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Full Length Research Paper

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

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In recent years domestic gardens in urban areas have been extensively studied, but findings from developed and developing countries do not always correspond. The disparity is ascribed to differences in climate, culture and socio-economics. This study from South Africa analyzes plant diversity patterns along a steep, indirect socio-economic gradient in a single city. The segregation laws of the apartheid era are responsible for the prevailing social and cultural heterogeneity. By combining cultural and socioeconomic variables into classes, the plant diversity turnover along a socio-economic gradient could be determined. This study provides further evidence of the effects that socio-economic factors, other than ecological factors which are traditionally investigated, have on vegetation patterns. Socio-economic and cultural influences within the study area influenced plant diversity patterns, showing higher species richness in the more affluent, white-dominated suburbs. However, much of this plant diversity of affluent suburbs is made up of alien species, whereas utilitarian plants, for instance, are strongly associated with the lower socio-economic status of black suburbs, which includes many indigenous species.

Key words: Apartheid, alien species, biodiversity, homegardens, Potchefstroom, urban ecology, urban flora.

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, for example 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, therefore, 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 (Mabin, 1992), has therefore created steep socio-economic gradients in the urban environment 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

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be neglected. In the past, gardens were deliberately excluded from urban ecological studies because only the semi-natural areas were thought to be of ecological value. In 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 which, according to Colding (2007), 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., 2005; Mathieu et al., 2007). A good example of the realization 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., 2005; Smith et al., 2006). 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 realized once the interrelationships between biophysical and sociocultural 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 socioeconomic principles (Cilliers, 2010), but emphasized urban agriculture and agroforestry in Africa, Asia, Latin America and Amazonia and also include home gardens 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, according to Gosz (1992), to study the response of plant communities and populations to gradual changes in the environment. Gradients in urban areas (anthropogenic gradients) are indirect as they serve as surrogates for a variety of social, economical and even environmental variables, but they are also nonlinear as they are complex and cannot be studied using transects (McDonnell and Hahs, 2008). With the use of this 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 different socioeconomic groups have been documented for residential areas in general (Hope et al., 2003; Pedlowski et al., 2003; McConnachie et al., 2008) and even for domestic gardens (Kirkpatrick et al., 2007), albeit rarely so and then in areas with 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 (Nemudzudzanyi et al., 2010). The aims of this study were to determine the alpha, beta and gamma diversity of garden floras along a steep socioeconomic gradient of a city with a history of cultural segregation, comprising three cultural groups and to compare the species richness of domestic gardens to that of other land-use types.

Study area

The study area is situated in the Tlokwe City Municipality, North-West Province, South Africa, situated between 26°39' and 26°44' latitude and 27°00' and 27°08' longitude (Figure 1). The municipality is made up of four suburbs: Ikageng, Mohadin, Potchefstroom and Promosa. Pre-1994 segregation laws mandated that Ikageng and Promosa were towns inhabited by Africans, Potchefstroom by Europeans and Mohadin by Indians. In 2004, the City of Tlokwe had over 140 000 inhabitants (WorkWell, 2004). Informal settlements have developed on the edges of Ikageng in recent years and are also included in this study.

The study area lies in the Grassland Biome of South Africa (Mucina and Rutherford, 2006). Data on the vegetation of urban open spaces in Tlokwe was previously compiled during an urban ecological survey from 1996 - 1997 that focused on railway reserves, vacant lots, managed open spaces, wetlands, roadside verges, natural and semi-natural areas (Cilliers, 1998). This study expands on this survey by examining the flora of managed domestic gardens.

Major rock types of the study area form part of the Malmani subgroup of the Transvaal Supergroup which includes mostly Mispah, Glenrosa and Hutton soil forms (Mucina and Rutherford, 2006). Arcadia and Rensburg soil forms occur in the drainage depressions with alluvium along the rivers.

