Vegetation analysis of Pedlar's Bush, Mpumalanga, and its conservation

T.L. Morgenthal and S.S. Cilliers*

Section Botany, School for Environmental Sciences and Development, Potchefstroom University for CHE, Potchefstroom, 2531 Republic of South Africa

Received 16 September 1998; revised 22 February 1999

Little information is available on the forest vegetation of the Barberton and eastern Mpumalanga Mountains. The vegetation of Pedlar's Bush was phytosociologically described as part of a study to determine the conservation potential of this forest. Relevés were compiled in forty one plots of 0.04 ha each. The data were analysed according to TWINSPAN and Braun-Blanquet classification procedures. Two communities, four sub-communities and six variants were described in this forest fragment. Species richness of the communities was statistically compared. Floristic and environmental relationships were also identified by means of DECORANA ordination procedures. Moisture, terrain type and natural disturbances were identified as important environmental factors in the distribution of communities.

Keywords: Afromontane forest, Braun-Blaunquet, Pedlar's Bush, phytosociology.

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

Introduction

Rational land-use planning is necessary to conserve natural forest ecosystems (Deall *et al.* 1989). Seydeck (1991) proposed the use of vegetation classification because it provides information on the areal extent, utilisation potential and constraints on the resource base. Without sound knowledge of the different vegetation types and their floristic composition and habitat preferences, effective conservation and land use planning will not be possible.

A number of studies have been undertaken in the afromontane forests of the Transvaal escarpment and adjacent forest fragments such as those of Geldenhuys and Pieterse (1993) in the Wolkberg, Geldenhuys and Murray (1993) in the Soutpansberg, Muller (1994) in Mariti State Forest, Deall *et al.* (1989) in the Sabi area, von Breitenbach (1990) in the Kaapsehoop and Uitsoek forest, Scheepers (1978) on the vegetation of the Westvalia estate and van der Schijff and Schoonraad (1971) in the Mariepskop. Most of these studies were descriptive floristic studies. Not many phytosociological studies have been attempted in the Southern Transvaal Escarpment forests and Barberton mountains and their relation to surrounding forests is relatively unknown. The lack of phytosociological studies may be ascribed to the small size and fragmented occurrence of these forests. Pedlar's Bush is, however, one of the largest existing forest fragments in the Barberton Mountains. Cooper (1985) described this forest as one of the more important examples of afromontane forests in the Transvaal but noted that, although it is rich in wildlife, plantations have destroyed most of the forest-grassland ecotone.

This project was initiated to determine the conservation potential for the registration of Pedlar's Bush as a natural heritage site which should be managed as a conservation area. A floristic analysis and a phytosociological study of vegetation for conservation are priorities for proper planning and management of any conservation area (Edwards 1967, Bredenkamp & Theron 1978, Bredenkamp & Bezuidenhout 1990). It is, therefore, imperative that the same approach be followed in the case of Pedlar's Bush.

Study area

Pedlar's Bush is situated 10 km east of Barberton on the Farm Twello 373JU, grid reference 25°47'51"S 31°08'40"E (Figure 1). The forest consists of one fragment with a surface area of 85 ha (GIS calculated). Pedlar's Bush is part of the North Eastern Mountain Sourveld (Acocks 1988). According to Low and Rebelo (1996) the study area forms part of the Afromontane Forest region.

The forest is situated in the Makonjwa Mountains with a general south-eastern aspect. The topography of the area is an undulating mountain slope of which the crest grades into a steep middle and a moderate to gentle foot slope (transects A–B & C–D; Figures 1 and 2). Pedlar's Bush occurs predominantly along this steep middle and moderate to gentle foot slope (Figure 2). The forest has a relief of 300 m, the highest point being 1 529 m. On the western, southern and eastern margins of the forest, small streams form the boundary between the forest and pine plantations (Figure 1). The north-eastern margin forms the only remaining forest-grassland ecotone (Figure 1). The forest consists of a number of sheltered ravines that form part of the Hlatikulu river catchment area, a tributary of the Lomati River.

The underlying geology of the study area is dominated by the Moodie geological group consisting of non-differentiated sandstone, shale, quartz and conglomerate (Anhausser *et al.* 1981).

The soils of the area are predominantly of the Hutton form with a fine sandy clay loam texture (clay 30–50% B-horison) (Land Type Survey Staff 1989). The middle slopes of the area are dominated by shallow lithosols (Mispah and Glenrosa soil forms) and soils of the Hutton form. Deep soils of the Hutton soil form have developed where deep weathering of underlying shale has occurred. The lower middle slope and footslope are characterised by deep (600–1200 m) Hutton and Clovelly soil forms (Land Type Survey Staff 1989). From field observations it was found that soils in the streambeds were shallow to nonexistent. The dominant soil form in the valley bottom is Oakleaf (Land Type Survey Staff 1989).

According to the Köppen classification the region has a warm temperate climate with a winter dry season, the warmest month with a temperature over 22°C (Schulze & McGee 1978). The average rainfall for the Highlands Forestry station (1200 m above sea level) near the study area is 971 mm. Average rainfall data for the period 1949–1995, measured at this forestry station is presented in Figure 3. The minimum and maximum temperatures for Barberton (800 m above sea level) are presented in Figure 4 for the period 1951–1973. The highest occurrence of fog is from October to December and in autumn (Weather Bureau 1984).

Materials and Methods

Relevés were compiled in 41 sample plots. The forest was initially surveyed by 28 sample plots evenly spaced through the use of a grid system. Thirteen additional sample plots were randomly allocated to

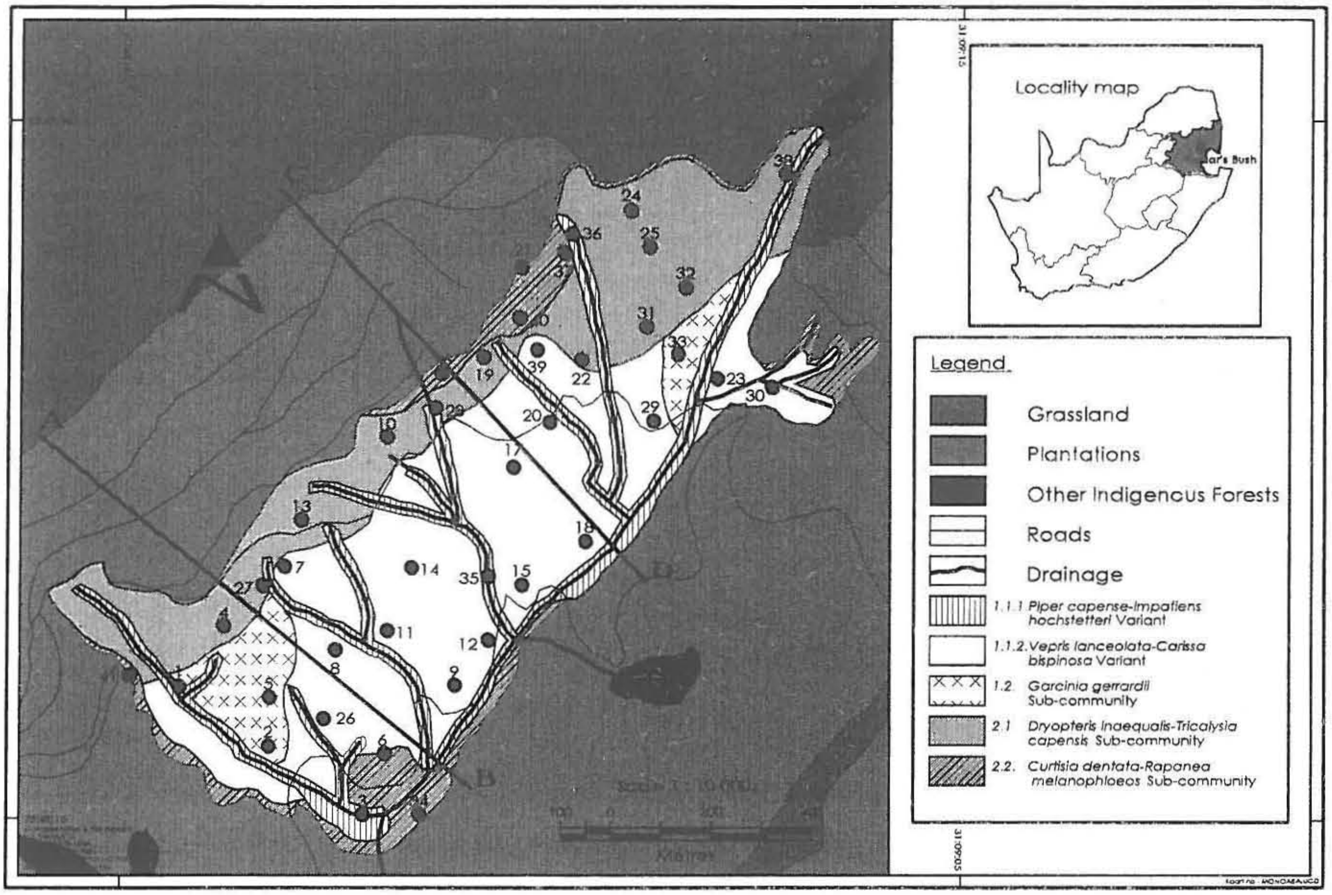

Figure 1 The location of Pedlar's Bush, Barberton district in Mpumalanga, South Africa, as well as a vegetation map of Pedlar's Bush, also indicating the positions of the relevés.

