Ruderal and degraded natural vegetation on vacant lots in thePotchefstroom Municipal Area, North West Province, South Africa

S.S. Cilliers* and G.J. Bredenkamp[1]

*School for Environmental Sciences and Development, Section Botany, Potchefstroom University for C.H.E., Potchefstroom, Republic of South Africa

[1]Department of Botany, University of Pretoria, Pretoria, Republic of South Africa

Received 5 February 1998; revised 7 December 1998

Relatively little is known about ruderal and degraded natural vegetation in urban open spaces in the Grassland Biome of South Africa. The classification of the vegetation on vacant lots forms part of a research programme on spontaneous vegetation in urban open spaces in the North West Province, South Africa. Using a numerical classification technique (TWINSPAN) as a first approximation, the classification was refined by applying Braun-Blanquet procedures. The result is a phytosociological table from which six communities and seven sub-communities, belonging to two main groups, namely degraded natural and ruderal communities, are recogised. The communities which are mainly characterised by one dominant species, a few abundant species and many species with low frequency, are described. Associated gradients in habitat or disturbances are identified by using an ordination algorithm (DECORANA). Possible dynamic relationships between the communities are also discussed.

Keywords: Braun-Blanquet, DECORANA, disturbed areas, MEGATAB, Phytosociology, plant communities, TURBOVEG, TWINSPAN.

*To whom correspondence should be addressed, (E-mail: plbssc@puknet.puk.ac.za).

Introduction

Ruderal plant species can be described as species which are able to grow in severely disturbed habitats. According to Grime (1979), these disturbances may be the result of the effect of natural catastrophies such as floods and windstorms, or they can be attributed to more drastic forms of human impact such as ploughing, mowing, weeding, trampling and burning. More subtle effects such as those due to climatic fluctuations and the activities of herbivores, decomposing organisms and pathogens, must, however, not be overlooked (Grime 1979).

In recent years, ruderals have been the subject of many studies, especially in Europe. Recent interest in ruderal vegetation is partially due to the growing importance of man-made habitats which are linked with ever-increasing synanthropisation of vegetation (changes in plant cover caused directly or indirectly by human activities). Results of studies on ruderal plant communities are quite useful for urban land management and urban nature conservation (Henke & Sukopp 1986; Pyšek 1995a). Only a few studies on ruderal vegetation of urban vacant lots were done outside Europe. Vincent and Bergeron (1985) studied vacant lots in Montreal, Canada and Franceschi (1996) concentrated on the vegetation of vacant lots in the most densely populated zone of Rosario City in Argentina

Apart from studies on invasive alien woody plants (Henderson & Musil 1984) and naturalised species (Henderson 1991), the only vegetation analyses of spontaneous vegetation in urban open spaces in the Grassland Biome of South Africa, that we are aware of, are those in the Potchefstroom and Klerksdorp Municipal Areas (Cilliers 1998; Cilliers & Bredenkamp 1998, Cilliers & Bredenkamp in press; Van Wyk 1998 and Van Wyk *et al.* 1997). The vegetation of vacant lots were, however, not included in any of the mentioned studies. In a thorough syntaxonomical and synecological study of the western Transvaal Grasslands, which included the natural area around Potchefstroom, Bezuidenhout (1993) did not describe ruderal communities at all. Although not specifically dealing with ruderal vegetation a number of ruderal communities were described in urban areas in Kwazulu-Natal in the Savanna Biome (Boswell 1993; Roberts 1993; Seppings 1994).

In their plea for a new approach in management of urban open spaces in South Africa, Roberts & Poynton (1985) mentioned the possible function of areas such as vacant lots in the provision of ecological continuity throughout the urban environment. It is, therefore, necessary to first of all, analyse the vegetation in these areas, because vegetation information can only be used in planning and management programmes, if it is accurate and scientific in terms of floristic detail and actual community distribution (Roberts 1993).

Spontaneous vegetation reflects the interaction between human impact and natural development and can be used as a general indicator of environmental conditions and ecological processes in the urban environment (Sukopp & Werner 1983). Another important reason for studies of spontaneous vegetation in urban environments is that understanding of the synecology and dynamics of the so-called weedy plant communities will enhance better control of the particularly noxious species (Vincent & Bergeron 1985). Franceschi (1996) stated that knowledge of urban ruderal vegetation is very important, because it could include new invading species or allergen species, as well as vectors of disease, or insect host species that could cause damage to cultivated plants. Urban ruderal vegetation also contributes to the biological diversity in a city and some species could be used as ornamentals if vacant lots were converted into green spaces or parks (Franceschi 1996).

The aim of this study was to analyse the vegetation of vacant lots in the municipal area of Potchefstroom, and to describe its communities and the origins of its flora. This study forms part of an extensive study of urban open spaces in a number of cities in the North West Province, South Africa, with the ultimate aim of a phytosociological and syntaxonomical synthesis of these urban open spaces.

Study Area

This study was done on a number of vacant lots in residential, business and industrial areas in the municipal area of Potchefstroom, situated between 27°04' and 27°07' longitude and 26°40' and 26°44' latitude. Potchefstroom is situated in the Dry Sandy

Highveld Grassland (Bredenkamp & Van Rooyen 1996) of the Grassland Biome (Rutherford & Westfall 1994).

The major rock types in the natural area surrounding Potchefstroom are from the Pretoria Group of the Transvaal Sequence and vary from Hekpoort andesites to Daspoort and Strubenkop shale, including the intrusion of diabase into the Strubenkop shale (Nel *et al.* 1939). The average rainfall in the Potchefstroom area is more than 600 mm per annum. Summer temperatures are high with the mean monthly maximum temperature higher than 32°C during October to January, while the mean monthly minimum temperatures are below -1°C during May to September. Severe frost occurs during the winter months (Weather Bureau 1988). It must, however, be taken into consideration that urban areas could be much warmer than the surrounding natural areas, forming a so-called urban heat island, mainly because of the presence of roads, buildings, pavements and other areas which absorb heat (Von Stülpnagel *et al.* 1990). Research in cities in South Africa has shown that the urban environment can be about 3–4°C warmer than the adjacent natural environment (Von Gogh 1979).

Materials and Methods

Relevés were compiled in 50 stratified sample plots in residential, commercial and industrial areas of municipal Potchefstroom. Most of these plots were sampled from March to May 1995, but an additional 2 sample plots were studied in winter (July and August 1995) and 9 sample plots just after winter (November 1995). The survey was done on vacant lots which previously supported buildings and which, therefore, have severely disturbed soils, but was not restricted to these areas. A number of sample plots were also studied on the city margin.

Plot sizes were fixed at 16 m^2 for grassland and 100 m^2 for woody vegetation in accordance to Bredenkamp and Theron (1978). Cover-abundance values were allocated according to the Braun-Blanquet scale, as given by Mueller-Dombois and Ellenberg (1974). Habitat parameters recorded, included topography, aspect, slope, soil forms (Soil Classification Work Group 1991) and various soil properties, including physical and chemical properties. The properties in the A and B horizons include percentage gravel, sand, silt and clay; exchangeable K^+, Na^{2+}, Mg^+ and Ca; soil conductivity, soil pH (H_20), soil depth and the *in situ* soil compaction (together with gravimetric water content) in accordance to the Soil Classification Work Group (1991). At each sample plot the type and intensity of human impact, such as mowing (no, sporadically or low, frequent or high), weeding (no or yes), trampling (no, moderate, heavy), grazing (no or yes), use of chemicals (no or yes) and dumping of refuse and debris (no or yes) were qualitatively described. Accurate descriptions of anthropogenic influences were difficult because information on the history of land use and type and intensity of management was not available.

The TWINSPAN classification algorithm (Hill 1979a) and the utility BBPC program of Bezuidenhout *et al.* (1996) were used to analyse the floristic data on a personal computer. The result of the final classification is presented in a phytosociological table (Table 1). Additional software packages were used for input, processing, and presentation of phytosociological data (TURBOVEG - Hennekens 1996a) as well as a visual editor for phytosociological tables (MEGATAB - Hennekens 1996b). Introduced species are clearly marked in the phytosociological table, and the occurrence of each species in a specific stratum is indicated with a symbol in Table 1. Differentiation between trees and shrubs were based on definitions proposed by Edwards (1983). Species which were encountered only once or twice during the study and have relatively low cover are not included in the phytosociological table (Table 1), but are listed in Table 2.

The relevé numbers indicated in Table 1 are TURBOVEG numbers which indicate the unique relevé number in the South African phytosociological data base. All numbers start with 300xx, where only the xx are placed in Table 1 to save space.