The study area lies at an altitude of 1350 m above sea level. Climatic data were acquired from WeatherSA (McBride, 2008). Tlokwe receives, on average, 593 mm of rain per annum, mostly during the summer months. Winters are very dry. The mean maximum temperature during summer months is 30.7°C and the mean minimum is 0.3°C in winter months. Frost occurs frequently during

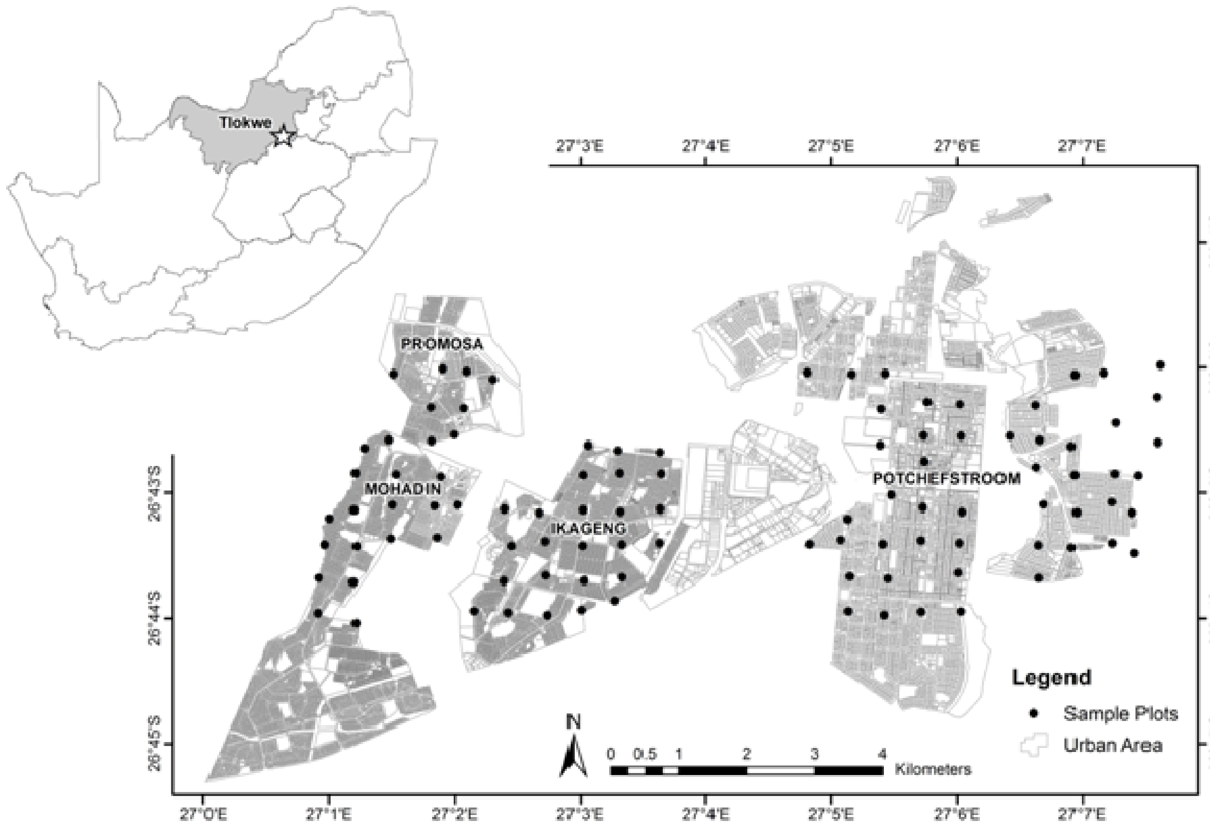


Figure 1. Locality and layout of the study area, Tlokwe City Municipality, in the North-West Province, South Africa. Black dots represent the positions of the sample plots, 500 m apart, according to the grid sampling approach. Residential areas are shaded. Map by M du Toit.

the colder months (Mucina and Rutherford, 2006).

MATERIALS AND METHODS

Determination of socio-economic status (SES)

Data from the 2001 Census Survey (Municipal Demarcation Board, 2006) were used to determine the SES of all the wards in the Tlokwe City Municipality, South Africa (Figure 1). Five different parameters were considered to determine the SES classes (Table 1).