obtain representative data of all forest types and physiographical variations in the forest (Figure 1). Plot sizes were fixed at 0.04 ha This plot size was also used by Cawe and McKenzie (1989) and Geldenhuys and Murray (1993) for their studies of Transkei and Soutpansberg forests respectively. The cover-abundance values were estimated for each species present in the sample plot according to the

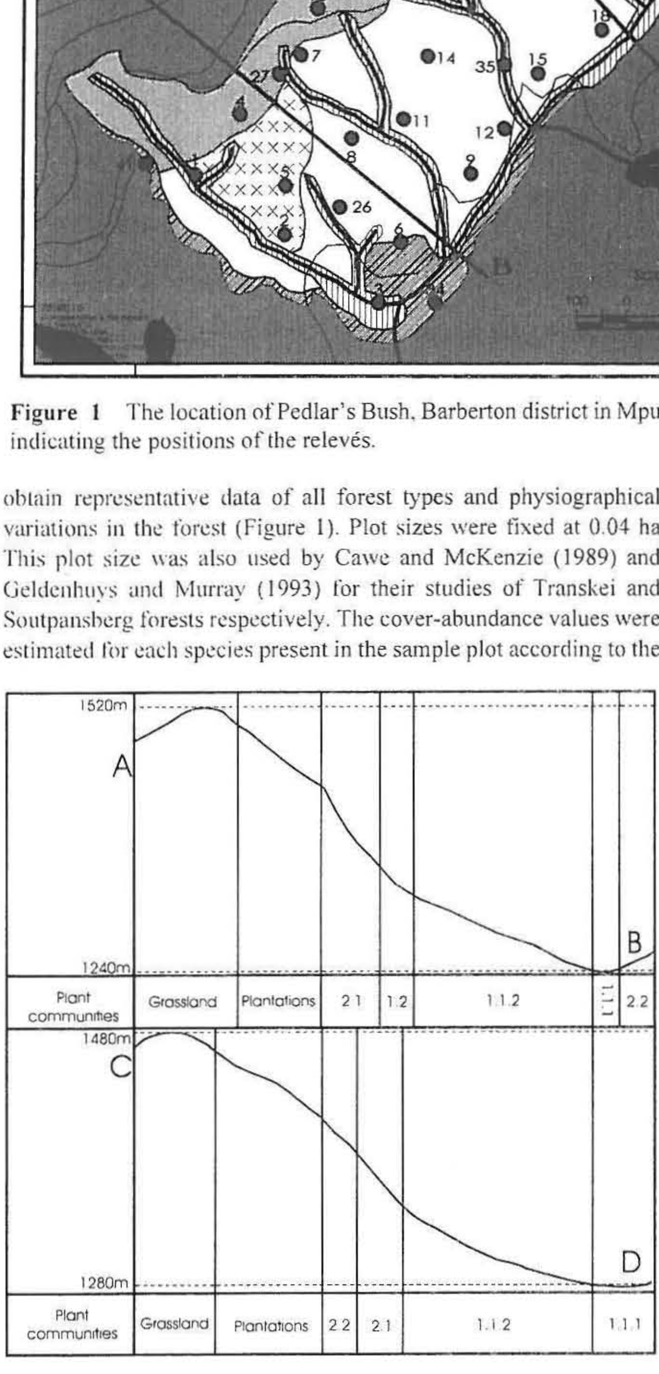

Figure 2 Topography of Pedlar's Bush and associated plant communities along two transects, A–B and C–D.

Braun-Blanquet scale (Muellér-Dombois & Ellenberg 1974). The physiognomic structure was also estimated by means of the average canopy height and cover for the community and conforms to the structural classification of Edwards (1983). These data were used to determine the dominant occurrence of woody species in four strata. Environmental data included aspect, slope, topography and surface rockiness.

The TWINSPAN classification algorithm (Hill 1979a) was used to analyse the floristic data, as first approximation and further refined by application of Braun-Blanquet procedures by means of the BBPC-suite (Bezuidenhout *et al.* 1996). The final results of the classification are listed in a phytosociological table (Table 1). This classification method was successfully used for the syntaxonomic classification of afromontane forests of the Eastern Free State Drakensberg by Du Preez *et al.* (1991) and Du Preez (1991). Species which were recorded only once are not included in the phytosociological table, but are included in Table 2.

An ordination algorithm, DECORANA (Hill 1979b) was also applied to the data to illustrate possible floristic relationships between communities and to detect possible habitat or disturbance gradients associated with vegetation gradients (Figure 5).

No formal syntaxonomic classification was done in this study. An informal classification was used with a diagnostic and dominant species indicating the names of different communities. Taxa names conform to those of Arnold and De Wet (1993) except where differently specified.

Species richness (α-diversity) for every relevé was determined and statistically compared with Tukeys test (Spjotvoll & Stoline 1973) for unequal populations according to different growth forms and total species richness for the different communities and between identified core and margin communities (Figure 6) using the STATISTICA program (1995). Significant differences was tested at a $p < 0.05$ level.

Table 1 Phytosociological table of the vegetation of Pedlars's Bush

Relevès	3	35	36	38	8	18	26	12	15	20	9	11	14	23	29	39	30	1	2	13	17	5	7	33	4	10	27	19	22	25	28	31	32	24	16	21	37	40	6	34	41
Communities	1																								2																
	1.1																	1.2							2.1										2.2						
	1.1.1				1.1.2																														2.2.1				2.2.2		
SPECIES GROUP A																																									
Cola greenwayi		+		R	4	+	1		+	1	R	A	B	1			A	+	1	1	+	3	3	4		1		1		R	+		R								
Oxyanthus speciosus subsp. *gerrardii*			+	+	+	+	+	+	+	+	+	1	+	1	+	1			+	A	R		R	1	R			+	1			R				+					
Oricia bachmannii	R				+	+	+	+	1	R	+	1	1			R		R	R	R		1		+	R		+														
Calodendrum capense		1				A	1	1	+	1	A	3	1	+					+		A			A					+											1	
Homalium dentatum	R	A					+	+			1	+	R		A	B					+	+	+				1										+				
Maytenus mossambicensis	A							3			A	+	1	+	A				+	R							R									+			1	3	
Drypetes gerrardii		+			1		+				+			+						+			1				+														
Allophylus chaunostachys					+		+	+	+							+				1			R																		
Thelypteris dentata	+															R																									
Dracaena hookeriana				+														R																							
SPECIES GROUP B																																									
Ficus craterostoma		1		1	1	B				+						+					1			+	R						1			1							
Kiggelaria africana		1		1						1	1	+		+			1							1								+									
Prunus africana	+	A				A					1		1																												
Croton sylvaticus		A			3	1	4																																		+
Ilex mitis	3														B																									B	
SPECIES GROUP C																																									
Piper capense	1	4		3						R		R					+																								
Asplenium boltonii			A	+																																					
Polystichum transvaalense			R	R																																					
Asplenium gemmiferum		R		+																																					
SPECIES GROUP D																																									
Vepris lanceolata		R				+		+	A	+	1	R	+	1	B	A	B				1			R							1								R		R
Calpurnia aurea subsp. *aurea*	+						+	+	+	1	+	+	1	1	+						+																				
Dovyalis rhamnoides	R	+			+	1	+	B	A		1			1	1	+	+		+												R								1	R	R
Maytenus undata	R						+		+		+	+	+		R	+			+																				+	B	
Allophylus africanus						R	+	1		+		+		+																											
Asplenium erectum				R	+	R				R			R	+		R	R																								
Clausena anisata						R		+	+		+					+	R	R																		R			R		
Celtis africana						+		A	1	1				+							R								R												
Maytenus nemorosa				R	+	A			1		1						1	R																					1	+	
Scolopia zeyheri	+					1	1	+	1																														A		
Clerodendrum glabrum								+	B	+																															
Dietes iridioides								R	R		+	R				+																						+	+		R
Strophanthus speciosus						R			+			R	R								R			R			R					R									
Cnestis natalensis								+	+		+																														
SPECIES GROUP E																																									
Garcinia gerrardii																			+		+		A		R		R		+												
SPECIES GROUP F																																									
Pterocelastrus echinatus										1															+	+	1					+	1	+	B	A	1	A	B		A
Podocarpus latifolius							+							+	+	R			+		R	R				+		+		B	A	+	1	A		A	1	+	+		+
Canthium inerme										R	+					1		R											+	+		R			R	1		R	R		R
Cheilanthes viridis subsp. *viridis*	R																	R		R			R		+	R					R			+	+			+	A	+	1
Schefflera umbellifera																		1							1			+			1			+	3	R		1			
Faurea galpinii																				A						1				+	3		R	1			+				
Ocotea kenyensis						R														R									+	R		+	+			R			R		
Chlorophytum comosum			1																										+				R	+			3				
Cassine eucleiformis																														+		+				1		+			

