The physical environment and major plant communities of the Heilbron–Lindley–Warden–Villiers area, northern Orange Free State

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Received 28 December 1992; revised 10 March 1993

An analysis of the physical environment and associated major plant communities of the Heilbron–Lindley–Warden–Villiers area (northern Orange Free State) is presented. Relevés were compiled in 263 stratified random sample plots. Care was taken to avoid severely degraded areas. A TWINSPAN classification, refined by Braun-Blanquet procedures, revealed three distinct vegetation types. These vegetation types were subdivided into seven major plant communities. A hierarchical classification, description and ecological interpretation of the seven major plant communities are presented. The easily distinguishable major plant communities should be managed as separate ecological units in order to achieve optimal utilization and conservation of the vegetation of this part of the Grassland Biome.

'n Analise van die fisiese omgewing en geassosieerde hoofplantgemeenskappe van die Heilbron–Lindley–Warden–Villiers gebied (noordelike Oranje-Vrystaat) word aangebied. Relevés is in 263 gestratifiseerde, ewekansig gekose monsterpersele saamgestel. Daar is deurgaans gepoog om erg versteurde gebiede te vermy. 'n TWINSPAN-klassifikasie, verfyn deur Braun-Blanquet-prosedures, toon drie duidelik onderskeibare plantegroeitipes. Hierdie plantegroeitipes is onderverdeel in sewe hoofplantgemeenskappe. 'n Hiërargiese klassifikasie, beskrywing en ekologiese interpretasie van hierdie sewe hoofplantgemeenskappe word gegee. Die maklik uitkenbare hoofplantgemeenskappe moet bestuur word as afsonderlike ekologiese eenhede om optimale benutting en bewaring van die plantegroei van hierdie deel van die Grasveldbioom te verseker.

Keywords: Braun-Blanquet classification, ecological units, Grassland Biome, southern Africa, synecology.

Introduction

The world-wide retrogression of natural resources can primarily be ascribed to a 'cleverer-than-nature' approach towards land-use and resource management (Jackson & Piper 1989). To manage natural resources in step with nature, it is essential to conduct both extensive and intensive baseline environmental surveys in all areas. Vegetation classification and mapping are prerequisites for ecologically and economically sound land-use planning, resource management, optimal and sustainable resource utilization and conservation (Edwards 1972). Grazing areas in particular need to be subdivided into ecologically homogeneous grazing units to ensure optimal and sustainable utilization of forage resources (Tainton 1984; Danckwerts & Teague 1989). Identification of ecologically sensitive areas, rare and endangered plant communities and species, protection of biodiversity and evaluations of the conservation status of an area all depend on baseline vegetation and habitat surveys.

In order to provide a main classificatory reference framework of plant communities and their associated habitats within the western Grassland Biome, a detailed vegetation classification and mapping of the area has been undertaken (see also Kooij 1990; Eckhardt *et al.* 1993; Fuls *et al.* 1992). This study forms an integral part of the long-term goal to compile a detailed syntaxonomic synthesis of the Grassland Biome of southern Africa (Scheepers 1986).

Study area

The study area lies within the climatic climax Grassland Biome of southern Africa (Mentis & Huntley 1982) and is situated between 27°45′ and 29°E longitude and 27° and 28°S latitude (Figure 1), covering approximately one million hectares. Larger towns situated in, or bordering on, the study area are Heilbron, Lindley, Reitz, Warden, Frankfort and Villiers. The study area forms part of the Highveld inland plateau and consists predominantly of smoothly planed or gently rolling land surfaces of the miocene age (Mentis & Huntley 1982). The area is situated between 1500 and 1800 m above sea-level. Acocks (1988) recognized two veld types within the study area, *Themeda* Veld to *Cymbopogon – Themeda* Veld transition (Veld Type 53) in the north and *Cymbopogon – Themeda* Veld (Veld Type 48) in the south.