An ordination algorithm, DECORANA (Hill 1979b) was also applied to the floristic data to indicate possible gradients in the vegetation. In addition, estimated height and canopy cover averages for the tree, shrub and herbaceous strata are given for each community.

Taxa names conform to those of Arnold and De Wet (1993), but are updated to November 1996 according to the PRECIS floristic database of South Africa managed by the National Botanical Institute in Pretoria. No formal syntaxonomical classification was done. Formal syntaxonomy should follow after the analyses of all the different land-use types in the urban area of Potchefstroom.

Different terms are used to describe whether a species is native or alien to an area and whether it is spreading or not. To prevent any confusion with respect to the terms being used in this report, definitions are given of these terms, taken partly from Pyšek (1995b) and which were followed as far as possible:

1. Indigenous (native) species are those which evolved in the area or which arrived there by one means or another before the beginning of the neolithic period or which arrived there since that time by a method entirely independent of human activity.
2. Introduced (alien, exotic, weed, adventive) species are those which reached the area as a consequence of the activities of neolithic or post-neolithic man or of his domestic animals.
3. Invasive (naturalised, invader) species are aliens whose distribution and/or abundance is increasing regardless of their habitat.

Different terms are used to describe the extension and/or increase in abundance of species. The term invading is used for introduced species and the terms expanding or encroaching are used for indigenous species. Sometimes the term apophyte is also used for those indigenous species which are able to expand/encroach into man-made sites (Kowarik 1991). Where the terms declared weeds or declared invaders are used in the text, it refers to legislation being granted with respect to these species in South Africa (Wells *et al.* 1986).

Results and Discussion

Classification

From the classification (Table 1), the following communities were recognised:

1. *Conyza podocephala–Hyparrhenia hirta* Community
2. *Hermannia depressa–Themeda triandra* Community
   2.1 *Lippia scaberrima* Sub-community
   2.2 *Eragrostis chloromelas* Sub-community
3. *Bidens bipinnata–Acacia karroo* Community
4. *Guilleminea densa–Alternanthera pungens* Community
   4.1 *Cichorium intybus* Sub-community
   4.2 *Chloris virgata* Sub-community
   4.3 *Cynodon dactylon* Sub-community
5. *Lactuca serriola–Lepidium africanum* Community
   5.1 *Melia azedarach* Sub-community
   5.2 *Tragopogon dubius–Cynodon dactylon* Sub-community
6. *Malva neglecta–Sisymbrium orientale* Community

From the dendrogram of the original TWINSPAN classification (Figure 1) it is evident that the relevés are divided into two main groups. In group A the dominant species are mainly perennial, while annual species dominated in group B. Group A is further divided into groups A1 and A2. Group A1 associates vacant lots which are situated on the city margins, and contains two communities (1 and 2) which can be regarded as degraded natural communitites. The communities in group A2 (3 and 4) are ruderal communities which are situated mainly in or near the city centre on commercial and residential sites but also on the city margin. Group B also contains ruderal communitites (5 and 6), but in these communities annual plants dominate.

Table 1 A phytosociological table of vacant lots in the Potchefstroom Municipal Area, North West Province, South Africa

NUMBERS IN	1	1	1	2	0	1	2	2	1	1	1	1	2	2	2	2	4	1	2	0	3	3	3	0	0	3	0	0	2	0	1	3	3	3	2	3	0	0	4	4	4	5	4	5	4	4	4	4	3	3
TURBOVEG	2	8	9	6	5	1	5	8	3	4	5	6	0	2	3	4	5	7	1	4	2	3	4	6	9	0	2	8	7	7	0	6	7	5	9	1	3	1	9	4	6	0	7	1	2	0	1	3	8	9
NUMBER OF SPECIES	2	1		2	3	4	3	2	2	3	1	3	1	2	1	1	1	1	1	2	2	2	1	1	1	1	1	2	2	1	2	1	1		2	2	2	2	1		1	1	1	1	1	1	1	1		
PER RELEVE	3	4	9	8	4	0	0	7	9	5	6	1	4	2	4	0	3	9	8	4	0	5	4	8	6	2	9	0	2	9	5	9	5	9	0	1	1	3	4	8	6	5	5	1	0	3	0	2	5	3
COMMUNITIES	1			2.1					2.2				3				4.1				4.2										4.3								5.1				5.2						6	
SPECIES GROUP A																																																		
Hyparrhenia hirta -hl	3	3	4																+																															
Conyza podocephala -hl	A	A	+			1		+				+						+							1						+				+															
Chamaesyce inaequilatera -hl	+	r						r		r											+																													
Lotononis listii -hl	A																																																	
Gazania krebsiana serrulata -hl	1																																																	
SPECIES GROUP B																																																		
Themeda triandra -hl	A			3	3	3	B	3	B	A								r											+									+												
Hermannia depressa -hl	+			r	A	A	+	+	+	+		1								+																														
Hibiscus pusillus -hl				1	1	+	+	+	+	+				r						r															r															
Urginea multisetosa -hl				+	B	1	+			+		r																					1					1												
Tragus berteronianus -hl				+	+	+	+		+	+																				+					+															
Corchorus asplenifolius -hl	+			r		+		r	+		r	+																							+	+														
Pollichia campestris -hl	+			1		1	+				+	+																																						
Blepharis serrulata -hl						+	+		+	+																																								
Crabbea acaulis -hl					r	r		+	+																																									
*Gomphrena celosioides -hl				+					+	+	A												+						r				r		r	r														
Delosperma herbeum -hl				A					+			r																																						
Ziziphus zeyheriana -s2						1	+			1				1	+																																			
Bulbine narcissifolia -hl				+			+			+																																								
Cryptolepis transvaalensis -hl				+					r	+																																								
Monsonia angustifolia -hl	+								r			r																																						
Mariscus albomarginatus -hl					1				+																																									
Chaetacanthus costatus -hl						+						1																																						
Setaria sphacelata -hl			+			1				+																																								
Ledebouria ovatifolia -hl						1				+																																								
Vernonia oligocephala -hl						+				+																																								
Talinum arnotii -hl							+			+																																								
Eragrostis superba -hl				+						+																					r							r												
Indigofera heterotricha -hl				+								+																																						
Phyllanthus maderaspatensis -hl							+					+																																						
Rhynchosia totta -hl						+						r																																						
Deverra burchellii -hl							r			+																																								
Blepharis integrifolia -hl				r								r																																						
SPECIES GROUP C																																																		
Lippia scaberrima -hl				A	+		+			r			+	+																																				
Panicum coloratum -hl	+			+	+			+						+																																				
Eragrostis obtusa -hl				r			+	+												r															r															
Tephrosia rhytidocarpa -hl					r		+	+																																										
Thesium species -hl					r	+		+				+																																						
Eragrostis curvula -hl					A	3											A																				+			1										
Heteropogon contortus -hl					1		+																																											
Tephrosia burchellii -hl				+		1																																												
Berkheya radula -hl						+		1																																										
Elionurus muticus -hl					+	+																																												
Polygala amatymbica -hl				+		+																																												
Tripteris aghillana v. *aghillana* -hl	+			+			+			+																																				+				
Oenothera tetraptera -hl						r	+																																											
Digitaria eriantha -hl						1																															r													
Cymbopogon plurinodis -hl					1																																													
Aristida canescens -hl		+				1																		+					+																					
Stachys spathulata -hl								+																																										
SPECIES GROUP D																																																		
Eragrostis chloromelas -hl	1			1					+	+	1	B																	A				+																	
*Verbena tenuisecta -hl									+	+	+	+																							+															
Acacia karroo -s2									+	+									+																															
Asparagus suaveolens -s2									+	+				r		+			r																															
Walafrida densiflora -hl											B																																							
Andropogon schirensis -hl												B																																						
*Oxalis corniculata -hl		+						+	+	r																																								
Turbina oblongata -hl									1																																									

