A phytosociological classification of the Witwatersrand National Botanic Garden

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The vegetation of the Witwatersrand National Botanic Garden was classified using two-way indicator species analysis and the Braun–Blanquet technique. The analyses resulted in the identification of 12 habitat-related plant communities that can be related to specific habitat conditions. Descriptions of the plant communities include diagnostic species as well as prominent and less conspicuous species of the tree, shrub and herbaceous strata. Habitat features include topography, especially elevation, aspect and slope, and soil factors such as soil type, depth and rockiness of the soil surface.

Die plantegroei van die Witwatersrand Nasionale Botaniese Tuin is deur middel van twee-rigting indikator-spesie-analise en die Braun–Blanquet-tegniek geklassifiseer. Die analises het die identifikasie van 12 ekologies-verantwoordbare plantgemeenskappe, wat met spesifieke habitattoestande geassosieer is, tot gevolg gehad. Beskrywings van die plantgemeenskappe sluit diagnostiese spesies sowel as prominente en minder opvallende spesies van die boom-, struik- en kruidstratums in. Habitatkenmerke sluit topografiese faktore, veral hoogte bo seespiëel, aspek en helling, en grondfaktore soos grondtipe, diepte en klipperigheid van die grondoppervlak in.

Keywords: Braun–Blanquet technique, habitat related, plant communities

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Introduction

The Witwatersrand National Botanic Garden is situated at 26° 05′ latitude and 27° 50′ longitude, along the Linksfield–Northcliff–Krugersdorp quartzite ridge, on the north-western boundary of Roodepoort and about 24 km west of the Johannesburg city centre. The Garden was proclaimed as a National Botanic Garden during 1982, and it is at present in the first stages of development. It was thus decided that an ecological survey and phytosociological classification would be valuable for the developmental planning of the Garden, as well as for the management of the conservation area that will remain undeveloped as a nature reserve. The vegetation represents the central variation of the Bankenveld (Acocks 1975).

The survey was planned to fit in with the standard procedures of phytosociological survey on a national basis, as applied by the Botanical Research Institute, in order to obtain the required uniformity and comparability. The classification would therefore not only be of value for the Garden, but should also contribute to a better understanding of the Bankenveld vegetation.

The study area

Topography and geology

At the time of this study the Garden covered approximately 104 ha, situated between 1 482 and 1 680 m above sea level. Extension of the garden is envisaged. The site has a complex and unique topography caused by a ridge formed by alternating bands of quartzite and shale. The rocky and exposed north, north-west and north-east facing slopes vary greatly in inclination and include a vertical cliff, exposing the bands of quartzite and shale. The Muldersdrift-se-loop flows over this cliff, creating a waterfall of about 70 m in height. Below the falls the stream flows northwards in a sheltered and densely vegetated valley. The quartzite and shale layers of the Orange Grove subgroup form the base of the Witwatersrand supergroup. The quartzite is more resistant to weathering than the underlying and overlying formations (Beukes 1986). The rocky plateau above the waterfall consists of the overlying Parktown shales, and interbedded in these is a magnetic iron-rich layer, known as the Water Tower formation. The underlying ancient Greenstone lava of the Swaziland supergroup is more than 3 400 million years old (Beukes 1986), being of the oldest rocks in South Africa. These are covered by scree in the vicinity of the waterfall (Beukes 1986). A relatively low altitude, slightly undulating plain occurs at the foot of the hills.

Soils

The soils of the Garden are fairly limited in variety, and mainly represent shallow, rocky and slightly acidic lithosols. The soils are mainly formed by weathering of fine- to medium-grained quartzites and shales of the Witwatersrand supergroup, and the sand fraction is accordingly fine- to medium-grained. Munnik (1985) associates the soil types to three topographic units, namely (i) crests and steep slopes, (ii) middle slopes, and (iii) footslopes and valley floor. The soils of the crests and steep slopes (> 25% slope) are very shallow, dark grey lithosols, representing mainly the Mispah soil form (Verster 1983; Munnik 1985). Rocks cover more than 50% of the soil surface and the underlying bedrock forms outcrops in places. Allthough the soils of the middle slopes (15–25% slope) are often also shallow Mispah soils, deeper soils representing the Hutton and Shortlands forms are frequently found locally. The soils of the footslopes (4–15% slope) and flat valley floors are deeper (0,5–1,5 m), mainly of depositional origin, and varying in colour and depth (Verster 1983; Munnik 1985). The dominating soils are of the Hutton, Shortlands, Westleigh and Clovelly forms. The Oakleaf and Dundee forms are associated with the stream banks. Some of these soils have a high clay content and show varying degrees of structure. These soils have been greatly disturbed by man and often show compaction and poor drainage patterns (Verster 1983; Munnik 1985).

Climate

No local climatic records were kept prior to the proclamation of the Garden. Climatic data are, however, available from nearby weather stations, and this gives an indication of the general climate of the area. Climatic data have been recorded for the Garden since 1983.

The Roodepoort area has a typical highveld climate. The mean annual rainfall over 33 years (1951–1984) is 767 mm at Krugersdorp, most falling in summer between October and April (Weather Bureau 1986). At Krugersdorp the mean temperature for January is 20,2°C and for July 9,5°C. The mean daily maximum temperature is 26°C for January and 16,8°C for July, while the mean daily minimum is 14,2°C for January and 2,3°C for July (Weather Bureau 1986). Owing to the great variation in topography and vegetation structure, considerable variation may be expected in microclimate, but this aspect was not included in this study.