Percentage unemployment is the percentage of unemployed people per household, excluding economically non-active persons. Household size is the percentage of households with five or more people. Number of rooms is the percentage of households with two or less rooms. 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. Schooling status is the percentage of people older than 18 years of age with no schooling.

For all categories, a higher percentage indicates a lower SES. These parameters were scored (Table 2), with high percentage values scoring 1 point and the lower percentages scoring 5 points. The highest total score therefore reflects the economically most affluent households (> USD 3000 per month). Class 1, would therefore be the economically most stressed household (< USD 100 per month). The definite range in total parameter scores allowed for the placement of each of the gardens in one of the five classes (socio-economic groups).

Vegetation sampling

A topographic map of the Tlokwe City Municipal area (Figure 1) with a grid overlay (grid points 500 m apart) was used to identify sampling points, ensuring a representative number of sample plots within each SES group. A global positioning system (GPS) was used to locate each sample point and the closest urban domestic garden within a radius of 100 m was chosen to place a sample plot. For the purpose of this study a domestic garden is defined as a fenced yard containing one or more of the following micro-gardens: ornamental plantings, lawn, vegetable garden, orchard, hedge, or medicinal (herb) garden. A microgarden is an area specifically planted with a group of plants with similar uses. A planted yard must be attached to a permanently inhabited dwelling (house). Sampling took place during the summer of 2009 in plots of 20 × 20 m (400 m^2). Each plot was placed to include at least three micro-gardens. The number of sample plots totalled 100. Within each plot, quantitative data were gathered in the form of a complete list of plant species and their frequency of occurrence. To put the sample plots' richness in a perspective, a total floristic survey of the whole yard was also conducted based on presence-absence. This was required to calculate gamma diversity.

Identification was done to the species level, with infraspecific taxa being merged into species. Vegetation data was sourced from a

Table 1. Five parameters examined to define the five socio-economic classes of the Tlokwe City Municipality.

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] % unemployed household members, [2] % households with five or more persons, [3] % households with one or two rooms only, [4] % households with pipe water >200 m away, [5] % individuals with no schooling per household.

Table 2. Scored parameters to differentiate between the five socio-economic classes of the Tlokwe City Municipality.

Parameter	SES (class) scores				
	1	2	3	4	5
[1]Unemployment	1	2	3	4	5
[2]Household size	2	3	1	4	5
[3]Number of rooms	1	2	3	4	5
[4]Access to basic services	2	1	3	4	5
[5]Schooling status	2	1	4	3	5
Score	8	9	14	19	25

[1] % unemployed household members, [2] % households with five or more persons, [3] % households with one or two rooms only, [4] % households with pipe water >200 m away, [5] % individuals with no schooling per household.

1996 survey (Cilliers, 1998) of land-use types in the Tlokwe Municipal area for comparative purposes. Indigenous and alien species were artificially classified into categories as useful (ornamental, vegetable, fruit, medicinal and hedge) or weeds (ruderals) based on several publications (Bromilow, 1995; Van Wyk et al., 1997; Pienaar, 2000; Van Wyk and Gericke, 2000; Henderson, 2001; Glen, 2002; Van Wyk, 2005).

Data analysis

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.

Data consolidation and processing of beta diversity were performed with an indirect ordination (DCA) in CANOCO (Ter Braak and 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.

RESULTS AND DISCUSSION

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. Each of these land-uses has a different number and composition of indigenous and alien species (Figure 2), 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 2). 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 (Table 3). 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).

