuk, I., *eds.* Globalisation and landscape architecture: issues for education and practice. Proceedings of international conference held at St Petersburg State Forest Technical Academy, 3-6 June 2007, Polytechnic University Publishing House, St Petersburg, p. 88–91.)

CILLIERS, S.S., MŰLLER, N. & DREWES, E. 2004. Overview on urban nature conservation: situation in the western-grassland biome of South Africa. *Urban Forestry and Urban Greening*, 3:49–62.

CILLIERS, S.S., SCHOEMAN, L.L. & BREDENKAMP, G.J. 1998. Wetland plant communities in the Potchefstroom municipal area, North West Province, South Africa. *Bothalia*, 28:213–229.

CILLIERS, S.S. & SIEBERT, S.J. 2010. Urban flora and vegetation: patterns and processes. (*In* Niemelä, J., *ed.* Urban ecology: patterns, processes, and applications. Oxford: Oxford University Press. p.148–158.)

CILLIERS, S.S., SIEBERT, S.J., DAVOREN, E. & LUBBE, C.S. (*in press* a). Social aspects of urban ecology in developing countries, with an emphasis on urban domestic gardens. (*In* Richter, M. & Weiland, U., *eds.* Urban ecology: a global framework. Blackwell Publishing).

CILLIERS, S.S., VAN WYK, E. & BREDENKAMP, G.J. 1999. Urban nature conservation: vegetation of natural areas in the Potchefstroom municipal area, North West Province, South Africa. *Koedoe*, 42:1–30.

CLARKE, K.R. & GORLEY, R.N. 2001. 'PRIMER v.5: User manual/Tutorial.' PRIMERE Ltd.: Plymouth, UK.

CLAYTON, S. 2007. Domesticated nature: motivations for gardening and perceptions of environmental impact. *Journal of Environmental Psychology*, 27:215–224.

CLEMENT, S. & MOORE, G. 2003. Patterns of species richness in eight north-eastern United States cities. *Urban Habitats*, 1:4–13.

COETZEE, M.M., VAN AVERBEKE, W., WRIGHT, S.C.D. & HAYCOCK, E.T. 2007. Understanding urban home garden design in Ga-Rankuwa, Pretoria. Unpublished paper presented at the Institute of Environment and Recreation Management Conference on Expanding Opportunities, October 5-6, Pietermaritzburg, South Africa. http://www.ierm.org.za/library/convention-papers/convention-2007/papers/2.%20%20Magriet%20Coetzee.pdf.

COLDING, J. 2007. 'Ecological land-use complementation' for building resilience in ecosystems. *Landscape and Urban Planning*, 81:46–55.

COLEY, R.L., SULLIVAN, W.C. & KUO, F.E. 1997. Where does community grow? :The social context created by nature in urban public housing. *Environment and Behaviour*, 29(4):468–494.

COLLINS, J.P., KINZIG, A., GRIMM, N.B., FAGAN, W.F., HOPE, D., WU, J. & BORER, E.T. 2000. A new urban ecology: modelling communities as integral parts of ecosystems poses special problems for the development and testing of ecological theory. *American Scientist*, 88:416–425.

COSTANZA, R., D'ARGE, R., DE GROOT, R., FARBER, S., GRASSO, M., HANNON, B., LIMBURG, K., NAEEM, S., O'NEILL, R., PARUELO, J., RASKIN, R., SUTTON, P., VAN DEN BELT, M. 1997. The value of the world's ecosystem services and natural capital. *Nature* 387:253–260.

CRAUL, P.J. 1985. A description of urban soils and their desired characteristics. *Journal of Arboriculture*, 11(11):330–339.

CRAWLEY, M.J. & HARRAL, J.E. 2001. Scale dependence in plant biodiversity. *Science*, 291:864–868.

DAEMANE, M.E., CILLIERS, S.S. & BEZUIDENHOUT, H. 2010. An ecological study of the plant communities in the proposed Highveld National Park, in the peri-urban area of Potchefstroom, South Africa. *Koedoe*, 52:708. Available: Academic Search Premier. Date of access: Mar. 2011.

DANIELS, G.D. & KIRKPATRICK, J.B. 2006. Comparing the characteristics of front and back domestic gardens in Hobart, Tasmania, Australia. *Landscape and Urban Planning*, 78:344–352.

DAS, T. & DAS, A.K. 2005. Inventorying plant biodiversity in home gardens: A case study in Barak Valley, Assam, North East India. *Current Science*, 89:155-163.

DAVIES, Z.G., FULLER, R.A., LORAM, A., IRVINE, K., SIMS, V. & GASTON, K.J. 2009. A national scale inventory of resource provision for diversity within domestic gardens. *Biological Conservation*, 142:761–771.

DAVOREN, E. 2009. Plant diversity patterns of a settlement in the North West Province, South Africa. Potchefstroom: NWU. (Dissertation - M.Env.Sc.) 168 p.

DIAZ, S., FARGIONE, J., STUART, C.F. & TILMAN, D. 2006. Biodiversity loss threatens human well-being. *PLoS Biol,* 4(8):1300–1305.

DÍAZ-BETANCOURT, M., LÓPEZ-MORENO, I. & RAPOPORT, E.H. 1987. Vegetacíon y ambiente urbano en la Ciudad de México. (*In* Rapoport, E.H., López-Moreno, I., *eds*. Las plantas de los jardines privados, Aportes a la Ecología Urbana de la Ciudad de México. México: Limusa, p. 13−72.)

DOW, K. 2000. Social dimensions of gradients in urban ecosystems. *Urban Ecosystems*, 4:255–275.

DU TOIT, J. 2010. Personal communication with the author. Potchefstroom. (Interview was done at Garden Pavilion Nursery on 19 Feb.)

DU TOIT, M.J. 2009. Grassland ecology along an urban-rural gradient using GIS techniques in Klerksdorp, South Africa. Potchefstroom: NWU. (Dissertation - M.Env.Sc.) 203 p.

DU TOIT, M.J. & CILLIERS, S.S. 2011. Aspects influencing the selection of representative urbanization measures to quantify urban-rural gradients. *Landscape Ecology*, 26:169−181.

ESRI (Environmental Systems Research Institute). 2006. ArcView 9.2. www.esri.com. Redlands, CA: USA ESRI.

ETHEKWINI MUNICIPALITY ENVIRONMENTAL MANAGEMENT DEPARTMENT. 2009. Durban Metropolitan Open Space System. http://www.durban.gov.za/durban/services/epcpd/documents/DMOSS%20FAQ.pdf Date of access: May 2011.

FAGGI, A. & IGNATIEVA, M. 2009. Urban green spaces in Buenos Aires and Christchurch. *Municipal Engineer*, 162(4):241–250.

FENGER, J. 1999. Urban air quality. *Atmospheric Environment*, 33:4877–4900.

FORTIN, M.-J. & DALE, M. 2005. Spatial analysis: a guide for ecologists. Cambridge: Cambridge University Press. 380 p.

FRY, G., TRESS, B. & TRESS, G. 2007. Integrative landscape research: facts and challenges. (*In* Wu, J. & Hobbs, R.J., *eds.* Key topics in landscape ecology. New York, NY: Cambridge University Press. p. 246–268.)

FULLER, R.A., IRVINE, K.N., DEVINE-WRIGHT, P., WARREN, P.H. & GASTON, K.J. 2007. Psychological benefits of greenspace increase with biodiversity. *Biology Letters*, 3:390–394.

GASTON, K.J., SMITH, R.M., THOMPSON, K. & WARREN, P.H. 2005a. Urban domestic gardens (II): experimental tests of methods for increasing biodiversity. *Biodiversity and Conservation*, 14:395–413.

GASTON, K.J., WARREN, P.H., THOMPSON, K. & SMITH, R.M. 2005b. Urban domestic gardens (IV): the extent of the resource and its associated features. *Biodiversity and Conservation*, 14:3327–3349.

GERMISHUIZEN, G., MEYER, N.L., STEENKAMP, Y. & KEITH, M. 2006. A checklist of South African plants: Southern African Botanical Diversity Network Report No. 41. Pretoria: SABONET. 1126 p.

GILBERT, O.L. 1989. The ecology of urban habitats. London: Chapman & Hall. 384 p.

GILOMEE, H. & MBENGA, B. 2007. Nuwe geskiedenis van Suid-Afrika. Kaapstad: Tafelberg Uitgewers. 454 p.

GLEN, H.F. 2002. Cultivated plants of southern Africa. Jacana Education: Johannesburg. 428 p.

GODDARD, M.A., DOUGILL, A.J., BENTON, T.G. 2009. Scaling up from gardens: biodiversity conservation in urban environments. *Trends in Ecology and Evolution*, 25: 90–98.

GODEFROID, S. & KOEDAM, N. 2007. Urban plant species patterns are highly driven by density and function of built-up areas. *Landscape Ecology*, 22: 1227–1239.

GOSZ, J.R. 1992. Gradient analysis of ecological change in time and space: implications for forest management. *Ecological Applications*, 2:248–261.

GRIMM, N.B., GROVE, J.M., P, S.T.A. & REDMAN, C.L. 2000. Integrated approaches to long-term studies of urban ecological systems. *BioScience* 50:571–584.

GRIMM, N.B., FAETH, S.H., GOLUBIEWSKI, N.E., REDMAN, C.L., WU, J., BAI, X. & BRIGGS, J.M. 2008. Global change and the ecology of cities. *Science*, 319:756–760.

GROBLER, A. 2010. Personal communication with the author. Potchefstroom. (Interview was done at Chalet Nursery on 19 Feb.)

GROSS, H. & LANE, N. 2007. Landscapes of the lifespan: exploring accounts of own gardens and gardening. *Journal of Environmental Psychology*, 27:225–241.

HAHS, A.K. & MCDONNELL, M.J. 2006. Selecting independent measures to quantify Melbourne’s urban-rural gradient. *Landscape and Urban Planning*, 78(4):435–448.

HAIR, J.F., ANDERSON, R.E., TATHAM, R.L. & BLACK, W.C. 1998. Multivariate data analysis. 5th ed. Upper Saddle River, N.J.: Prentice-Hall. 743 p.

HAMILTON, H.R. 1999. The case for abundant species management. *Human dimensions of wildlife*, 4:74–85.

HANSEN, H.J., KNIGHT, R.L., MARZLUFF, J.M., POWELL, S., BROWN, K., GUDE, P.H. & JONES, K. 2005. Effects of exurban development on biodiversity: patterns, mechanisms, and research needs. *Ecological Applications,* 15:1893–1905.

HAWAIIAN ECOSYSTEMS AT RISK. 2010. Hawaiian Ecosystems at Risk Project. http://www.hear.org/. Date of access: 3 Feb. 2010.

HENDERSON, L. 2001. Alien weeds and invasive plants. Pretoria: Agricultural Research Council. 300 p.

HENDERSON, L. 2006. Comparisons of invasive plants in southern Africa originating from southern temperate, northern temperate and tropical regions. *Bothalia*, 36:201–222.

HENNESSY, K. 2000. Towards a metropolitan open space system for the city of Cape Town.

HODKINSON, D.J. & THOMPSON, K. 1997. Plant dispersal: the role of man. *Journal of Applied Ecology*, 34:1484–1496.

HOPE, D., GRIES, C., CASAGRANDE, D., REDMAN, C.L., GRIMM, N.B. & MARTIN, C. 2006. Drivers of spatial variation in plant diversity across the Central Arizona-Phoenix ecosystem. *Society and Natural Resources*, 19:101–116.

HOPE, D., GRIES, C., ZHU, W., FAGAN, W.F., REDMAN, C.L., GRIMM, N.B., NELSON, A.L., MARTIN, C. & KINZIG, A. 2003. Socioeconomics drive urban plant diversity. *Proceedings of the National Academy of Sciences*, 100:8788–8792.

ISAACSON, R.T. 2004. The Anderson Horticultural Library's source list of plants and seeds: a completely revised listing of 2000-2003 catalogues. 6th ed. Chanhassen, MN: Anderson Horticultural Library. 367 p.

ISAAKS, E.H. & SRIVASTAVA, R.M. 1989. An introduction to applied geostatistics. Oxford: Oxford University Press. 561 p.

JANSEN VAN RENSBURG, N.S. 2002. The representation of social meaning by bureaucrats: removal of the disempowered from Willem Klopperville (1958–1965). (*In* LeBeau, D. & Gordon, R., *eds.* Challenges for anthropology in the 'African Renaissance': a southern African contribution. Windhoek: University of Namibia Press. p. 266–281.)

JHA, S. & BAWA, K.S. 2006. Population growth, human development, and deforestation in biodiversity hotspots. *Conservation Biology*, 20:906–912.

JIM, C.Y. & CHEN, W.Y. 2009. Urbanization effect on floristic and landscape patterns of green spaces. *Landscape Research*, 34:581–598.

JOFFE, P. 2007. Skeppende tuinmaak met inheemse plante: 'n Suid-Afrikaanse gids. Pretoria: Briza. 372 p.

KAHN, P.H., Jr. 2002. Children's affiliations with nature: structure, development, and the problem of generational amnesia. (*In* Kahn, P.H., Jr. & Kellert, S.R., *eds.* Children and nature: psychological, sociocultural, and evolutionary investigations. Cambridge, MA: MIT Press. p. 93–116.)

KENDLE, T. & FORBES, S. 1997. Urban nature conservation: landscape management in the urban countryside. London: E & FN Spon. 352 p.

KENT, M. & COKER, P. 1992. Vegetation description and analysis. London, UK : Wiley & Sons. 319 p.

KINZIG, A.P., WARREN, P., MARTIN, C., HOPE, D. & KATTI, M. 2005. The effects of human socioeconomic status and cultural characteristics on urban patterns of biodiversity. *Ecology and Society* 10: 23 (online).

KIRKPATRICK, J.B., DANIELS, G.D. & ZAGORSKI, T. 2007. Explaining variation in front gardens between suburbs of Hobart, Tasmania, Australia. *Landscape and Urban Planning*, 79:314–322.

KOLEFF, P., GASTON, K.J. & LENNON, J.J. 2003. Measuring beta diversity for presence-absence data. *Journal of Animal Ecology*, 72:367–382.

KÜHN, I., BRANDL, R. & KLOTZ, S. 2004. The flora of German cities is naturally species rich. *Evolutionary Ecology Research*, 6:749–764.

KÜHN, I. & KLOTZ, S. 2006 Urbanization and homogenization: comparing floras of urban and rural areas in Germany. *Biological Conservation*, 127:292–300.

KUO, F.E. & SULLIVAN, W.C. 2001. Environment and crime in the inner city: does vegetation reduce crime? *Environment and Behaviour*, 3:343–367.

LAWTON, J.H. 1999. Are there general laws in ecology? *Oikos*, 84:177–192.

LEMON, A. 2003. Urbanization and urban forms. (*In* Fox, R. & Rowntree, K., *eds.* The geography of South Africa in a changing world. Cape Town, Oxford University Press South Africa. p. 186–210.)

LEPŠ, J. & ŠMILAUER, P. 2003. Multivariate analysis of ecological data using CANOCO. New York: Cambridge University Press. 269 p.

LINDEMAN, E.C. 1940. Ecology: an instrument for the integration of science and philosophy. *Ecological Monographs*, 10:367–372.

LORAM, A., TRATALOS, J., WARREN, P.H. & GASTON, K.J. 2007. Urban domestic gardens (X): the extent & structure of the resource in five major cities. *Landscape Ecology*, 22: 601–615.

LUBBE, C.S., SIEBERT, S.J. & CILLIERS, S.S. 2010. Political legacy of South Africa affects the plant diversity patterns of urban domestic gardens along a socio-economic gradient. *Scientific Research and Essays*, 5:2900–2910.

LUBBE, C.S., SIEBERT, S.J. & CILLIERS, S.S. 2011. A floristic analysis of domestic gardens in the Tlokwe City Municipality, South Africa. *Bothalia*, 41(2): *in press*.

LUCK, M. & WU, J. 2002. A gradient analysis of urban landscape pattern: a case study from the Phoenix metropolitan region, Arizona, USA. *Landscape Ecology*, 17:327–339.

MABIN, A. 1992. Comprehensive segregation: The origins of the Group Areas Act and its planning apparatuses. *Journal of Southern African Studies*, 18:405–429.

MACAULAY, D., BUCHANAN, N., BURTON, R. & MURPHY, M. 2009. RHS plant finder 2009–2010. Dorling, Kindersley: London, UK. 976 p.

MACK, R.N. 1999. Two recommendations for more rapid publication in ESA journals: observations of a subject editor. *ESA Bulletin*, 80:83–84.

MAGURRAN, A. E. 1988. Ecological diversity and its measurement. Princeton, N.J.: Princeton University Press. 179 p.

MANGOLD, S., MOMBERG, M. & NEWBERY, R. 2002. Biodiversity and conservation. (*In* Mangold, S. & Kalule-Sabiti, M., *eds.* North West Province State of the environment report. Department of Environmental Affairs and Tourism. pp. 1–33.)