Methods

Releves were compiled in 87 stratified random sample plots (Table 1). Stratification of the area was done on basis of physiographic and physiognomic units. Nine such units were distinguished within the area and these were delineated on aerial photographs. The number of plots was determined on an area basis among the nine units (Table 1). Cultivated and built up areas were excluded from this survey. Sample plot size was fixed on 100 m^2, as Bredenkamp & Theron (1978) found this size adequate for similar Bankenveld woody vegetation types. Total floristic composition was recorded in each plot, using the Domin-Krajina cover-abundance scale (Mueller-Dombois & Ellenberg 1974) for estimating cover of each species. Percentage canopy cover and height of each stratum were visually estimated and recorded in each sample plot and the average canopy cover and height were calculated for each of the plant communities distinguished (Table 2). Physiographic data included estimates for altitude, aspect, slope and surface rockiness. Geological data were obtained from Beukes (1986) and soil data from Verster (1983).

Two-way indicator species analysis (TWINSPAN) (Hill 1979) was used to derive a first approximation of the vegetation types. The results of this classification were refined by the Braun–Blanquet classification technique in order to obtain a final, as ecologically sound as possible classification. The results are presented in a phytosociological table (Table 3).

Results and Discussion

The analyses resulted in the identification of 12 plant communities, each related to a specific set of environmental conditions. In a hierarchical classification the 12 communities are grouped into four major communities. The hierarchical classification and brief ecological interpretation are given in Table 4. The distribution of the different communities is shown in a vegetation map (Figure 1). A list of all plant species with author citations is given by Behr & Bredenkamp (1988).

1. The *Protea caffra* major community

This major plant community is characterized by the species of species group M in Table 3. It occupies a large area of the Garden and occurs on a variety of habitats, including different geological formations, soil types, altitudes and aspects. However it occurs mostly on rocky slopes of > 15%.

Diagnostic species include the woody *Protea caffra*, the grasses *Rhynchelytrum repens, Themeda triandra, Brachiaria serrata* and *Bewsia biflora* and herbs such as *Senecio venosus, Athrixia elata, Vernonia natalensis, Tephrosia capensis, Gerbera ambigua, Tritonia nelsonii, Protasparagus suaveolens, Bulbostylis burchellii* and *Acalypha angustata* var. *glabra*.

The *Protea caffra* major community is divided into two communities, namely the *Protea caffra–Loudetia simplex* and the *Protea caffra–Panicum natalense* communities.

1.1 The *Protea caffra–Loudetia simplex* community

This community occurs above the waterfall on the high altitude quartzite plateaux or on steep, rocky south-facing slopes. In exceptional cases (sample plot 53) the community may occur lower down on east-facing slopes, on rocky quartzite outcrops or among liberal scatterings of quartzite rocks.

Table 2 The average height (H) and cover (C) of the tree, shrub and herbaceous strata of the 12 plant communities distinguished in the Witwatersrand National Botanic Garden

Community no.	Stratum					
	Tree		Shrub		Herbaceous	
	H (m)	C (%)	H (m)	C (%)	H (m)	C (%)
1.1.1.1a	1,88	6,3	1,3	26,3	0,4	35,0
1.1.1.1b	2,5	15,0	1,2	27,5	0,38	25,0
1.1.1.2	2,1	4,7	1,2	12,5	0,4	37,6
1.1.2.1	–	–	1,1	3,8	0,71	55,3
1.1.2.2	1,5	12,1	1,5	16,4	0,56	55,0
1.2.1	0,8	2,5	0,97	9,2	0,73	58,3
1.2.2	3,6	17,9	1,5	17,8	0,53	45,2
2.	1,5	5,0	0,9	2,5	0,55	47,5
3.	6,3	33,2	1,5	23,6	0,52	28,2
4.1	13,7	45,8	1,47	15,0	0,48	24,2
4.2	15,0	39,2	1,77	16,7	0,4	15,3
4.2.1	18,0	45,5	1,75	35,0	0,4	12,5

See Table 4 for plant community names

Table 1 The distribution of 87 sample plots in the physiographic — physiognomic units

Physiographic–physiognomic units	Vegetation below falls (northern side of ridge)					Vegetation above falls (top and southern side of ridge)				Total
	Kloof vegetation	Dense bush	Open bush	Grass-land	Stream vegetation	Stream vegetation	Out-crops	Open bush	Grass-land	
Number of sample plots	3	13	31	7	4	2	12	10	5	87