Table 1 Continued

Relevès	3	35	36	38	8	18	26	12	15	20	9	11	14	23	29	39	30	1	2	13	17	5	7	33	4	10	27	19	22	25	28	31	32	24	16	21	37	40	6	34	41
Communities	1																								2																
	1.1																	1.2							2.1										2.2						
	1.1.1				1.1.2																														2.2.1				2.2.2		
SPECIES GROUP G																																									
Dryopteris inaequalis			R						R		+			+	R								1		+	+	+	+	+		+	+				R					
Quisqualis parviflora																R								+			R			+		+	+								+
Faurea macnaughtonii							1													+		+			+		+						1	1		1					
Trichocladus grandiflorus																											+							3			+				
SPECIES GROUP H																																									
Curtisia dentata																+					+					1									+	3		1	3		
Ekebergia pterophylla																									1										A	+			+		B
Halleria lucida				1		+															+							+				R			+	R			R	+	+
Aphloia theiformis																					+							1										1	3	+	+
Trimeria grandifolia	R								+		+															R										1			+	A	+
Cassine tetragona									+		R																						R					+	+	1	+
Clivia sp			R																																1			R		+	
Asplenium aethiopicum			+																																		A	R		R	
Rhus sp.																																			R					R	R
Carex spicato-paniculata																																			+				+		
Burchellia bubalina																																					+				1
Begonia sutherlandii		R																																			R			+	
Protasparagus africanus																																				R				R	
SPECIES GROUP I																																									
Peperomia retusa			+	R																													R		+		+	+			
SPECIES GROUP J																																									
Pittosporum viridiflorum																																							1	1	
Ekebergia capensis	+							R									R																						+	+	
Scolopia mundii					+																																		+		+
Pavonia burchellii.																																							R	R	R
Rhamnus prinoides																																							+	R	
Smilax anceps																																							R		R
Cassinopsis ilicifolia		+						+																																1	
SPECIES GROUP K																																									
Podocarpus falcatus					1	R	+		B	R	A		A	R	3			+	+	A	B				A		B	+			+	1	+	+	1			1			
Rawsonia lucida						R			+		+		1	+	R	+	+		1	+		A	1		R		+	+			R	R									
Clutia pulchella								+	1	1		+	+													R		R				R			+	+	1				1
Polypodium polypodioides												R							R	R	R				R	R							R		+		R				
Olinia radiata						+		+				1	1	1	A			+	1	A	1	1		B			1			1	1	+	1					1			
SPECIES GROUP L																																									
Tricalysia capensis					+				+	R	+	+	+	+		+		R	B	A		1	A	+	A	A	3		B	B	A	B	3	+			+	+	+		+
Syzygium gerrardii								+		+				+	1	+		+		+	+		1		+	+	+	B	1	A	A	3	A	A	3	B	+	3	+		A
Rothmannia capensis						+						R		+		A			R		1		R	+		R	+	A	+	+	A	1	1	+				+		+	
Olea capensis subsp. *macrocarpa*					+	1	+		1		+			1	+	R		+		1	B			1	1	1	3	1	A	A	1	1	3	1		1		1	R		R
Behnia reticulata	R				R	R		R	R	+	R		+	+	R	R		R	R		+	R	R	R				R		R		R	R			R				+	
Rapanea melanophloeos								R	R	A		+				R					+							+	+	B		+	1		A	3	3		1	+	R
Secamone alpini					R		R	R	+		R	R	R			R	R							+				R					R		R				R		R
Pavetta inandensis						R			+		+			+	R	+														+		+				R	+	R	R		

Table 1 Continued

Relevès	3	35	36	38	8	18	26	12	15	20	9	11	14	23	29	39	30	1	2	13	17	5	7	33	4	10	27	19	22	25	28	31	32	24	16	21	37	40	6	34	41
Communities	1																								2																
	1.1																	1.2							2.1										2.2						
	1.1.1				1.1.2																														2.2.1				2.2.2		
SPECIES GROUP M																																									
Xymalos monospora		A	3	B	A	A	A	B	B	A	B	B	3	3	+	A	+	1	1	1	1	+	R		+		+		+			R	R		+	+	B			R	
Carissa bispinosa subsp. *zambesiensis*	1				1	A	A	A	3	A	A	A	A	1	A	1	A	+	+	1	1	1	+		1	1	+	A		+	+	1	+		1	1		1	+	+	+
Cussonia spicata	R	A	+	+		1	B	1	1	3	B	1	1	3	A	A	1	1			1	+	R	+		+	+		+	+	1	1	1					1		R	+
Chionanthus foveolatus	+	+		3		+	1	A		+	1	+	A	A	1	+	1	A	+	+	R	R			1	1	1	1		R	+	A	R	+	1	A			+	R	+
Prosphytochloa prehensilis	+				+	+	1	1	1	+	1	A	1	1	1	A	+	1	+	1	3	+	A	1	+	+	+	A	1	1	+	1				+			R		
Cassipourea gerrardii	+		1	3		+	B	+	+		+	A	B	A	1	1	B			+		1	1	A	+	+	A	1	A	1	1		A	1			1	+		+	+
Ochna holstii		R		R	+	1	+	1	+	+	1	R	+	1	1	R	+	1	R	+	1	1				+		A	1	A	+	1		B	+	+	+	1	R	R	1
Zanthoxylum davyi	+			+		+	A	+	1	R	A	1	B	+			B	R	1			A	A	A	+	+	1	A	B	B	B	B	1		+			+		+	+
Pteris catoptera	+	1	+	+	+	+	+	+		+	1	1	+	+	+	1	+	1		1	1	+	R	R		+		R	R		+	+						+			
Keetia gueinzii	+				+	+	+	+	1	+	+	1	+	+		+	+	R	+	+	+		+			+	+	+	+		+	+	R	+		R		1	+		
Rhoicissus rhomboidea	+	+			+	+	+	R	M	+	+	1	+	+	1	+		+	+	+	+		+		R	+	+	+	+		+	+		+	+	+	+	+	+	1	
Asplenium splendens			+							R	R	R	R	+	R	+		R		+	R	R					R		+	R		+	+		1			+			+
Dovyalis lucida		R	+			+			+	+	+	1	+	+	1	+	1		R	+	1		R			+	+	+				B	+	+	+	+	+	+		+	
Protasparagus setaceus	R					R		R	+	R	+	R	R	+	+	R			+	+	1	R	+	R	+		R	+	R	R	R	+	R		+	+		R	+		
Asplenium rutifolium		R	R	R		+								+	+		R							R								R	R				R			R	
Hypoetes aristata var. *alba*			4	3				+		+	R	+	+	R		1	+				+			1		R			3		R	A	4					+		+	R
Pavetta barbertonensis	+				+		+	+		+	+	1	+	1	1	1		1	+	1	1				3	1	+	+	A	+		1	1		+	+	+	A	1		A
Plectranthus fruticosus		1	+	R						+				R		R		R	+	R	R			+		+	+		A	+	+	+	1	+	A		1	+		1	
Peddiea africana	R	+			+	R		+	+	+	+	+	1	+	+	R					+				+		+	+	+	1	+	1	1	+	R			R	1	+	+
Cryptocarya liebertiana		R			+	+		A	+	R	1		+	+		1								R			+	1	+	+		A	1	1		R		R		R	R
Cyperus albostriatus	+	R	R					+	R	+		+		R	R			+		R	+	R	+	+	1	1	+	+	+	+	1	1	+	B	+	1		1		+	+
Micrococca capensis		R	A			+					+	1	1		R	+		+	+	+	+	R	+	+		+		1	+	1	A	1	1	1	R	1	R	1			
Combretum kraussii	R	1				1		+	+	+	+		+	+		R				+	+	1	+	+		+	+					+	A		+	+		1	+	A	A
Diospyros whyteana	R	+		1		A	A	1	3	+	B	1	A	1	+	A			A		+						+		+			R	R			R	+	+		+	
Aristea ecklonii	+									R				+	+		1		+	R			R		+	+	R				+				R					+	+
Oplismenus hirtellus	+	A	+				R	3	1	4							+										R					+		A	+	1		A	4	A	1
Bersama tysoniana	+						+	+		1				+		R	+						+	+				R				R	+			+			+		
Riocreuxia picta		R								+		R	R	+	R	R	+							R												R			R	+	
Senecio tamoides		+	R									+			+	R	+	R		R	+		R	R								+	R	R	R					R	+
SPECIES GROUP M																																									
Ochna serrulata	R								+									1		R	+	R	1		1	+	+	+			+				1	1		+	+	A	1
Impatiens hochstetteri	3	A	3	+													R							R						R		R	+	4		R	A			1	
Streptocarpus spp.		+	3	+											R			+		R			+	R					+	1		R	1	1	R	+		+		1	
Setaria megaphylla	R	3	R							+					R						+				R							R			R	R				R	
Grewia occidentalis		+			R			+	+				+		+																					R			R	+	1
Dalbergia armata						+					R									+						R													+	R	
Cissampelos torulosa		R						R							R		R						R																	R	R
Psychotria capensis	+		+	+																+	+		+	+									+	+	+	+	1			+	1
Cheilanthes bergiana												R	R																											R	
Asplenium rutifolium									R	R	R		R							R	R		1		R				R					R	R						
Cyphostemma sp.								R													R														R						
Strychnos decussata					+								+			1											+				R										
Maesa lanceolata		1								+									+							R															
Selaginella kraussiana	A																R																							+	
Andrachne ovalis		1																																						+	
Rubus sp.		A																																		R					+
Eugenia natalitia				R												R																								R	
Trichillia dregeana					+								R																												
Scutia myrtina									+								+																							R	R
Leonotis ocymifolia	+																																			R					
Peperomia tetraphylla			R																																		R				