MARCO, A., BARTHELEMY, C., DUTOIT, T. & BERTAUDIÉRE-MONTES, V. 2010. Bridging human and natural sciences for a better understanding of urban floral patterns: the role of planting practices in Mediterranean gardens. *Ecology and Society*, 15(2): article 2, 18 p. URL: http://www.ecologyandsociety.org/vol15/iss2/art2/. Date of access: Sep. 2010.

MARCO, A., DUTOIT, T., DESCHAMPS-COTTIN, M., MAUFFREY, J., VENNETIER, M. & BERTAUDIERE-MONTES, V. 2008. Gardens in urbanizing rural areas reveal an unexpected floral diversity related to housing density. *C.R.Biologies*, 331:452–465.

MARTIN, C.A., WARREN, P.S. & KINZIG, A.P. 2004. Neighbourhood socioeconomic status is a useful predictor of perennial landscape vegetation in residential neighbourhoods and embedded small parks of Phoenix, AZ. *Landscape and Urban Planning*, 69:355–368.

MATHIEU, R., FREEMAN, C. & ARYAL, J. 2007. Mapping private gardens in urban areas using object-oriented techniques and very high-resolution satellite imagery. *Landscape and Urban Planning*, 81:179–192.

MATSON, P.A., PARTON, W.J., POWER, A.G. & SWIFT, M.J. 1997. Agricultural intensification and ecosystem properties. *Science*, 277:504–509.

MAY, J. & ROGERSON, C.M. 1995. Poverty and sustainable cities in South Africa: the role of urban cultivation. *Habitat International*, 19:165–181.

MCBRIDE, C. (charlotte.mcbride@weathersa.co.za) 26 September 2008. Climate data. E-mail to: Lubbe, C.S (20141424@student.nwu.ac.za).

MCCONNACHIE, M.M., SHACKLETON, C.M. & MCGREGOR, G.K. 2008. The extent of public green space and alien plant species in 10 small towns of the sub-tropical thicket biome, South Africa. *Urban Forestry and Urban Greening*, 7:1–13.

MCCONNACHIE, M.M. & SHACKLETON, C.M. 2010. Public green space inequality in small towns in South Africa. *Habitat International*, 34:244–248.

MCDONALD, D. 1998. Three steps forward, two steps back: ideology and urban ecology in South Africa. *Review of African Political Economy*, 75:73–88.

MCDONNELL, M.J. 1988. The challenge of preserving urban natural areas: a forest for New York. *Journal of American Association of Botanical Gardens and Arboreta,* 3:27–31.

MCDONNELL, M.J. 2007. Restoring and managing biodiversity in an urbanizing world filled with tensions. *Ecological Management and Restoration*, 8(2):83–84.

MCDONNELL, M.J. & HAHS, A.K. 2008. The use of gradient analysis studies in advancing our understanding of the ecology of urbanizing landscapes: current status and future directions. *Landscape Ecology*, 23:1143–1155.

MCDONNELL, M.J. & PICKETT, S.T.A. 1990. Ecosystem structure and function along urban-rural gradients: an unexploited opportunity for ecology. *Ecology*, 71:1232–1237.

MCDONNELL, M.J., PICKETT, S.T.A., GROFFMAN, P., BOHLEN, P., POUYAT, R.V., ZIPPERER, W.C., PARMELEE, R.W., CARREIRO, M.M. & MEDLEY, K. 1997. Ecosystem processes along an urban-to-rural gradient. *Urban Ecosystems*, 1:21–36.

MCGRANAHAN, G. & SATTERTHWAITE, D. 2003. Urban centers: an assessment of sustainability. *Annual Review of Environment and Resources*, 28:243–274.

MCINTYRE, N.E., KNOWLES-YANEZ, K. & HOPE, D. 2000. Urban ecology as an interdisciplinary field: differences in the use of “urban” between the social and natural sciences. *Urban Ecosystems*, 4:5–24.

MCKINNEY, M.L. 2002. Urbanization, biodiversity, and conservation. *BioScience*, 52:883–890.

MCKINNEY, M.L. 2006. Urbanization as a major cause of biotic homogenization. *Biological Conservation*, 127:247–260.

MCKINNEY, M.L. 2008. Effects of urbanization on species richness: a review of plants and animals. *Urban Ecosystems*, 11:161–176.

MCKINNEY, M.L. & LOCKWOOD, J.L. 1999. Biotic homogenization: a few winners replacing many losers in the next mass extinction. *Tree*, 14:450–453.

MENNIS, J. 2006. Socioeconomic-vegetation relationships in urban, residential land: the case of Denver, Colorado. *Photogrammetric Engineering & Remote Sensing*, 72(8):911–921.

MILLENNIUM ECOSYSTEM ASSESSMENT. 2003. Ecosystems and human well-being: a framework for assessment. Washington DC, WA: Island Press. 245 p.

MILLER, J.R. 2005. Biodiversity conservation and the extinction of experience. *Trends in Ecology and Evolution*, 20:430–434.

MILLER, J.R. & HOBBS, R.J. 2002. Conservation where people live and work. *Conservation Biology*, 16:330–337.

MOLEBATSI, L.Y., SIEBERT, S.J., CILLIERS, S.S., LUBBE, C.S. & DAVOREN, E. 2010. The Tswana tshimo: a homegarden system of useful plants with a particular layout and function. *African Journal of Agricultural Research*, 5:2952–2963.

MOLES, A.T., GRUBER, M.A.M. & BONSER, S.P. 2008. A new framework for predicting invasive plant species. *Journal of Ecology*, 96:13–17.

MUCINA, L. & RUTHERFORD, M.C (*eds*). 2006. The vegetation of South Africa, Lesotho and Swaziland. Pretoria: South African National Biodiversity Institute. 807 p.

MUNICIPAL DEMARCATION BOARD. 2006. Municipal Demarcation Board, South Africa. http://www.demarcation.org.za Date of access: 7 June 2008.

MUSACCHIO. L.R. & WU, J. 2004. Collaborative landscape-scale ecological research: emerging trends in urban and regional ecology. *Urban Ecosystems*, 7:175–178.

MUTH, N.Z. & PIGLIUCCI, M. 2006. Traits of invasives reconsidered: phenotypic comparisons of introduced invasive and introduced noninvasive plant species within two closely related clades. *American Journal of Botany*, 93:188–196.

MYERS, N., MITTERMEIER, R.A., MITTERMEIER, C.G., DA FONSECA, G.A.B. & KENT, J. 2000. Biodiversity hotspots for conservation priorities. *Nature*, 403:853–858.

NASSAUER, J.I., WANG, Z. & DAYRELL, E. 2009. What will the neighbors think? Cultural norms and ecological design. *Landscape and Urban Planning*, 92:282–292.

NEIL, K. & WU, J. 2006. Effects of urbanization on plant flowering phenology: a review. *Urban Ecosystems*, 9:243–257.

NELSON, A.L., SCHWIRIAN, K.P. & SCHWIRIAN, P. 1998. Social and economic distress in large cities, 1970–1990: a test of the urban crisis thesis. *Social Science Research*, 27:410–431.

NEMUDZUDZANYI, A.O., SIEBERT, S.J., ZOBOLO, A.M. & MOLEBATSI, L.Y. 2010. The Zulu muzi: a home garden system of useful plants with a specific layout and function. *African Journal of Indigenous Knowledge Systems*, 9:57–72.

NIINEMETS, Ü. & PEÑUELAS, J. 2008. Gardening and urban landscaping: significant players in global change. *Trends in Plant Science,* 13:60–65.

OBERHOLZER, R. 2005. A survey of the perceptions of previously disadvantaged South Africans on taxation. *Critical Perspectives on Accounting*, 16:249–275.

OLDEN, J.D. & POFF, N.L. 2003. Towards a mechanistic understanding of prediction of biotic homogenization. *American Naturalist*, 162:442–460.

OLIVIER, D.F. 1999. Please, more real farmers in our cities! *Faith & Earthkeeping*, 16:1–13.

OWEN, J. 1991. The ecology of a garden: the first fifteen years. Cambridge University Press: Cambridge. 403 p.

PANDEY, C.B., RAI, R.B., SINGH, L. & SINGH, A.K. 2007. Home gardens of Andaman and Nicobar, India. *Agricultural Systems*, 92:1–22.

PAOLETTI, E. 2009. Ozone and urban forests in Italy. *Environmental Pollution*, 157:1506–1512.

PARSONS, R. & DANIEL, T.C. 2002. Good looking: in defense of scenic landscape aesthetics. *Landscape and Urban Planning*, 60:43–56.

PAUCHARD, A., AGUAYO, M., PEÑA, E. & URRUTIA, R. 2006. Multiple effects of urbanization on the biodiversity of developing countries: the case of a fast-growing metropolitan area (Concepción, Chile). *Biological Conservation*, 127:272–281.

PAUSAS, J.G. & AUSTIN, M.P. 2001. Patterns of plant species richness in relation to different environments: an appraisal. *Journal of Vegetation Science*, 12:153–166.

PEDLOWSKI, M.A., DA SILVA, V.A., ADELL, J.J. & HEYNEN, N.C. 2003. Urban forest and environmental inequality in Campos dos Goytacazes, Rio de Janeiro, Brazil. *Urban Ecosystems*, 6:9–20.

PICKETT, S.T.A., BURCH, W.R. Jr., DALTON, S.E., FORESMAN, T.W., GROVE, J.M. & ROWNTREE, R. 1997. A conceptual framework for the study of human ecosystems in urban areas. *Urban Ecosystems*, 1:185–199.

PICKETT, S.T.A., CADENASSO, M.L., GROVE, J.M., NILON, C.H., POUYAT, R.V., ZIPPERER, W.C. & COSTANZA, R. 2001. Urban ecological systems: linking terrestrial ecological, physical and socioeconomic components of metropolitan areas. *Annual Review of Ecology and Systematics* 32:127-157.

PICKETT, S.T.A. & MCDONNELL, M.J. 1993. Humans as components of ecosystems: a synthesis. (*In* McDonnell, M.J. & Pickett, S.T.A., *eds.* Humans as components of ecosystems: the ecology of subtle human effects and populated areas. New York, NY: Springer-Verlag. p. 310–316.)

PIENAAR, K. 1994. The ultimate southern African gardening book. Pretoria: Southern Book Publishers. 528 p.

PIENAAR, K. 2000. The South African what flower is that? Cape Town: Struik Publishers. 368 p.

PIMENTEL, D., LACH, L., ZUNIGA, R. & MORRISON, D. 2000. Environmental and economic costs of nonindigenous species in the United States. *BioScience*, 50:53–65.

POYNTON, J.C. & ROBERTS, D.C. 1985. Urban open space planning in South Africa: a biogeographical perspective. *South African Journal of Science*, 81:33–37.

PYŠEK, P. 1998. Alien and native flora in Central European urban floras: a quantitative comparison. *Journal of Biogeography*, 25:155–163.

PYŠEK, P., PRACH, K. & ŠMILAUER, P. 1995. Relating invasion success to plant traits: an analysis of the Czech alien flora. (*In* Pyšek, P., Prach, K., Rejmánek, M. & Wade, M., *eds.* Plant invasions – general aspects and special problems. Amsterdam, the Netherlands: SRB Academic Publishing. p. 39–60.)

QUINN, G.P. & KEOUGH, M.J. 2002. Experimental design and data analysis for biologists. Cambridge: Cambridge University Press. 537 p.

RAIMONDO, D., VON STADEN, L., FODEN, W., VICTOR, J.E., HELME, N.A., TURNER, R.C., KAMUNDI, D.A. & MANYAMA, P.A. 2009. Red List of South African plants 2009. Strelitzia 25:53–559. Pretoria: South African National Biodiversity Institute.

RAPOPORT, E.H. 1993. The process of plant colonization in small settlements and large cities. (*In* McDonnell, M.J. & Pickett, S.T.A., *eds*. Humans as components of ecosystems: the ecology of subtle human effects and populated areas. New York, NY: Springer-Verlag. p. 190–207.)

REBELE, F. 1994. Urban ecology and special features of urban ecosystems. *Global Ecology and Biogeography Letters*, 4:173–187.

REES, W. & WACKERNAGEL, M. 1996. Urban ecological footprints: why cities cannot be sustainable – and why they are the key to sustainability. *Environmental Impact Assessment Review*, 16:223–248.

REICHARD, S.H. & WHITE, P. 2001. Horticulture as a pathway of invasive plant introductions in the United States. *BioScience*, 51:103–113.

RICHARDSON, D.M., ROUGET, M., RALSTON, S.J., COWLING, R.M., VAN RENSBURG, B.J. & THUILLER, W. 2005. Species richness of alien plants in South Africa: environmental correlates and the relationship with indigenous plant species richness. *Ecoscience*, 12:391–402.

RICHARDSON, D.M. & VAN WILGEN, B.W. 2004. Invasive alien plants in South Africa: how well do we understand the ecological impacts? *South African journal of science*, 100:45–52.

RICOTTA, C. 2010. On beta diversity decomposition: trouble shared is not trouble halved. *Ecology*, 91:1961–1963.

ROBERTS, D.C. 1993. The vegetation ecology of municipal Durban, Natal: floristic classification. *Bothalia*, 23:271-326.

ROGERSON, C.M. 1993. Urban agriculture in South Africa: scope, issues and potential. *GeoJournal*, 30:21–28.

RUGALEMA, G.H., OKTING'ATI, A., JOHNSEN, F.H. 1994. The home garden agroforestry system of Bukoba district, North-Western Tanzania. 1. Farming system analysis. *Agroforestry Systems*, 26:53–64.

SAVARD, J.L., CLERGEAU, P. & MENNECHEZ, G. 2000. Biodiversity concepts and urban ecosystems. *Landscape and Urban Planning*, 48:131–142.

SAX, D.F. & GAINES, S.D. 2003. Species diversity: from global decreases to local increases. *Trends in Ecology and Evolution* 18:561–566.

SCHEEPERS, I. 2010. Personal communication with the author. Potchefstroom. (Interview was done at Eb's Nursery on 19 Feb.)

SCHWARTZ, M.W. 1997. Defining indigenous species. (*In* Luken, J.O. & Thieret, J.W., *eds*. Assessment and management of plant invasions. New York: Springer. p. 7–17.)

SHACKLETON, C.M., MCCONNACHIE, M., CHAUKE, M.I., MENTZ, J., SUTHERLAND, F., GAMBIZA, J. & JONES, R. 2006. Urban fuelwood demand and markets in a small town in South Africa: livelihood vulnerability and alien plant control. *International Journal of Sustainable Development & World Ecology*, 13:481–491.

SHACKLETON, S.E., CAMPBELL, B., LOTZ-SISITKA, H. & SHACKLETON, C.M. 2008. Links between the local trade in natural products, livelihoods and poverty alleviation in a semi-arid region of South Africa. *World Development*, 36:505–526.

SHARPE, D.M., STEARNS, F., LEITNER, L.A. & DORNEY, J.R. 1986. Fate of natural vegetation during urban development of rural landscapes in southeastern Wisconsin. *Urban Ecology*, 9:267–287.

SHAW, P.J.A. 2003. Multivariate statistics for environmental sciences. London: Arnold Publishers. p. 233.

SIEBERT, S.J., ZOBOLO, A.M. & DOWE, J.L. 2010. *Livistona chinensis*: a first record of a naturalised palm in South Africa. *Bothalia* 40:55–57.

SMITH, G.F. & VAN WYK, B.-E. 2008. Guide to garden succulents. Pretoria: Briza. 320 p.

SMITH, R.M., THOMPSON, K., HODGSON, J.G., WARREN, P.H. & GASTON, K.J. 2006a. Urban domestic gardens (IX): Composition and richness of the vascular plant flora, and implications for native biodiversity. *Biological Conservation* 129:312–322.

SMITH, R.M., WARREN, P.H., THOMPSON, K. & GASTON, K.J. 2006b. Urban domestic gardens (VI): environmental correlates of invertebrate species richness. *Biodiversity and Conservation*, 15:2415–2438.

SNYMAN, H. (H.Snyman@sanbi.org.za) 4 Dec. 2009. *Top 20 SA plant families.* E-mail to: Lubbe, C.S. (20141424@student.nwu.ac.za).

SOUTH AFRICA. 1983. Conservation of Agricultural Resources Act OF 1983. Pretoria: Government Printer.

STATSOFT, INC. 2009. STATISTICA (data analysis software system), version 9.0. www.statsoft.com.

STATSOFT, INC. 2010. Electronic Statistics Textbook. http://www.statsoft.com/textbook/ Date of access: 15 Nov. 2010.

STEWART, W. 2006. Nelson Mandela Metropolitan Open Space System. *Unpublished report.*

STRATEGIC ENVIRONMENTAL FOCUS. 2002. Johannesburg Open Space System. www.joburg-archive.co.za/planning/jmossreport.doc Date of access: May 2011.