Species richness of different socio-economic status groups

Along the indirect SES gradient, a clear indication of the

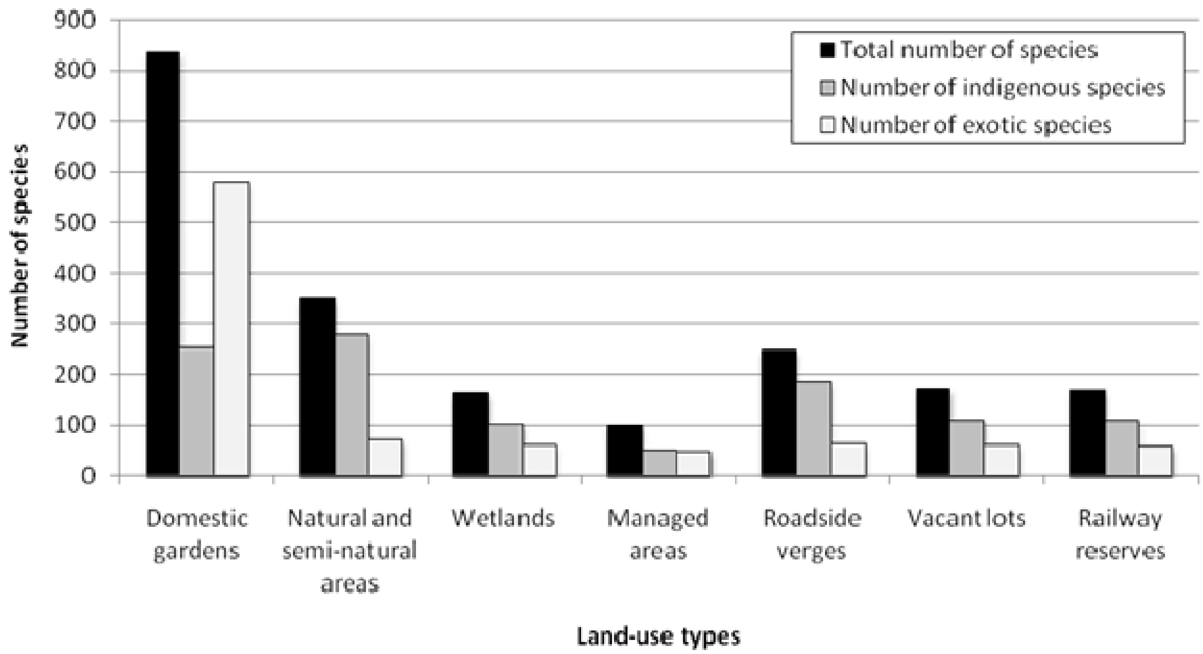


Figure 2. Number of total, indigenous and alien (exotic) species for seven land-use types in the Tlokwe City Municipality.

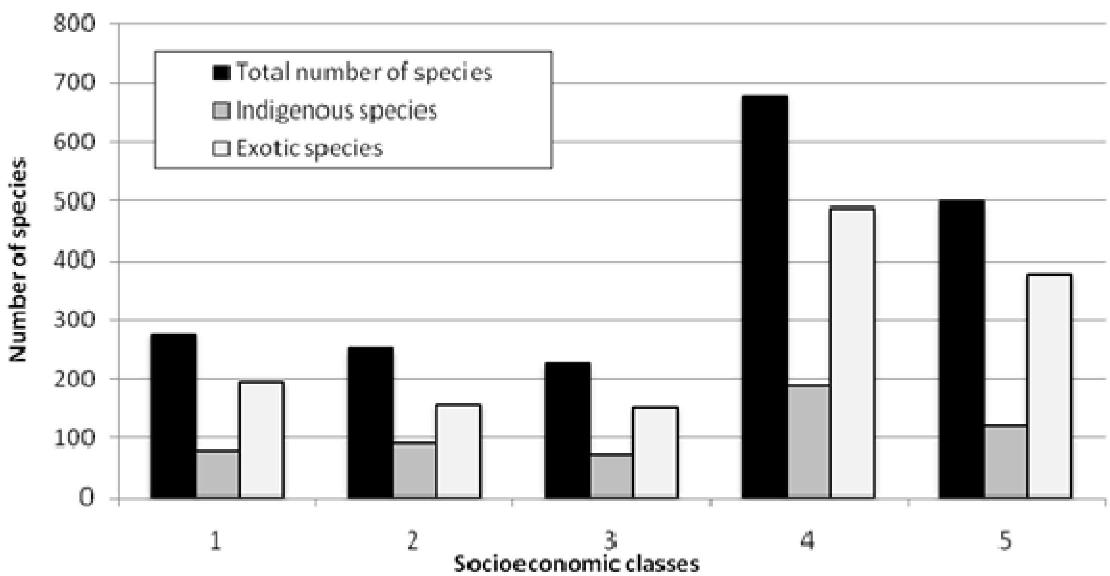


Figure 3. Gamma diversity, namely the total number of species recorded for all gardens in each socio-economic class, and differentiating between indigenous and alien (exotic) species, for the Tlokwe City Municipality.