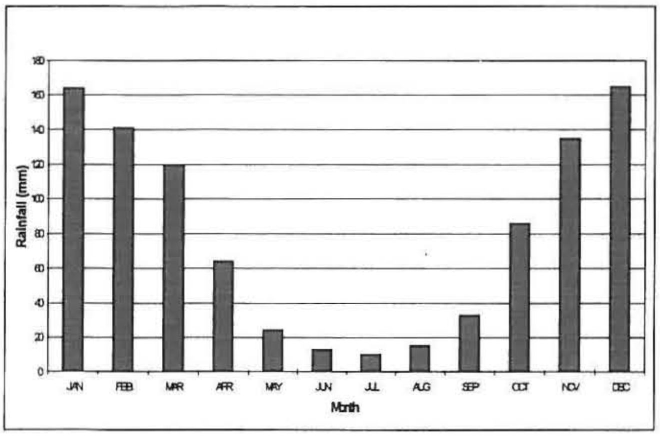

Figure 3 Monthly average precipitation for the Highlands Forestry station for the period 1949–1995.

Results

Classification

From the phytosociological table two plant communities, four sub-communities and four variants are recognised (Table 1).

1 *Cola greenwayi—Xymalos monospora* Community
1.1 *Ficus craterostoma—Cussonia spicata* Sub-community
1.1.1 *Piper capense—Impatiens hochstetteri* Variant
1.1.2 *Vepris lanceolata—Carissa bispinosa* Variant
1.2 *Garcinia gerrardii* Sub-community
2 *Pterocelastrus echinatus—Syzygium gerrardii* Community
2.1 *Dryopteris inaequalis—Tricalysia capensis* Sub-community
2.2 *Curtisia dentata—Rapanea melanophloeos* Sub-community
2.2 1 *Peperomia retusa* Variant
2.2.2 *Pittosporum viridiflorum—Oplismenus hirtellus* Variant

Description of the communities

Cola greenwayi—Xymalos monospora Community

This is a lower altitude forest community beneath the mist belt, including the footslopes and the moister sites in the study area. This community has a closed canopy except along streambeds where the canopy tends to be more open, with a estimated canopy height over 20 m. Diagnostic species include *Cola greenwayi, Oxyanthus speciosus, Oricia bachmannii, Calodendrum capense, Dovyalis rhamnoides, Maytenus mossambicensis* and *Drypetes gerrardii* (species group A, Table 1).

This community is in many aspects similar to the lower montane forest type described by von Breitenbach (1990). Similar forest types were described by Geldenhuys and Murray (1993). Stand types that may be related to this community are types 3 and 4 of the Hanglip forest (Soutpansberg) with the following species in common: *Drypetes gerrardii, Calodendrum capense* and *Kiggelaria africana* (Geldenhuys & Murray 1993). Stand type 3 of the Wonderwoud forest has also species in common with this community e.g. *Oricia bachmannii* (indicator species), *Crotan sylvaticus* and *Celtis africana* (preferential species) (Geldenhuys & Pieterse 1993). A difference between the two communities is that *Xymalos monospora* does not form dense populations in stand type 3 of the Wonderwoud forest (Geldenhuys & Pieterse 1993). The *Cola greenwayi—Xymalos monospora* Community described in the current study comprises, however, of a number of uncommon and rare species for the Transvaal afromontane forests such as *Cola greenwayi, Maytenus nemorosa, Garcinia gerrardii* and *Allophylus chaunostachys.* Two sub communities can be distinguished in this community.

1.1 *Ficus craterostoma—Cussonia spicata* Sub-community

The species of species group B (Table 1) are the diagnostic species of this sub-community, namely *Ficus craterostoma, Kiggelaria africana, Prunus africana* and *Croton sylvaticus*.

The Uitsoek Lower Montane *Cryptocarya liebertiana* Climax forest, which is situated on the eastern and southern slopes or level kloof bottom areas between 1350–1550 m of the Uitsoek forest (von Breitenbach 1990), is similar to this sub-community. The following two variants can be distinguished in the *Ficus craterostoma—Cussonia spicata* Sub-community.

1.1.1 *Piper capense—Impatiens hochstetteri* Variant

This variant can be regarded as a high riparian forest. Moist conditions in and adjacent to streams and drainage lines provide a specific habitat for hydrophilic plants in the forest. Along drainage lines gorges have been formed, exposing the underlying bedrock. Tree growth is impaired by the lack of soil that creates an alteration of the forest tree layer in the streambeds. The moist groundlayer and sparser tree cover result in a denser herb and shrub layer. Species group C (Table 1) contains the diagnostic species of this variant. This variant may also be characterised by the absence of most of the species groups D, K and L (Table 1). Diagnostic species for this variant are the shrubs *Piper capense* (Species group C, Table 1) and *Mackaya bella*, the herb *Thalictrum rhynchocarpum* (Table 2) and the ferns *Asplenium boltonii* and *Asplenium gemmiferum* (Species group C, Table 1). A number of ferns are associated with moist, deeply-shaded streambanks such as *Thelypteris dentata* (Species group C, Table 1), *Marattia fraxinea* and *Didymochlaena truncatula* (Table 2). Other species include the dominant herb *Impatiens hochstetteri*, the undershrubs *Hypoestes aristata* var. *alba* and *Rubus* sp. (Species group M, Table 1), the shrubs and small trees *Diospyros whyteana* and *Plectranthus fruticosus* (Species group M, Table 1) and the canopy trees *Xymalos monospora, Cussonia spicata, Chionanthus foveolatus, Cassipourea gerrardii* (Species group M, Table 1), *Kiggelaria africana* and *Prunus africana* (Species group B, Table 1).