Table 1 Continued

NUMBERS IN	1	1	1	2	0	1	2	2	1	1	1	1	2	2	2	2	4	1	2	0	3	3	3	0	0	3	0	0	2	0	1	3	3	3	2	3	0	0	4	4	4	5	4	5	4	4	4	4	3	3
TURBOVEG	2	8	9	6	5	1	5	8	3	4	5	6	0	2	3	4	5	7	1	4	2	3	4	6	9	0	2	8	7	7	0	6	7	5	9	1	3	1	9	4	6	0	7	1	2	0	1	3	8	9
COMMUNITIES	1			2.1					2.2				3				4.1				4.2										4.3								5.1				5.2						6	
SPECIES GROUP E																																																		
Acacia karroo -t2													4	3	3							r									+					r														
Setaria verticillata -hl													1	A	+	1													+			+																		
**Amaranthus hybridus* -hl													+	+	+				+			+					r		+													+								
**Chenopodium mucronatum* -hl													1	1																																				
Asparagus laricinus -s2													1	r				+	r																			+												
Grewia flava -s2							+							r		+																																		
SPECIES GROUP F																																																		
**Guilleminea densa* -hl				+					+	+	+						1			+	+	+	+	1	3		A	1	+	4	+	+			+	+	1	1								+				
**Malvastrum coromandelianum* -hl							+						1						+	+	r	1	+		3	r	3	+	+	1	1	+		+			3													
Sporobolus fimbriatus -hl					+		+				+							+	+	1									+	+	+				+			+												
**Taraxacum officinale* -hl																	+	+		r	+			+							r					+							+						+	
Chloris pycnothrix -hl		+												+						A				+	1					+	A	B																		
SPECIES GROUP G																																																		
**Cichorium intybus* -hl					r												4	A	B	1							+																				+			
Lactuca inermis -hl		+															1			+													r																	
Dichondra repens -hl																				A																														
Tolpis capensis -hl																	1																																	
SPECIES GROUP H																																																		
Chloris virgata -hl					1			+	1		+										B	B	B	+	3	1	3	3	+	A	1		+																	
Tribulus terrestris -hl					+																+	+		+	+		+	1		+		+				+			+				+							
**Solanum sisymbrifolium* -hl																								A	r			3																						
**Portulaca oleracea* -hl																				+				+	+								r																	
**Zinnia peruviana* -hl																						r					+																							
**Portulaca quadrifida* -hl					r																							r		r																				
SPECIES GROUP I																																																		
Enneapogon cenchroides -hl							+							+	+							+		B		+	3	3	3	A	+	+			+	A	B	B												
**Schkuhria pinnata* -hl	+			+						+	+								+		+	+	+				B	r	+	r	+				r	+	+	1			1									
Convolvulus sagittatus -hl	+							+	+												r	+								r	+	r			+		r		+											
Urochloa mosambicensis -hl								+											1		+							+		A	+							+												
Stachys hyssopoides -hl																								+				+	+									+	+					+						
Eragrostis plana -hl										1								+			+	+				+							+		+	1						3								
**Ailanthus altissima* -t2																						r	+									+		3											B					
**Ambrosia psilostachya* -hl																											r				1					1	+													
**Modiola caroliniana* -hl																				1								r	+		+					+														
**Medicago sativa* -hl																							+						+			1						1												
SPECIES GROUP J																																																		
**Physalis viscosa* -hl	r	1	+			+	1	+	+		r	+	+	1	1			+		+							+	1		+			+			A	+	+					+	B						
Sida spinosa -hl	+		+			+		+	+	+		+		1	1	+			+	1		+			+				+							1		1												
**Verbena bonariensis* -hl	1	+			+			+	+			+							+	+						+			+				+		+	1		+												
**Tagetes minuta* -hl			+			+				+				1		A		r	r								1				r			+		+	+				1			+						
Aristida congesta -hl				+		+	+	+	+	+		+											+							1					3	A	+													
Felicia muricata -hl				+		+		+			+	+						+			r			+						A	+	+			A		+											+		
Eragrostis lehmanniana -hl		+			r		1	1												+	1	A	1		1	+							+													1				
**Plantago lanceolata* -hl	+		+						+									+		+					1				+		+	+						r												
Solanum panduriforme -hl					+	+	1	+						1				+				+				A											A													
SPECIES GROUP K																																																		
**Lactuca serriola* -hl																	1																						1	A	+	+		1	4	3	+	3		
**Chenopodium* species -hl																																							1	1	+	+	3	+		+		+		
**Tragopogon dubius* -hl																								+															1		+		1		1	3	A	1		
**Solanum elaeagnifolium* -hl																	+			1																				+	+	+	+	1			4	+		
SPECIES GROUP L																																																		
**Melia azedarach* -s1																					r																		3	4	3	4								
SPECIES GROUP M																																																		
Lepidium africanum -hl					+																+	+		+	+	+		+				r	r			1	3		A	1	+	B	3	1	1	A	B	3	r	
**Atriplex semibaccata* -hl					+								1		1		+								A	B		+									1				1	+	1	4		1	1	1		
**Boerhavia erecta* -hl																					+	+	+	+		+	+			3	+								+			+	+					+		
**Argemone mexicana* -hl					+																	+						+											1		1		A	1	1	1				
**Chenopodium album* -hl					+	r								+	+												+										+	+	1						+					
SPECIES GROUP N																																																		
**Alternanthera pungens* -hl					+		+		+	+				+	+		A		1	+	+	1		1	B	1	+	1	A	A	1	+	1	+	+	+	1	A			1	1	1			1		A		

Table 1 Continued

NUMBERS IN	1	1	1	2	0	1	2	2	1	1	1	1	2	2	2	2	4	1	2	0	3	3	3	0	0	3	0	0	2	0	1	3	3	3	2	3	0	0	4	4	4	5	4	5	4	4	4	4	3	3
TURBOVEG	2	8	9	6	5	1	5	8	3	4	5	6	0	2	3	4	5	7	1	4	2	3	4	6	9	0	2	8	7	7	0	6	7	5	9	1	3	1	9	4	6	0	7	1	2	0	1	3	8	9
COMMUNITIES	1			2.1					2.2				3				4.1				4.2										4.3								5.1				5.2						6	
SPECIES GROUP O																																																		
Cynodon dactylon -hl	1	1	B			1	1	+			B	+	1	B	A	1	B	3	3	1	+	A	A	4	+	3			1	+	4	A	3	+	1	A	1		A	A	B	B	A	A	3	3	4	3		
Urochloa panicoides -hl		+		+	+	+								+	B				+	+		+	+	1	A		A	A	+		1	+	+		+		+	3	1		1	+	+							
Bidens bipinnata -hl						+				+	+		+	A	1	B		+				+						r	1					+		+		r			1	1			1	1				
SPECIES GROUP P																																																		
Malva neglecta -hl																																																	A	+
Sisymbrium orientale -hl																																										B							B	3
SPECIES GROUP Q																																																		
Conyza bonariensis -hl					r												+	+		+	r	+						+			r		r			r		+	1	+	A	1	1	A	+	1	+	A	1	+

* = introduced species
t1 = high tree layer (>10 m); t2 = intermediate tree layer (5-10 m); t3= low tree layer (< 5 m)
s1 = high shrub layer (> 2 m); s2 = low shrub layer (< 2 m); hl = herbaceous layer

Description of the degraded natural communities

Degraded natural communities share certain species with some of the ruderal communities, for example, the highly invasive grass *Cynodon daclylon* and to a lesser extent, *Urochloa panicoides* and *Bidens bipinnata* (species group O, Table 1). Other species which are shared between the degraded natural and the ruderal communities where perennials are dominant, are the species in species group J (Table 1). The shared species include herbaceous introduced species such as *Physalis viscosa*, *Verbena bonariensis*, *Tagetes minuta* and *Solanum panduriforme* and herbaceous indigenous species such as *Sida spinosa*, *Felicia muricata* and the grasses *Aristida congesta* and *Eragrostis lehmanniana*. Although the species mentioned are important in the communities as they are regarded as invaders or weeds (Wells *et al.* 1986) or as indicators of grassland degradation (Bezuidenhout & Bredenkamp 1991; Bredenkamp *et al.* 1994), they are never dominant in any of the communities described.

1. *Conyza podocephala–Hyparrhenia hirta* Community

The *Conyza podocephala–Hyparrhenia hirta* Community is a grassland community situated on the wet, clayey soils (more than 30% clay) in the low-lying areas on the city margin. Soil forms present in this community include Valsrivier and Hutton (Soil Classification Work Group 1991).