Physical environment

Climate

Rainfall is erratic, consisting mainly of thunder-showers which are restricted to the warm summer months. The winter months are arid and cold with frost occurring both frequently and extensively (Weather Bureau 1986). Generally speaking, the long-term average annual rainfall within the study area varies between 600 and 700 mm per year. There is a discernible increase in rainfall from the north-west/north to the south-east/south. This is illustrated by the average annual rainfall recorded (1984 – 1991) for the following localities within the study area (Figure 1) (Weather Bureau 1992a): Villiers 607 mm, Frankfort 636 mm, Reitz 653 mm, Lindley 703 mm and Warden 708 mm. In addition, the southern and south-eastern parts are slightly cooler. The average annual temperature (1988 – 1991) recorded for Frankfort is 15.3°C and for Warden 14.3°C (Weather Bureau 1992b).

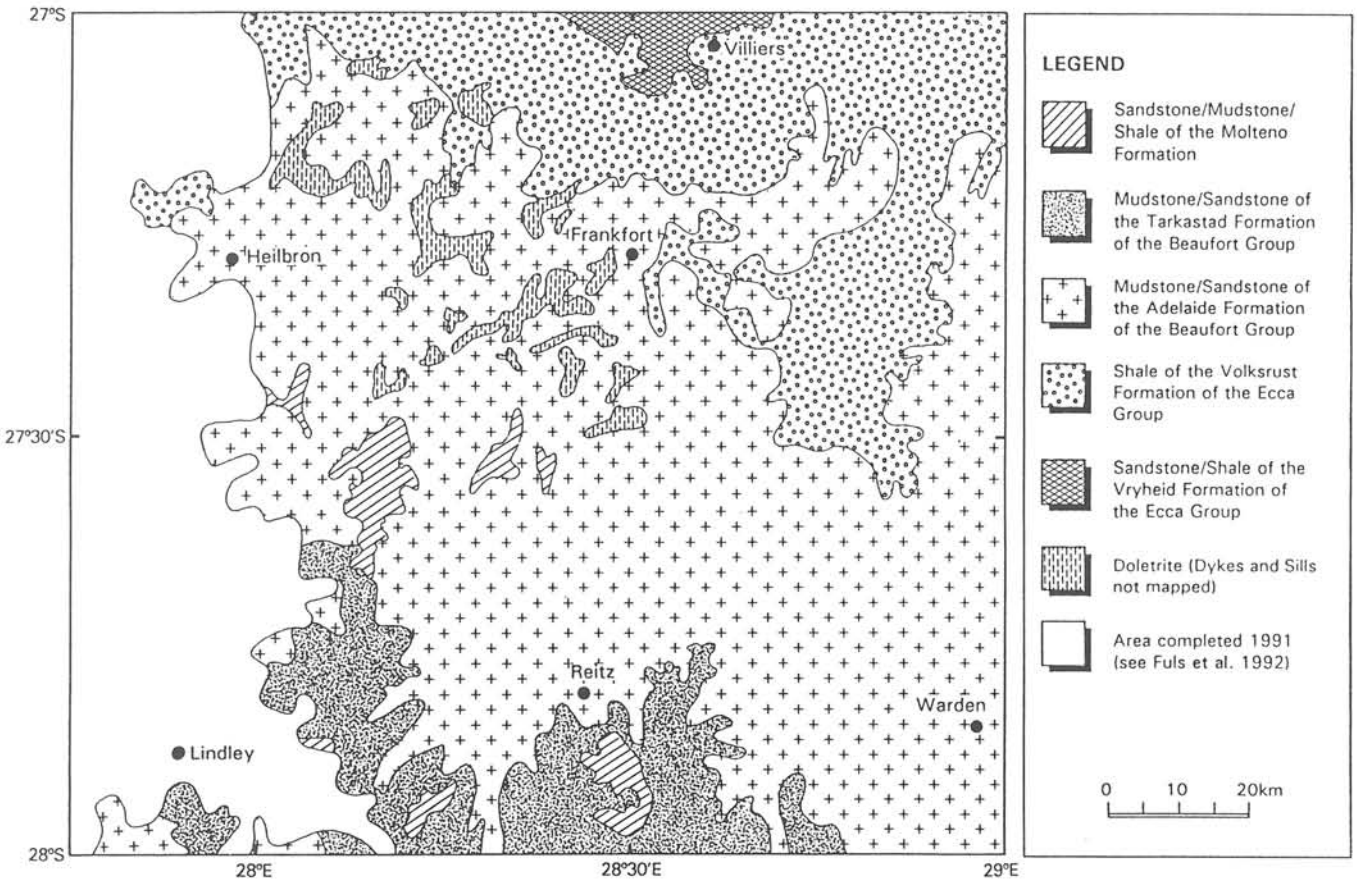

Figure 1 Geology of the study area [adapted from Department of Mineral and Energy Affairs data (1984)].