Table 3 A phytosociological table of the Witwatersrand National Botanic Garden

Species	0000 7777 1452	00 77 67	0000000 8877785 4538963	0000 0001 7890	0000000 1111188 4567823	000000 000000 123456	00000000000000000000000000 33334441122222222223333835 178901219012345678903456724	00 88 01	00000000000 54444466155 23546723301	000000 445666 899410	00 67 90
Species group A											
Bequaertiodendron magalismontanum	2121	11	1						231 1		
Pittosporum viridiflorum	1 1	11							1	1	
Crassula swasiensis	1 3	11									
Rhynchosia venulosa	1 2	11			1						
Tapiphyllum parvifolium	1 1	11					1		1		
Species group B											
Nuxia congesta	1111		1						1 1111		
Sutera campanulata	111		11								
Species group C											
Ficus ingens		11							1		
Haemanthus nelsonii	1	11									
Commelina eckloniana	1	11		1					1		
Mundulea sericea	1	11									
Crassula setulosa	1	11	1		1				1	1	
Xerophyta retinervis		11	2								
Species group D											
Mohria caffrorum		11	1111111								
Oxalis corniculata	1		11 1111		1		1 1 1	1	1		
Helichrysum lepidissimum			11111 1					1			
Senecio oxyriifolius	1		1 111		1		1 1		1		
Myrsine africana			11 11						1		
Pteridium aquilinum			1111					21			
Species group E											
Aristida transvaalensis	212	11	2222231		1 1		1	1	1 1		
Crassula alba	1 1		11111						11		
Species group F											
Justicia anagalloides				11	1 1 11						
Tristachya rehmannii	1			11	1 111		1	1			
Cassia mimosoides				1	111						
Species group G											
Loudetia simplex	1111	11	1 121	3332	12111 1		1 1				
Rhus magalismontanum	11 1	11	1 1	11	111						
Pearsonia sessilifolia	11		1 111	1 11	1 11						
Alloteropsis semialata			11 11	1	111111		1	11			
Vernonia galpinii	1 1	1	11	1 1	1						
Species group H											
Heteropogon contortus	1 2	1		11 1	221111	323222	1 1 1111 1		11 1		
Cyperus obtusifolia				1	1	212111					
Aristida canescens				1 1	1	11111	1 1 11 1		1		
Convolvus sagitatus						11 1 1					
Sphenostylis angustifolia					1	1111	1 1				
Crabbea angustifolia					11	11 11					
Species group I											
Elionurus muticus				1	1 1	1	1111 1111 11 111111 11		1		
Hypericum aethiopicum			1				111 1111111111 1	11			
Thesium transvaalensis				1			11 11111 1 1 11 1 1	1			
Rhus zeyheri			1		1		11 11111111 1 1 1		11 11		
Aristida diffusa	2			4 1			11 1111 1 111 12				
Kohautia amatymbica			1		1		1 1 11 11 1 11	1	1		
Sonchus dregeanus	1					1	111 1 1 1 1 1 1				
Ipomoea bathycolpos					1		11 1 1 11 1 11		11 1		
Ipomoea crassipes							1 1 11111 11		1		
Vernonia oligocephala						11	11 1 1 1 1 11 1				
Sida dregei							1 1111 11		1	1	
Pulicaria scabra							1 1 1 1 1				
Scabiosa columbaria						1	1 111 1 1	11			
Setaria nigrirostris			11				1 1 2 1 11	1		1	
Ruellia patula			1				11 11 11		1		
Tulbaghia acutiloba							1 1 1 1				
Species group J											
Nidorella hottentotta			1	1	1	11 211	11 111 1111111 1 1 1		1		
Hypoxis rigidula			1	1		11 11	1 1 11111 1 111 1	1	1		
Eriosema cordata			1			111	1 1 1111 1111 1 111				
Hyparrhenia hirta			11		2	1 1	1 111 1 1 21111 11	1	2		
Gnidia caffra			1	1	1	11 11	1 111 1111 1 1 11	1			
Lippia javanica						11 1	111 1 1 111 11 111		1 1		
Polygala hottentotta						111 11	1 1111 1 1 11 1 1	1			
Pachycarpus schinzianus						1 11	111 1 1111 11 111				
Lantana rugosa						1 1	1 1 1 1 1 11 1 111 11		1		
Dicoma zeyheri						1 1 11	1111 11 111 11 1 11 1		1		
Elephantorrhiza elephantina		11			1	1 1211	111 11 1				
Striga asiatica				1	1	11	1 1 11 1 1				
Drimiopsis burkei			1		11	111	1 1 1 1				
Eragrostis curvula				1	1	21 1	1 12 21		11 1		
Species group K											
Setaria flabellata	1			1	1 1	1 1 12	11 111 211111111122 112121		2 11		
Ledebouria marginata				111	1 11	111111	1111 1 11 111 111111 1 11	1	1 11		1
Pentanisia angustifolia			1	1	11111	111111	111111 111111 11 111 111	1			
Anthericum fasciculatum			1	1 11	1 1 1	111 11	1 1 111 1 11111111111	11			
Urelytrum agropyroides	1		1	1111	211		112111 1111 1111 1 1 11	1	1		
Helichrysum nudifolium				1	1 1	11111	111 11 11111 1 1 1 111 1	1	1		
Tephrosia elongata			1	111	111	1 1111	111 1 111111 1 1 1				