Diagnostic species of this community are indigenous herbaceous plants such as the dominant grass *Hyparrhenia hirta* and the forbs *Conyza podocephala*, *Chamaesyce inaequilatera*, *Lotononis listii* and *Gazania krebsiana* subsp. *serrulata* (species group A, Table 1). *Cynodon dactylon* (species group 0, Table 1) has a high cover in this community in comparison with the other degraded natural communities on vacant lots. A low average number of 15 species per sample plot was recorded for this community, of which only 22% were introduced and 22% were therophytes. Tree and shrub strata were totally absent in this community, but the herbaceous layer is well developed with a canopy cover of 80% and a height of 1.4 m. Not many disturbances such as trampling, weeding, grazing, etc. were observed on the vacant lots containing this community, although these areas were mown sporadically. The *Conyza podocephala–Hyparrhenia hirta* Community probably represents a degraded form of the *Paspalo dilatati–Hyparhenietum hirtae* (Bezuidenhout *et al.* 1994b), an association which belongs to the *Eragrostido planae–Hyparrhenietea hirtae*, a phytosociological class described by Bezuidenhout *et al.* (1994a) for floodplains and dry watercourses in the western Transvaal. This community also resembles the already degraded *Hyparrhenia hirta–Verbena bonariensis* Variant of the *Hyparrhenia hirta* Wetland Community, described by Bredenkamp *et al.*, (1994) in the Boskopdam Nature Reserve near Potchefstroom, to a certain extent.

2. *Hermannia depressa–Themeda triandra* Community

Another grassland community on the city margin, but on drier, sandy or gravelly soils, although the clay content of some of the soils can be high. Dominant soil forms are Hutton and Glenrosa, and occassionally Westleigh (Soil Classification Work Group 1991).

Diagnostic species of the *Hermannia depressa–Themeda triandra* Community are species group B (Table 1), which include the dominant perennial grass *Themeda triandra*, an annual grass *Tragus berteronianus*, indigenous perennial forbs such as *Hermannia depressa*, *Hibiscus pusillus*, *Corchorus asplenifolius* and *Blepharis serrulata* and geophytes *Urginea multisetosa* and *Bulbine narcissifolia*. Other species which occur in this community are those of species groups J and O (Table 1), which indicate the degraded nature of some grassland communities (Wells *et al.* 1986; Bezuidenhout & Bredenkamp 1991; Bredenkamp *et al.* 1994). Different levels of disturbance or management were observed on the vacant lots which represent this community. Management practises varied from no mowing and no trampling to sporadically and frequent mowing and moderate trampling. Garden refuse and building rubble are occasionally dumped on some of the vacant lots. The presence of the introduced species *Physalis viscosa*, *Tagetes minuta*, *Alternanthera pungens* and *Bidens bipinnata* may be an indication of the future development of ruderal communities on sites with fairly natural vegetation.

The *Hermannia depressa–Themeda triandra* Community is probably a degraded form of the *Themedo triandrae–Heteropogonetum contorti*, a common association described by Bezuidenhout and Bredenkamp (1991) for the Bc land type at Potchefstroom. Interestingly, the *Themedo triandrae–Heteropogonetum contorti* contain less species per sample plot than was encountered for the degraded form discussed in the current study. The general tendency in degraded or encroached grasslands of railway reserves in the Potchefstroom Municipal Area was that species number decreased with increased disturbance (Cilliers & Bredenkamp 1998).

Two sub-communities can be distinguished in this community, based on species composition as well as degree of disturbance.

2.1 *Lippia scaberrima* Sub-community

This sub-community of the *Hermannia depressa–Themeda triandra* Community seems to be less disturbed than the *Eragrostis chloromelas* Sub-community. The *Lippia scaberrima* Sub-community can be regarded as the remains of the natural grasslands as it has a species composition similar to the natural grasslands, described by Bezuidenhout and Bredenkamp (1991). Diagnostic species are the perennial grasses *Panicum coloratum, Eragrostis obtusa, Eragrostis curvula* and *Elionurus muticus*, and forbs such as *Lippia scaberrima, Thesium* sp. and *Tephrosia burchellii* (species group C, Table 1). A number of species only occurred once in the *Lippia scaberrima* Sub-community (Table 2). A tree layer is absent and a low shrub layer of 0.2 m tall covers less than 5% of the area. The herbaceous layer is well developed with a canopy cover of about 65% and is 0.8–1 m tall. An average number of 31 species per sample plot was recorded for this community of which only 20% were introduced and 7% were therophytes.

2.2 *Eragrostis chloromelas* Sub-community

The *Eragrostis chloromelas* Sub-community is regarded as the more degraded variation of the *Hermannia depressa–Themeda triandra* Community. Some of the sites are characterised by the encroachment of woody shrubs such as *Acacia karroo* and *Asparagus suaveolens*. The phenomenon of bush encroachment in degraded grasslands in the western Transvaal was described extensively by a number of authors (Louw 1951; Friedel 1987, Bezuidenhout *et al.* 1 994b and Cilliers & Bredenkamp 1998).

Excluding the mentioned two diagnostic species, other diagnostic species include the perennial grasses *Eragrostis chloromelas* and *Andropogon schirensis* as well as the forb *Verbena tenuisecta*, (species group D, Table 1). The latter species was introduced to South Africa for cultivation as an ornamental, but has escaped and became naturalised throughout the country on roadsides and other waste places (Bromilow 1995). A further 14 species were only observed once in this sub-community (Table 2). The tree layer is absent, the shrub layer (cover of 15%, height of 0.8 m) is relatively well developed and the herbaceous layer is well developed with a canopy cover of about 70% and a height of 0.6–0.8 m. An average number of 27 species per sample plot were recorded of which only 18% were introduced and 10% were therophytes.

Description of ruderal communities where perennial plants dominated

Ruderal communities have a number of unique species (species groups E, F, G, H and 1, Table 1) although they share the species of species group J (Table 1) with the degraded natural communities.

3. *Bidens bipinnata–Acacia karroo* Community

The *Bidens bipinnata–Acacia karroo* Community is a woodland situated mainly in residential and industrial areas on the city margin. It will probably never develop on residential and commercial vacant lots closer to the city centre, because of strict maintenance policies being implemented by the Potchefstroom Municipality. The grass layer is continuously mown on vacant lots closer to the city centre and young *Acacia karroo* plants are also cut down in the process.

Initially this woodland community seems to be a degraded natural community, but could be better described as a degraded encroached community, as the dominant species *Acacia karroo* was not found in the original grasslands of this area. The *Bidens bipinnata–Acacia karroo* Community probably established because of the encroachment of the woody species *Acacia karroo* and *Asparagus laricinus* from the *Acacion karroo*, an alliance described by Bezuidenhout and Bredenkamp (1991) for the footslopes and bottomlands of the Bc land type, into the grasslands. These indigenous woody species can be classified as apophytes, because they are able to establish in man-made habitats. Similar communitites were described along railway lines in the municipal area of Potchefstroom (Cilliers & Bredenkamp 1998). Further degradation of these encroached communities is indicated in this community by the establishment of annual shade-loving weeds such as *Setaria verticillata, Chenopodium mucronatum* and *Amaranthus hybridus*, under the trees after the removal of the original herbaceous and shrub layers.

The diagnostic species of this community are species group E (Table 1). It includes *Acacia karroo*, the dominant tree in the

Table 2 List of species which occurred only a few times and have relatively low cover, on vacant lots in the Potchefstroom municipal area, North West Province, South Africa

Communities	Species (relevé number)(cover abundance values)
1	*Brachiaria eruciformis* (18)(+); **Conyza albida* (12)(r); *Osteospermum muricatum* (18)(+), (5)(r)
2.1	*Aerva leucura* (26)(r); *Bulbine abyssinica* (11)(+); *Cucumis zeyheri* (5)(+); *Gnidia capitata* (25)(+); *Ledebouria luteola* (28)(+); *Ledebouria revoluta* (25)(+); *Leucas capensis* (26)(+);**Solanum mauritianum* (5)(+); *Turbina oenotheroides* (11)(+); **Verbascum virgatum* (5)(r)
2.2	*Aristida junciformis* (16)(+); *Chamaecrista biensis* (16)(+); *Chlorophytum cooperi* (16)(+); *Commelina africana* (14)(r); *Crabbea angustifolia* (13)(+); *Helichrysum coriaceum* (16)(+); *Ipomoea obscura* (16(r); *Kohautia lasiocarpa* (16)(+); **Melinis repens* (15)(+); *Stoebe vulgaris* (16)(+); *Sutera aurantiaca* (14)(r); *Tephrosia capensis* (13)(+); *Trichoneura grandiglumis* (1)(r), (16)(+), **Tropaeolum major* (14)(r)
3	**Araujia sericifera* (20)(+); *Celtis africana* (24)(+); **Datura stramonium* (2)(+), (23)(+); **Gleditsia triacanthos* (20)(+); *Rhus pyroides* var. *pyroides* (24)(+)
4.1	*Crotalaria virgulata* (17)(r); *Gomphocarpus decipiens* (17)(r); **Melilotus alba* (17)(+); *Pavonia burchellii* (21)(+)
4.2	**Chamaesyce hirta* (32)(+); **Chenopodium carinatum* (8)(r); *Gomphocarpus fruticosa* (33)(+); **Ipomoea purpurea* (2)(+); **Lathyrus odoratus* (34)(r); **Malva parviflora* (7)(r)
4.3	**Cestrum* sp. (35)(+); **Chamaesyce prostrata* (36)(+); *Falckia oblonga* (10)(1), (28)(+); *Indigofera cryptantha* (29)(+); **Mirabilis jalapa* (35)(1), (36)(+); **Moraea thomsonii* (36)(+), (1)(+); **Morus alba* (35)(1); **Nicotiana glauca* (3)(r); *Setaria nigrirostris* (1)(+)
5.1	**Picris echioides* (46)(+)
5.2	*Commelina benghalensis* (41)(1); *Eragrostis trichophora* (43)(A); **Sonchus asper* (41)(+); **Sonchus oleraceus* (47)(+)
No specific community	**Pennisetum clandestinum* (17)(+), (10)(+), (36)(+), (23)(+), (42)(3);