Geology

The study area lies within the main Karoo Basin (SACS 1980). The area is primarily underlain by the Ecca and Beaufort groups of the Karoo Sequence (Figure 1). The Ecca Group consists essentially of shale with sandstone featuring permanently only at the margin of the basin (SACS 1980). The Beaufort Group consists primarily of mudstone with cross-bedded sandstone occurring frequently. Argillaceous rocks are generally laminated and platy-weathering in the Ecca Group and blocky-weathering in the Beaufort Group (SACS 1980). Between Heilbron and Frankfort massive dolerite intrusions are found (Figure 1). Hills and ridges in the study area are predominantly associated with dolerite dykes and sills which occur throughout the area.

Land types

Land types are distinguished from each other in terms of one, or a combination, of the following parameters: terrain morphology, soil pattern/types and climate (Land Type Survey Staff 1984). Five different land types are encountered in the study area (Figure 2).

It was found that the vegetation of the study area is not discernibly related to land types *per se*, therefore the land types will not be discussed individually. The phytosociology of the vegetation of the study area is primarily influenced by soil moisture variations on a macro- and micro-scale, utilization by herbivores and terrain morphology.

Terrain morphology and soils

According to terrain morphology variations, the study area can be divided into a northern part and southern part. In the northern areas the terrain is mostly mildly undulating to flat with a few distinct hills and ridges. Schematic illustrations of the generalized terrain morphology encountered in the northern areas are presented in Figures 3A and 3B. The southern areas often have a more distinct undulating terrain morphology, frequented by low to medium-high hills and ridges. The generalized terrain morphology of the southern areas is summarized in Figures 4A and 4B.

Soil type apparently has a lesser influence on the vegetation distribution than soil depth, soil moisture and rockiness. Plant communities could not be related exclusively to specific soil forms. The soil forms which were encountered in the different terrain units are given in Figures 3 and 4. The dominant soil forms recorded were Glenrosa, Mayo, Avalon, Bonheim, Tukulu, Sepane and Rensburg (Department of Agricultural Development 1991).

Drainage

The entire study area lies within the catchment area of the Vaal Dam (Figure 5). The drainage, water availability and water utilization within this area is therefore of great importance to the densely populated Pretoria–Witwatersrand–Vereniging area, which relies heavily on the water resources of the Vaal Dam. Major rivers associated with the study area include the Vaal River, Wilge River, Klip River, Liebenbergsvlei River and Cornelis River (Figure 5). Most rivers and streams within the study area end up as tributaries to the Wilge River which, together with the Vaal River, contributes most of the water to the Vaal Dam water resources.