Table 3 Continued

Species	0000 7777 1452	00 77 67	0000000 8877785 4538963	0000 0001 7890	0000000 1111188 4567823	000000 000000 123456	00000000000000000000000000 33334441122222222233333835 17890121901234567890345624	00 88 01	00000000000 54444466155 23546723301	000000 445666 899410	00 67 90
Panicum natalensis	1 1		11	1	11111 1	12213	1111 1 1 1 111 1	1	1		
Indigofera hedyantha	1		1	1 1	111	1 11	1111 1 1 11 1	1			
Senecio affinis			1	1 1	11		1 11 11 1				
Species group L											
Senecio isatideus								33			
Sporobolus africanus							1	21			1
Pelargonium luridum					1			11			
Digitaria diagonalis							1 1	11			
Gerbera kraussii								11			
Berkeya setifera								2			
Species group M											
Protea caffra	1 1 11		11111	1	2332211		1221121 2221121211221 221				
Senecio venosus	1 11		1 111	111	1111111	112111	11111111 111111111 1 1111		1 1		
Gerbera ambigua	11 11		11 111	11 1	1111111	1 1111	1 1 1111111111 111 11	11	1		
Rhynchelytrum repens	11 1		111 11	111	1111111	11111	11111211 1 1 1 13 2121 1		11 1 1 11		
Themeda triandra	1 1		111	1	31122 1	131133	11111111212 111111 1111 1	11	11		
Brachiaria serrata	11 1		1	1112	1211111	121211	2111112311111111 1221122111	11	11		
Athrixia elata	1 11		11111	11	1 1 1	11111	134321 1 11122 1222 1212		11		
Vernonia natalensis	1 1 11		1 1	1111	111 1	1111 1	11 1 11 1 11111 11 1	1			
Tephrosia capensis	1 1		11 1	1	1 11	11111	11 1 1111 1 1111111 1 1 11	1	1		
Tritonia nelsonii	1 11		111111			1 11	1111111 11111111 1 1111		1 1	1	
Acalypha angustata	1		11 1		11 1	1	1211111 11 112 1 111 1111	21	1		
Bulbostylis burchellii	1111 1		1	1 1	11 1	121	1111 1 1 11 111 1	1			
Protasparagus suaveolens	1		11 1	1 1	1 11	11 1	1 11 1+ 1 111 111 11111		11 1		
Bewsia biflora	1		1	1 1	1 11	111 11	1 1111 11 11 1 1	11	1		
Species group N											
Acacia caffra			1			1 1	11 11 1 11121111112213111121		1112 11	1 2 11	
Ozoroa paniculosa	1			1	1		1222111 12111111111111 122		11111 11		
Maytenus heterophylla	11	1					1111 1111111111		12 1 1	1	
Cussonia paniculata	11	1					1 11111 11 1 1		11	1 1	
Rhynchosia totta							11 1 1 1 1 1 1111 1	11	1111 1		
Grewia occidentalis							1 1 1 111		1 11	11111	
Species group O											
Combretum molle	11 1 11						1 1 11 1		1221131111	1	
Rhus leptodictya	1				1		1 1		111 111 111	11	
Cyphostemma lanigerum	1						1		1 111121	2	
Eleusine indica							2		22 1 21		
Hermannia floribunda							1		1 1 1 1	1	
Mariscus uitenhagensis	1 1								111 1		
Species group P											
Celtis africana							1 11		11 11	221122	11
Combretum erythrophyllum							1		11 1	11111	
Acokanthera oppositifolia			1						1 11 1	111 12	
Cyperus albostriatus			2	1					311	111	
Diospyros whyteana									1 1	221111	
Kiggelaria africana							1		1	1 1	1
Cheilanthes viridis							1 1			12 11	1
Species group Q											
Ziziphus mucronata	11						1 1 11		1	111 1	
Zanthoxylum capensis	1 11						1		1 1	11 11	1
Ehretia rigida							1			111 1	
Pupalia lapacea									1	1231	
Littonia modesta										111 1	
Maytenus undata									1	1 111	1
Abutilon sonneratianum									1	1 1	
Maytenus polyacantha							1		1 1	11	
Species group R											
Setaria megaphylla											1
Buddleja salviifolia							1		2		11
Rhamnus prinoides							1 1				
Leucosidea sericea			1		1		1 11	11			11
Solanum pseudo-capsicum											1
Ilex mitis											
Halleria lucida			1								1
Species group S											
Acacia mearnsii								1			23
Species group T											
Canthium gilfillanii	111		1 2		1		11 1 1 1 1		411 1211123	1111 1	
Dombeya rotundifolia	11						1		1212 1111	11 11	
Rhus pyroides					11		1 111 1 11		11 11111	11 111	1
Setaria lindenbergiana	11						1		1131 1 4	111 1	1
Kalanchoe rotundifolia							1		1 111	111111	
Pappea capensis									1 1 1	1 1	
General species											
Diospyros lycioides	1 1 11		11 1		12	1	1 11 1 1 11 111 11111 11		11 1111 11	1 111	11
Rhus dentata			1111 1		121		1 1 11 111111111 11111 122	1	1 11 11	11 1	11
Aloe davyana			11	1	1	13322	1111111 1121211122222111 21		11 1 111	1	
Ledebouria marginata				111	1 11	111111	1111 1 11 111 111111 1 11	1	1 11		1
Pallaea calomelanos	1111 1		11 1111	111	1 1 1		11111 1 11 1 1 1112		11 1 1 11	1	
Anthospermum rigidum				1	11 1	1111 1	111 11 111 1 1		1		
Cheilanthes hirsutus	1		11 111		1		1 1		1 111	11	
Commelina africana	11 11		111 1				1 1		1 11		
Bidens pilosa					1		1 11 11		1 211	1 11	
Hemizygia pretoriae	1 1 11		1	1 11	1 1 1	1	1				
Tagetus minuta					1		1 11		1 1 21	1 1	
Solanum retroflexum				1	1	1	1 1 1 1 11				

Table 3 Continued

Species	0000 7777 1452	00 77 67	0000000 8877785 4538963	0000 0001 7890	0000000 1111188 4567823	000000 000000 123456	00000000000000000000000000 33334441122222222233333835 17890121901234567890345672 4	00 88 01	0000000000 54444466155 23546723301	000000 445666 899410	00 67 90
Nolletia rarifolia	1 1		1	1 1	11	1	1 11				
Cheilanthes involuta	1				1		1 1		1111 1	2	
Heteromorpha trifoliata							1 11		1 11	1 1	
Acalypha peduncularis	11	1	11		2 1 1		11				
Vangueria infausta	1 11	1 1					1 1		11		
Asclepias stellifera		1	11				11 1 11	1			
Graderia subintegra			11				1 1 1 1				
Protasparagus africanus							1 1		1 1	1 1	
Rhus eckloniana		1 1				1	1 1 11				
Senecio inornatus	1		1				11	1			
Parinari capensis	1			11	1		1 11				
Striga elegans					1 1 1		1 1 1 1				
Vernonia sutherlandii	11	1 1	1				11				
Rhus lancea							11 1 1		1	1	
Gazania krebsiana			1		1		11 1 1				
Senecio lydenbergensis	11	1			1 1		1				
Anthospermum hispidulum	111	1		1					1		
Kalachoe thyrsiflora	11		1				1		1 1		
Lannea edulis			1				111 1		1		
Monocymbium ceresiiforme	1 1		1	1 1			1				
Polygala uncinata							1 11 11	1			
Raphionachme galpinii		1	1	1			1 1				
Schoenoxiphum sparteum							11 1 2				
Striga bilabiata		1	1		11		1				
Helichrysum rugulosum				1			1	11	1		
Chamaesyce inaequilatera							1 1 1		1 1		

General species occuring with a frequency of less than five are omitted from the table