* = introduced species

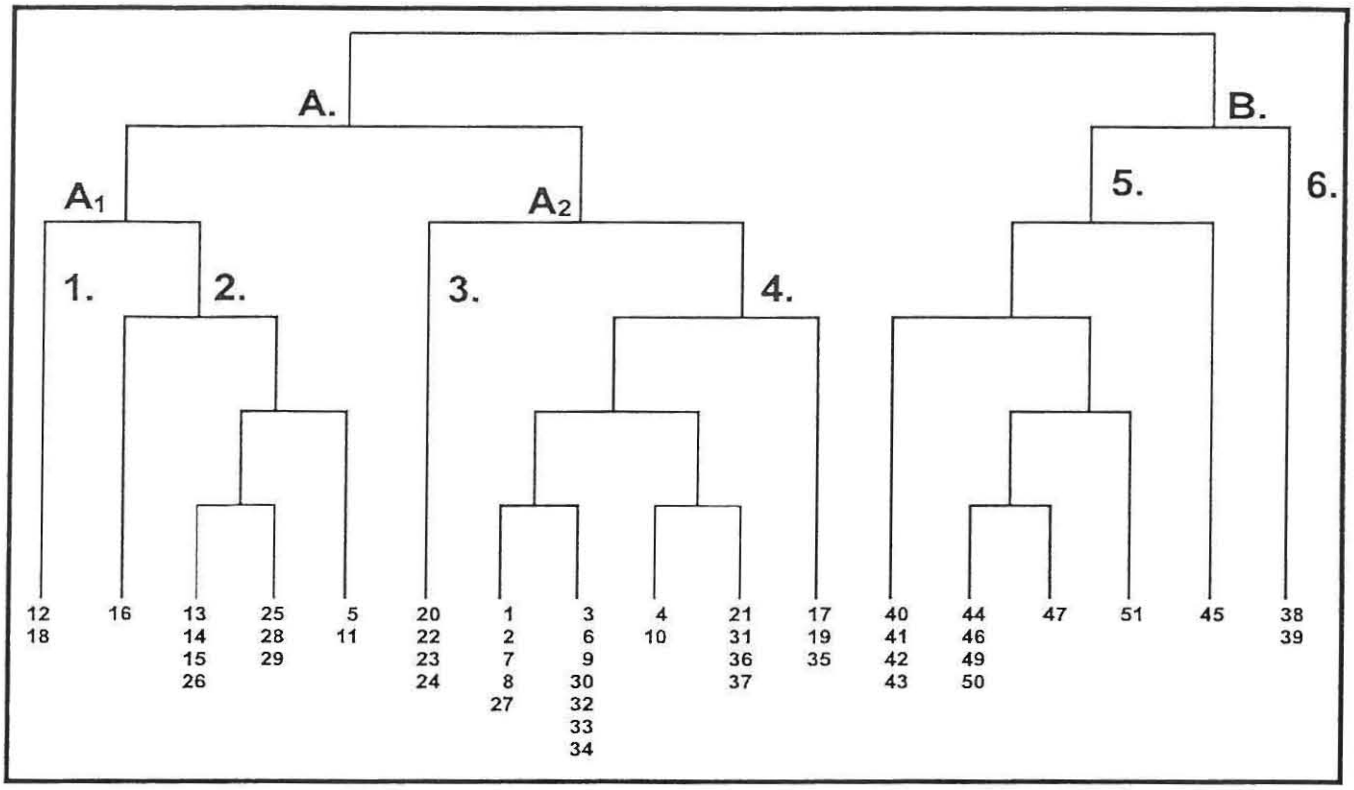

Figure 1 Dendogram of the TWINSPAN classification of relevés on vacant lots in the Potchefstroom Municipal Area, North West Province, South Africa. (A - communities where perennial plants dominated, A1 - degraded natural communities, A2 - ruderal communities, B - ruderal communities where annual plants dominated, other numbers refer to those in text and in Table 1).

well developed tree stratum with a canopy cover of 65% and an average height of 4.5 m. Other trees in this stratum which occurred only once during the study are *Celtis africana* and *Gleditsia triacanthos* (Table 2). The shrub stratum with *Grewia flava* and *Asparagus laricinus* the diagnostic shrubs, is not so well developed (lower than 10% cover and 1.2 m tall). The herbaceous stratum is, however, well developed in certain areas, with a canopy cover of up to 40% and a height of 1 m. Diagnostic herbaceous species include the annual grass *Setaria verticillata* and the annual forbs *Amaranthus hybridus* and *Chenopodium mucronatum*. The introduced annual, *Bidens bipinnata* (species group O, Table 1) is the dominant forb in this community. A relatively low average number of 15 species per sample plot were recorded for this community of which 43% were introduced and 25% were therophytes.

4. *Guilleminea densa–Alternanthera pungens* Community

The *Guilleminea densa–Alternanthera pungens* Community is situated on vacant lots in commercial areas in the city centre, as well as residential areas closer to the city centre or to main roads. All vacant lots on which this community was encountered have undergone some type of disturbance and all of them were previously built on. The anthropogenic soil form, Witbank, is the dominant soil type, but other soil forms such as Hutton, Bainsvlei, Westleigh and even a vertic soil of the Arcadia soil form (Soil Classification Work Group 1991) occur on some of the vacant lots.

The diagnostic species of this community are species group F (Table 1), including the introduced forbs *Guilleminea densa*, *Malvastrum coromandelianum* and *Taraxacum officinale*, and the indigenous grasses *Sporobolus fimbriatus* and *Chloris pycnothrix*. Other species which occur in this community are species group J, N and O (Table 1). The dominant species in this community is the invasive grass *Cynodon dactylon*. A similar community was described on heavily compacted pavements which were not covered by paving stones or slabs (Cilliers & Bredenkamp in press).

This ruderal community consists of three sub-communities which can sometimes exist as small mosaics on the same vacant lot. They differ from each other with respect to species composition, intensity of trampling and accompanied soil compaction

4.1 *Cichorium intybus* Sub-community

The *Cichorium intybus* Sub-community is situated mainly on residential sites in relatively wet places which are not frequently mown. Soil compaction is, however, high (> 4 kg/m^2) and crust formation is evident in some areas.

Dominant species in this community are the creeping grass *Cynodon dactylon* (species group O, Table 1) and the tall-growing, introduced perennial forb, *Cichorium intybus* (species group G, Table 1). Other diagnostic species are indigenous forbs such as *Lactuca inermis*, *Dichondra repens* and *Tolpis capensis* (species group G, Table 1). A well developed herbaceous layer (canopy cover of 80% and height of up to 1.2 m) exists in this sub-community. An average number of 18 species per sample plot were recorded of which 42% were introduced and 22% were therophytes.

4.2 *Chloris virgata* Sub-community

This sub-community is situated mainly in commercial areas in the city centre or residential areas near the city centre, in dry, hot conditions. Maintenance, for example the intensity of mowing and the rate and intensity of trampling are high, and subsequently soil compaction is high (> 4 kg/m^2).

The dominant species and also one of the diagnostic species of this community is the indigenous pioneer grass, *Chloris virgata* (species group H, Table 1). The other diagnostic species are all creeping or low-growing forbs such as *Tribulus terrestris*, *Portulaca oleracea*, *Zinnia peruviana*, *Portulaca quadrifida* and the declared weed *Solanum sisymbrifolium* (species group H, Table 1). Other species which occur in this sub-community are species group I (Table 1), which includes another indigenous pioneer grass *Enneapogon cenchroides*, and species groups J, M, N and O (Table 1). An average number of 18 species per sample plot were recorded of which 57% were introduced and 37% were therophytes. A tree layer, consisting of the invasive alien, *Ailanthus altissima* (species group I, Table 1) is poorly developed (less than 5% canopy cover and lower than 3 m). The shrub layer is absent, while the herbaceous layer is well developed with a canopy cover of 65% and an average height of 0.3 m.