The overall drainage of the study area is variable with the

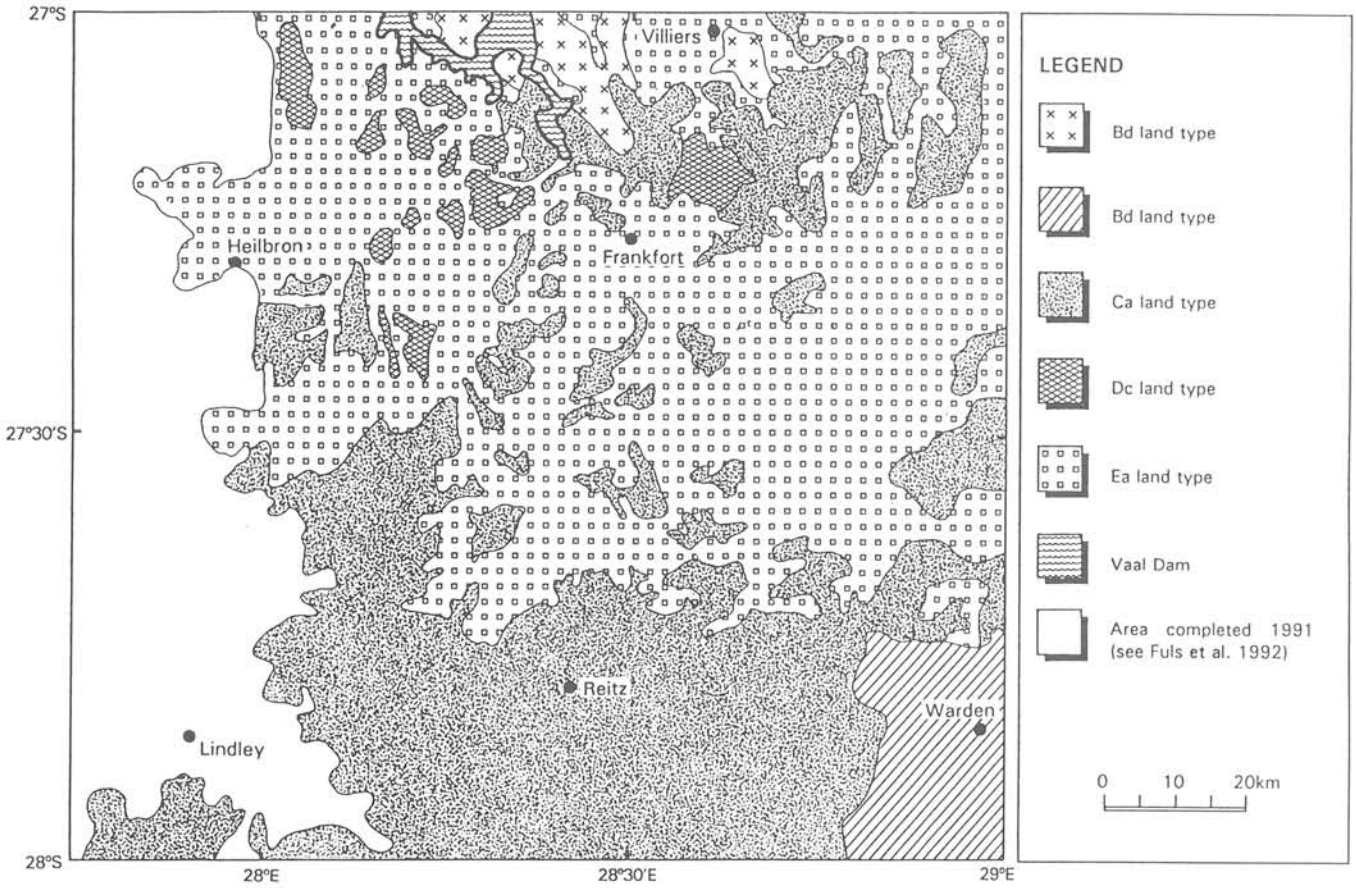

Figure 2 Land types of the study area [adapted from Department of Agriculture (1979)].

major portion thereof reasonably to well drained. Incision of smaller streams is mostly shallow owing to the flat to undulating terrain. For the same reason streamflow tends to be rather slow. Only a few pans, which are mainly restricted to the southern and south-western parts, are found in the study area. Permanently waterlogged soils and vleis are uncommon and seasonally standing water is restricted to slow-draining watercourses.

Methods

Relevés were compiled in 263 stratified random sample plots. However, care was taken to avoid sampling of severely degraded vegetation and excessively disturbed areas. Stratification was based on land type and terrain morphology (terrain unit, aspect, slope). Plot sizes were fixed at approximately 100 m^2 (Scheepers 1975). In each sample plot all species were recorded and their respective canopy cover assessed according to the Braun-Blanquet cover-abundance scale (Mueller-Dombois & Ellenberg 1974). Taxon names and taxon author names conform to those of Gibbs Russell *et al.* (1985, 1987). Environmental data recorded include geology, terrain morphology and terrain unit, soil type and depth, soil texture, aspect, slope, rockiness of the soil surface, drainage, erosion, soil crusting, overall condition of the vegetation and utilization by herbivores.