Table 4 A hierarchical classification and brief ecological interpretation of the plant communities of the Witwatersrand National Botanic Garden

1.	*Protea caffra* major community on rocky slopes
1.1	*Protea caffra–Loudetia simplex* community on the extremely rocky, high altitude plateaux and steep south-facing slopes
1.1.1	*Protea caffra–Loudetia simplex–Aristida transvaalensis* community on high altitude plateaux
1.1.1.1	*Protea caffra–Aristida transvaalensis–Bequaertiodendron magalismontanum* subcommunity on extremely rocky north-facing quartzite outcrops
	(a) *Nuxia congesta* variant on exposed xeric sites (b) *Ficus ingens* variant on sheltered mesic sites
1.1.1.2	*Protea caffra–Aristida transvaalensis–Mohria caffrorum* subcommunity on less rocky, steep south-facing slopes
1.1.2	*Protea caffra–Loudetia simplex–Tristachya rehmannii* community of high altitude slopes on shale
1.1.2.1	*Loudetia simplex* variant on steep west-facing slopes
1.1.2.2	*Protea caffra* variant on moderately steep west-facing slopes
1.2	*Protea caffra–Panicum natalensis* community on less rocky moderately steep slopes
1.2.1	*Protea caffra–Panicum natalensis–Heteropogon contortus* subcommunity on moderately steep, moderately rocky north-east facing slopes
1.2.2	*Protea caffra–Panicum natalensis–Acacia caffra* subcommunity on lower, rocky, gradual slopes
2.	*Sporobolus africanus–Senecio isatideus* major community on deep, wet soils along streams at high altitudes above the falls
3.	*Canthium gilfillanii–Combretum molle* major community on steep, hot and dry north-facing slopes
4.	*Combretum erythrophyllum–Celtis africana* major community on deep soils of the flat valley floor and river banks
4.1	*Combretum erythrophyllum–Celtis africana–Pupalia lapacea* community on flat valley floors
4.2	*Combretum erythrophyllum–Celtis africana–Setaria megaphylla* community along moist stream banks
4.2.1	*Acacia mearnsii* facies

The community is characterized by species group G (Table 3). Diagnostic species include the prominent grass species *Loudetia simplex* the conspicuous woody dwarf shrub *Rhus magalismontanum*, and also *Pearsonia sessilifolia* subsp. *sessilifolia, Alloteropsis semialata* subsp. *eckloniana* and *Vernonia galpinii*. The most prominent woody species are *Protea caffra* and *Diospyros lycioides* subsp. *guerkei*, while the grasses *Loudetia simplex* and *Rhynchelytrum repens* and the forbs *Tritonia nelsonii, Vernonia natalensis, Senecio venosus* and the xerophytic fern *Pellaea calomelanos* are conspicuously present.

The rugged terrain formed by the undulating plateaux, the rocky outcrops, the quartzite ridges and steep south-facing slopes create numerous and diverse habitats, resulting in a diverse vegetation. Consequently various subcommunities could be distinguished.

1.1.1 *The* Protea caffra–Loudetia simplex–Aristida transvaalensis *community*.
This occurs on the extremely rocky, high altitude plateaux, at 1 580–1 680 m above sea level. The community is characterized by species group E (Table 3), which includes the very prominent *Aristida transvaalensis* and the less conspicuous *Crassula alba* var. *alba*.

1.1.1.1 *The* Protea caffra-Aristida transvaalensis–Beqaertiodendron magalismontanum *subcommunity*.
This occurs on extremely rocky (> 70% rock) quartzite outcrops and small krantzes on the transitional zone between north-facing slopes and the plateaux area. It also occurs at similar situations on the Water Tower formation. This subcommunity is characterized by species group A (Table 3), and diagnostic species include the conspicuous woody *Bequaertiodendron magalismontanum, Pittosporum viridiflorum* and *Tapiphyllum parvifolium* as well as *Rhynchosia venulosa* and *Crassula swaziensis*. Two variants of this subcommunity are distinguished namely the *Nuxia congesta* variant on exposed, extremely rocky (> 70% of the area covered with rocks) xeric sites on quartzite and the *Ficus ingens* variant on equally rocky, though sheltered mesic sites on the Water Tower formation.