4.3 *Cynodon dactylon* Sub-community

This sub-community of the *Guilleminea densa–Alternanthera pungens* Community is situated mainly on residential sites where maintenance, for example mowing, is done sporadically. The soil compaction is much lower (lower than 3 kg/m^2) in the *Cynodon dactylon* Sub-community in comparison with the *Chloris virgata* Sub-community, because less trampling occurs in this sub-community.

No diagnostic species exist for this sub-community, and it is characterised by the absence of species group H (Table 1) which are diagnostic species for the *Chloris virgata* Sub-community. There is, however, an affinity between the *Cynodon dactylon* Sub-community and the previous sub-community, because of the presence of species in species group I (Table 1). These species include indigenous grasses such as *Enneapogon cenchroides* and *Urochloa mosambicensis* and the forbs *Schkuhria pinnata*, *Convolvulus sagittatus* and *Stachys hyssopoides*. Other species which occur in this sub-community are .those of species groups J, M and N (Table 1). An average number of 19 species per sample plot was recorded for this sub-community of which 45% were introduced and 24% were therophytes. A tree stratum occurs on some of the vacant lots, which is better developed than in the *Chloris virgata* Sub-community, with a canopy cover of 15% and a height of 3 m. There is still no shrub stratum and the herbaceous stratum is also well developed (canopy cover of 80% and an average height of 0.7 m).

Description of ruderal communities where annual plants dominated

Except for a number of common species such as the grasses *Cynodon dactylon* and *Urochloa panicoides* and the annual weed *Bidens bipinnata* (species group O, Table 1) as well as species groups M and N (Table 1) these ruderal communities do not share many species with the other communities on vacant lots.

5. *Lactuca serriola–Lepidium africanum* Community

The *Lactuca serriola–Lepidium africanum* Community established during late winter and early spring on most of the vacant lots where community 4 (*Guilleminea densa–Alternanthera pungens* Community) exists, but on soil heaps or building debris, in less trampled and less compacted parts of these sites. The affinity between this community and two of the sub-communities of the *Guilleminea densa–Alternanthera pungens* Community is shown by the co-existence of species such as the annual forbs *Lepidium africanum* and *Chenopodium album* (species group M, Table 1) and the perennial forbs *Atriplex semibaccata* (species group M, Table 1) and *Alternanthera pungens* (species group N, Table 1).

The diagnostic species of the *Lactuca serriola–Lepidium africanum* Community are those of species group K (Table 1). These species are *Lactuca serriola* and a *Chenopodium* species, which are annual exotics from Europe and Asia and a perennial species from the Americas, *Solanum elaeagnifolium*, which is a declared weed in South Africa (Wells *et al.* 1986). The dominant species of this community are *Lepidium africanum* (species group M, Table 1) and *Cynodon dactylon* (species group O, Table 1). Although *Lepidium africanum* is usually an annual, it may persist for two years, and because of its frost resistance, it is more prominent in the *Lactuca serriola–Lepidium africanum* Community than in the *Guilleminea densa–Alternanthera pungens* Community. Other species in this community are those of species groups N, O, and Q (Table 1).

The *Lactuca serriola–Lepidium africanum* Community has never been described before in South Africa. This community, however, seems to be similar with respect to floristic composition and habitat, to communities described in Europe, for example the *Lactuca serriola* dominated type of the *Erigeronto–Lactucetum* Lohmeyer in Oberdorfer 1957 mentioned by Mucina and Kolbek (1989). This *Lactuca serriola* type is characteristic of warm and dry climates of eastern Europe where it occurs on heaps of loam and sandy-loam materials in close vicinity to building sites, or on ruins of old houses (Mucina & Kolbek 1989).

Two sub-communities are recognised in the *Lepidium africanum–Lactuca serriola* Community, based upon the presence of a woody component.

5.1 *Melia azedarach* Sub-community

This sub-community is characterised by the presence of a low (maximum height of 1.2 m), relatively well developed shrub stratum (canopy cover of 40%), which consists of the dominant species, *Melia azedarach* (species group L, Table 1). These shrubs are cut down three to four times a year, and will under these strict maintenance policies not grow into trees. The herbaceous stratum is also well developed with a canopy cover of 60% and a maximum height of 1.2 m, and consists of the species of species groups K, M, N, O, and Q. An average number of 13 species per sample plot were recorded of which 72% were introduced and 64% were therophytes.

5.2 *Tragopogon dubius–Cynodon dactylon* Sub-community

Although no diagnostic species are present in this sub-community, it is characterised by the absence of a tree and shrub stratum, including the shrub *Melia azedarach*. The herbaceous stratum, however, is well developed with a canopy cover of nearly 100% and is 1 m tall. The dominant species is the invasive grass *Cynodon dactylon* (species group O, Table 1) while the forb *Tragopogon dubius* (species group K, Table 1) is conspicuous in late winter and early spring due to the presence of large capitula. An average number of 11 species per sample plot were recorded of which 71% were introduced and 50% were therophytes.

6. *Malva neglecta–Sisymbrium orientale* Community

The *Malva neglecta–Sisymbrium orientale* Community seems to be unique for vacant lots and could only be observed once during winter months, as a linear community along south-facing walls. The plants of this community are usually removed during or shortly after winter. The diagnostic species for this community are two exotic species from Europe and Asia which can be annual or bi-annual, namely *Sisymbrium orientale* and *Malva neglecta* (species group P, Table 1). These two species were also found in other urban open spaces such as fragmented natural areas and in cracks on pavements or around buildings, but never in such a distinct community as this one. This community differs distinctively from all the other communities found on vacant lots (Figure 1) because it does not contain any of the so-called common species (species group O, Table 1). It shows, however, affinities with the *Lactuca serriola–Lepidium africanum* Community, as both share the annual species, *Conyza bonariensis* (species group Q). A very low average of only 5 species were recorded per sample plot, of which most are introduced and annual species. No tree or shrub strata exist, but the herbaceous stratum is relatively well developed with a canopy cover of 50% and 1.2 m tall.

The *Malva neglecta–Sisymbrium orientale* Community was never before described in South Africa. For Europe, however, quite a number of communities where *Malva neglecta* is dominant have been described. One similar community is an association (*Malvetum neglectae*), which occurs on small areas in sunny to semi-shaded moist habitats enriched by liquid rubbish and poultry mutes (Jarolímek & Zaliberova 1995). This association, and probably the one in the current study, belong to the *Malvion neglectae* (Gutte 1972: referred to by Mucina 1987). Mucina (1989) mentioned that communities of the *Malvion neglectae* in Slovakia are nowadays situated along walls and fences where the soil is enriched by liquid nitrogen-rich wastes. It is not yet known if this is also one of the reasons for the establishment of the *Malva neglecta–Sisymbrium orientale* Community along walls in Potchefstroom.

Species number and origin of species

From a total number of 172 species recorded on vacant lots in Potchefstroom, only 35.4% were introduced species. In studies from other parts of the world, the contribution of introduced species was usually much higher. In Rosario City, Argentina, Franceschi (1995) also recorded 172 species, but more than 50% of them were introduced from Europe and Asia or other countries in the Americas. Vincent and Bergeron (1985) observed 136 species on vacant lots in Montreal, Canada, of which 58.8% were introduced. With respect to the origin of the introduced species, the data from Potchefstroom is much more comparable with studies being done elsewhere. American species (mainly from South America) comprise 45.9% of the total number of introduced species and 39.3% are European or Euro-Asian, with the remaining species from Australia, elsewhere in Africa or with uncertain origin.

When only the ruderal communities (communities 3, 4, 5, and 6) of Potchefstroom are taken into consideration, the total number of species is 114, of which 46.4% are introduced. These numbers are closer to those obtained from studies in Canada (Vincent & Bergeron 1985) and Argentina (Franceschi 1996).

Ordination

In the scatter diagram (Figure 2) the distribution of the communities described for vacant lots along ordination axes 1 and 2 of the DECORANA ordination is given. The distribution of the relevés indicates a distinct discontinuity between the plant communities, with the exception of the three sub-communities of community 4 (*Guilleminea densa –Alternanthera pungens* Community).