SUKOPP, H. 2002. On the early history of urban ecology in Europe. *Preslia*, 74:373–393.

SULLIVAN, J.J., TIMMINS, S.M. & WILLIAMS, P.A. 2005. Movement of exotic plants into coastal native forests from gardens in northern New Zealand. *New Zealand Journal of Ecology*, 29:1–10.

TABACHNICK, B.G. & FIDELL, L.S. 2007. Using multivariate statistics. 5th ed. Boston: Allyn & Bacon. 980 p.

TANSLEY, A.G. 1935. The use and abuse of vegetational concepts and terms. *Ecology*, 16:284–387.

TER BRAAK, C.J.F. & SMILAUER, P. 2002. CANOCO reference manual and CanoDraw for Windows user's guide: Software for Canonical Community Ordination (version 4.5). New York: Ithaca.

THEOBALD, D.M. 2004. Placing exurban land-use change in a human modification framework. *Frontiers in Ecology and the Environment*, 2:139–144.

THOMPSON, K., AUSTIN, K.C., SMITH, R.M., WARREN, P.H., ANGOLD, P.G. & GASTON, K.J. 2003. Urban domestic gardens (I): putting small-scale plant diversity in context. *Journal of Vegetation Science*, 14:71–78.

TRINH, L.N., WATSON, J.W., HUE, N.N., DE, N.N., MINH, N.V., CHU, P., STHAPIT, B.R. & EYZAGUIRRE, P.B. 2003. Agrobiodiversity conservation and development in Vietnamese home gardens. *Agriculture, Ecosystems & Environment*, 97:317–344.

TROWBRIDGE, A.V. 1998. Start or join an ecocircle. *Land*:10–12.

TROY, A.R., GROVE, J.M., O'NEIL-DUNNE, J.P.M., PICKETT, S.T.A. & CADENASSO, M.L. 2007. Predicting opportunities for greening and patterns of vegetation on private urban lands. *Environmental Management*, 40:394–412.

ULRICH, R.S. 1981. Natural versus urban sciences: some psycho-physiological effects. *Environment and Behavior*, 13:523–556.

UNITED NATIONS DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS. 2008. World urbanization prospects: the 2007 revision. New York: United Nations. 230 p.

UNITED STATES DEPARTMENT OF AGRICULTURE (USDA). 2009. Plants database. http://www.plants.usda.gov/ Date of access: 3 Feb. 2010.

VAN OUDTSHOORN, F. 1999. Gids tot grasse van Suider-Afrika. Pretoria : Briza. 288 p.

VAN ROOYEN, D. 2009. Verbal communication with the author. Potchefstroom : Department Housing and Planning, Tlokwe City Council.

VAN WYK, B-E. 2005. Food Plants of the World. Pretoria: Briza.

VAN WYK, B.E. & GERICKE, N. 2000. People's plants: a guide to useful plants of Southern Africa. Pretoria: Briza. 351 p.

VAN WYK, B. & MALAN, S. 1997. Field guide to the wild flowers of the Highveld. Cape Town : Struik Publishers. 352 p.

VAN WYK, B.E., VAN OUDTSHOORN, B. & GERICKE, N. 1997. Medicinal plants of South Africa. Pretoria: Briza. 304 p.

VAN WYK, E., CILLIERS, S.S. & BREDENKAMP, G.J. 1997. Ranteveldplantegroei van Klerksdorp, Noordwes Provinsie, Suid-Afrika. *Suid-Afrikaanse Tydskrif vir Natuurwetenskap en Tegnologie*, 16:74–85.

VAN WYK, E., CILLIERS, S.S. & BREDENKAMP, G.J. 2000. Vegetation analysis of wetlands in the Klerksdorp Municipal Area, North West Province, South Africa. *South African Journal of Botany*, 66:52–62.

VEECH, J.A. & CRIST, T.O. 2010. Toward a unified view of diversity partitioning. *Ecology*, 91:1988–1992.

VENTER, F. & VENTER, J.-A. 2002. Making the most of our indigenous trees. Pretoria : Briza. 320 p.

VITOUSEK, P.M., MOONEY, H.A., LUBCHENCO, J. & MELILLO, J.M. 1997. Human domination of earth's ecosystems. *Science*, 277:494–499.

VOGL, C.R., VOGL-LUKASSER, B. & PURI, R.K. 2004. Tools and methods for data collection in ethnobotanical studies of homegardens. *Field methods*, 16:285–306.

WANIA, A., KÜHN, I. & KLOTZ, S. 2006. Plant richness patterns in agricultural and urban landscapes in Central Germany: spatial gradients of species richness. *Landscape and Urban Planning*, 75:97–110.

WEZEL, A. & BENDER, S. 2003. Plant species diversity of homegardens of Cuba and its significance for household food supply. *Agroforestry Systems*, 57:39–49.

WHELAN, R.J., ROBERTS, D.G., ENGLAND, P.R. & AYRE, D.J. 2006. The potential for genetic contamination vs. Augmentation by native plants in urban gardens. *Biological Conservation*, 128:493–500.

WHITNEY, G.G. & ADAMS, S.D. 1980. Man as a maker of new plant communities. *Journal of Applied Ecology*, 17:431–448.

WHITTAKER, R.H. 1960. Vegetation of Siskiyou Mountains, Oregon and California. *Ecological Monographs*, 30:279–338.

WHITTAKER, R.H. 1972. Evolution and measurement of species diversity. *Taxon*, 21:213–251.

WHITTAKER, R.H. 1977. Evolution of species diversity in land communities. *Evolutionary Biology*, 10:1–67.

WILLIAMS, J.W., SEABLOOM, E.W., SLAYBACK, D., STOMS, D.M. & VIERS, J.H. 2005. Anthropogenic impacts upon plant species richness and net primary productivity in California. *Ecology letters*, 8:127–137.

WILLIAMS, N.S.G., SCHWARTZ, M.W., VESK, P.A., MCCARTHY, M.A., HAHS, A.K., CLEMANTS, S.E., CORLETT, R.T., DUNCAN, R.P., NORTON, B.A., THOMPSON, K. & MCDONNELL, M.J. 2009. A conceptual framework for predicting the effects of urban environments on floras. *Journal of Ecology*, 97:4–9.

WILSON, M.V. & SHMIDA, A. 1984. Measuring beta diversity with presence-absence data. *Journal of Ecology*, 72:1055–1062.

WINKLERPRINS, A.M.G.A. 2002. House-lot gardens in Santarém, Pará, Brazil: linking rural with urban. *Urban Ecosystems*, 6:43–65.

WINTER, J.H.S. & BOTHA, D.J. 1994. The release of endangered plants into the horticultural trade: conservation or exploitation? *Biodiversity & Conservation*, 3:142–147.

WORKWELL. 2004. *Potchefstroom socio-economic survey*. WorkWell research unit for people, policy and performance. pp. 1–115.

WORLD BANK. 1984. World development report 1984. Oxford: Oxford University Press. 286 p.

WORLD COMMISSION ON ENVIRONMENT AND DEVELOPMENT. 1987. Our common future. Oxford: Oxford University Press. 254 p.

WU, J. 2008. Making the case for Landscape Ecology: an effective approach to urban sustainability. *Landscape Journal*, 27:41–50.

WU, J. & HOBBS, R. 2002. Key issues and research priorities in landscape ecology: an idiosyncratic synthesis. *Landscape Ecology*, 17:355–365.

WU, J., JENERETTE, G.D. & DAVID, J. 2003. Linking land-use change with ecosystem processes: a hierarchical patch dynamic model. Integrated land use and environmental models. Berlin: Springer. p. 99–119.

ZMYSLONY, J. & GAGNON, D. 1998. Residential management of urban front yard landscape: a random process? *Landscape and Urban Planning*, 40:295–307.

Appendix A: Questionnaire

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

Private Bag X6001, Potchefstroom
South Africa 2520

Tel: (018) 299-1111/2222
Web: http://www.nwu.ac.za

Tel: (018) 299-2499/2509
Date: August 2008

To Whom It May Concern:

My name is Rina Lubbe. I am a student at the North-West University in Potchefstroom and am currently enrolled for a Masters degree in Environmental Sciences and Development. This is a letter to request permission to conduct research in your garden.

My research project is about the plant diversity in domestic gardens within Potchefstroom and Ikageng (including surrounding small holdings). Gardens are an important part of the ecology of the city and one that has previously received little or no attention. The effects of human impacts (degree of urbanisation, socio-economic status, etc.) on garden plant diversity will be examined. This study is the first of its kind in South Africa and based on studies done in the United Kingdom.

As is the case with most research involving plants, this study is seasonally restricted. For this reason, all the research will be done during plant growing season. Proposed dates are from November 2008 to April 2009. The surveys basically include a non-destructive notation of all the plant species present in the garden. Samples of some of the species may be needed for identification purposes, for example a twig from a shrub or tree.

Your cooperation will be greatly appreciated.

Regards

Rina Lubbe

Urban ecological survey
School of Environmental Sciences and Development
North-West University
Potchefstroom Campus

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

Name: ________________________________ **Questionnaire no.:**_______________________
Adress: ________________________________ **Date:** ________________________________
________________________________ **GPS:** __________________/______________
________________________________ **Phone no.:**______________________________

Section 1: Management and maintenance

1. Which of the following activities takes places in your garden?

Activity	Yes	No
Water the garden **(1 – rain only; 2 – once a fortnight; 3 – once a week; 4 - > once a week)**		
Fertilise the garden **(0 – none; 1 - < once a year; 2 – once a year; 3 – twice a year; 4 quarterly; 5 – once a month)**		
Weed the garden – chemically **(0 – none; 1 – when needed; 2 – twice a year; 3 – once a month)**		
Weed the garden – mechanically **(0 – none; 1 – once a month; 2 – once a fortnight; 3 – once a week)**		
Sweep the garden **(1 – once a month; 2 – once a fortnight; 3 – once a week; 4 - > once a week)**		
Prune the hedges / trees **(1 – once a year; 2 – twice a year; 3 – once a month)**		
Remove dead plant material **(1 – once a year; 2 – once a month; 3 – once a week)**		
Rake lawn **(1 – once a month; 2 – once a fortnight; 3 – once a week)**		
Topsoil lawn **(1 – < once a year; 2 – once a year)**		
Spike lawn **(0 – none; 1 – once a year; 2 – once a month)**		
Mow lawn **(1 – once a month; 2 – once a fortnight; 3 – once a week)**		
Graze lawn **(0 – none; 1 – once a week; 2 – daily)**		

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 garden?

			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 garden?

			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. 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

6. Do you have any of the following?

	Yes	**No**
Vegetable garden		
Herb garden		
Fruit trees / orchard		
Medicinal garden / plants		

7. 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							

8. **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		

9. **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

10. **Do you have gardening assistance?**

Gardening services	1
Gardeners	2
None	3

11. **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

12. **Are you aware of any declared weeds and invaders in your garden?**

____

____

13. **Do you plant only indigenous species in your garden?**

____

____

Section 2: Social aspects

14. How long have you been living in this house?____

15. Do you know how old this garden is?____

16. 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

17. Where do you get the water in your garden?

Bore hole in your yard	4
Water tap in your yard	3
Communal water tap	2
Natural source (river/stream or dam/pan)	1

18. 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

19. What is the age of the garden manager/decision maker?

    ____

20. Would you like feedback on this study? Yes/No

Appendix B: Species list

Table B.1: Complete species list of all the vascular plant species recorded in the domestic gardens of the TCM. Superscript indicates species group (refer to section 3.3.2 for definitions): ^{A} for alien cultivated; ^{IC} for indigenous cultivated; ^{N} for naturalised and ^{I} for indigenous species.

Family	Species	Add. info
Acanthaceae	^{A}*Acanthus mollis* L.*	
	^{I}*Barleria obtusa* Nees	
	^{A}*Beloperone guttata* Brandegee*	
	^{IC}*Hypoestes aristata* (Vahl) Sol. ex Roem. & Schult.	
	^{IC}*Thunbergia alata* Sims	
Aceraceae	^{A}*Acer buergerianum* Miq.*	C3 invader
	^{A}*Acer negundo* L.*	C3 invader
	^{A}*Acer palmatum* Thunb.*	
Agapanthaceae	^{IC}*Agapanthus africanus* (L.) Hoffmans.	Endangered
	^{IC}*Agapanthus praecox* Willd.	
Agavaceae	^{N}*Agave americana* L.*	Special effect weed
	^{A}*Agave filifera* Salm-Dyck*	
	^{A}*Agave victoriae-reginae* T.Moore*	
	^{A}*Beschorneria yuccoides* Hort. ex Hook. *	
	^{A}*Cordyline australis* (G.Forst.) Endl. *	
	^{A}*Dasylirion wheeleri* S.Watson*	
	^{A}*Phormium colensoi* Hook.f.*	
	^{A}*Phormium tenax* J.R.Forst. & G.Forst*	
	^{A}*Ruscus aculeatus* L.*	
	^{A}*Yucca aloifolia* L.*	
	^{A}*Yucca filamentosa* L.*	
	^{A}*Yucca gloriosa* L.*	
Alliaceae	^{G}*Allium cepa* L.*	
	^{A}*Allium porrum* L.*	
	^{N}*Nothoscordum borbonicum* Kunth*	
	^{I}*Tulbaghia acutiloba* Harv.	
	^{IC}*Tulbaghia simmleri* P.Beauv.	
	^{IC}*Tulbaghia violacea* Harv.	
Alstroemeriaceae	^{A}*Alstroemeria aurea* Graham*	
	^{A}*Alstroemeria psittacina* Lehm.*	
	^{A}*Alstroemeria pulchella* L.f.*	
Amaranthaceae	^{N}*Alternanthera pungens* Kunth*	
	^{N}*Amaranthus caudatus* L.*	
	^{N}*Amaranthus deflexus* L.*	
	^{N}*Amaranthus hybridus* L.*	
	^{N}*Amaranthus spinosus* L.*	
	^{N}*Amaranthus viridis* L.*	
	^{A}*Celosia cristata* L.*	
	^{N}*Gomphrena celosioides* Mart.*	
	^{N}*Guilleminea densa* (Willd. ex Roem. & Schult.) Moq.*	
	^{A}*Iresine herbstii* Hook.f.*	

Amaryllidaceae	[I]*Ammocharis coranica* (Ker Gawl.) Herb.	
	[I]*Crinum bulbispermum* (Burm.f.) Milne-Redh. & Schweick.	Declining
	[I]*Crinum macowanii* Baker	Declining
	[I]*Nerine laticoma* (Ker Gawl.) T.Durand & Schinz	
	[I]*Scadoxus puniceus* (L.) Friis & Nordal	
	[IC]*Clivia miniata* (Lindl.) Regel	Vulnerable
	[IC]*Crinum moorei* Hook.f.	Vulnerable
	[IC]*Cyrtanthus elatus* (Jacq.) Traub	
	[IC]*Haemanthus albiflos* Jacq.	
	[A]*Hippeastrum puniceum* (Lam.) Voss*	
	[A]*Hymenocallis festalis* Hort. ex Schmarse *	
	[A]*Hymenocallis littoralis* Salisb.*	
	[A]*Sprekelia formosissima* Herb.*	
	[A]*Zephyranthes grandiflora* Lindl.*	
	[G]*Narcissus* cultivar*	
Anacardiaceae	[I]*Searsia lancea* (L.f.) F.A.Barkley	
	[I]*Searsia leptodictya* (Diels) T.S.Yi, A.J.Mill. & J.Wen	
	[I]*Searsia pyroides* B (A.Rich.) T.S.Yi, A.J.Mill. & J.Wen	
	[IC]*Searsia pendulina* (Jacq.) Moffett	
	[N]*Schinus molle* L.*	C3 invader
	[N]*Schinus terebinthifolius* Raddi*	C3 invader
	[A]*Searsia chinensis* Mill.*	
Anthericaceae	[IC]*Chlorophytum comosum* (Thunb.) Jacques	
Apiaceae	[IC]*Berula erecta* (Huds.) Coville	
	[N]*Ammi majus* L.*	
	[N]*Apium graveolens* L.*	
	[N]*Ciclospermum leptophyllum* (Pers.) Sprague*	
	[N]*Coriandrum sativum* L.*	
	[N]*Daucus carota* L.*	
	[N]*Foeniculum vulgare* Mill.*	
	[A]*Petroselinum crispum* (Mill.) Nyman*	
Apocynaceae	[I]*Acokanthera oppositifolia* (Lam.) Codd	
	[I]*Pentarrhinum inspidum* E.Mey.	
	[IC]*Huernia hystrix* (Hook.f.) N.E.Br.	
	[IC]*Orbea variegata* (L.) Haw.	
	[IC]*Stapelia leendertziae* N.E.Br.	
	[N]*Araujia sericifera* Brot.*	C1 weed
	[N]*Catharanthus roseus* (L.) G.Don.*	
	[N]*Nerium oleander* L.*	C1 weed
	[N]*Vinca major* L.*	
	[A]*Hoya carnosa* (L.) R.Br.*	
	[A]*Pachypodium baronii* Costantin & Bois*	
	[A]*Plumeria rubra* L.*	
	[A]*Trachelospermum jasminoides* Lem.*	
Aponogetonaceae	[I]*Aponogeton junceus* Lehm.	
Aquifoliaceae	[A]*Ilex aquifolium* L.*	
	[A]*Ilex crenata* Thunb.*	
	[A]*Ilex wilsonii* Loes*	