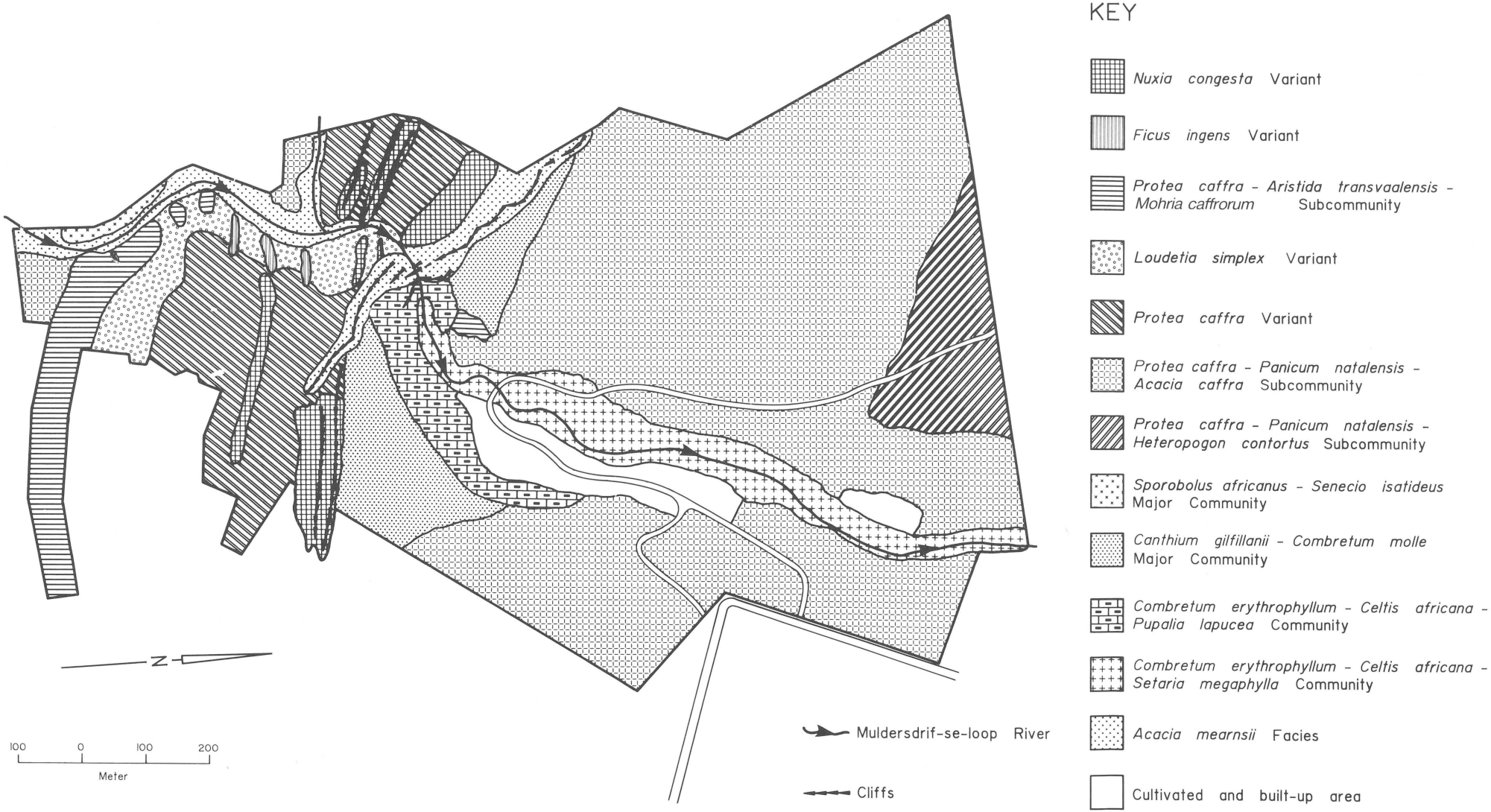

Figure 1 A vegetation map of the Witwatersrand National Botanic Garden

(a) The *Nuxia congesta* variant is characterised by species group B (Table 3). Diagnostic species are *Nuxia congesta* and *Sutera campanulata*. The scanty low tree stratum is poorly developed on these rocky sites, covering only 1,88%. Although the shrub stratum is on average only 1,3 m tall, it is well developed and has an average cover of 26,3% (Table 2). The most prominent and constantly present woody species include *Bequaertiodendron magalismontanum, Rhus magalismontanum, Pittosporum viridiflorum, Nuxia congesta, Tapiphyllum parvifolium* and *Diospyros lycioides* subsp. *guerkei*.

The herbaceous layer is very short (0,4 m on average) and covers up to 35,0% of the area. Prominent grass species are *Aristida transvaalensis, Loudetia simplex, Panicum natalense, Heteropogon contortus, Rhynchelytrum repens* and *Brachiaria serrata*, while forbs include *Sutera campestris, Crassula swaziensis, Rhynchosia venulosa, Pellaea calomelanos* and *Bulbostylis burchellii*.

(b) The *Ficus ingens* variant is characterized by species group C, and the diagnostic species are *Ficus ingens, Haemanthus nelsonii, Commelina eckloniana, Mundulea sericea, Crassula setulosa* var. *jenkinsii* and *Xerophyta retinervis*. Owing to the relatively favourable habitat conditions, many species, especially woody plants are found in this variant.

Both the tree and shrub strata are short but well developed, covering 15,0% and 27,5% respectively (Table 2). Prominent woody species include *Bequaertiodendron magalismontanum, Rhus magalismontanum, Pittosporum viridiflorum, Diospyros lycioides* subsp. *guerkei, Ficus ingens, Mundulea sericea, Elephantorrhiza elephantina, Protea caffra, Maytenus heterophylla, Cussonia paniculata, Dombeya rotundifolia, Ziziphus mucronata* and the semi-woody *Xerophyta retinervis* and *Athrixia elata*.

The herbaceous layer is poorly developed (Table 2). The most conspicuous grasses are *Aristida transvaalensis, Loudetia simplex* and *Setaria lindenbergiana*.

Prominent forbs include *Senecio venosus, Vernonia natalensis, Tritonia nelsonii, Gerbera ambigua, Hemizygia pretoriae* subsp. *pretoriae, Kalanchoe thyrsiflora* and *Senecio lydenburgensis*.

1.1.1.2 *The* Protea caffra–Aristida transvaalensis–Mohria caffrorum *subcommunity*. This occurs on less rocky (50% rock), steep (> 40%), predominantly south-facing slopes. This subcommunity is characterized by species group D (Table 3) and diagnostic species are *Mohria caffrorum, Oxalis corniculata, Helichrysum lepidissimum, Senecio oxyriifolius, Myrsine africana* and *Pteridium aquilinum*.

Both the tree and shrub strata are poorly developed (Table 2) and woody species are limited to *Protea caffra, Diospyros lycioides* subsp. *guerkei, Rhus dentata* and *Myrsine africana*.

The herbaceous layer is short but well developed, covering 37,6% of the area (Table 2). Dominant grasses include *Aristida transvaalensis, Loudetia simplex, Alloteropsis semialata* subsp. *eckloniana, Rhynchelytrum repens* and *Themeda triandra*.