The scatter diagram also illustrates a gradient on axis 1. Along axis 1, the degraded natural communities (1, 2.1 and 2.2) occur to the left of the diagram while the ruderal communities where perennial plants dominate (3 and 4) occur in the centre with the ruderal communities which consist mainly of annual plants (5.1, 5.2 and 6) to the right of the diagram. A disturbance gradient is, therefore, evident on axis 1, from less disturbed (more indigenous species and perennials) on the left to more disturbed on the right (more introduced species and annuals) to the right. The position of community 3 (*Acacia karroo–Bidens bipinnata* Community) to the left may be misleading, as it was described as a ruderal or degraded encroached community. This is, however, the only community described for vacant lots where apophytes (for example *Acacia karroo*) dominate. Along axis 2 a gradient is

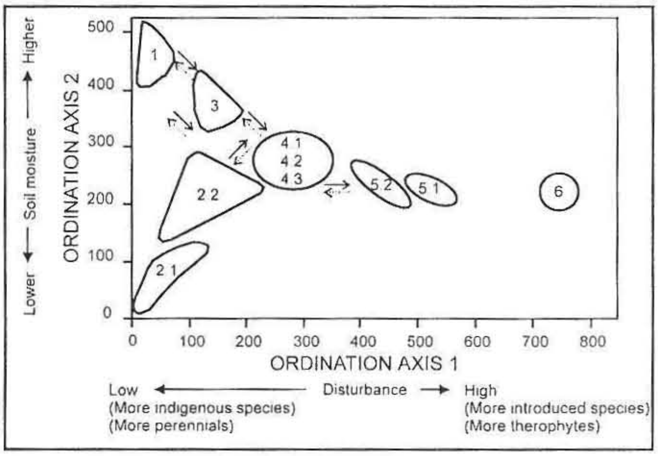

Figure 2 The relative positions of the communities along the first two axes of the ordination of vacant lots in the Potchefstroom Municipal Area, North West Province, South Africa (numbers refer to those in text).

illustrated, in the degraded natural communities, which may be related to soil moisture, namely wetter soils to the top and drier soils to the bottom of the scatter diagram.

An ordination was also performed on the relevés of community 4 (*Guilleminea densa–Alternanthera pungens* Community). On axis 1 of the scatter diagram (Figure 3) of this community the three sub-communities are clearly distinguished from each other. It also illustrates a gradient which could be related to soil moisture, from drier soils at the left to wetter soils to the right of the scatter diagram (Figure 3).

Conclusion

There is no substantial similarity between the ruderal communities on vacant lots of Potchefstroom and those of Rosario City (Franceschi 1996) or Montreal (Vincent & Bergeron 1985) with respect to species composition. Although there were some similar species found in the studies in Potchefstroom, Rosario City and Montreal, the large contribution of the South African species (42.4% in the ruderal communities and 64.6% in ruderal and degraded natural communities) lead to the development of a number of communities only found in South Africa. One important

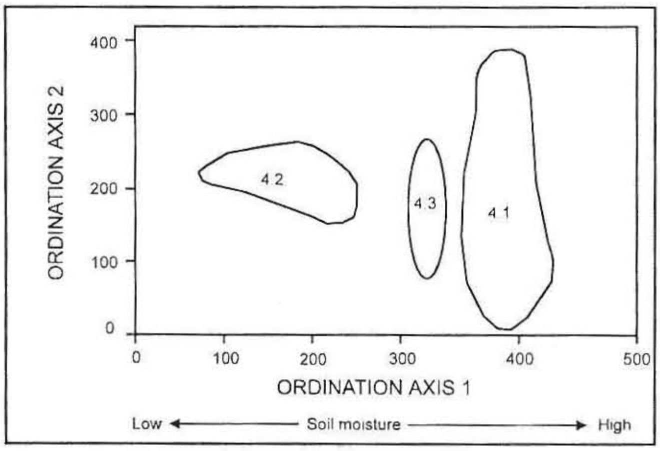

Figure 3 The relative positions of the sub-communities of the *Guilleminea densa–Alternanthera pungens* Community, along the first two axes of the ordination of vacant lots in the Potchefstroom Municipal Area, North West Province, South Africa (numbers refer to those in text).

aspect in which the current study corresponds to that in Rosario City (Franceschi 1996), is that the ruderal communities have one strong dominant species and a few abundant or constant species. There are, however, species with low frequency, for example 46% of the total number of species in the ruderal communities were recorded in only one or two sample plots (Table 2).

Ruderal communities described in fallow lands in the _Silverglen Nature Reserve just outside Durban (Boswell 1993), in the grassland complex of the Durban Municipal Area (Roberts 1993) and in grasslands of the Queensburgh Municipal area (Seppings 1994) do also not correspond with communities described in the current study. Certain similar species such as the weedy species *Cynodon dactylon*, *Tagetes minuta*, *Taraxacum officinale* and the proposed declared invader *Melia azedarach*, were however, encountered.

The specific role of vacant lots as dispersal corridors to provide ecological continuity in the urban environment (Roberts & Poynton 1985) could not be established in this study. Most of the degraded natural communities were situated on the city margin, while the ruderal communities have been established in the inner city as well as on the city margin. Information from other urban open spaces of Potchefstroom is needed before biogeographical issues such as those concerning islands and corridors can be dealt with.

Results from other urban open spaces in Potchefstroom (Cilliers 1998; Cilliers & Bredenkamp 1998; Cilliers & Bredenkamp in press), should eventually be included in the development of a management plan for the area. This study, however, already provides important information regarding community structure, species composition and habitat and disturbance factors, which can be used in the implementation of conservation orientated planning and management programmes. The results also contribute to the development of maintenance programmes that will enhance the development of more stable communities in urban open spaces. Changes to the frequency of mowing (less frequent) of the degraded natural grassland communities (*Conyza podocephala–Hyparrhenia hirta* Community and *Hermannia depressa–Themeda triandra* Community) must be taken into consideration. Due to relatively strict management policies, these grasslands are kept in a sub-climax condition and will probably be taken over by ruderal communities in the future.

The results of this study may also aid towards a better understanding of the dynamics of grasslands. The scatter diagram of the ordination (Figure 2) indicated that two major grassland community types (*Hyparrhenia*-dominated community 1 and *Themeda*-dominated community 2) degraded through a number of successive invasions, aided by anthropogenic influences towards a single pioneer type (community 4 with three sub-communities). These pioneer communities may degrade under further, but more specialised or urbanised anthropogenic influences, to form ruderal communities which only appear annually (communities 5 and 6). To determine whether these pioneer communitites on vacant lots will again develop towards climax communities if management practises are drastically changed, may be possible if vegetation dynamics over time are studied. Trepl (1995), however, stated that successions in biocoenoses which are subject to strong and extremely variable anthropogenic influences are of a historical rather than a merely dynamic character. These successions are, therefore, not deterministically directed towards a pre-determined state (climax) but are unpredictable and not repeatable (Trepl 1995). Further studies with respect to this hypothesis are necessary.

Acknowledgements

The first author wishes to thank the following institutions and persons: The Potchefstroom University for Christian Higher Education, Prof. L. Mucina, University of Kuwait, Prof. A.J.H. Pieterse, Head of the Section Botany of the School for Environmental Sciences and Development, Potchefstroom University for C.H.E., Dr. H. Bezuidenhout, Scientific Services, National Parks Board. The National Herbarium, Pretoria and Mr B. Ubbink, Botanical Garden, Potchefstroom University for C.H.E. are also thanked for assistance with plant identification.

References

ARNOLD, T.H. & DE WET, B.C. 1993. Plants of southern Africa: names and distribution. *Mem. bot. Surv. S. Afr.* 62: 1–825.

BEZUIDENHOUT, H. 1993. Syntaxonomy and Synecology of western Transvaal Grasslands. Ph. D. dissertation. University of Pretoria, Pretoria.

BEZUIDENHOUT, H. & BREDENKAMP, G.J. 1991. The vegetation of the Bc land type in the western Transvaal Grassland, South Africa. *Phytocoenologia* 19(4): 497–518.

BEZUIDENHOUT, H., BREDENKAMP, G.J. & THERON, G.K. 1994a. Phytosociological classes of the western Transvaal grassland, South Africa. *Koedoe* 37(1): 1–18.

BEZUIDENHOUT, H., BREDENKAMP, G.J. & THERON, G.K. 1994b. A classification of the vegetation of the western Transvaal dolomite and chert grassland, South Africa. *S. Afr. J. Bot.* 60(3): 152–161.