1.1.2 *Vepris lanceolata–Carissa bispinosa* Variant

Although this variant is also a high forest it is not associated with drainage lines and stream banks. It covers the largest area of the *Cola greenwayi—Xymalos monospora* Community (Figure 1) and is indicated by the tree species *Vepris lanceolata, Calpurnia aurea* subsp. *aurea, Maytenus undata* and the shrubs *Maytenus nemorosa, Cnestis natalensis* and *Dovyalis rhamnoides* (species group D, Table 1). Herbaceous species which are diagnostic for this variant are the geophyte *Dietes iridioides* and the fern *Asplenium erectum* (species group D, Table 1). Other ferns such as *Pteris catoptera, Asplenium splendens* and the low creepers *Prosphytochloa prehensilis* and *Protasparagus setaceus* (species

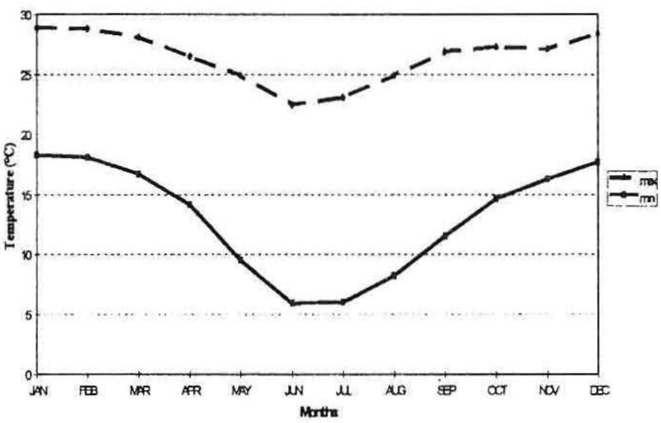

Figure 4 Minimum and maximum monthly average temperatures for Barberton during the period 1951–1973.

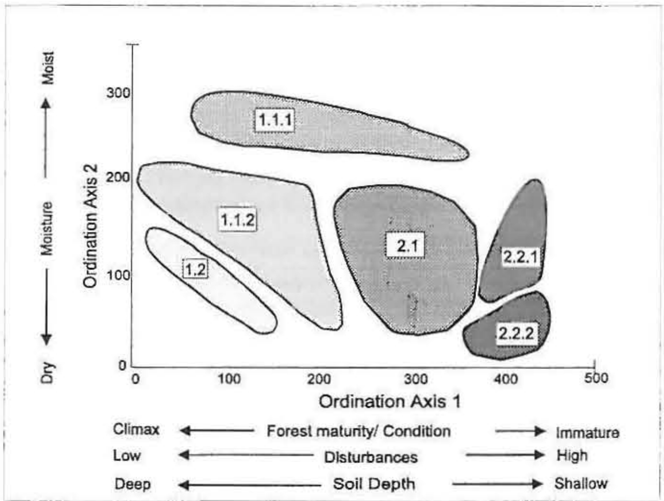

Figure 5 Scatter diagram representing the DECORANA ordination of the different communities of Pedlar's Bush (for clarification of symbols of communities, see text).

group M, Table 1) are also species worth mentioning. The ground and lower shrub layers are also characterised by dense stands of *Chionanthus foveolatus* seedlings and young trees. The shrub and lower tree layer is quite prominent with *Maytenus mossambicensis* var. *mossambicensis*, *Oricia bachmannii* (species group A, Table 1) and *Diospyros whyteana* (species group M, Table 1) as the dominant species in these layers. The intermediate tree-layer consists of trees like *Cola greenwayi* (species group A, Table 1), *Calpurnia aurea*, *Allophylus africanus* (species group D, Table 1) and *Cassipourea gerrardii* (species group M, Table 1). The most prominent tall trees are *Calodendrum capense* (species group A, Table 1), *Xymalos monospora*, *Cussonia spicata*, *Chionanthus foveolatus* and *Zanthoxylum davyi* (species group M, Table 1). In this variant a number of tree species form an emerging tree layer higher than 20 m namely *Calodendrum capense* (species group A, Table 1), *Vepris lanceolata*, (species group D, Tabte 1), *Podocarpus falcatus* (species group K, Table 1) and *Olea capensis* subsp. *macrocarpa* (species group L, Table 1).

The dynamics of this variant of the *Ficus craterostoma*–*Cussonia spicata* Sub-community is of particular interest because of the dominance of multi-stemmed *Xymalos monospora* trees. According to Palmer and Pitman (1972) this species is common in worked-out indigenous forests and occurs often on the margins of Transvaal forests. Geldenhuys and Pieterse (1993) suggested that *Xymalos monospora* occurs abundantly in specific forest types that are in a mature state. This is also implied by Cawe and Mckenzie (1989). The occurrence of young *Podocarpus falcatus* trees of different height classes may indicate that this forest type has been utilised in the past and that this species is regenerating. The topography of this variant is gentle, occurring on the lower footslopes of the study area.

1.2 *Garcinia gerrardii* Sub-community

The *Garcinia gerrardii* Sub-community is characterised by the absence of most of the species of species groups B, C and D (Table 1). The only species differentiating this sub-community is *Garcinia gerrardii* (species group E) (Table 1).

The shrub and low tree layer consist mainly of *Rawsonia lucida* (species group K, Table 1), *Tricalysia capensis* (species group L, Table 1) and *Micrococca capensis* (species group M, Table 1), while *Cola greenwayi* (species group A, Table 1), *Garcinia gerrardii* (species group E, Table 1) and *Cassipourea gerrardii* (species group M, Table 1) are the most prominent

Table 2 List of species only recorded once, with their respective cover abundance values (CAV)

Species	Community	CAV
Mackaya bella	1.1.1	A
Thalictrum rhynchocarpum	1.1.1	+
Didymochlaena truncatula	1.1.1	+
Sanicula elata	1.1.1	+
Festuca africana	1.1.1	+
Asplenium lobatum	1.1.1	R
Marattia fraxinea	1.1.1	R
Coccinia palmata	1.1.1	R
Stephania abyssinica var. *abyssinica*	1.1.2	R
Brachylaena discolor subsp. *transvaalensis*	1.2	1
Canthium ciliatum	1.2	+
Crotalaria sp.	1.2	+
Vangueria randii	1.2	+
Ptaeroxylon opbliquum	1.2	+
Hypolepis sparsisora	1.2	R
Polystachya transvaalensis	2.1	+
Bulbophyllum sandersonii	2.1	+
Asplenium anisophyllum	2.1	R
Englerophytum magalismontanum	2.1	R
Pleopeltis macrocarpa	2.1	R
Greyia sutherlandii	2.2.1	1
Aloe arborescens	2.2.1	1
Buddleja salviifolia	2.2.1	+
Pergularia sp.	2.2.1	+
Dombeya pulchra	2.2.1	R
Protorhus longifolia	2.2.2	A
Rhus lucida	2.2.2	1
Heteropyxis canescens	2.2.2	1
Maytenus peduncularis	2.2.2	1
Rhus pyroides var. *gracilis*	2.2.2	+
Rhus sp.	2.2.2	+
Bowkeria cymosa	2.2.2	+
Tephrosia shiluwanensis	2.2.2	+
Anemia dregeana	2.2.2	+
Mohria vestitta	2.2.2	R
Pinus sp.	2.2.2	R
Blechnum australe	2.2.2	R
Pteridium aquilinum	2.2.2	R
Galopina circaeoides	2.2.2	R