effect of SES on the plant species distribution patterns in urban domestic gardens was evident (Figure 3). 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 small farms of up to 8 ha with more permanent labour resources than the sample plots in class 5.

Table 3. Food (fruit and vegetables) and medicinal plants recorded from domestic gardens of the Tlokwe City Municipality. 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*

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 (Simon, 1989). These non-fertile areas include mostly classes 1 to 3, while the people are primarily from native African origin, namely Batswana. According to

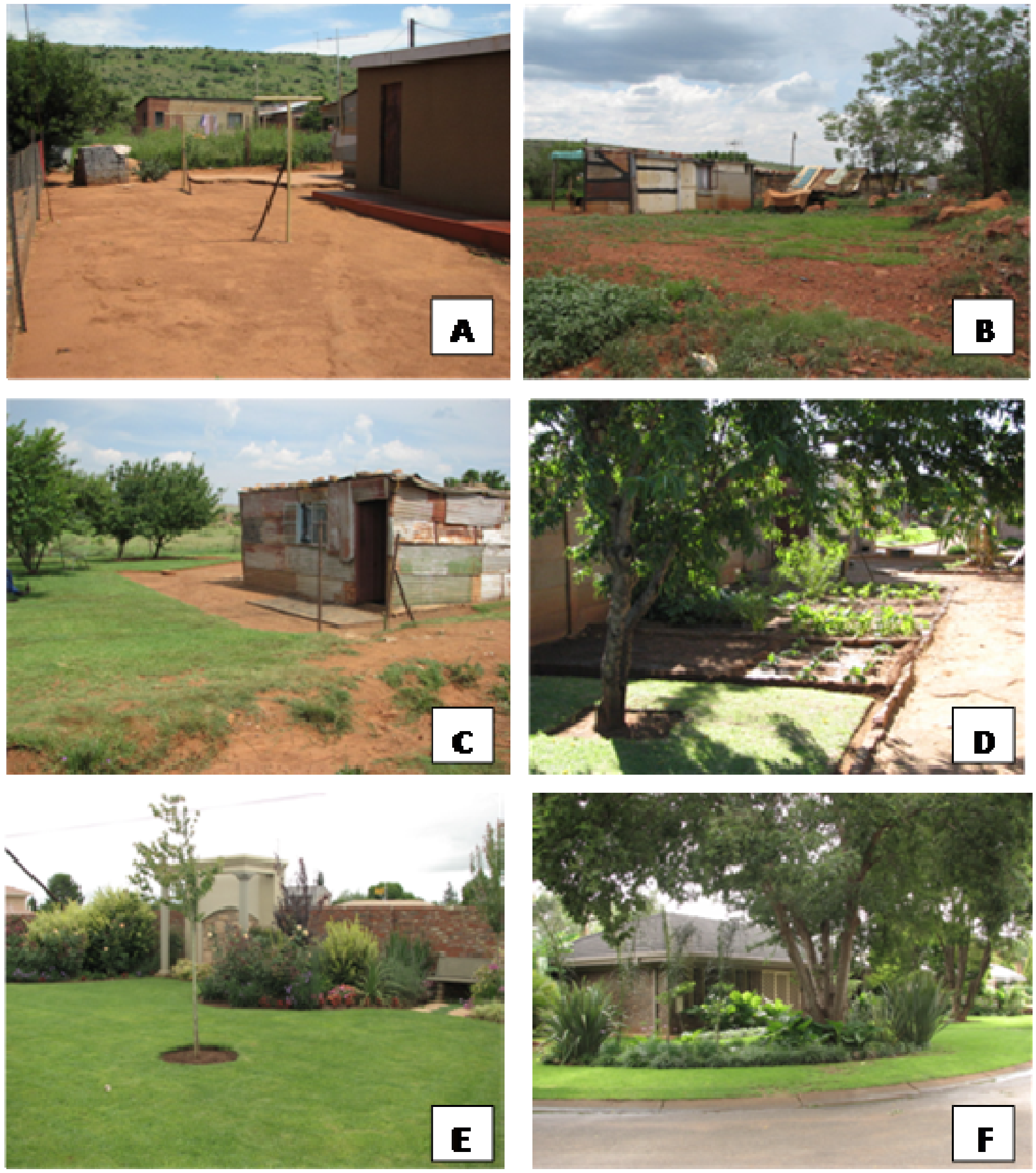


Figure 4. Visual representation of the change in domestic garden species composition along a socio-economic gradient in the Tlokwe Municipal area, with (B) representing the lowest class, and progressively (F) representing the highest class. The 'lebala' concept is depicted by (A). Photos: CS Lubbe.