Forbs are abundantly present and in addition to the diagnostic species mentioned, species such as *Pearsonia sessilifolia, Senecio venosus, Gerbera ambigua, Athrixia elata, Tritonia nelsonii, Pellaea calomelanos* and *Cheilanthes hirta* are often found in this vegetation.

1.1.2 *The* Protea caffra–Loudetia simplex–Tristachya rehmannii *community*.

This occurs at high altitudes above the falls, on steep to moderately steep slopes on the shales of the Parktown formation. This community is characterized by species group F (Table 3) and diagnostic species include *Justicia anagalloides, Tristachya rehmannii* and *Cassia mimosoides sensu latu*. Also characteristic is the conspicuous presence of species from species group K (Table 3) which are present in the subcommunities of the *Protea caffra–Panicum natalense* community.

Two closely related variants may be distinguished:

1.1.2.1 *The* Loudetia simplex *variant*. This is a grassland, mostly without trees and shrubs and it occurs on the steeper west-south-west facing slopes and is distinguished by the dominance of *Loudetia simplex* and the conspicuous absence of *Protea caffra, Alloteropsis semialata, Themeda triandra* and *Pentanisia angustifolia*.

The herbaceous layer is well developed and has an average height of 0,71 m and an average cover of 55,3% (Table 2).

1.1.2.2 *The* Protea caffra *variant*. In this variant, which occurs on more moderate slopes and at a higher altitude than the above-mentioned variant, is *Loudetia simplex*, less abundant but *Protea caffra* conspicuously present. The low-growing woody strata are more prominent, together covering 28,5% of the area (Table 2). The herbaceous layer is shorter than in the *Loudetia simplex* variant but with approximately the same cover (Table 2).

1.2 The *Protea caffra–Panicum natalense* community

This extensive community covers most of the relatively less rocky (20–50%), medium-steep (4–15%) to steep (15–30%) slopes of lower altitudes within the study area. The aspect, soil type and soil depth vary considerably, causing wide variation in the vegetation.

The community is characterized by species group J (Table 3) which includes the diagnostic species *Nidorella hottentotta, Hypoxis rigidula* var. *pilosissima, Eriosema cordata, Hyparrhenia hirta, Gnidia caffra, Lippia javanica, Polygala hottentotta, Pachycarpus schinzianus, Lantana rugosa, Dicoma zeyheri, Elephantorrhiza elephantina, Striga asiatica, Corchorus confusus, Drimiopsis burkei* and *Eragrostis curvula*.

The vegetation can generally be described as *Protea caffra*-dominated savanna. Shrubs of *Diospyros lycioides* subsp. *guerkei, Rhus dentata, Acacia caffra, Ozoroa paniculosa, Maytenus heterophylla* and *Cussonia paniculata* are often present.

Prominent grass species frequently found in this community include *Setaria flabellata, Rhynchelytrum repens, Themeda triandra, Brachiaria serrata* and *Bewsia biflora*.

Many forbs occur in this community. Some of the more prominent and constantly present species not mentioned above include *Aloe davyana, Ledebouria marginata, Pentanisia angustifolia, Anthericum fasciculatum, Urelytrum agropyroides, Helichrysum nudifolium, Senecio venosus, Gerbera ambigua, Athrixia elata, Vernonia natalensis, Tephrosia capensis, Tritonia nelsonii, Pellaea calomelanos, Bulbostylis burchellii, Protasparagus suaveolens, Tephrosia elongata* var. *elongata, Indigofera hedyantha*, and *Senecio affinis*.

The community is divided into two subcommunities.

1.2.1 *The* Protea caffra–Panicum natalense–Heteropogon contortus *subcommunity*.
This is predominantly a grassland (Table 2), typically found on moderately steep (4–15%), moderately rocky (20–40%) north-east facing slopes. The lithosols are 5–50 mm deep and are considered to be shallow to moderately deep.

This subcommunity is characterized by species group H (Table 3) and diagnostic species include *Heteropogon contortus, Cyperus obtusifolia, Aristida canescens, Sphenostylis angustifolia, Convolvulus sagitatus* and *Crabbea angustifolius*. The absence of *Protea caffra* and other woody species, and the prominence of the grasses *Heteropogon contortus, Themeda triandra* and *Panicum natalensis* and the forbs *Aloe davyana* and *Elephantorrhiza elephantina* are further conspicuous characteristics of this community.

1.2.2 *The* Protea caffra–Panicum natalensis–Acacia caffra *subcommunity*.
This covers a large area in the Garden, occuring largely on the lower, moderately rocky (20–50%), gradual to steep (8–25%) slopes. This subcommunity is characterized by species group I and the prominence of species group N (Table 3). Diagnostic species include *Elionurus muticus, Hypericum aethiopicum* subsp. *sonderi, Thesium transvaalensis, Rhus zeyheri, Rhynchosia totta, Eriosema cordata, Aristida diffusa, Kohautia amatymbica, Sonchus dregeanus, Ipomoea bathycolpos, I. crassipes, Vernonia oligocephala, Sida dregei, Pulicaria scabra, Scabiosa columbaria, Setaria nigrirostris, Ruellia patula* and *Tulbaghia acutiloba*.

Trees and shrubs are abundantly present. The tree stratum has an average height of 3,6 m and an average cover of 17,9%. The shrub stratum is equally well developed, with an average height of 1,5 m and with an average cover of 17,8% (Table 2). The prominence of *Acacia caffra, Ozoroa paniculosa, Rhus dentata, Maytenus heterophylla* and *Cussonia paniculata* in association with the dominant *Protea caffra* could also be considered to be diagnostic.

The herbaceous stratum is well developed (45,2% on average), but very short (Table 2).