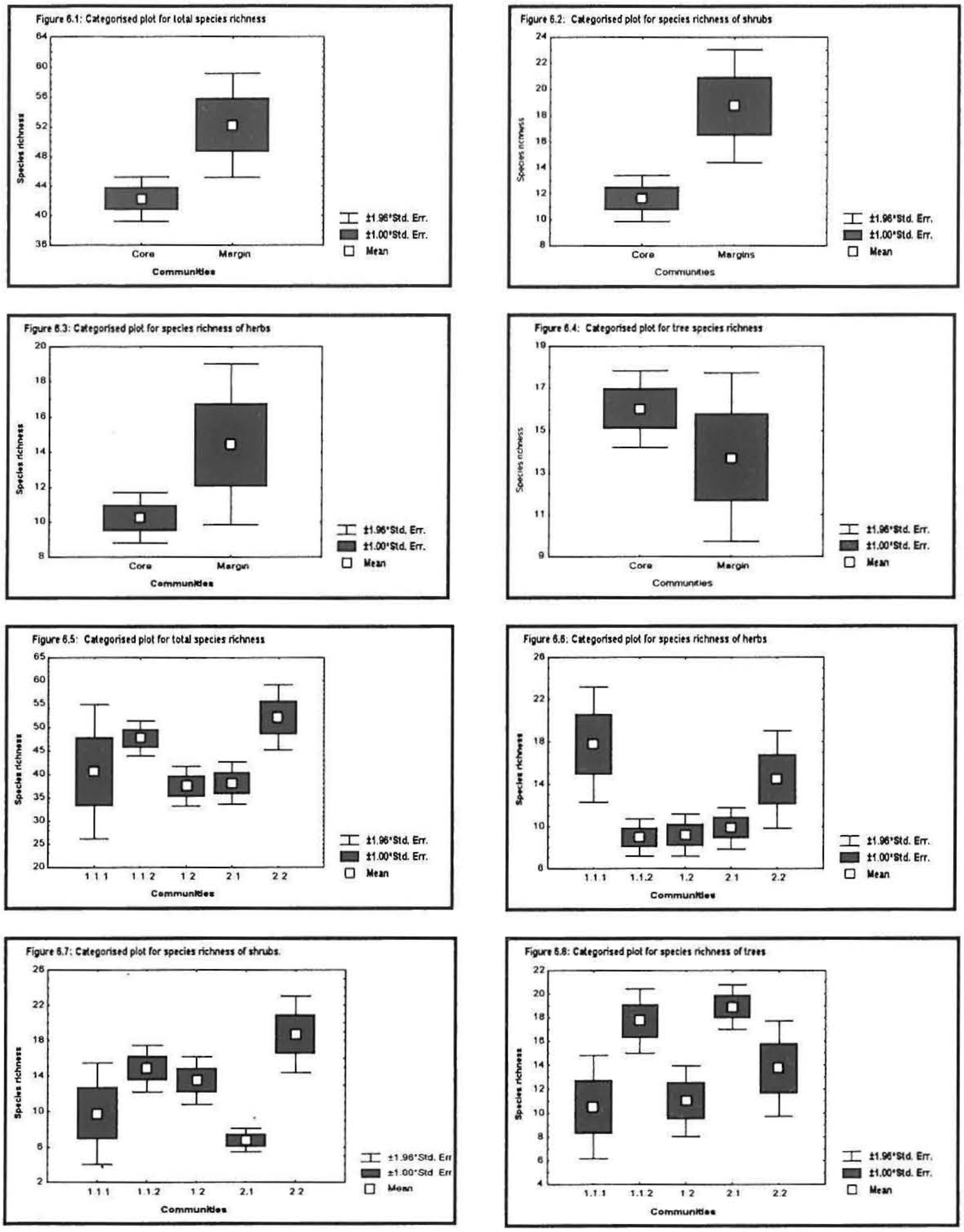

Figure 6 Categorised plots of species richness between plant communities in Pedlar's Bush (numbers of communities refer to text).

species of the intermediate tree layer. The tall and high tree layers consist predominantly of *Olinia radiata* (species group K, Table 1), *Zanthoxylum davyi, Xymalos monospora, Chionanthus foveolatus* and *Cussonia spicata* (species group M, Table 1). The intermediate and tall tree layers in this community have the highest cover, while the herbaceous layer is weakly developed. The lower steep middle slopes form the predominant terrain type on which the *Garcinia gerrardii* Sub-community occurs. This sub-community was only found in two localities in the forest between the *Ficus craterostoma—Cussonia spicata* Sub-community and the *Dryopteris inaequalis—Tricalysia capensis* Sub-community. This sub-community occurs on steeper slopes and different terrain types than the *Ficus craterostoma—Cussonia spicata* Sub-community.

2 *Pterocelastrus echinatus—Syzygium gerrardii* Community

The *Pterocelastrus echinatus—Syzygium gerrardii* Community is representative of highlying mist belt forest and forest margins. This community has a variable canopy height and cover and the diagnostic species are the trees *Pterocelastrus echinatus, Podocarpus latifolius, Ocotea kenyensis, Schefflera umbellifera,* and *Faurea galpinii,* the fern *Cheilanthes viridis* subsp. *viridis* and the geophyte *Chlorophytum comosum* (species group F, Table 1).

This community has a strong relation with the Upper montane forest type described by von Breitenbach (1990). Forest types of the Uitsoek and Kaapsehoop forests that are similar in species composition to the *Pterocelastrus echinatus—Syzygium gerrardii* Community are the Kaapsehoop Upper montane *Curtisia dentata* climax forest, Kaapsehoop lower montane *Syzygium gerrardii* climax forest, the Uitsoek upper montane *Schefflera umbellifera* climax forest and the Uitsoek Upper montane *Curtisia dentata* talus/fire climax forest. Although von Breitenbach (1990) originally classified the Kaapsehoop lower montane *Syzygium gerrardii* climax forest as lower montane forest, the classification obtained for Pedlar's Bush would suggest that this forest community has more in common with the Upper montane forest because of the occurrence of *Pterocelastrus echinatus* and *Faurea galpinii*.

The following two sub-communities are recognised:

2.1 *Dryopteris inaequalis—Tricalysia capensis* Sub-community

This sub-community occurs predominantly in the mistbelt at an altitude over 1300 m. The slope over most of the terrain in this forest type is steep, occurring on the higher middle slopes and ridges. The average estimated canopy height is 18 m and forms a predominantly closed canopy. Diagnostic species include the fern *Dryopteris inaequalis*, the trees *Faurea macnaughtonii, Quisqualis parviflora* and *Trichocladus grandiflorus* (species group G, Table 1). The dominant species of the ground layer are the geophytes *Chlorophytum comosum* (species group F, Table 1) and *Aristea ecklonii*, the grass *Prosphytochloa prehensilis* and the herbaceous shrubs *Hypoestes aristata* var. *alba* (species group M, Table 1). The shrub and small tree layer consist predominantly of *Tricalysia capensis* (species group L, Table 1), *Carissa bispinosa, Pavetta barbertonensis* and *Micrococca capensis* (species group M, Table 1). *Rothmania capensis, Syzygium gerrardii* (species group L, Table 1), *Chionanthus foveolatus, Cassipourea gerrardii*, and *Ochna holstii* (species group M, Table 1) are the dominant species of the intermediate layer. The tall tree layer, which forms the canopy, consists mainly of *Pterocelastrus echinatus* (species group F, Table 1), *Syzygium gerrardii, Olea capensis* subsp. *macrocarpa, Rapanea melanophloeos* (species group L, Table 1), *Cryptocarya liebertiana* and *Zanthoxylum davyi* (species group M, Table 1).

2.2 *Curtisia dentata—Rapanea melanophloeos* Sub-Community

The margins of the forest are represented by this sub-community which is characterised by species group H (Table 1), with diagnostic tree species *Curtisia dentata, Ekebergia pterophylla, Aphloia theiformis, Halleria lucida, Trimeria grandifolia, Cassine tetragona* and the geophyte *Clivia* sp. (growing on shallow lithosols). The structure of this sub-community can be regarded as a tall forest (12–15 m) which tends to become a short closed woodland and more shrubby along the forest margins. Two variants were recognised in this sub-community:

2.2.1 *Peperomia retusa* Variant

The small herb *Peperomia retusa* (Species group I, Table 1) and the tree *Greyia sutherlandii* are the diagnostic species (Table 2). *Aloe arborescens* (Table 2) may also be found on rocky outcrops. This is a more exposed forest community than the *Dryopteris inaequalis—Tricalysia capensis* Sub-community. It occurs along the margins of the high-lying *Pterocelastrus echinatus—Syzygium gerrardii* Community and on rocky outcrops in the forest. This variant is also situated in the mistbelt area. The groundlayer is characterised by a dense cover of the grass *Oplismenus hirtellus* (species group M, Table 1) and other herbaceous plants such as representatives of the family Cyperaceae and *Chlorophytum comosum* (species group F, Table 1) in some areas. The dominant shrubs and small trees are *Carissa bispinosa, Dovyalis lucida, Pavetta barbertonensis* and *Ochna serrulata* (species group M, Table 1). The tree stratum consist primarily of *Schefflera umbellifera* (species group F, Table 1), *Curtisia dentata, Ekebergia pterophylla* (species group H, Table 1), *Syzygium gerrardii, Rapanea melanophloeos* (species group L, Table 1) and *Combretum kraussii* (species group M, Table 1).