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 4A). Patterns were also found within the three classes of lower SES. Class 1 (lowest SES) consistently had a higher species richness than the other two groups, as it is an area that has only in recent years been developed for housing. This state of disturbance has resulted in a higher occurrence of weedy species (introduced and indigenous species that colonizes disturbed sites). The differences of urban domestic gardens can also be visually discerned along the SES gradient (Figure 4B lowest SES; Figure 4F highest SES).

Species diversity

The differences in alpha diversity between different SES groups (Figure 5) provided a similar result to gamma diversity (Figure 3) SES classes 1, 2 and 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. These inequities are well known for South African cities (Simon, 1989) with white affluent, suburbs with large plots and poor, black

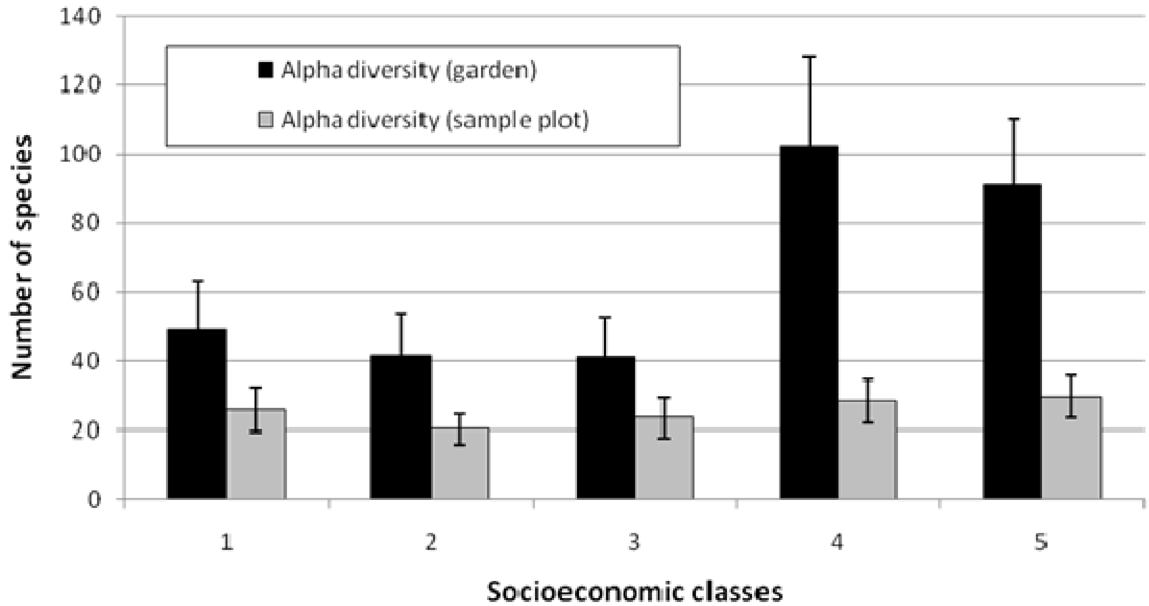


Figure 5. Alpha diversity for each of the five socio-economic classes in the Tlokwe City Municipality. Richness data was sampled in 20 × 20 m plots and the whole garden (yard, which varied in size).