Two-way indicator species analysis (TWINSPAN) (Hill 1979) was applied to the floristic data set in order to derive a first approximation of the major plant communities of the area. Refinement of this classification was done by the application of Braun-Blanquet procedures (see also Bredenkamp *et al.* 1989; Kooij *et al.* 1990). A synoptic table was compiled for the major plant communities from the final phytosociological table (Table 1) (see also Bredenkamp 1987). In this table the entries represent the constancy of the species as follows: 5, 81 – 100% presence; 4, 61 – 80% presence; 3, 41 – 60% presence; 2, 21 – 40% presence; and 1, 1 – 20% presence. Species with a constancy of 20% and less in all the respective plant communities have been omitted from the table.

Structural classifications and nomenclature are in accordance with Edwards (1983).

Results and Discussion

The hierarchical classification and associated environmental characteristics of the seven major plant communities are presented in Figure 6.

The only species with a high constancy (>2) in all plant communities is *Eragrostis curvula* (species group R, Table 1). However, this species seldom has a dominant canopy cover. The most dominant species in the study area are the medium-sized to large, tufted perennial grass species *Themeda triandra* and *Cymbopogon plurinodis* (species group N, Table 1). *Themeda triandra*, in particular, often comprises more than 60% of the total canopy cover. Other tufted, perennial graminoids with a high constancy, which may become dominant under specific environmental conditions, are *Elionurus muticus, Setaria sphacelata, Heteropogon contortus, Aristida junciformis, Setaria nigrirostris* (species group M, Table 1), and *Andropogon appendiculatus*