The *Ekebergia pterophylla—Psychotria zombamontana* Tall/short forest described by Deall *et al.* (1989) may have some relation to this variant because of the occurrence of *Clivia* spp., *Syzygium gerrardii* and *Ekebergia pterophylla*. The habitat of the *Ekebergia pterophylla—Psychotria zombamontana* Tall/short forest community is described as part of the humid mistbelt forest associated with Black Reef Quartzite outcrops.

2.2.2 *Pittosporum viridiflorum—Oplismenus hirtellus* Variant

This variant occurs below the mistbelt and is, therefore, drier than the *Peperomia retusa* Variant. The tree stratum forms an open canopy with an average canopy height of less than 15 m. This variant also has a strong relationship in species composition with the *Cola greenwayi—Xymalos monospora* Community. Species which occur in both of these communities are *Maytenus mossambicensis* (species group A, Table 1), *Maytenus undata, Maytenus nemorosa, Scolopia zeyheri* and *Dovyalis rhamnoides* (species group D, Table 1). The diagnostic species of this variant are the trees *Ekebergia capensis, Pittosporum viridiflorum, Rhamnus prinoides* (species group J, Table 1), *Protorhus longifolia, Heteropyxis canescens, Maytenus peduncularis* and the fern *Anemia dregeana* (Table 2). The dominant herbaceous species are the grass *Oplismenus hirtellus* (species group M, Table 1) and the fern *Cheilanthes viridis* (species group F, Table 1). The shrub and low tree layer consist predominantly of *Maytenus mossambicensis* (species group A, Table 1), *Cassine tetragona* (species group H, Table 1), *Carissa bispinosa* and *Ochna serrulata* (species group M, Table 1). Larger trees and canopy species are *Pterocelastrus echinatus* (species group F, Table 1), *Rapanea melanophloeos* (species group L, Table 1), *Combretum kraussii* (species group M, Table 1), *Curtisia dentata* and *Aphloia theiformis* (species group H, Table 1).

Ordination

The ordination indicated two possible gradients on the two ordination axes of the scatter diagram (Figure 5). Sample distribution in the ordination space is well correlated with the observed communities and forms distinct groups associated with the identified communities. The left of ordination axis 1 is represented by core forest [*Cola greenwayi—Xymalos monospora* Community (1) and *Dryopteris inaequalis—Tricalysia capensis* Sub-community (2.1)]. Marginal forests [*Curtisia dentata—Rapanea melanophloeos* Sub-Community (2.2)] are situated at the right of the ordination axis. The gradient along ordination axis 1 could be attributed to disturbance frequencies that are more severe and pronounced at the margins than in core communities and, therefore, form a gradient of forest maturity or condition from left to right along the first ordination axis. Another gradient is related to differences in soil depth from deep, well-drained soil (left side) to shallow stony soil at the right side of ordination axis 1. The opposite poles of the gradient along ordination axis 1 exhibit differences in canopy height (from left to right) and density, and also herbaceous layer cover differences with a decrease of canopy height and an increase in cover of the herbaceous component to the right of ordination axis 1. These physiognomical differences are probably the result of the environmental impact on different communities in the forest.

A moisture gradient may exist along ordination axis 2 from moist conditions associated with streambanks at the top and drier conditions at the bottom of this ordination axis. Most of the samples associated with drier forest at the bottom of the ordination axis 2 belong to the *Curtisia dentata—Rapanea melanophloeos* Sub-community (2.2). Ordination axis 2 also divides Pedlar's Bush into two distinct groups that can be recognised in the phytosociological table as represented by species group C [Moist forest (1.1.1)] and species group L [Mesic forest (1.1.2, 1.2, 2.1, 2.2)].

Deall and Theron (1990) obtained similar ordination results for Afromontane communities in the Sabi area. The DCA-ordination of their results indicated similar gradients in soil depth and exposure between communities for Sabi-forest and altitude and climate were regarded as important factors in the distribution of Sabi-forest communities. Altitude and climate did feature in the classification of the different community types for Pedlar's Bush but could not be identified as forming clear gradients in the ordination.

Species richness and diversity

The different forest communities identified varied considerably in species richness. The α-diversity (species richness) differed between 27 for the riparian forest community (1.1.1) and 69 species for the margin forest community (2.2) per 0.04 ha sample area. The margin forest community (2.2) has the largest average species number per relevé (52.14). The lowest average species richness was found in the riparian (1.1.1) and the *Garcinia gerrardii* Sub-community (1.2) namely 3740 species/0.04 ha). The *Vepris lanceolata—Carissa bispinosa* Variant (1.1.2) has with 33 species the largest average number of woody species per relevé. The α-diversity was exceptionally high where marginal and riparian forests meet, for example, relevé 34 with 69 species recorded for the relevé.

Forest communities were divided between core [*Cola greenwayi—Xymalos monospora* Community (1), *Dryopteris inaequalis—Tricalysia capensis* Sub-community (2.1)] and margin forests [*Curtisia dentata—Rapanea melanophloeos* Sub-community (2.2)]. The difference in total species richness (Figure 6.1, $p = 0.0459$) and shrub species richness (Figure 6.2, $p = 0.019$) between the core and margin communities was significant at the 0.05 level. Although differences in species richness for the herb (Figure 6.3) and tree layers (Figure 6.4) exist, these differences were not significant. The herb and shrub layer (Figures 6.3 and 6.4) of the margin communities are characterised by a large variation in their species richness.

Statistically significant differences in total species richness were found between the *Curtisia dentata—Rapanea melanophloeos* Sub-community (2.2) and the *Garcinia gerrardii* Subcommunity (1.2) ($p = 0.031$) and *Dryopteris inaequalis—Tricalysia capensis* Sub-community (2.1) (Figure 6.5) ($p = 0.023$). The *Piper capense—Impatiens hochstetteri* Variant (1.1.1) differs significantly in herb species richness from the *Vepris lanceolata—Carissa bispinosa* Variant (1.1.2) ($p = 0.031$) and *Garcinia gerrardii* Sub-community (1.2) (Figure 6.6) ($p = 0.0379$). The most significant statistical differences between the different communities were for the shrub layers (Figure 6.7, $p = 0.019$). The *Curtisia dentata—Rapanea melanophloeos* Sub-community (2.2) had the highest average shrub species richness (Figure 6.7). The *Dryopteris inaequalis—Tricalysia capensis* Sub-community (2.1) has a lower shrub species richness than the other forest communities except for the *Piper capense—Impatiens hochstetteri* Variant (1.1.1) associated with drainage lines that has a more variable species richness in the shrub layer (Figure 6.7). Tree species richness was also variable between communities (Figure 6.8). The *Dryopteris inaequalis—Tricalysia capensis* Sub-community (2.1) and *Vepris lanceolata—Carissa bispinosa* Variant (1.1.2) had higher species richness than the rest of the forest communities. The *Vepris lanceolata—Carissa bispinosa* Variant (1.1.2) had in both cases a high tree and shrub diversity but a low diversity of herbaceous plants. The *Piper capense—Impatiens hochstetteri* Variant (1.1.1) had in all cases a high standard error indicating an inconsistent species richness, probably a result of diverse habitat types along streambeds with differences in light, moisture and soil depth.

Conclusion

Distinct vegetation units that are characterised by certain species exist in Pedlar's Bush, although their boundaries are not always well defined with respect to structure and specific species composition. Species such as the trees *Xymalos monospora*, *Cussonia spicata* and *Carissa bispinosa*, the herbs *Prosphytochloa prehensilis*, *Hypoestes aristata* var. *alba*, the ferns *Pteris catoptera*, *Asplenium splendens* and *Asplenium rutifolium* and the lianes *Rhoicissus rhomboidea* and *Keetia guenzii* were, however, encountered in the entire forest, in different habitat types. The type of terrain, different landscape types and altitude all play an important role in the establishment of different forest communities.

Vegetation classification of Pedlar's Bush indicated the presence of dominant lower and weaker developed upper mountain forest communities. Although von Breitenbach (1990) used dominance and not total floristic composition as a classification criterion, his classification of Transvaal forests is also applicable to Pedlar's Bush. The forest communities identified in the present study have shown strong relationships with other Transvaal forests, especially the Uitsoek and Kaapsehoop forests (von Breitenbach 1990). It was observed that communities not only differ in species composition but also in species richness.