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).

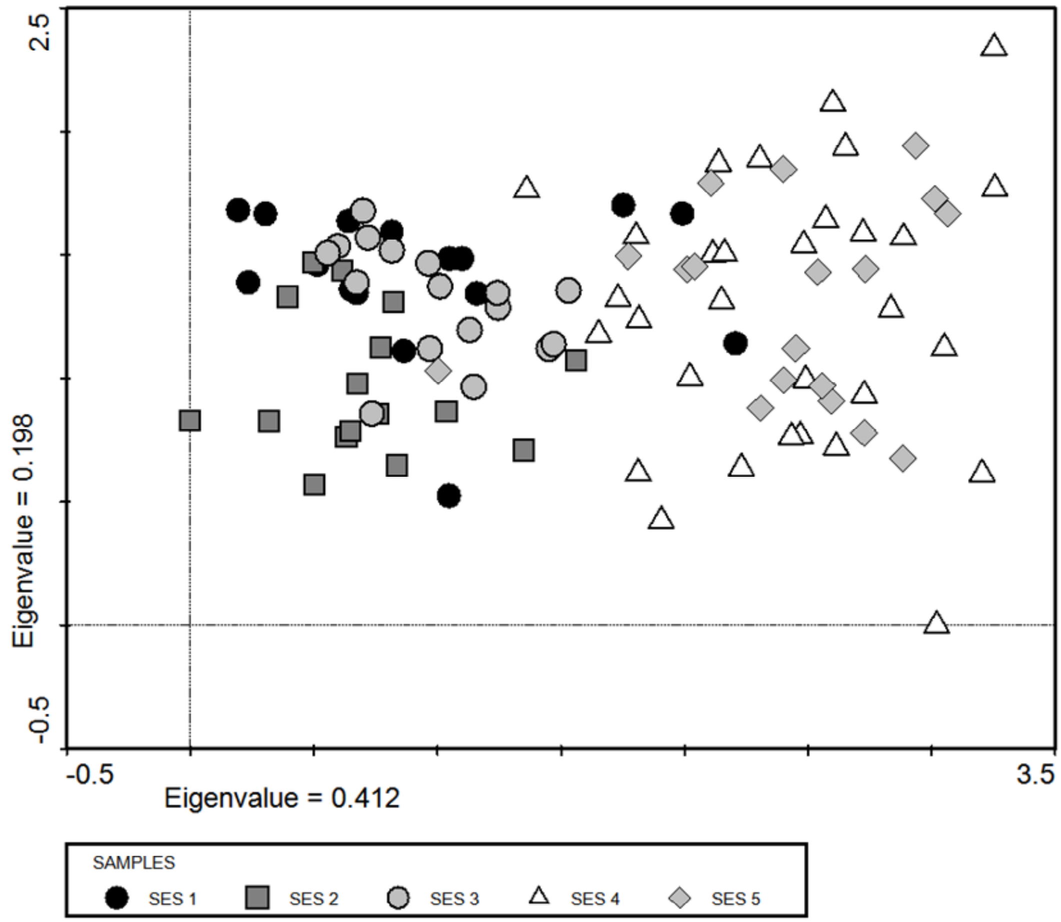
Similarity between the species composition of different sample plots revealed two distinct assemblages (Figure 6). In this ordination, representing beta diversity (species turnover), the plots of SES classes 4 and 5 shared a similar floristic composition, while classes 1, 2 and 3 were floristically more 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.

Utilitarian plants

The use value of plants also has an effect on the plant diversity of gardens. However, presence of a useful plant in a garden does guarantee that it was planted for its use value. When a useful plant forms part of a specifically planted microgarden 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 3) was plotted against each SES class (Figure 7). 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).