Araceae	[I]*Zantedeschia aethiopica* (L.) Spreng.	
	[IC]*Zantedeschia pentlandii* (R.Whyte ex W.Watson) Wittm.	Vulnerable
	[A]*Alocasia macrorrhiza* (L.) Schott.*	
	[A]*Alocasia sanderiana* Hort. ex Bull*	
	[A]*Anthurium cupa*?*	
	[A]*Arum palaestinum* Boiss.*	
	[A]*Colocasia esculenta* (L.) Schott*	
	[A]*Dypsis lutescens* (H.Wendl.) Beentje & J.Dransf.*	
	[A]*Monstera deliciosa* Liebm.*	
	[A]*Philodendron selloum* K.Koch. ?*	
	[A]*Spathiphyllum x hybridum* N.E.Br.*	
	[A]*Syngonium podophyllum* Schott*	
	[G]*Zantedeschia elliottiana* (W.Watson) Engl.*	
Araliaceae	[I]*Cussonia paniculata* Eckl. & Zeyh.	
	[A]*Hedera helix* L.*	C3 invader
	[A]*Schefflera actinophylla* (Endl.) Harms*	C3 invader
	[A]*Schefflera arboricola* (Endl.) Harms*	
	[G]*x Fatshedera lizei* (Hort. ex Cochet) Guillaumin *	
	[G]*Hedera canariensis* Willd.*	
Arecaceae	[A]*Butia capitata* (Mart.) Becc.*	
	[A]*Chamaedorea elegans* Mart.*	
	[A]*Livistona australis* (R.Br.) Mart.*	
	[A]*Phoenix canariensis* Hort. ex Chabaud*	
	[A]*Phoenix dactylifera* L.*	
	[A]*Trachycarpus fortunei* H.Wendl.*	
	[A]*Washingtonia filifera* (Linden ex André) H.Wendl.*	
Aristolochiaceae	[A]*Aristolochia littoralis* Parodi*	
Asparagaceae	[I]*Asparagus laricinus* Burch.	
	[I]*Asparagus plumosus* Baker	
	[I]*Asparagus setaceus* (Kunth) Jessop	
	[I]*Asparagus suaveolens* Burch.	
	[I]*Asparagus virgatus* Baker	
	[IC]*Asparagus africanus* Lam.	
	[IC]*Asparagus densiflorus* (Kunth) Jessop	
	[IC]*Asparagus falcatus* L.	
Asphodelaceae	[I]*Aloe arborescens* Mill.	
	[I]*Aloe grandidentata* Salm-Dyck	
	[I]*Aloe zebrina* Baker	
	[IC]*Aloe aristata* Haw.	
	[IC]*Aloe brevifolia* Mill.	Vulnerable
	[IC]*Aloe ferox* Mill.	
	[IC]*Aloe striatula* Haw.	
	[IC]*Aloe tenuior* Haw.	
	[IC]*Bulbine frutescens* (L.) Willd.	
	[IC]*Bulbine narcissifolia* Salm-Dyck	
	[IC]*Gasteria bicolor* Haw.	
	[IC]*Haworthia cymbiformis* (Haw.) Duval	
	[IC]*Haworthia fasciata* (Willd.) Haw.	Near threatened
	[IC]*Haworthia reinwardtii* (Salm-Dyck) Haw.	

	[IC]*Kniphofia praecox* Baker	
	[A]*Aloe striata* Haw.*	
	[A]*Aloe vera* (L.) Burm.f.*	
Aspleniaceae	[A]*Asplenium nidus* L.*	
Asteraceae	[I]*Artemisia afra* Jacq. ex Willd.	
	[I]*Berkheya radula* (Harv.) De Wild.	
	[I]*Conyza podocephala* DC.	
	[I]*Cotula australis* (Spreng) Hook.f.	
	[I]*Felicia muricata* (Thunb.) Nees	
	[I]*Gazania krebsiana* Less.	
	[I]*Gnaphalium nelsonii* Burtt Davy	
	[I]*Lactuca inermis* Forssk.	
	[I]*Pseudognaphalium luteo-album* (L..) Hilliard & B.L.Burtt	
	[I]*Senecio barbertonicus* Klatt	
	[I]*Tripteris aghillana* DC.	
	[IC]*Dimorphotheca ecklonis* DC.	
	[IC]*Dimorphotheca jucunda* E.Phillips	
	[IC]*Euryops chrysanthemoides* (DC.) B.Nord.	
	[IC]*Felicia amelloides* (L.) Voss	
	[IC]*Gerbera jamesonii* Bolus ex Adlam	
	[IC]*Senecio articulatus* (L.) Sch.Bip.	
	[IC]*Senecio rowleyanus* H.Jacobsen	
	[IC]*Senecio scaposus* DC.	Endangered
	[IC]*Senecio tamoides* DC.	
	[IC]*Ursinia chrysanthemoides* (Less.) Harv.	
	[N]*Achillea millefolium* L.*	
	[N]*Ambrosia psilostachya* DC.*	
	[N]*Aster squamatus (Spreng.)* Hieron.*	
	[N]*Bidens bipinnata* L.*	
	[N]*Bidens pilosa* L.*	
	[N]*Centaurea cyanus* E.J.Hill*	
	[N]*Cichorium intybus* L.*	
	[N]*Cirsium vulgare* (Savi) Ten.*	C1 weed
	[N]*Conyza bonariensis* (L.) Cronquist*	
	[N]*Conyza canadensis* (L.) Cronquist*	
	[N]*Cosmos bipinnatus* Cav.*	
	[N]*Cosmos sulphureus* Cav.*	
	[N]*Gaillardia aristata* Pursh*	
	[N]*Galinsoga parviflora* Cav.*	
	[N]*Helianthus annuus* L.*	
	[N]*Hypochaeris radicata* L.*	
	[N]*Lactuca serriola* L.*	
	[N]*Picris echioides* L.*	
	[N]*Schkuhria pinnata* (Lam.) Cabrera*	
	[N]*Sonchus asper* (L.) Hill*	
	[N]*Sonchus oleraceus* L.*	
	[N]*Tagetes erecta* L.*	
	[N]*Tagetes minuta* L.*	
	[N]*Taraxacum officinale* Weber*	

	[N]*Tragopogon dubius* Scop.*	
	[N]*Verbesina encelioides* (Cav.) Benth. & Hook.*	
	[N]*Xanthium spinosum* L.*	C1 weed
	[N]*Xanthium strumarium* L.*	C1 weed
	[N]*Zinnia peruviana* (L.) L.*	
	[A]*Artemisia absinthium* L.*	
	[A]*Artemisia lactiflora* Wall. ex DC.*	
	[A]*Aster laevis* L.*	
	[A]*Aster novi-belgii* L.*	
	[A]*Aster tradescantii* L.*	
	[A]*Calendula officinalis* L.*	
	[A]*Centaurea cineraria* L.*	
	[A]*Chamaemelum nobile* (L.) All.*	
	[A]*Chrysanthemum frutescens* L.*	
	[A]*Chrysanthemum maximum* Ramond*	
	[A]*Chrysanthemum morifolium* Ramat.*	
	[A]*Coreopsis grandiflora* Hogg ex Sweet*	
	[A]*Dahlia excelsa* Benth.*	
	[A]*Dahlia imperialis* Roezl*	
	[A]*Heliopsis helianthoides* Sweet*	
	[A]*Leucanthemum maximum* (Ramond) DC.*	
	[A]*Ligularia dentata* (A.Grey) Hara*	
	[A]*Parthenium integrifolium* L.*	
	[A]*Solidago canadensis* L.*	
	[A]*Solidago virgauria*?* Same as *S. canadensis*	
	[A]*Tagetes patula* L.*	
	[A]*Tanacetum parthenium* (L.) Sch.Bip.*	
	[A]*Zinnia elegans* Jacq.*	
	[G]*Gazania x hybrida*?*	
	[G]*Lactuca sativa* L.*	
Balsaminaceae	[N]*Impatiens walleriana* Hook.f.*	
	[A]*Impatiens balsamina* L.*	
	[A]*Impatiens hawkeri* W.Bull*	
Basellaceae	[N]*Anredera cordifolia* (Ten.) Steenis*	C1 weed
Begoniaceae	[IC]*Begonia homonyma* Steud.	Endangered
	[IC]*Begonia sutherlandii* Hook.f.	
	[A]*Begonia coccinea* Hook.*	
	[A]*Begonia masoniana* Irmsch.*	
	[G]*Begonia semperflorens* Hook.*	
Berberidaceae	[A]*Berberis julianae* C.K.Schneid.*	
	[A]*Berberis thunbergii* DC.*	C3 invader
	[A]*Mahonia aquifolium* Nutt.*	
	[A]*Mahonia lomariifolia* Takeda*	
	[A]*Nandina domestica* Thunb.*	
Bignoniaceae	[IC]*Podranea ricasoliana* (Tanfani) Spraque	
	[IC]*Tecoma capensis* (Thunb.) Lindl.	
	[N]*Macfadyena unguis-cati* (L.) A.H.Gentry*	C1 weed
	[A]*Campsis grandiflora* K.Schum.*	
Blechnaceae	[IC]*Blechnum tabulare* (Thunb.) Kuhn	

Boraginaceae	[I]*Ehretia rigida* (Thunb.) Druce	
	[N]*Anchusa azurea* Mill.*	
	[A]*Symphytum officinale* L.*	
Brassicaceae	[I]*Lepidium africanum* (Burm.f.) DC.	
	[N]*Brassica juncea* (L.) Czern. & Coss. / (L.) Czern.*	
	[N]*Capsella bursa-pastoris* (L.) Medik	
	[N]*Coronopus didymus* (L.) Sm.*	
	[N]*Lepidium bonariense* L.*	
	[N]*Lobularia maritima* (L.) Desv.*	
	[N]*Sisymbrium orientale* L.*	
	[A]*Armoracia rusticana* P.Gaertn., B.Mey & Scherb.*	
	[A]*Brassica oleracea* L.*	
	[A]*Iberis sempervirens* L.*	
	[A]*Iberis umbellata* L.*	
Bromeliaceae	[A]*Aechmea fasciata* Baker*	
	[A]*Aechmea fulgens* Brongn.*	
	[A]*Tillandsia tenuifolia* L.*	
Buddlejaceae	[I]*Buddleja saligna* Willd.	
	[I]*Buddleja salviifolia* (L.) Lam.	
	[I]*Gomphostigma virgatum* (L.f.) Baill.	
Buxaceae	[A]*Buxus sempervirens* L.*	
Cactaceae	[N]*Cereus jamacaru* DC.*	C1 weed
	[N]*Opuntia exaltata* A.Berger*	C1 weed
	[N]*Opuntia ficus-indica* (L.) Mill.*	C1 weed
	[A]*Chamaecereus silvestrii* (Speg.) Britton & Rose*	
	[A]*Echinocactus grusonii* Hildm.*	
	[A]*Echinopsis multiplex* (Pfeiff.) Zucc. ex Pfeiff. & Otto*	
	[A]*Ferocactus hamatacanthus* Britton & Rose*	
	[A]*Mammillaria bombycina* Quehl & Quehl*	
	[A]*Mammillaria elegans* DC.*	
	[A]*Mammillaria elongata* DC.*	
	[A]*Mammillaria spinosissima* Lem.*	
	[A]*Nopalxochia ackermannii* (Haw.) F.M.Knuth*	
	[A]*Nopalxochia phyllanthoides* Britton & Rose*	
	[A]*Opuntia verschaffeltii* Cels ex F.A.C.Weber *	
	[A]*Pachycereus marginatus* (DC.) Britton & Rose*	
	[G]*Lophocereus schottii* (Engelm.) Britton & Rose *	
	[G]*Schlumbergera x buckleyi* (T.Moore) Tjaden*	
Campanulaceae	[A]*Campanula carpatica* Jacq.*	
	[A]*Campanula trachelium* L.*	
Cannabacea	[N]*Cannabis sativa* L.*	
	[N]*Canna indica* L.*	C1 weed
	[N]*Canna x generalis* L.H.Bailey*	C1 weed
Capparidaceae	[A]*Cleome spinosa* (Jacq.) Link / Jacq.*	
Caprifoliaceae	[A]*Abelia floribunda* Decne.*	
	[A]*Lonicera sempervirens* L.*	
	[A]*Sambucus nigra* L.*	
	[A]*Viburnum odoratissimum* Ker Gawl.*	

	[A]*Viburnum suspensum* Lindl.*	
	[A]*Viburnum tinus* L.*	
	[A]*Weigela florida* A.DC.*	
	[G]*Abelia x grandiflora* (Andre) Rehder*	
Caryophyllaceae	[I]*Herniaria erckertii* Herm.	
	[N]*Stellaria media* (L.) Vill.*	
	[A]*Dianthus barbatus* L.*	
	[A]*Dianthus caryophyllus* L.*	
	[A]*Dianthus chinensis* L.*	
	[A]*Gypsophila elegans* M.Bieb*	
	[A]*Saponaria ocymoides* L.*	
Casuarinaceae	[N]*Casuarina cunninghamiana* Miq*	C3 invader
Celastraceae	[A]*Euonymus fortunei* (Turcz.) Hand.-Mazz.*	
	[A]*Euonymus japonicus* Thunb.*	
Celtidaceae	[I]*Celtis africana* Burm.f.	
	[A]*Celtis australis* L.*	Proposed invaders
	[A]*Celtis occidentalis* L.*	Proposed invaders
	[A]*Celtis sinensis* Pers.*	Proposed invaders
Chenopodiaceae	[N]*Atriplex semibaccata* R.Br.*	
	[N]*Beta vulgaris* L.*	
	[N]*Chenopodium album* L.*	
	[N]*Chenopodium ambrosioides* L.*	
	[N]*Chenopodium carinatum* R.Br.*	
	[A]*Spinacia oleracea* L.*	
Combretaceae	[I]*Combretum erythrophyllum* (Burch.) Sond.	
Commelinaceae	[I]*Commelina benghalensis* L.	
	[I]*Commelina livingstonii* C.B.Clarke	
	[N]*Tradescantia fluminensis* Vell.*	
	[A]*Callisia repens* L.*	
	[A]*Tradescantia blossfeldiana* Hort. ex Blossfeld *	
	[A]*Tradescantia sillamontana* Matuda*	
	[A]*Tradescantia virginiana* L.*	
	[G]*Tradescantia discolor* L'Hér.*	
	[G]*Tradescantia pallida* (Rose) Hunt*	
Convallariaceae	[A]*Ophiopogon jaburan* Lodd.*	
	[A]*Ophiopogon japonicus* Ker Gawl.*	
Convolvulaceae	[I]*Convolvulus sagittatus* Thunb.	
	[I]*Ipomoea crassipes* Hook.	
	[I]*Ipomoea oblongata* E.Mey. ex. Choisy	
	[N]*Convolvulus arvensis* L.*	C1 weed
	[N]*Dichondra micrantha* Urb.*	
	[N]*Ipomoea purpurea* (L.) Roth*	C3 invader
	[A]*Evolvulus glomeratus* Nees & Mart.*	
	[A]*Ipomoea batatas* (L.) Lam.*	
Cornaceae	[G]*Aucuba japonica* Thunb.*	
Crassulaceae	[I]*Cotyledon orbiculata* L.	
	[I]*Kalanchoe thyrsiflora* Harv.	
	[IC]*Crassula capitella* Thunb.	