Climax forest in Pedlar's Bush consists of the *Cola greenwayi—Xymalos monospora* Community (1) and *Dryopteris inaequalis—Tricalysia capensis* Sub-community (2.1). A gradient in disturbance frequencies was identified in the DCA ordination of data in the sub-tropical lowland forests (van Wyk *et al.* 1996). A similar type of gradient was identified for Pedlar's Bush (Figure 5). The core communities in Pedlar's Bush [*Cola greenwayi—Xymalos monospora* Community (1) and the *Dryopteris inaequalis—Tricalysia capensis* Sub-community (2.1)] form a spatial distribution of edaphic or climatic climax communities. The *Curtisia dentata—Rapanea melanophloeos* Sub-community (2.2) is serial and may form a chronosequence of developing forests, depending on the chronological variation of disturbance frequencies. The *Curtisia dentata—Rapanea melanophloeos* sub-community forms an important part in the management and conservation of this forest. Absence of margin vegetation leads to the deterioration of core forest because it removes the outer protection around the forest and changes the microclimate inside the forest (Jacobs 1994). Everard *et al.* (1994) argued that a certain degree of disturbance frequency must prevail in indigenous forest for the maintenance of its present species diversity. Absence of disturbance agents may, therefore, result in a loss of plant species diversity and the formation of a homogenous stand of core forest communities. Armstrong and van Hensbergen (1996) however argued that pine plantations may act as nurseries for shade tolerant species and could, therefore, lead to the expansion of the forest. Observations during the study also indicated that the pine plantations might act as protection against fire but were also a cause for the destruction of the forest margin (Cooper 1985). The frequency of fire along the northern margin of the forest must be carefully controlled and the pine plantations carefully managed to maintain the condition of Pedlar's Bush forest margin.

Many communities representing certain forest habitats similar to Pedlar's Bush were also described in other studies, for example, the Sabi-transect (Deall *et al.* 1989) and Hanglip forest (Geldenhuys & Murray 1993), although the total species composition varies. The current study should, however, contribute greatly to a future formal syntaxonomy for forests in South Africa.

Small forest fragments such as Pedlar's Bush are relatively homogenous in their species composition and all communities (species group M, Table 1), share a large number of species.

The unique species composition and high species richness of the communities in Pedlar's Bush warrants the inclusion of this and related forest fragments in the area as well as surrounding grassland into a conservation management program such as the natural heritage site program. One of the major concerns for forests in South Africa is the destruction of the forest grassland ecotone and forest margin communities (Cooper 1985). The *Curtisia dentata—Rapanea melanophloeos* Sub-community (2.2) can, therefore, be regarded as ecologically sensitive because most of these areas border *Pinus* plantations. This sub-community also has the largest species richness in Pedlar's Bush.

Acknowledgments

Without the financial support of SAPPI-TWELLO this project would not have been possible. We acknowledge the help of the cartographic division of the PU for CHE for the drawing of the Pedlar's Bush map and Mr. J. Burrows for the identification of most of the ferns and the National Herbarium, Pretoria for the identification of some of the flowering plants.

References

ACOCKS, J.P.H. 1988. Veld types of South Africa. *Mem. bot. Surv. S Afr.* 57: 1–146.

ANHAUSSER, C.R., ROBB, L.J. & VILJOEN, M.G. 1981. Provisional geological map of the Barberton greenstone belt and surrounding granite terrain, Eastern Transvaal and Swaziland. Geological Society of South Africa, Johannesburg.

ARMSTRONG, A.J & VAN HENSBERGEN, H.J. 1996. Impacts of afforestation with Pines on Assemblages of native Biota in South Africa. *S. Afr. For. J.*, 175: 35–42.

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., 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.

BREDENKAMP, G.J. & BEZUIDENHOUT, H. 1990. The phytosociology of the Faan Meintjies Nature Reserve in the western Transvaal grassland. *S. Afr. J. Bot.* 56: 54–64.

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: 513–539.

CAWE, S.G. & MCKENZIE, B. 1989. The Afromontane forest of Transkei, southern Africa. 2: Floristic classification. *S. Afr. J. Bot.* 55(1): 31–39.

COOPER, K.H. 1985. The conservation status of indigenous forest in Transvaal, Natal and Orange Free State, South Africa. Wildlife society of Southern Africa, Durban.

DEALL, G.B. & THERON, G.K. 1990. Ordination as a tool for substantiating and interpreting floristic classifications: a case study. *Bothalia* 20(2): 223–227.

DEALL, G.B., THERON, G.K. & WESTFALL, R. 1989. The vegetation ecology of the Eastern Transvaal escarpment in the Sabie area, nr.2: Floristic classification. *Bothalia* 19(1): 69–89.

DU PREEZ, P.J. 1991. A syntaxonomical and synecological study of the vegetation of the southern and eastern Orange Free State and related areas with special reference to the Korannaberg. D.Sc. dissertation. University of the Orange Free State, Bloemfontein.

DU PREEZ, P.J., BREDENKAMP, G.J. & VENTER, H.J.T. 1991. The syntaxonomy of the forest in the Eastern Orange Free State, South Africa. nr1: The *Podocarpetalia latifolii. S. Afr. J. Bot.* 57(4): 198–206.

EDWARDS, D. 1967. A plant ecological survey of the Tugela basin. Natal. *Mem. bot. Surv. S. Afr.* 36: 1–285.

EDWARDS, D. 1983. A broad-scale structural classification of vegetation for practical purposes. *Bothalia* 14(3&4): 704–712.

EVERARD, D.A., VAN WYK, G.F. & MIDGLEY, J.J. 1994. Disturbances and the diversity of forest in Natal, South Africa: lessons for their utilisation. *Strelitzia* 1: 275–286.

GELDENHUYS, C.J. & MURRAY, B. 1993. Floristic and structural composition of Hanglip forest in the Soutpansberg, Northern Transvaal. *S Afr. For. J.* 165: 9–19

GELDENHUYS, C.J. & PIETERSE, F.J. 1993. Floristic and structural composition of Wonderwoud forest in the Wolkberg, north-eastern Transvaal. *S. Afr. For. J.* 164: 9–19.

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

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

JACOBS, C. 1994. Inheemse woude: Benutting en bewaring. *Spectrum* 32: 14–16.

LAND TYPE SURVEY STAFF. 1989. Landtypes of the maps 2530 Barberton. *Mem. agric. nat. Resour. S. Afr.* 14: 1–390.

LOW, A.B. & REBELO, A.G. 1996. Vegetation of South Africa, Lesotho and Swaziland. Department of Environmental Affairs and Tourism, Pretoria

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

MULLER, D.J. 1994. Resultate van 'n voorraadsopname in die inheemse bos op Mariti, Oos Transvaal. *S. Afr. J. For.* 168: 27–31.

PALMER, E. & PITMAN, N. 1972. Trees of southern Africa. A.A. Balkema, Cape Town.

SCHEEPERS, J.C. 1978. The vegetation of the Westfalia Estate on the North-Eastern Transvaal escarpment. *Mem. bot Surv. S. Afr.* 42.

SCHULZE, R.E. & MCGEE, O.S. 1978. Climatic indices and classifications in relation to the biogeography of southern Africa. In:. Biogeography and ecology of southern Africa. Ed. M.J.A Werger, Vol. I, pp. 19–52. W. Junk, The Hague.

SEYDECK, A.H.W. 1991. Inventory of South African natural forests for management purposes. *S. Afr. For. J.* 158: 105–108.

SPJOTVOLL, E. & STOLINE, M.R. 1973. An extension of the T-method of multiple comparison to include the cases with unequal sample sizes. *J. Am. Stat. A.* 68: 976–978.

STATISTICA for Windows. 1995 [Computer program manual]. StatSoft, Tulsa.

VAN DER SCHIJFF, H.P. & SCHOONRAAD, E. 1971. The flora of the Mariepskop complex. *Bothalia* 10: 461–500.

VAN WYK, G.F., EVERARD, D.A., MIDGLEY, J.J. & GORDON, I.G. 1996. Classification and dynamics of a southern African subtropical coastal lowland forest. *S. Afr J. Bot.* 62(3):133–142.

VON BREITENBACH, F. 1990. Reports on indigenous forest, Part 1. Department of Environmental Affairs, Pretoria.

WEATHER BUREAU. 1984. Climate of South Africa. Weather Bureau WB4. Government Printer, Pretoria.