Conclusion

This study provides further 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 richnesss in the more affluent white-dominated



Axis	Eigenvalues	Lengths of gradients	Percentage variance
1	0.412	3.255	4.4
2	0.198	2.339	6.5

Figure 6. 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 Tlokwe City Municipality; samples grouped closer together share a similar species composition.

suburbs. However, much of this diversity is made up of alien species which contributes to biotic homogenization of urban environments. 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 collectively urban domestic garden floras 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.

This study, as well as others focusing on the integration between social, cultural and ecological aspects, especially 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 steep socio-economic gradient in Tlokwe, a consequence of the apartheid regime, enabled us also to explore at one locality the effect of socio-economic aspects on plant diversity, as would be experienced in both developed and developing countries. According to Marco et al. (2010) we need a better understanding of how natural and social factors contribute to urban biodiversity patterns. In our study some of these issues have now been addressed by garden studies in contrasting social contexts.

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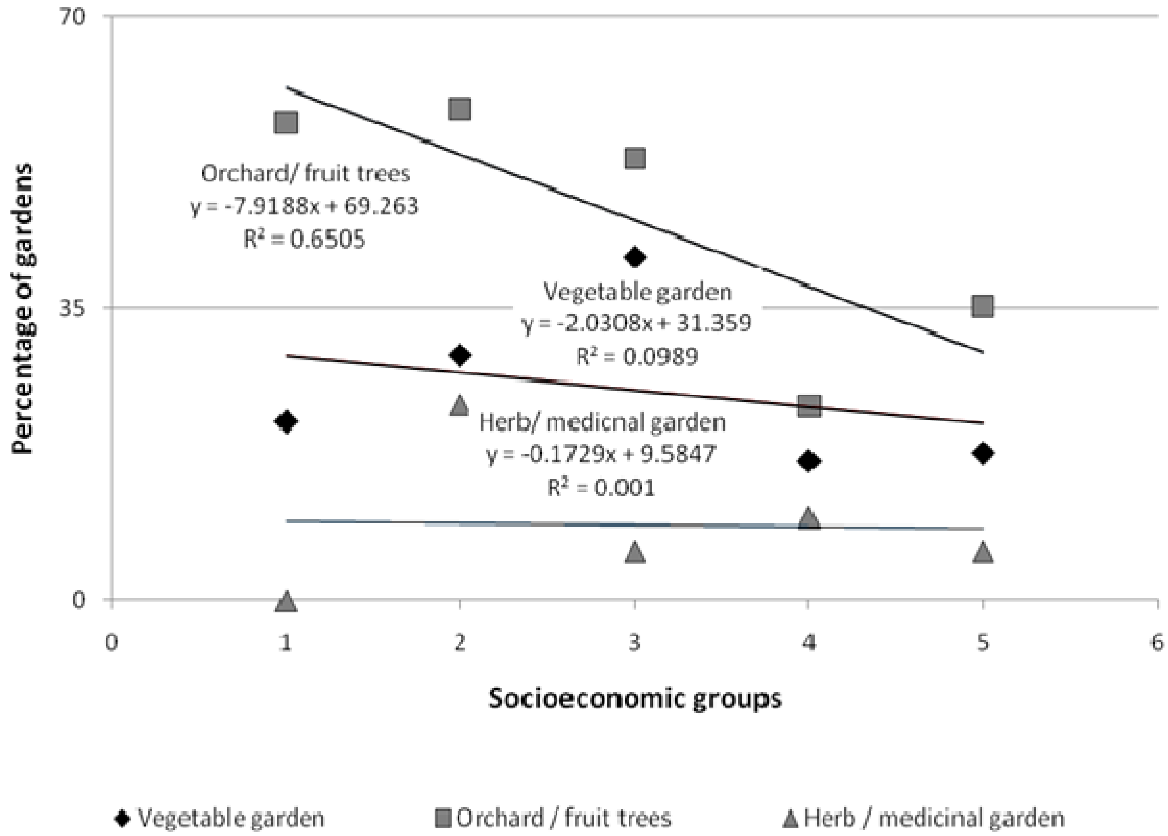

Figure 7. Regression analysis of the percentage of gardens containing micro-gardens with specific utilitarian plants across a socio-economic gradient in the Tlokwe City Municipality.

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