	[IC]*Crassula multicava* Lem.	
	[IC]*Crassula ovata* (Mill.) Druce	
	[IC]*Crassula tetragona* L.	
	[IC]*Kalanchoe crenata* (Andrews) Haw.	
	[N]*Bryophyllum delagoense* (Eckl. & Zeyh.) Schinz*	C1 weed
	[A]*Aeonium arboreum* (L.) Webb & Berthel.*	
	[A]*Aeonium canariense* Webb & Berthel.*	
	[A]*Echeveria elegans* A.Berger*	
	[A]*Echeveria pringlei* (S.Watson) Rose *	
	[A]*Echeveria pulvinata* Rose ex Hook.f.*	
	[A]*Echeveria secunda* Booth ex Lindl.*	
	[A]*Kalanchoe blossfeldiana* Poelln.*	
	[A]*Kalanchoe fedtschenkoi* Raym.-Hamet & H.Perrier*	
	[A]*Rosularia chrysantha* (Boiss.) Takht.*	
	[A]*Sedum morganianum* Walther*	
	[A]*Sedum pachyphyllum* Rose*	
	[A]*Sedum rubrotinctum* R.T.Clausen*	
	[A]*Sedum sieboldii* Hort. ex G.Don *	
Cucurbitaceae	[I]*Citrullus lanatus* (Thunb.) Matsum. & Nakai	
	[I]*Cucumis myriocarpus* Naudin	
	[A]*Cucurbita pepo* L.*	
Cupressaceae	[N]*Cupressus arizonica* Greene*	
	[N]*Juniperus virginiana* L.*	Proposed invaders
	[A]*Chamaecyparis lawsoniana* (A.Murr.) Parl.*	
	[A]*Chamaecyparis obtusa* (Siebold & Zucc.) Endl.*	
	[A]*Cupressus macrocarpa* Hartw.*	
	[A]*Cupressus sempervirens* L.*	
	[A]*Juniperus media* V.D.Dmitriev *	
	[A]*Juniperus scopulorum* Sarg.*	
	[A]*Platycladus orientalis* (L.) Franco*	
	[A]*Thuja occidentalis* L.*	
Cyatheaceae	[A]*Cyathea australis* (R.Br.) Domin*	
Cycadaceae	[A]*Cycas revoluta* Thunb.*	
Cyperaceae	[I]*Bulbostylis hispidula* (Vahl) R.W.Haines	
	[I]*Cyperus albostriatus* Schrad.	
	[I]*Cyperus esculentus* L.	
	[I]*Cyperus haematocephalus* C.B.Clarke	
	[I]*Schoenoplectus corymbosus* (Roem. & Schult.) J.Raynal	
	[IC]*Cyperus involucratus* Rottb.	
	[IC]*Cyperus prolifer* Lam.	
	[IC]*Cyperus textilis* Thunb.	
	[G]*Carex oshimensis* Nakai*	
Dicksoniaceae	[N]*Dicksonia antarctica* Labill.*	
Dipsacaceae	[IC]*Scabiosa africana* L.	
Dracaenaceae	[A]*Sansevieria trifasciata* Prain*	
	[G]*Dracaena deremensis* Engl.*	
Dryopteridaceae	[IC]*Polystichum wilsonii* H.Christ	
	[A]*Polystichum proliferum* (R.Br.) C.Presl*	

Elaeagnaceae	^{A}*Elaeagnus pungens* Thunb.*	
Equisetaceae	^{I}*Equisetum ramosissimum* Desf.	
Ericaceae	^{A}*Rhododendron indicum* Sweet / (L.) Sweet*	
Escalloniaceae	^{A}*Escallonia rubra* Pers.*	
Euphorbiaceae	^{I}*Euphorbia inaequilatera* Sond.	
	^{N}*Euphorbia hirta* L.*	
	^{N}*Euphorbia peplus* L.*	
	^{N}*Euphorbia prostrata* Aiton*	
	^{N}*Euphorbia pulcherrima* Willd. ex Klotzsch*	
	^{N}*Jatropha multifida* L.*	
	^{N}*Manihot esculenta* Crantz*	
	^{N}*Ricinus communis* L.*	C2 invader
	^{A}*Acalypha hispida* Burm.f*	
	^{A}*Breynia disticha* J.R.Forst. & G.Forst.*	
	^{A}*Codiaeum variegatum* (L.) A.Juss. *	
Fabaceae	^{I}*Acacia caffra* (Thunb.) Willd.	
	^{I}*Acacia erioloba* E.Mey.	Declining
	^{I}*Acacia galpinii* Burtt Davy	
	^{I}*Acacia karroo* Hayne	
	^{I}*Lotononis listii* Polhill	
	^{I}*Vigna unguiculata* (L.) Walp.	
	^{IC}*Acacia ataxacantha* DC.	
	^{IC}*Bolusanthus speciosus* (Bolus) Harms	
	^{IC}*Faidherbia albida* (Delile) A.Chev.	
	^{IC}*Indigofera pechuelii* Kuntze	
	^{N}*Acacia baileyana* F.Muell.*	C3 invader
	^{N}*Acacia melanoxylon* R.Br.*	C2 invader
	^{N}*Albizia julibrissin* (Willd.) Durazz.*	C3 invader
	^{N}*Ceratonia siliqua* L.*	
	^{N}*Crotalaria agatiflora* Schweinf.*	C3 invader
	^{N}*Erythrina crista-galli* L.*	
	^{N}*Gleditsia triacanthos* L.*	C2 invader
	^{N}*Medicago laciniata* (L.) Mill.*	
	^{N}*Medicago sativa* L.*	
	^{N}*Melilotus alba* Desr.*	
	^{N}*Parkinsonia aculeata* L.*	Proposed invaders
	^{N}*Prosopis glandulosa* Torr.*	C2 invader
	^{N}*Robinia pseudoacacia* L.*	C2 invader
	^{N}*Senna corymbosa* (Lam.) Irwin & Barneby*	Special effect weed
	^{N}*Spartium junceum* L.*	C1 weed
	^{N}*Trifolium repens* L.*	
	^{A}*Bauhinia variegata* L.*	C3 invader
	^{A}*Caesalpinia ferrea* Mart. ex Tul. *	
	^{A}*Calliandra brevipes* Benth.*	
	^{A}*Cercis siliquastrum* L.*	
	^{A}*Lathyrus latifolius* L.*	
	^{A}*Lathyrus odoratus* L.*	
	^{A}*Phaseolus vulgaris* L.*	
	^{A}*Styphnolobium japonicum* (L.) Schott*	

	[A]*Wisteria floribunda* (Willd.) DC.*	
	[A]*Wisteria sinensis* Sweet*	
Fagaceae	[N]*Quercus robur* L.*	
	[A]*Quercus suber* L.*	
Fumariaceae	[N]*Fumaria muralis* Sond. ex. W.D.J.Koch*	
Geraniaceae	[IC]*Geranium incanum* Burm.f.	
	[IC]*Pelargonium crispum* (P.J.Bergius) L'Hér.	
	[IC]*Pelargonium peltatum* (L.) L'Her.	
	[IC]*Pelargonium reniforme* Curtis	
	[A]*Geranium macrorrhizum* L.*	
	[A]*Pelargonium hortorum* L.H.Bailey*	
	[G]*Pelargonium domesticum* L.H.Bailey *	
Ginkgoaceae	[A]*Ginkgo biloba* L.*	
Gunneraceae	[A]*Gunnera manicata* Linden*	
Hamamelidaceae	[A]*Liquidambar styraciflua* L.*	
Hyacinthaceae	[I]*Eucomis autumnalis* (Mill.) Chitt.	Declining
	[I]*Ornithogalum abyssinicum* (Jacq.) J.C.Manning & Goldblatt	
	[I]*Ornithogalum viride* (L.) J.C.Manning & Goldblatt	
	[IC]*Eucomis pallidiflora* Baker	Near threatened
	[IC]*Ledebouria petiolata* J.C.Manning & Goldblatt	
	[IC]*Ledebouria socialis* (Baker) Jessop	
	[IC]*Ornithogalum setosum* (Jacq.) J.C. Manning & Goldblatt	
	[IC]*Ornithogalum tenuifolium* F.Delaroche	
	[IC]*Ornithogalum thyrsoides* Jacq.	
Hypericaceae	[IC]*Hypericum revolutum* Vahl	
Hypoxidaceae	[I]*Hypoxis hemerocallidea* Fisch., C.A.Mey. & Avé-Lall.	Declining
Iridaceae	[I]*Gladiolus dalenii* Van Geel	
	[IC]*Crocosmia aurea* (Pappe ex Hook.f.) Planch.	
	[IC]*Crocosmia paniculata* (Klatt) Goldblatt	
	[IC]*Dietes bicolor* (Steud.) Sweet ex Klatt	Rare
	[IC]*Dietes grandiflora* N.E.Br.	
	[IC]*Dietes iridioides* (L.) Sweet ex Klatt	
	[A]*Iris ensata* Thunb.*	
	[A]*Iris pseudacorus* L.*	
	[A]*Iris x germanica* L.*	
	[A]*Iris xiphium* L.*	
	[G]*Freesia hybrida* Hort.*	
Juglandaceae	[A]*Carya illinoinensis* (Wangenh.) K.Koch*	
Juncaceae	[I]*Juncus effusus* L.	
Lamiaceae	[I]*Ocimum labiatum* (N.E.Br.) A.J.Paton	
	[I]*Plectranthus madagascariensis* (Pers.) Benth.	
	[I]*Plectranthus neochilus* Schltr.	
	[I]*Salvia repens* Burch. ex Benth.	
	[I]*Salvia runcinata* L.f.	
	[I]*Teucrium trifidum* Retz.	
	[IC]*Hemizygia pretoriae* (Gürke) M.Ashby	
	[IC]*Karomia speciosa* (Hutch. & Corbishley) R.Fern.	
	[IC]*Ocimum serratum* (Schltr.) A.J.Paton	

	[IC]*Plectranthus ciliatus* E.Mey. ex. Benth [IC]*Plectranthus hilliardiae* Codd [IC]*Plectranthus saccatus* Benth. [N]*Plectranthus barbatus* Andrews* [N]*Salvia reflexa* Hornem.* [N]*Scutellaria racemosa* Pers.* [A]*Ajuga reptans* L.* [A]*Coleus thyrsoideus* Baker* [A]*Galeobdolon argentatum* Smejkal* [A]*Lamium galeobdolon* (L.) Crantz* [A]*Lavandula angustifolia* Mill.* [A]*Lavandula latifolia* Medik.* [A]*Lavandula stoechas* L.* [A]*Mentha pulegium* L.* [A]*Nepeta cataria* L.* [A]*Ocimum basilicum* L.* [A]*Origanum majorana* L.* [A]*Origanum vulgare* L.* [A]*Rosmarinus officinalis* L.* [A]*Salvia elegans* Vahl* [A]*Salvia farinacea* Benth.* [A]*Salvia greggii* A.Gray* [A]*Salvia leucantha* Cav.* [A]*Salvia microphylla* Kunth* [A]*Salvia splendens* Sellow ex Schult.* [A]*Stachys byzantina* K.Koch.* [A]*Thymus vulgaris* L.* [G]*Coleus hybridus* Hort ex Voss.* [G]*Mentha spicata* L.*	
Lauraceae	[A]*Cinnamomum camphora* (L.) J.Presl * [A]*Laurus nobilis* L.* [A]*Litsea glutinosa* (Lour.) C.B.Rob.* [A]*Persea americana* Mill.*	C1 weed C1 weed
Liliaceae	[A]*Aspidistra elatior* Blume* [A]*Dianella intermedia* Endl.* [A]*Hemerocallis aurantiaca* Baker* [A]*Hemerocallis fulva* L.* [A]*Hemerocallis lilioasphodelus* L.* [A]*Lilium lancifolium* Thunb.* [A]*Liriope muscari* L.H.Bailey*	
Lobeliaceae	[IC]*Lobelia erinus* L.	
Lythraceae	[A]*Cuphea hyssopifolia* Kunth* [A]*Cuphea ignea* A.DC.* [A]*Cuphea micropetala* Kunth.* [A]*Lagerstroemia indica* L.*	
Magnoliaceae	[A]*Magnolia grandiflora* L.* [G]*Magnolia x soulangiana* Soul.-Bod.*	
Malvaceae	[I]*Sida chrysantha* Ulbr.	

	[I]*Sida rhombifolia* L. [I]*Sida spinosa* L. [IC]*Anisodontea elegans* (Cav.) Bates [IC]*Anisodontea julii* (Burch. ex DC.) Bates [N]*Malva neglecta* Wallr.* [N]*Malva parviflora* L.* [N]*Malva verticillata* L.* [N]*Malvastrum coromandelianum* (L.) Garcke* [N]*Modiola caroliniana* (L.) G.Don* [A]*Abutilon megapotamicum* St.-Hil. & Nauden* [A]*Abutilon pictum* (Gillies ex Hook. & Arn.) Walp.* [A]*Alcea rosea* L.* [A]*Hibiscus rosa-sinensis* L.* [A]*Hibiscus syriacus* L.*	
Marantaceae	[A]*Calathea musaica* (Bull.) L.H.Bailey* [G]*Maranta leuconeura* Morren*	
Meliaceae	[N]*Melia azedarach* L.*	C3 invader
Melianthaceae	[IC]*Melianthus elongatus* Wijnands	
Mesembryan-themaceae	[I]*Delosperma herbeum* (N.E.Br.) N.E.Br. [IC]*Aptenia cordifolia* (L.f.) Schwantes [IC]*Carpobrotus dimidiatus* (Haw.) L.Bolus [IC]*Carpobrotus edulis* (L.) L.Bolus [IC]*Dracophilus dealbatus* (N.E.Br.) Walgate [IC]*Lampranthus aureus* (L.) N.E.Br. [IC]*Lampranthus blandus* (Haw.) Schwantes [IC]*Lampranthus glaucoides* (Haw.) N.E.Br. [IC]*Lampranthus glaucus* (L.) N.E.Br. [IC]*Lampranthus roseus* (Willd.) Schwantes	 Endangered Vulnerable
Moraceae	[N]*Morus alba* L.* [A]*Ficus benjamina* L.* [A]*Ficus carica* L.* [A]*Ficus elastica* Roxb.* [A]*Ficus lyrata* Warb.* [A]*Ficus pumila* L.*	C3 invader
Musaceae	[IC]*Ensete ventricosum* (Welw.) Cheesman [G]*Musa paradisiaca* L.* [G]*Musa acuminata* Colla*	
Myrtaceae	[N]*Myrtus communis* L.* [A]*Acca sellowiana* (Berg) Burret* [A]*Callistemon citrinus* (Curtis) Stapf / (Curtis) Skeels* [A]*Callistemon viminalis* (Sol. ex Gaertn.) Cheel* [A]*Eucalyptus rhodantha* Blakely & Steedm. * [A]*Leptospermum scoparium* J.R. & G. Forst.* [A]*Melaleuca armillaris* (Sol. ex Gaertn.) Sm.* [A]*Melaleuca linariifolia* Sm.* [A]*Syzygium paniculatum* Gaertn.*	 C3 invader Proposed invaders
Nephrolepidaceae	[N]*Nephrolepis exaltata* (L.) Schott*	C3 invader
Nyctaginaceae	[N]*Boerhavia diffusa* L.*	

	[N]*Boerhavia erecta* L.*	
	[N]*Mirabilis jalapa* L.*	C3 invader
	[A]*Bougainvillea glabra* Choisy*	
Nymphaeaceae	[I]*Nymphaea nouchali* Burm.f.	
Oleaceae	[I]*Olea europaea* L.	
	[IC]*Jasminum multipartitum* Hochst.	
	[N]*Fraxinus angustifolia* Vahl*	
	[A]*Fraxinus pennsylvanica* Marsh*	
	[A]*Fraxinus velutina* Torr.*	
	[A]*Jasminum humile* L.*	Special effect weed
	[A]*Jasminum nudiflorum* Lindl.*	
	[A]*Jasminum officinale* L.*	
	[A]*Jasminum polyanthum* Franch*	
	[A]*Ligustrum ibota* Siebold*	
	[A]*Ligustrum lucidum* W.T.Aiton*	C3 invader
Onagraceae	[N]*Gaura lindheimeri* Engelm. & A.Gray*	
	[N]*Oenothera rosea* L'Hér. ex. Aiton*	C3 invader
	[A]*Oenothera speciosa* Nutt*	
	[G]*Fuchsia x hybrida* Hort.*	
Orchidaceae	[A]*Cymbidium insigne* Rolfe*	
Oxalidaceae	[I]*Oxalis purpurea* L.	
	[IC]*Oxalis lanata* L.f.	
	[N]*Oxalis corniculata* L.*	
	[N]*Oxalis latifolia* Kunth*	
	[A]*Oxalis articulata* Sav.*	
Papaveraceae	[N]*Argemone ochroleuca* Sweet*	C1 weed
	[N]*Eschscholzia californica* Cham.*	
Passifloraceae	[A]*Passiflora aculeata* Hort. ex Mast. *	
Phyllanthaceae	[I]*Phyllanthus parvulus* Sond.	
Phytolaccaceae	[N]*Phytolacca dioica* L.*	C3 invader
Pinaceae	[N]*Pinus halepensis* Mill.*	C2 invader
	[A]*Cedrus deodara* (Roxb. ex D.Don) G.Don *	
	[A]*Pinus mugo* Turra*	
	[A]*Pinus roxburghii* Sarg.*	C2 invader
	[A]*Sciadopitys verticillata* Siebold & Zucc. *	
Piperaceae	[A]*Peperomia marmorata* Hook.f.*	
Plantaginaceae	[I]*Plantago lanceolata* L.	
	[I]*Plantago major* L.	
Platanaceae	[A]*Platanus occidentalis* L.*	
	[G]*Platanus x acerifolia* Willd.*	
Plumbaginaceae	[IC]*Plumbago auriculata* Lam.	
	[A]*Armeria maritima* (Mill.) Willd.*	
	[A]*Ceratostigma willmotianum* Stapf*	
Poaceae	[I]*Brachiaria eruciformis* (Sm.) Griseb.	
	[I]*Brachiaria marlothii* (Hack.) Stent	
	[I]*Chloris pycnothrix* Trin.	
	[I]*Cynodon dactylon* (L.) Pers.	C2 invader
	[I]*Cynodon hirsutus* Stent	