BEZUIDENHOUT, H., BIGGS, H.C. & BREDENKAMP, G.J. 1996. A process supported by the utility BBPC for analysing Braun-Blanquet data on a personal computer. *Koedoe* 39(1): 107–112.

BOSWELL, P.S. 1993. The development of a conservation and management plan for Silverglen Nature Reserve, Durban. M.Sc. thesis, University of Natal, Durban.

BREDENKAMP, G.J. & THERON, G.K. 1978. A synecological account of the Suikerbosrand Nature Reserve. I. The phytosociology of the Witwatersrand geological system. *Bothalia* 12: 513–529.

BREDENKAMP, G.J. & VAN ROOYEN, N. 1996. Dry Sandy Highveld Grassland. In: Vegetation of South Africa, Lesotho and Swaziland, eds. A.B. Low & A.G. Rebelo, pp. 41,42. Dept. Environmental Affairs & Tourism, Pretoria.

BREDENKAMP, G.J., BEZUIDENHOUT, H., JOUBERT, H. & NAUDÉ, C. 1994. The vegetation of the Boskop Dam Nature Reserve, Potchefstroom. *Koedoe* 37(1): 19–33.

BROMILOW, C. 1995. Problem plants of South Africa. Briza, Arcadia.

CILLIERS, S.S. 1998. Phytosociological studies of urban open spaces in Potchefstroom, North West Province, South Africa. Ph.D. dissertation, Potchefstroom University for Christian Higher Education, Potchefstroom.

CILLIERS, S.S. & BREDENKAMP, G.J. 1998. Vegetation analysis of railway reserves in the Potchefstroom Municipal Area, North West Province, South Africa. *S. Afr. J. Bot.* 64(5): 271–280.

CILLIERS, S.S. & BREDENKAMP, G.J. in press. Analysis of the spontaneous vegetation of intensively managed urban open spaces in the Potchefstroom Municipal Area, North West Province, South Africa. *S. Afr. J. Bot.*

EDWARDS, D. 1983. A broad-scale structural classification of vegetation for practical purposes. *Bothalia* 14(3 & 4): 705-712.

FRANCESCHI, E.A. 1996. The ruderal vegetation of Rosario City, Argentina. *Landscape Urban Plann.* 34: 11–18.

FRIEDEL, M.H. 1987. A preliminary investigation of woody plant increase in the western Transvaal and implications for veld assessment. *J. Grassl. Soc. South. Afr.* 4: 25–30.

GRIME, J.P. 1979. Plant Strategies and Vegetation Processes. Wiley, Chichester.

HENDERSON, L. 1991. Invasive alien woody plants of the Orange Free State. *Bothalia* 21(1): 73–89.

HENDERSON, L. & MUSIL, K.J. 1984. Exotic woody plant invaders of the Transvaal. *Bothalia* 15(1 & 2): 297–313.

HENKE, H. & SUKOPP, H. 1986. A natural approach in cities. In: Ecology and Design in Landscape, 24th Symposium of the British Ecological Society, eds. A.D. Bradshaw, D.A. Goode, & E.H.P. Thorp, pp. 307–324. Blackwell, Oxford.

HENNEKENS, S.M. 1996a. TURBOVEG: Software package for input, processing, and presentation of phytosociological data. IBN-DLO, University of Lancaster.

HENNEKENS, S.M. 1996b. MEGATAB: a visual editor for phytosociological tables. Giesen & Geurts, Ulft.

HILL, M.O. 1979a. TWINSPAN: a Fortran program for arranging multivariate data in an ordered two-way table by classification of individuals and attributes. Cornell University, Ithaca, New York.

HILL, M.O. 1979b. DECORANA: a Fortran program for detrended correspondence analysis and reciprocal averaging. Cornell University, Ithaca, New York.

JAROLÍMEK, I. & ZALIBEROVA, M. 1995. Ruderal plant communities of north-eastern Slovakia II. Chenopodietea, Plantaginetea. *Thaiszia - J. Bot. Kosice* 5: 61–79.

KOWARIK, I. 1991. The adaptations of urban flora to man-made perturbations. In: Terrestrial and aquatic ecosystems: perturbation and recovery, ed. O. Raviera, pp. 176–184. Ellis Horwood, London.

LOUW, W.J. 1951. An ecological account of the vegetation of the Potchefstroom area. *Mem. bot. Surv. S. Afr.* 24: 1–105.

MUCINA, L. 1987. The ruderal vegetation of the northwestern part of the Podunajská nizina Lowland. 5. *Malvion neglectae. Folia Geobot. Phytotax Praha* 22: 1–23.

MUCINA, L. 1989. Endangered ruderal plant communities of Slovakia and their preservation. *Phytocoenologia* 17(2): 271–286.

MUCINA, L. & KOLBEK, J. 1989. Some anthropogenous vegetation types of southern Bulgaria. *Acta Bot. Croatia* 48: 83–102.

MUELLER-DOMBOIS, D. & ELLENBERG, H. 1974. Aims and methods of vegetation ecology. Wiley, New York.

NEL, L.T., TRUTER, F.C. & WILLEMSE, J. 1939. The geology of the country around Potchefstroom and Klerksdorp. An explanation of sheet 61. Geological Survey. Union of South Africa. Dept. of Mines.

PYSEK, P. 1995a. Approaches to studying spontaneous settlement flora and vegetation in Central Europe: a review. In: Urban ecology as the basis for urban planning, eds. H. Sukopp, M. Numata, & A. Hüber, pp. 23–39. SPB Academic Publishing, The Hague.

PYSEK, P. 1995b. On the terminology used in plant invasion studies. In: Plant Invasions - General Aspects and Special Problems, eds. P. Pyšek, K. Prach, M. Rejmanek & M. Wade, pp. 71–81. SPB Academic Publishing, Amsterdam.

ROBERTS, D.C. 1993. The vegetation ecology of municipal Durban. Floristic classification. *Bothalia* 23(2): 271–326.

ROBERTS, D.C. & POYNTON, J.C. 1985. Central and peripheral open spaces: need for biological evaluation. *S. Afr. J. Science* 81: 464–466.

RUTHERFORD, M.C. & WESTFALL, R.H. 1994. Biomes of southern Africa: An objective categorization. 2nd ed. *Mem. bot. Surv. S. Afr.* 63: 1–94.

SEPPINGS, K.A. 1994. The development of an open space system for the Queensburgh Municipal Area. M.Sc. thesis, University of Natal, Durban.

SOIL CLASSIFICATION WORK GROUP. 1991. Soil classification - A taxonomic system for South Africa. 2nd edition. Dept. Agricultural Development, Pretoria.

SUKOPP, H. & WERNER, P. 1983. Urban environments and vegetation. In: Man's impact on vegetation, eds. W. Holzner, M.J.A. Werger, & I. Ikusima, pp. 247–260. Dr. W. Junk, The Hague.

TREPL, L. 1995. Towards a theory of urban biocoenoses: some hypotheses and research questions. In: Urban Ecology as the Basis of Urban Planning, eds. H. Sukopp, M. Numata & A. Hüber, A., pp. 3–21. SPB Academic Publishing, Amsterdam.

VAN WYK, E. 1998. Vegetation studies of the Klerksdorp Municipal Area: A floristic and phytosociological study (In Afrikaans). M.Sc. thesis, Potchefstroom University for Christian Higher Education, Potchefstroom.

VAN WYK, E., CILLIERS, S.S. & BREDENKAMP, G.J. 1997. Vegetation of the ridges of Klerksdorp, Nort West Province, South Africa (In Afrikaans). *SA Tydshrif vir Natuurwetenskap en Tegnologie* 16(2): 74–85.

VINCENT, G. & BERGERON, Y. 1985. Weed synecology and dynamics in urban environment. *Urban Ecology* 9: 161–175.

VON GOGH, R.G. 1979. A Note on the Pretoria Urban Heat Island of 15–16 June, 1977. *S. Afr. Geogr. J.* 61(1): 29–34.

VON STÜLPNAGEL, A., HORBERT, M. & SUKOPP, H. 1990. The importance of vegetation for the urban climate. In: Urban Ecology, eds. H. Sukopp & S. Hejny, pp. 175–193. SPB Academic Publishing, The Hague.

WEATHER BUREAU. 1988. Climate of South Africa. Report No. 40. Government Printer, Pretoria.

WELLS, M.J., BALSINHAS, A.A., JOFFE, H., ENGELBRECHT, V.M., HARDING, G. & STIRTON, C.H. 1986. A Catalogue of problem plants in southern Africa, incorporating the National Weed List of South Africa. *Mem. bot. Surv. S. Afr.* 53: 1–658.