2. The *Sporobolus Africanus–Senecio isatideus* major community

This wet grassland is restricted to a small area above the falls in the south-western corner of the Garden. It occurs along the stream on deep soils with a high clay content and very little surface rock. It is characterized by species group L (Table 3). Diagnostic species include *Senecio isatideus, Sporobolus africanus, Pelargonium luridum, Gerbera kraussii, Digitaria diagonalis* and *Berkeya setifera*.

Only two releves represent this community. Species present in both releves are *Anthericum fasciculatum, Alloteropsis semialata* subsp. *ecklonii, Acalypha angustata* var. *glabra, Hypericum aethiopicum, Rhynchosia totta, Scabiosa columbaria, Gerbera ambigua, Themeda triandra* and *Brachiaria serrata*. The scanty woody component is less than 2 m tall and consists of scattered individuals of *Leucosidea sericea* along the stream bank. The tree and shrub strata cover 5% and 2,5% respectively. The herbaceous layer is well developed with an average height of 0,55 m and an average cover of 47,5% (Table 2).

3. The *Canthium gilfillanii–Combretum molle* major community

This xeric savanna occurs on the lower steep (> 25%), hot and dry north to north-east facing slopes. The soils are very shallow, often less than 50 mm deep, and more than 50% of the soil surface is covered with rocks or rocky outcrops.

The community is characterized by species group O (Table 3), and diagnostic species include the dominant *Combretum molle* and other woody species such as *Rhus leptodictya* and *Cyphostemma lanigerum* and the herbs *Hermannia floribunda, Mariscus uitenhagensis* and *Eleusine africana*. The presence of species from species group T is also a conspicuous characteristic of this community. These species include the prominent trees *Canthium gilfillanii, Dombeya rotundifolia, Rhus pyroides* and *Pappea capensis*, the tall-growing conspicuous grass, *Setaria lindenbergiana* and the succulent *Kalanchoe rotundifolia*.

The tree stratum is well developed, with an average height of 6,3 m and an average cover of 33,2%. The shrub stratum covers 23,6% of the area (Table 2). Woody plants not mentioned above include *Bequaertiodendron magalismontanum, Nuxia congesta, Acacia caffra, Ozoroa paniculosa, Rhus dentata, Diospyros lycioides* subsp. *guerkei, Celtis africana, Acokanthera oppositifolia* and *Grewia occidentalis*.

The herbaceous layer covers only 28,2%. Prominent or conspicuous herbaceous plants include the grass *Rhynchelytrum repens*, the succulent *Aloe davyana* and the xerophytic ferns *Pellaea calomelanos, Cheilanthes hirta* and *C. involuta*.

4. The *Combretum erythrophyllum–Celtis africana* major community

This dense woodland vegetation is limited to the deep soils of the flat valley floor, adjacent moist foot slopes or the river banks.

The community is characterized by species group P (Table 3). Diagnostic species include *Celtis africana, Combretum erythrophyllum, Acokanthera oppositifolia, Diospyros whyteana, Kiggelaria africana, Cyperus albostriatus* and *Cheilanthes viridis*.

Other species often present are *Acacia caffra, Rhus pyroides, R. dentata, Cussonia paniculata, Diospyros lycioides* subsp. *guerkei* and *Setaria lindenbergiana*.

Within the *Combretum erythrophyllum–Celtis africana* major community two communities and a facies are distinguished.

4.1 The *Combretum erythrophyllum–Celtis africana–Pupalia lappacea* community

This community represents the woodland on the footslopes and the flat valley floor. The soils are deeper than 500 mm and mostly represent the Hutton or the Shortlands soil forms. Rocks cover less than 20% of the soil surface.

Floristically the community is characterized by species group Q (Table 3), and diagnostic species include the woody *Ziziphus mucronata, Zanthoxylum capense, Ehretia rigida, Maytenus undata*, and *M. polyacantha* and the herbs *Pupalia lappacea, Littonia modesta* and *Abutilon sonneratianum*.

The strongly developed tree stratum is 13,7 m tall with an average cover of 45,8%. The shrub stratum is 1,5 m tall, covering 15,0% of the area. The herbaceous layer covers 24,2% (Table 2).

4.2 The *Combretum erythrophyllum–Celtis africana–Setaria megaphylla* community

This is restricted to the Dundee and Oakleaf soil forms along the moist stream banks. These soils are > 1 000 mm deep with the only rocks being a few large quartzite boulders in the stream.

Species group R (Table 3) characterizes this forest-like community and diagnostic species include *Setaria megaphylla, Buddleja salviifolia, Rhamnus prinoides, Leucosidea sericea, Solanum pseudo-capsicum, Ilex mitis*, and *Halleria lucida*.

The tree stratum is 15,0 m tall and covers 39,2% of the area. The shrub and herbaceous layers are poorly developed (Table 2).

4.2.1 *The* Acacia mearnsii *facies*

In some places, especially above the falls, the *Acacia mearnsii* facies occurs. Here the tall-growing (18 m) invasive exotic *Acacia mearnsii* established, became dominant, and replaced most of the indigenous vegetation. Only scattered individuals of the natural species, e.g. *Leucosidea sericea, Celtis africana, Buddleja salviifolia, Halleria lucida* and a few herbaceous species still occur in these localities. A reclamation programme is in progress at present.

Conclusion

The classification obtained by TWINSPAN, refined by Braun–Blanquet procedures resulted in vegetation units that are related to the environmental factors observed, and should therefore be considered a reliable representation of the vegetation of the Garden. The classification and accompanying vegetation map should serve as a valuable basis for the planning of future development and the conservation and management of the natural vegetation in the Garden. A special attempt should be made to ensure the preservation of the extraordinarily rich indigenous flora (Behr & Bredenkamp 1988) as well as the different plant communities which occur within the Garden.

Although a hierarchical classification was derived, no attempt was made to assign ranks to the identified syntaxa, and names of syntaxa were not fixed. This classification should however contribute to a synthesis of Bankenveld vegetation.

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