	[I]*Cynodon transvaalensis* Burtt Davy	
	[I]*Digitaria eriantha* Steud.	
	[I]*Digitaria ternata* (A.Rich.) Stapf	
	[I]*Eleusine coracana* (L.) Gaertn.	
	[I]*Enneapogon scoparius* Stapf	
	[I]*Eragrostis barbinodis* Hack.	
	[I]*Eragrostis biflora* Hack. ex Schinz	
	[I]*Eragrostis cilianensis* (All.) Vignolo ex Janch.	
	[I]*Eragrostis curvula* (Schrad.) Nees	
	[I]*Eragrostis inamoena* K.Schum.	
	[I]*Eragrostis lehmanniana* Nees	
	[I]*Eragrostis superba* Peyr.	
	[I]*Eragrostis trichophora* Coss. & Durieu	
	[I]*Eustachys paspaloides* (Vahl) Lanza & Mattei	
	[I]*Hyparrhenia hirta* (L.) Stapf	
	[I]*Melinis repens* (Willd.) Zizka	
	[I]*Panicum coloratum* L.	
	[I]*Panicum maximum* Jacq.	
	[I]*Paspalum scrobiculatum* L.	
	[I]*Setaria lindenbergiana* (Nees) Stapf	
	[I]*Setaria sphacelata* (Schumach.) Moss	
	[I]*Setaria verticillata* (L.) P.Beauv.	
	[I]*Sorghum bicolor* (L.) Moench	
	[I]*Sporobolus africanus* (Poir.) A.Robyns & Tournay	
	[I]*Sporobolus fimbriatus* (Trin.) Nees	
	[I]*Tragus berteronianus* Schult.	
	[I]*Triraphis andropogonoides* (Steud.) E.Phillips	
	[I]*Urochloa panicoides* P.Beauv.	
	[IC]*Dactyloctenium australe* Steud.	
	[N]*Agrostis montevidensis* Spreng. ex Nees*	
	[N]*Arundo donax* L.*	C1 weed
	[N]*Bromus catharticus* Vahl*	
	[N]*Cortaderia selloana* (Schult.) Asch. & Graebn.*	C1 weed
	[N]*Cynodon aethiopicus* Clayton & Harlan*	
	[N]*Eragrostis tef* (Zucc.) Trotter*	
	[N]*Lolium perenne* L.*	C2 invader
	[N]*Paspalum dilatatum* Poir.*	
	[N]*Pennisetum clandestinum* Hochst. ex Chiov.*	C2 invader
	[N]*Pennisetum setaceum* (Forssk.) Chiov.*	C1 weed
	[N]*Poa annua* L.*	
	[N]*Poa pratensis* L.*	
	[A]*Arundinaria pygmaea* (Miq.) Asch & Graebn*	
	[A]*Arundinaria variegata* (Siebold ex Miq.) Makino*	
	[A]*Cymbopogon nardus* (L.) Rendle*	
	[A]*Festuca rubra* L.*	
	[G]*Bambusa glaucescens* Siebold ex Munro *	
	[G]*Zea mays* L.*	
Podocarpaceae	[IC]*Podocarpus falcatus* (Thunb.) R.Br. ex. Mirb.	
	[IC]*Podocarpus henkelii* Stapf ex Dallim. & Jacks.	

	[IC] *Podocarpus latifolius* (Thunb.) R.Br. ex Mirb.	
Polygalaceae	[IC] *Polygala myrtifolia* L.	
Polygonaceae	[N] *Fallopia convolvulus* (L.) Holub*	
	[N] *Rumex crispus* L.*	C3 invader
	[A] *Antigonon leptopus* Hook. & Arn.*	Special effect weed
Polypodiaceae	[A] *Cyrtomium falcatum* (L.f.) C.Presl*	
Portulacaceae	[I] *Portulaca grandiflora* Hook.	
	[I] *Portulaca quadrifida* L.	
	[I] *Portulacaria afra* Jacq.	
	[I] *Talinum arnotii* Hook.f.	
	[N] *Portulaca oleracea* L.*	
	[N] *Talinum portulacifolium* (Forssk.) Asch. ex Schweinf.*	
Primulaceae	[A] *Lysimachia nummularia* L.*	
	[A] *Primula obconica* Hance*	
	[G] *Primula polyantha* Mill.*	
Proteaceae	[N] *Grevillea robusta* Cunn. ex R.Br.*	C3 invader
	[A] *Banksia coccinea* R.Br.*	
	[A] *Grevillea rosmarinifolia* A.Cunn.*	
Pteridaceae	[N] *Adiantum raddianum* C.Presl*	
Punicaceae	[A] *Punica granatum* L.*	
Ranunculaceae	[I] *Clematis brachiata* Thunb.	
	[I] *Ranunculus multifidus* Forssk.	
	[A] *Clematis campaniflora* Brot.*	
	[G] *Anemone coronaria* L.*	
Restionaceae	[IC] *Chondropetalum tectorum* (L.f.) Raf.	
Rhamnaceae	[I] *Ziziphus zeyheriana* Sond.	
Rosaceae	[N] *Cotoneaster franchetii* Boiss.*	C3 invader
	[N] *Cotoneaster pannosus* Franch.*	C3 invader
	[N] *Cydonia oblonga* Mill.*	
	[N] *Duchesnea indica* (Andrews) Focke*	
	[N] *Prunus persica* (L.) Batsch.*	
	[N] *Pyracantha angustifolia* (Franch.) C.K.Scheid.*	C3 invader
	[N] *Pyracantha coccinea* M.Roem.*	
	[N] *Pyracantha crenulata* (D.Don) M.Roem.*	C3 invader
	[N] *Pyrus communis* L.*	
	[N] *Rosa rubiginosa* L.*	C1 weed
	[A] *Chaenomeles speciosa* (Sweet) Nakai*	
	[A] *Cotoneaster frigidus* Wall. ex Lindl.*	
	[A] *Cotoneaster horizontalis* Decne.*	
	[A] *Cotoneaster hupehensis* Rehder & E.H.Wilson*	
	[A] *Crataegus pubescens* (Kunth) Steud.*	C3 invader
	[A] *Eriobotrya japonica* (Thunb.) Lindl.*	C3 invader
	[A] *Malus spectabilis* (Aiton) Borkh.*	
	[A] *Malus sylvestris* Mill.*	
	[A] *Photinia glabra* (Thunb.) Maxim.*	
	[A] *Photinia serrulata* Lindl.*	
	[A] *Prunus armeniaca* L.*	
	[A] *Prunus cerasifera* Ehrh.*	C3 invader

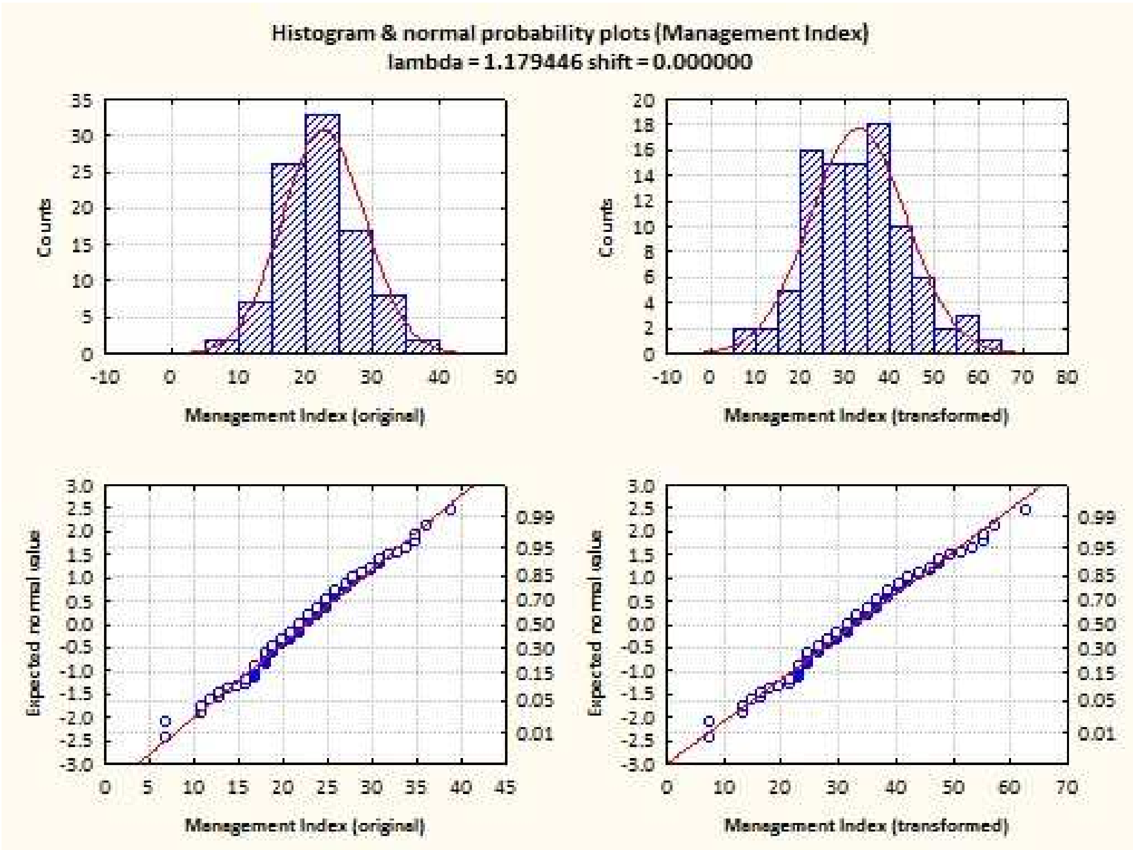
	[A] *Prunus laurocerasus* L.* [A] *Prunus domestica* L.* [A] *Raphiolepis indica* Lindl* [A] *Rosa banksiae* R.Br. in W.T.Aiton* [A] *Spiraea arguta* Hoffm.-Grob.* [A] *Spiraea cantoniensis* Lour.* [G] *Fragaria ananassa* Duchesne* [G] *Malus domestica* (Borkh.) Likhonos* [G] *Prunus nigra* Ait.* [G] *Rosa chinensis* Jacq.* [G] *Rosa x rehderiana* Blackb.*	
Rubiaceae	[N] *Richardia brasiliensis* Gomez* [A] *Coprosma repens* A.Rich.* [A] *Gardenia augusta* (L.) Merr.* [G] *Coprosma kirkii* Cheeseman*	
Rutaceae	[IC] *Coleonema pulchellum* I.Williams [N] *Ruta graveolens* L.* [A] *Citrus aurantifolia* (Christm.) Swingle* [A] *Citrus calamondin*?* [A] *Citrus limon* (L.) Burm.f.* [A] *Citrus reticulata* Blanco* [A] *Fortunella japonica* (Thunb.) Swingle* [A] *Fortunella margarita* Swingle* [G] *Citrus sinensis* (L.) Osbeck*	
Salicaceae	[I] *Salix mucronata* Thunb. [IC] *Dovyalis caffra* (Hook.f. & Harv.) Hook.f. [N] *Salix babylonica* L.* [N] *Salix fragilis* L.* [A] *Populus deltoides* Bartram ex Marsh* [A] *Populus simonii* Carrière*	 C2 invader C2 invader Proposed invaders C3 invader
Sapindaceae	[I] *Dodonaea viscosa* Jacq.	
Saururaceae	[A] *Houttuynia cordata* Thunb.*	
Saxifragaceae	[A] *Hydrangea macrophylla* (Thunb.) Ser.* [A] *Hydrangea quercifolia* Bertram* [A] *Hydrangea serrata* (Thunb.) Ser.*	
Scrophulariaceae	[IC] *Freylinia tropica* S.Moore [IC] *Nemesia strumosa* (Herb. Banks. ex. Benth.) Benth. [IC] *Phygelius capensis* E.Mey. ex Benth. [N] *Linaria maroccana* Hook.f.* [N] *Veronica persica* Desf. ex Poir.* [A] *Antirrhinum majus* L.* [A] *Hebe pimeleoides* (Hook.f.) Cockayne & Allan * [A] *Hebe salicifolia* (G.Forst.) Pennell* [A] *Hebe speciosa* Andersen* [A] *Scrophularia nodosa* L.* [A] *Verbascum thapsus* L.*	Rare Near threatened
Simaroubaceae	[A] *Ailanthus altissima* (Mill.) Swingle*	C3 invader
Solanaceae	[I] *Solanum lichtensteinii* Willd.	

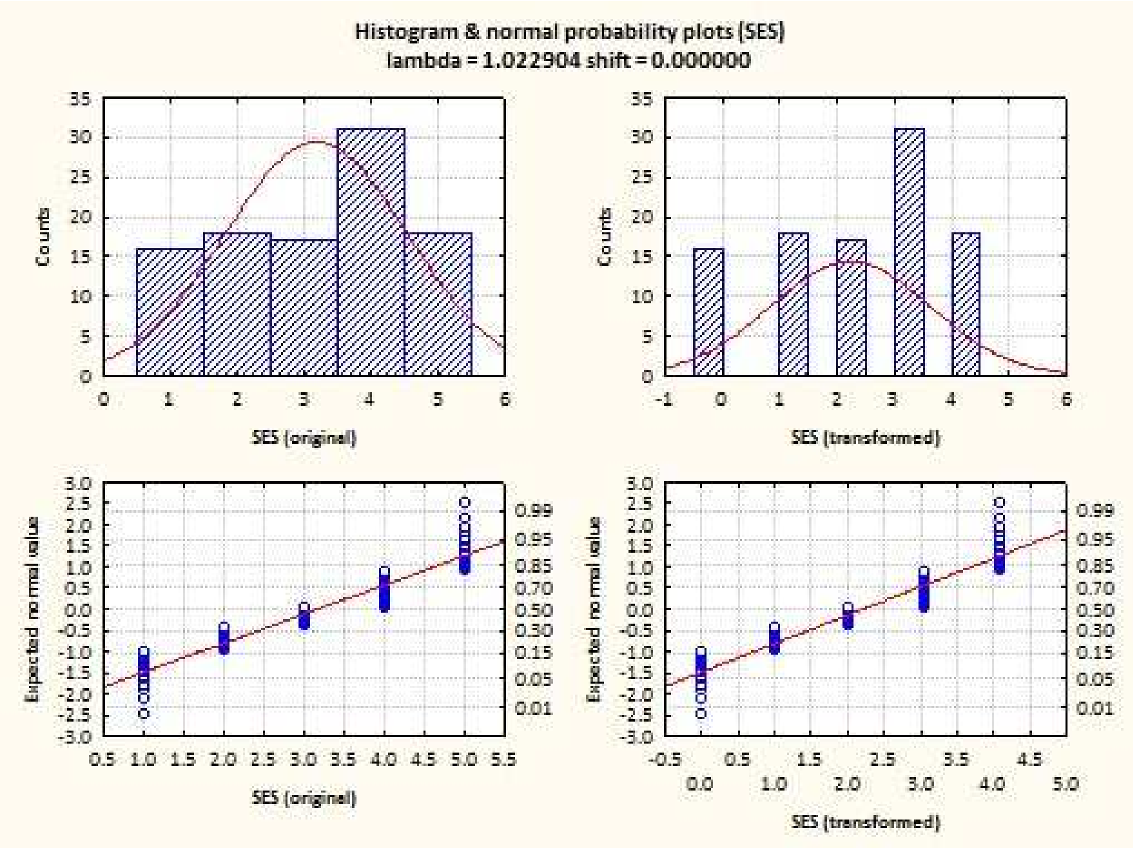
	[I]*Solanum panduriforme* E.Mey.	
	[N]*Capsicum annuum* L.*	
	[N]*Capsicum frutescens* L.*	
	[N]*Cestrum elegans* (Brongn.) Schltdl.*	C1 weed
	[N]*Cestrum laevigatum* Schltdl.*	C1 weed
	[N]*Datura ferox* L.*	C1 weed
	[N]*Datura inoxia* Mill.*	C1 weed
	[N]*Datura stramonium* L.*	C1 weed
	[N]*Nierembergia linariifolia* Graham*	
	[N]*Physalis angulata* L.*	
	[N]*Physalis viscosa* L.*	
	[N]*Solanum elaeagnifolium* Cav.*	C1 weed
	[N]*Solanum mauritianum* Scop.*	C1 weed
	[N]*Solanum nigrum* L.*	
	[N]*Solanum pseudocapsicum* L.*	C3 invader
	[N]*Solanum sisymbriifolium* Lam.*	C1 weed
	[N]*Solanum tuberosum* L.*	
	[A]*Brunfelsia pauciflora* (Cham. & Schltdl.) Benth.*	
	[A]*Cestrum diurnum* L.*	
	[A]*Cestrum nocturnum* L.*	
	[A]*Cestrum parqui* L'Hér.*	C1 weed
	[A]*Lycopersicon esculentum* Mill.*	
	[A]*Solanum capsicastrum* Link ex. Schauer*	
	[A]*Solanum melongena* L.*	
	[A]*Solanum rantonnetii* Carriere*	
	[A]*Solanum wrightii* Benth.*	
	[G]*Brugmansia x candida* Pers.*	
	[G]*Petunia x hybrida* Vilm.*	
Sterculiaceae	[A]*Brachychiton populneus* (Schott & Endl.) R.Br.*	C3 invader
Strelitziaceae	[IC]*Strelitzia alba* (L.f.) Skeels	
	[IC]*Strelitzia nicolai* Regel & Körn	
	[IC]*Strelitzia reginae* Aiton	
Tamaricaceae	[N]*Tamarix ramosissima* Ledeb.*	C3 invader
Theaceae	[A]*Camellia japonica* L.*	
Thymelaeaceae	[IC]*Dais cotinifolia* L.	
Tiliaceae	[I]*Corchorus asplenifolius* Burch.	
	[I]*Grewia flava* DC.	
	[I]*Grewia occidentalis* L.	
Tropaeolaceae	[G]*Tropaeolum majus* L.*	
Ulmaceae	[N]*Ulmus parvifolia* Jacq.*	C3 invader
	[N]*Ulmus procera* Salisb.*	
	[A]*Zelkova serrata* (Thunb.) Makino*	
Urticaceae	[N]*Urtica urens* L.*	
Verbenaceae	[I]*Lantana rugosa* Thunb.	
	[N]*Duranta erecta* L.*	Proposed invaders
	[N]*Lantana camara* L.*	C1 weed
	[N]*Phyla nodiflora* (L.) Greene*	
	[N]*Verbena aristigera* S.Moore*	

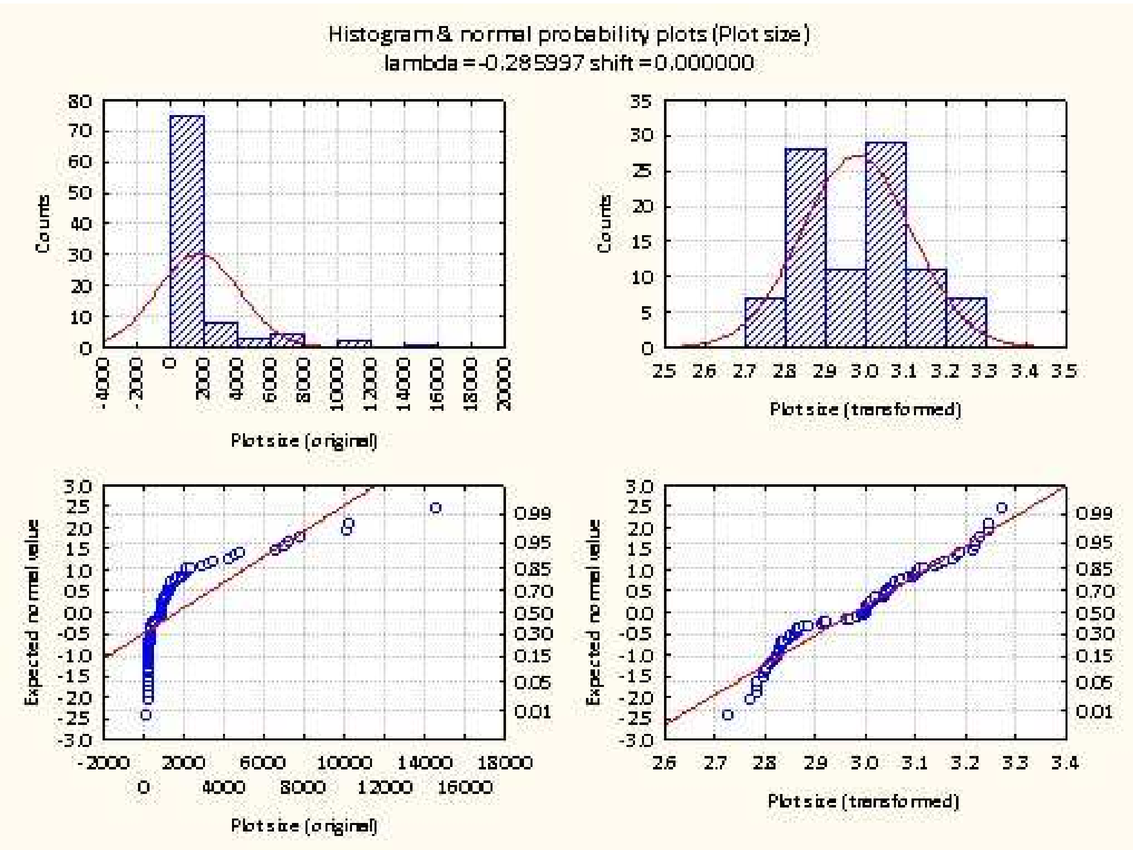
	[N]*Verbena bonariensis* L.* [A]*Aloysia triphylla* (L'Her.) Britton* [A]*Lantana montevidensis* (Spreng.) Briq.* [A]*Petrea volubilis* L.* [A]*Vitex agnus-castus* L.* [G]*Verbena hybrida* Groenland & Rümpler *	
Violaceae	[A]*Viola odorata* L.* [N]*Viola tricolor* L.* [G]*Viola wittrockiana* Gams ex Nauenb. & Buttler *	
Vitaceae	[IC]*Rhoicissus rhomboidea* (E.Mey. ex Harv.) Planch. [IC]*Rhoicissus tomentosa* (Lam.) Wild & R.B.Drumm. [A]*Parthenocissus quinquefolia* (L.) Planch.* [A]*Parthenocissus tricuspidata* Planch.* [A]*Parthenocissus vitacea* Hitchc. * [A]*Vitis vinifera* L.*	
Woodsiaceae	[A]*Athyrium filix-femina* (L.) Roth *	
Zamiaceae	[IC]*Encephalartos horridus* (Jacq.) Lehm. [IC]*Encephalartos lebomboensis* I.Verd. [IC]*Encephalartos natalensis* R.A.Dyer & I.Verd.	Endangered Endangered Near threatened
Zygophyllaceae	[I]*Tribulus terrestris* L.	

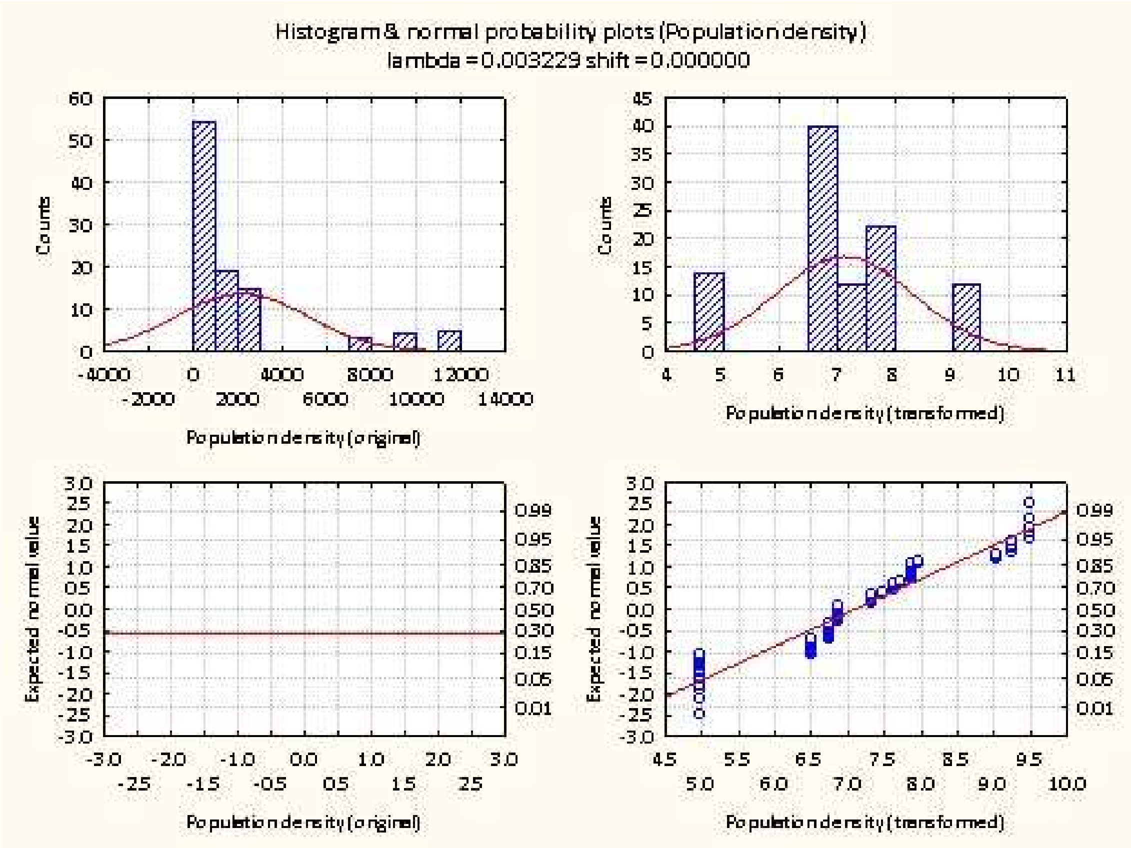
Appendix C: Box-Cox transformation of data

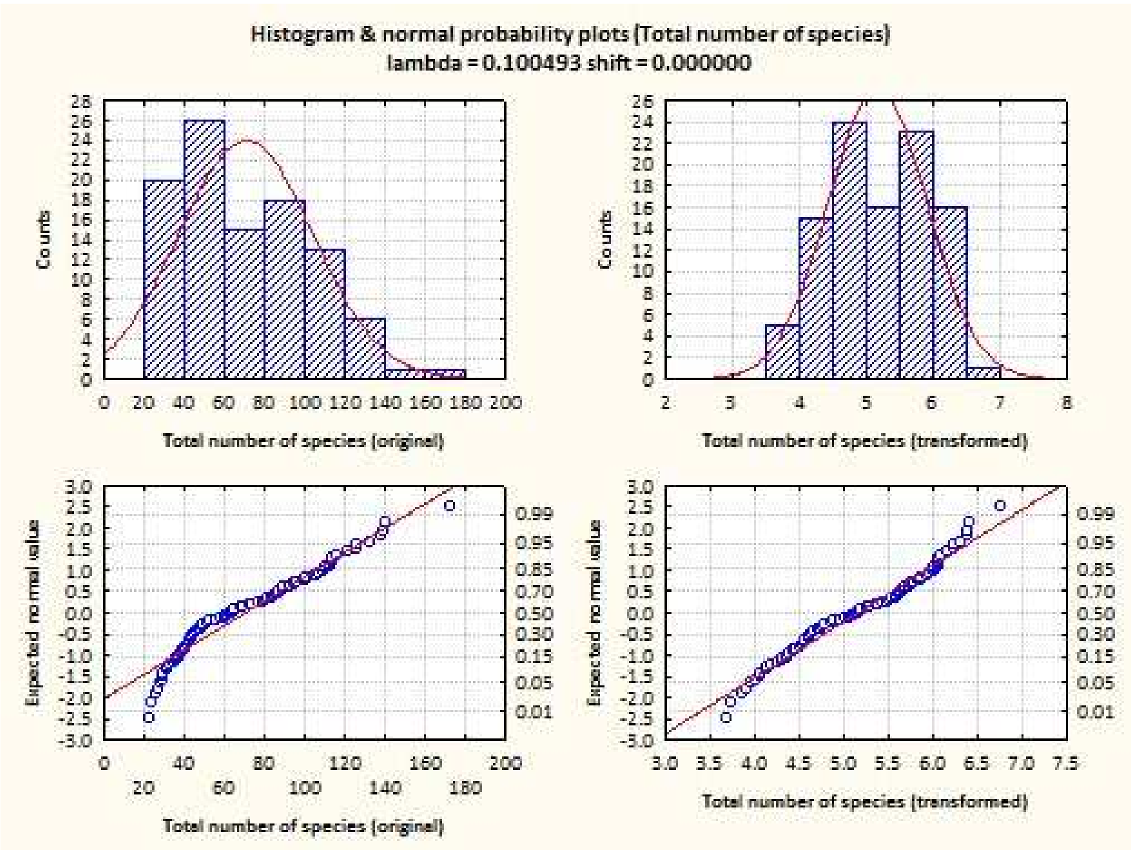
The original and transformed normal distribution plots for the drivers of plant species richness as well as the different species groups for correlations (Chapter 6) are shown in the following graphs, created in STATISTICA 9.0.

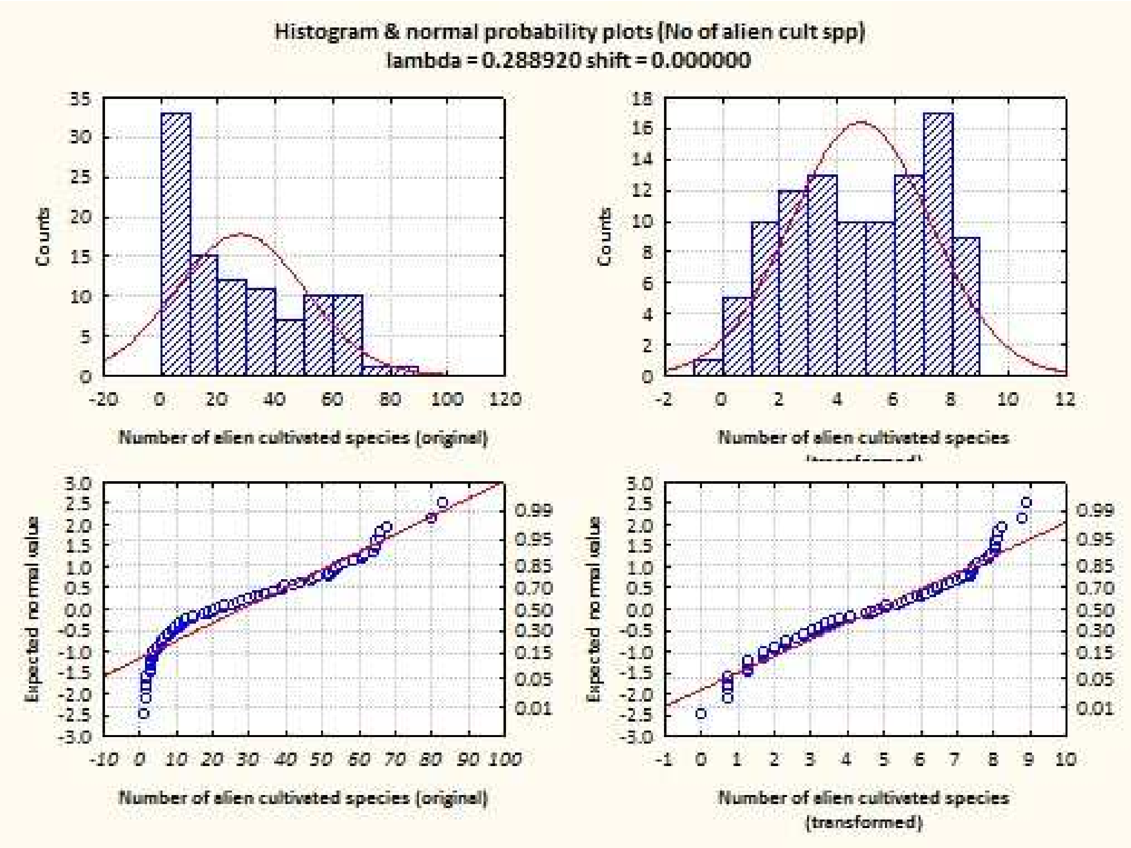


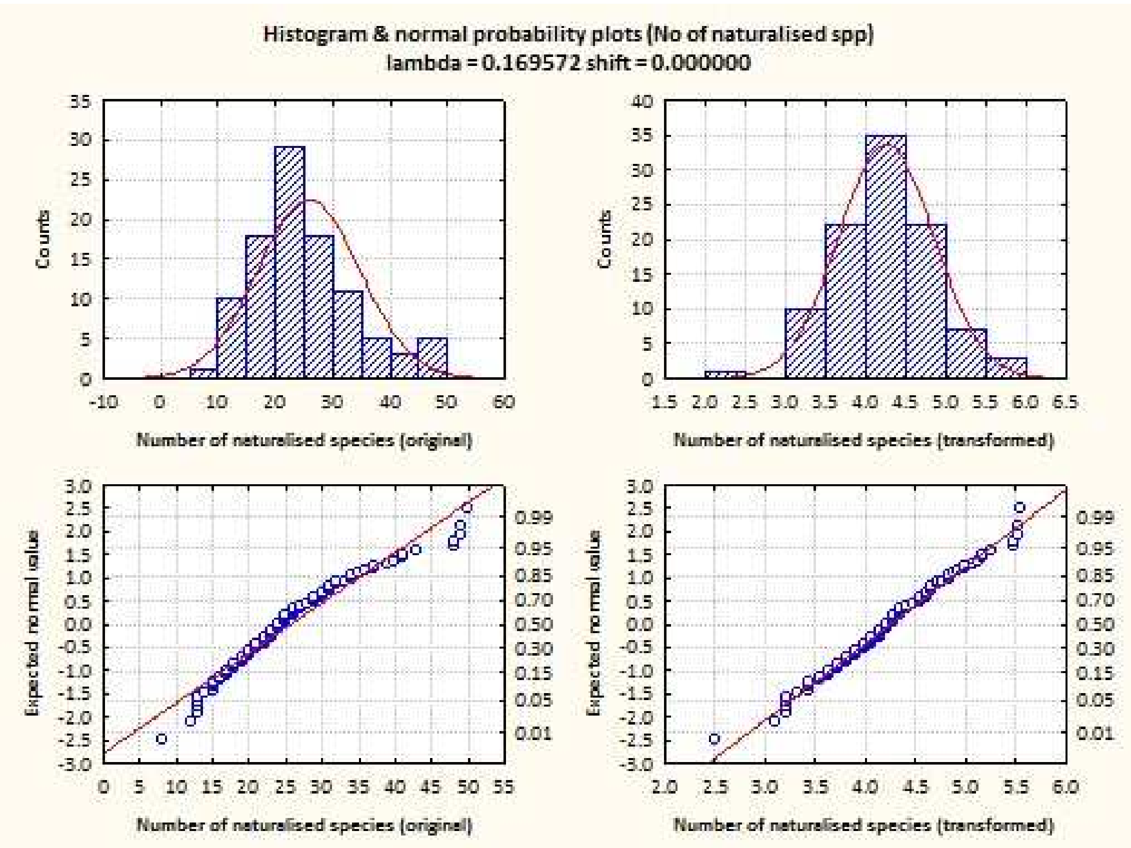

Histogram & normal probability plots (SES)
lambda = 1.022904 shift = 0.000000
Counts
SES (original)
SES (transformed)
Expected normal value

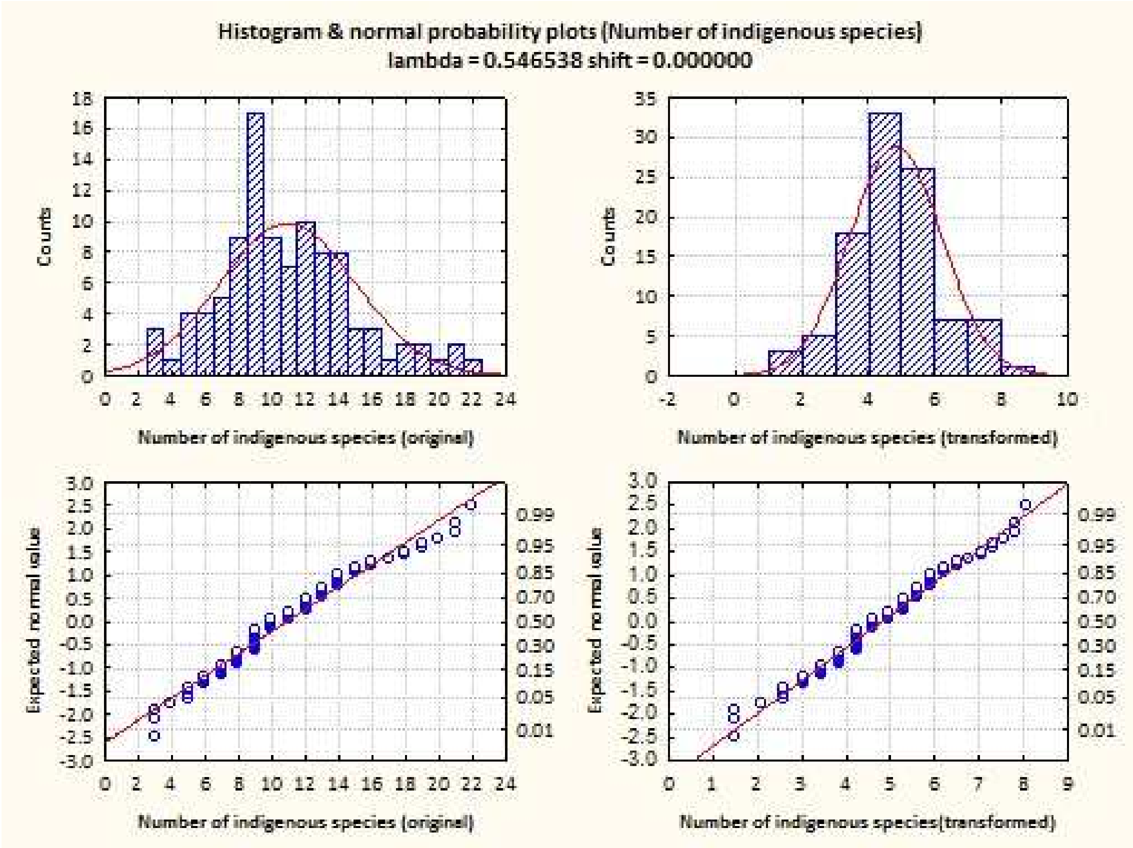

Histogram & normal probability plots (Plot size)
lambda = -0.285997 shift = 0.000000
Counts
Plot size (original)
Plot size (transformed)
Expected normal value


Histogram & normal probability plots (Population density)
lambda = 0.003229 shift = 0.000000
Counts
Population density (original)
Population density (transformed)
Expected normal value
Population density (original)
Population density (transformed)


Histogram & normal probability plots (Total number of species)
lambda = 0.100493 shift = 0.000000
Counts
Total number of species (original)
Total number of species (transformed)
Expected normal value
Total number of species (original)
Total number of species (transformed)


Histogram & normal probability plots (No of alien cult spp)
lambda = 0.288920 shift = 0.000000
Counts
Number of alien cultivated species (original)
Number of alien cultivated species (transformed)
Expected normal value
Number of alien cultivated species (original)
Number of alien cultivated species (transformed)


Histogram & normal probability plots (No of naturalised spp)
lambda = 0.169572 shift = 0.000000
Counts
Number of naturalised species (original)
Number of naturalised species (transformed)
Expected normal value
Number of naturalised species (original)
Number of naturalised species (transformed)



Histogram & normal probability plots (Number of indigenous species)
lambda = 0.546538 shift = 0.000000
Counts
Number of indigenous species (original)
Number of indigenous species (transformed)
Expected normal value
Number of indigenous species (original)
Number of indigenous species(transformed)

Appendix D: Construction of the Management Index (MI)

The information gathered by means of the questionnaire was compiled into Table D.1 and D.2 to produce a score for each management action in every garden (shown in Table D.3). Some management actions were weighted by doubling their scores, as they were thought to represent a higher management input. These categories were: fertilise, weed chemically, topsoil lawn, mow lawn and irrigation system.

Table D.1: Management actions undertaken in the domestic gardens of the TCM, as determined with a questionnaire (Appendix A). Scores were assigned according to the frequency of execution of each specific action.

Activity
Water the garden (1 – rain only; 2 – once a fortnight; 3 – once a week; 4 - > once a week)
Fertilise the garden (0 – none; 1 - < once a year; 2 – once a year; 3 – twice a year; 4 quarterly; 5 – once a month)
Weed the garden – chemically (0 – none; 1 – when needed; 2 – twice a year; 3 – once a month)
Weed the garden – mechanically (0 – none; 1 – once a month; 2 – once a fortnight; 3 – once a week)
Sweep the garden (1 – once a month; 2 – once a fortnight; 3 – once a week; 4 - > once a week)
Prune the hedges / trees (1 – once a year; 2 – twice a year; 3 – once a month)
Remove dead plant material (1 – once a year; 2 – once a month; 3 – once a week)
Rake lawn (1 – once a month; 2 – once a fortnight; 3 – once a week)
Topsoil lawn (1 – < once a year; 2 – once a year)
Spike lawn (0 – none; 1 – once a year; 2 – once a month)
Mow lawn (1 – once a month; 2 – once a fortnight; 3 – once a week)
Graze lawn (0 – none; 1 – once a week; 2 – daily)

Table D.2: Type of irrigation systems found in the gardens of the TCM, as scored for the management index (MI).

Fixed irrigation with timer	4
Fixed irrigation without timer	3
Non-fixed irrigation	2
None	1

Table D.3: Individual and unweighted values scored for the management actions of each garden in the TCM, as well as the constructed management index (MI) score after weighting.

Sample	Water	Fertilise	Weed chemically	Weed mechanically	Sweep	Prune	Remove dead material	Rake lawn	Topsoil lawn	Spike lawn	Mow lawn	Irrigation system	MI
1	4	5	0	3	3	3	0	1	2	1	2	2	**37**
2	4	0	0	1	3	3	0	1	0	2	2	2	**22**
3	4	0	0	1	1	0	0	0	2	1	3	2	**21**
4	3	1	0	1	1	0	0	1	2	1	1	2	**19**
6	4	1	0	0	3	0	0	0	0	0	0	2	**13**
7	4	0	0	1	3	3	0	3	0	2	2	2	**24**
8	3	2	0	1	3	3	0	3	2	1	1	2	**28**
9	3	2	0	3	4	3	0	3	2	0	1	2	**30**
10	3	0	0	3	3	1	0	3	2	1	1	2	**24**
11	4	2	0	3	3	1	3	0	0	1	3	2	**29**
12	4	0	1	1	3	2	2	1	0	0	3	3	**27**
13	4	0	0	3	3	0	2	3	0	0	3	2	**25**
14	4	2	0	3	0	0	1	3	0	1	3	3	**28**
15	4	4	0	3	3	1	2	3	0	0	3	3	**36**
17	4	2	0	1	0	1	2	0	2	1	3	3	**29**
18	4	1	0	3	3	0	3	1	0	0	3	3	**28**
19	4	2	0	3	0	1	0	0	2	0	3	3	**28**
20	3	2	0	3	3	1	3	0	0	1	3	2	**28**
22	4	0	0	3	3	0	0	1	0	0	2	2	**19**
23	3	0	0	1	3	3	0	1	0	0	2	2	**19**
24	3	0	0	1	4	1	0	0	0	2	3	2	**21**
25	4	2	0	1	3	0	2	0	2	1	3	3	**31**
27	4	0	0	3	0	0	0	0	0	0	0	2	**11**
28	3	0	0	1	1	0	0	1	0	0	1	2	**12**
29	4	0	0	0	3	0	0	3	0	1	3	2	**21**
30	4	5	0	3	0	3	0	0	2	2	2	2	**34**
31	4	2	0	3	1	2	0	0	2	1	3	2	**29**

Sample	Water	Fertilise	Weed chemically	Weed mechanically	Sweep	Prune	Remove dead material	Rake lawn	Topsoil lawn	Spike lawn	Mow lawn	Irrigation system	MI
32	3	0	0	3	1	1	3	3	0	0	3	3	**26**
33	4	2	1	3	3	1	0	0	2	1	3	3	**34**
34	4	2	1	1	1	1	1	1	1	1	3	3	**30**
35	3	0	0	1	3	2	2	3	0	0	3	2	**24**
37	4	2	1	3	3	0	1	1	2	1	3	2	**33**
38	4	2	0	3	3	1	3	1	2	0	3	2	**33**
39	4	2	0	3	3	1	3	0	0	0	3	3	**30**
40	3	2	0	3	1	1	1	0	0	1	3	2	**24**
43	4	2	0	1	0	1	0	1	0	1	1	2	**18**
44	4	2	0	1	4	0	0	0	2	1	2	2	**26**
45	4	0	0	3	3	0	0	3	0	1	3	2	**24**
49	3	0	0	1	3	3	0	3	0	1	1	3	**22**
50	2	0	0	3	3	3	0	3	2	1	1	2	**25**
51	3	2	0	3	1	0	2	1	2	1	3	2	**29**
53	3	0	0	3	3	0	3	0	0	1	3	3	**25**
56	4	5	0	3	3	0	0	0	2	0	3	2	**34**
58	4	1	0	3	1	0	0	0	1	0	3	2	**22**
59	4	2	0	3	0	1	3	3	0	1	3	3	**31**
62	4	2	0	1	3	0	0	1	0	1	1	2	**20**
63	4	0	0	1	3	0	0	0	0	1	3	2	**19**
64	3	1	0	1	1	1	0	0	2	2	1	2	**20**
65	4	0	0	1	0	0	0	0	0	1	3	2	**16**
68	4	2	0	3	3	3	0	3	2	1	2	2	**33**
69	4	2	0	2	2	0	0	0	0	0	1	2	**18**
70	4	0	0	3	3	0	0	1	0	2	1	2	**19**
71	4	2	0	1	0	2	3	0	1	0	3	2	**26**
72	4	2	0	3	3	1	3	3	0	0	3	2	**31**
73	4	0	0	3	0	3	2	3	0	0	3	2	**25**
74	4	2	0	1	3	1	1	3	1	0	3	2	**29**

Sample	Water	Fertilise	Weed chemically	Weed mechanically	Sweep	Prune	Remove dead material	Rake lawn	Topsoil lawn	Spike lawn	Mow lawn	Irrigation system	MI
75	4	2	1	1	1	1	3	3	0	1	3	3	**32**
76	4	2	0	3	3	1	0	1	0	0	3	2	**26**
77	4	5	1	3	3	1	3	0	2	0	3	3	**42**
78	4	2	0	1	0	1	3	1	0	0	3	3	**26**
84	4	0	0	4	0	3	0	3	0	2	3	2	**26**
88	4	1	0	3	0	0	0	0	2	1	3	3	**26**
89	4	3	0	3	0	0	0	0	0	0	3	3	**25**
90	4	2	0	3	3	1	0	0	1	1	3	2	**28**
92	4	3	0	3	3	1	3	0	2	0	3	4	**38**
95	3	1	0	3	3	1	1	0	0	0	3	3	**25**
99	4	0	0	1	0	1	0	2	2	1	2	2	**21**
100	4	0	0	3	0	0	0	0	0	0	3	3	**19**
101	4	5	0	2	2	3	0	3	2	1	3	2	**39**
102	3	2	0	3	3	1	0	2	2	2	2	2	**30**
108	4	2	0	3	3	1	0	0	0	0	3	3	**27**
109	3	0	3	0	0	0	0	3	0	0	3	2	**22**
115	4	4	2	3	0	0	3	0	0	1	3	4	**37**
116	3	1	0	3	0	1	0	0	0	1	3	2	**20**
117	4	2	0	2	3	0	2	0	1	1	3	2	**28**
119	2	0	0	3	0	3	0	3	2	0	3	2	**25**
122	1	0	0	2	0	1	0	0	0	0	1	1	**8**
123	4	2	0	3	0	1	0	1	0	0	1	2	**19**
124	4	0	0	2	0	3	0	1	2	0	1	2	**20**
125	3	0	0	3	3	2	0	2	2	1	2	2	**26**
126	4	0	0	2	0	1	0	3	0	0	3	2	**20**
130	4	2	0	1	0	1	0	2	0	0	2	3	**22**
131	4	2	0	3	0	0	0	3	2	0	3	3	**30**
132	4	2	0	3	3	0	0	3	0	1	3	2	**28**
133	4	0	1	3	3	0	0	3	0	1	3	3	**28**

Sample	Water	Fertilise	Weed chemically	Weed mechanically	Sweep	Prune	Remove dead material	Rake lawn	Topsoil lawn	Spike lawn	Mow lawn	Irrigation system	MI
135	3	0	0	2	0	1	0	0	2	2	1	2	**18**
136	4	0	0	1	0	2	0	2	2	1	2	2	**22**
140	4	0	0	3	0	1	0	1	2	1	3	2	**24**
141	2	0	0	1	0	1	0	1	0	2	1	2	**13**
142	1	0	0	2	2	0	0	0	0	0	0	1	**7**
143	2	0	0	3	3	0	0	0	0	0	2	2	**16**
146	4	2	0	1	0	1	0	0	0	0	3	1	**18**
147	4	0	0	3	3	1	0	0	0	0	3	2	**21**
149	3	0	0	3	3	1	0	3	0	0	3	2	**23**
151	4	3	1	2	0	0	0	0	0	0	2	3	**24**