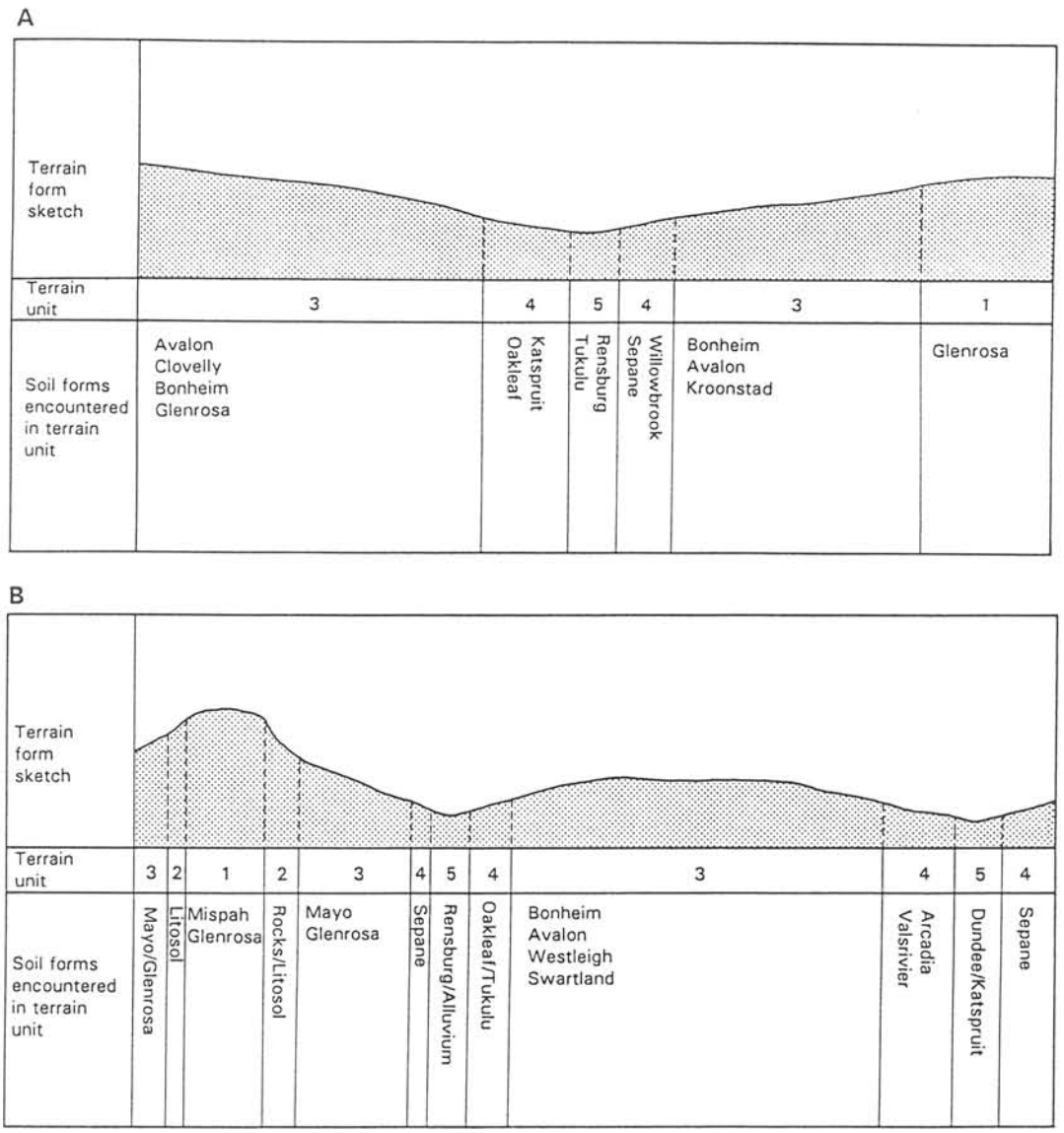

Figure 3 General terrain forms and soils encountered in the northern part of the study area.

(species group T, Table 1). If combined, the dominant graminoids often comprise more than 90% of the total canopy cover. Subsequently, the grassland communities are not species-rich. This is in line with the recorded species richness of adjacent grasslands (Eckhardt *et al.* 1993; Fuls *et al.* 1992), but contrary to that of the moist grasslands of the high-altitude escarpment areas of the north-eastern Transvaal (Matthews 1991).

Trees and shrubs are absent from the flat and undulating grassland areas, being restricted to rocky outcrops. This can be ascribed to the protection of the woody seedlings from frost and fire by the rocks. Furthermore, the taproot systems of woody vegetation are advantaged by the rainfall run-off from rocks and deeper rainfall infiltration owing to the volume occupied by the rocks in the soil profile. Conspicuous but often stunted trees encountered frequently on rocky outcrops are *Heteromorpha trifoliata, Kiggelaria africana* and *Maytenus heterophylla* (species group C, Table 1). The trees appear shrublike, seldom exceeding 3 m in height. Trees and shrubs seldom comprise more than 50% of the total canopy cover of the thicket communities, occurring mainly in small to large patches on the rocky slopes. Shrubs which are often associated with the rocky outcrops are *Diospyros lycioides* (species group B), *Protasparagus setaceus, P. laricinus* (species group C) and *Diospyros austro-africana* (species group F) (Table 1).

Salix babylonica, a naturalized, medium-sized, hygrophilous tree species, can often be found on streambanks (species group O). The smaller, indigenous tree species *Salix fragilis* is occasionally associated with watercourses (species group O, Table 1). Hydrophilic graminoids with a high constancy, sometimes becoming dominant, include *Eragrostis plana* (species group S), *Paspalum dilatatum, Pennisetum sphacelatum* (species group R), *Agrostis lachnantha* and *Hemarthria altissima* (species group Q) (Table 1).

Conspicuous sedges, reeds and herbs associated with streams and stream-beds include, respectively, *Mariscus congestus* (species group Q), *Cyperus fastigiatus, Phragmites australis, Typha capensis, Pulicaria scabra* (species group O) and *Aster squamatus* (species group Q) (Table 1).

Three vegetation types, containing seven major plant communities, were distinguished within the study area:

1. *Mohria caffrorum – Heteromorpha trifoliata* Low Thicket of the rocky outcrops;

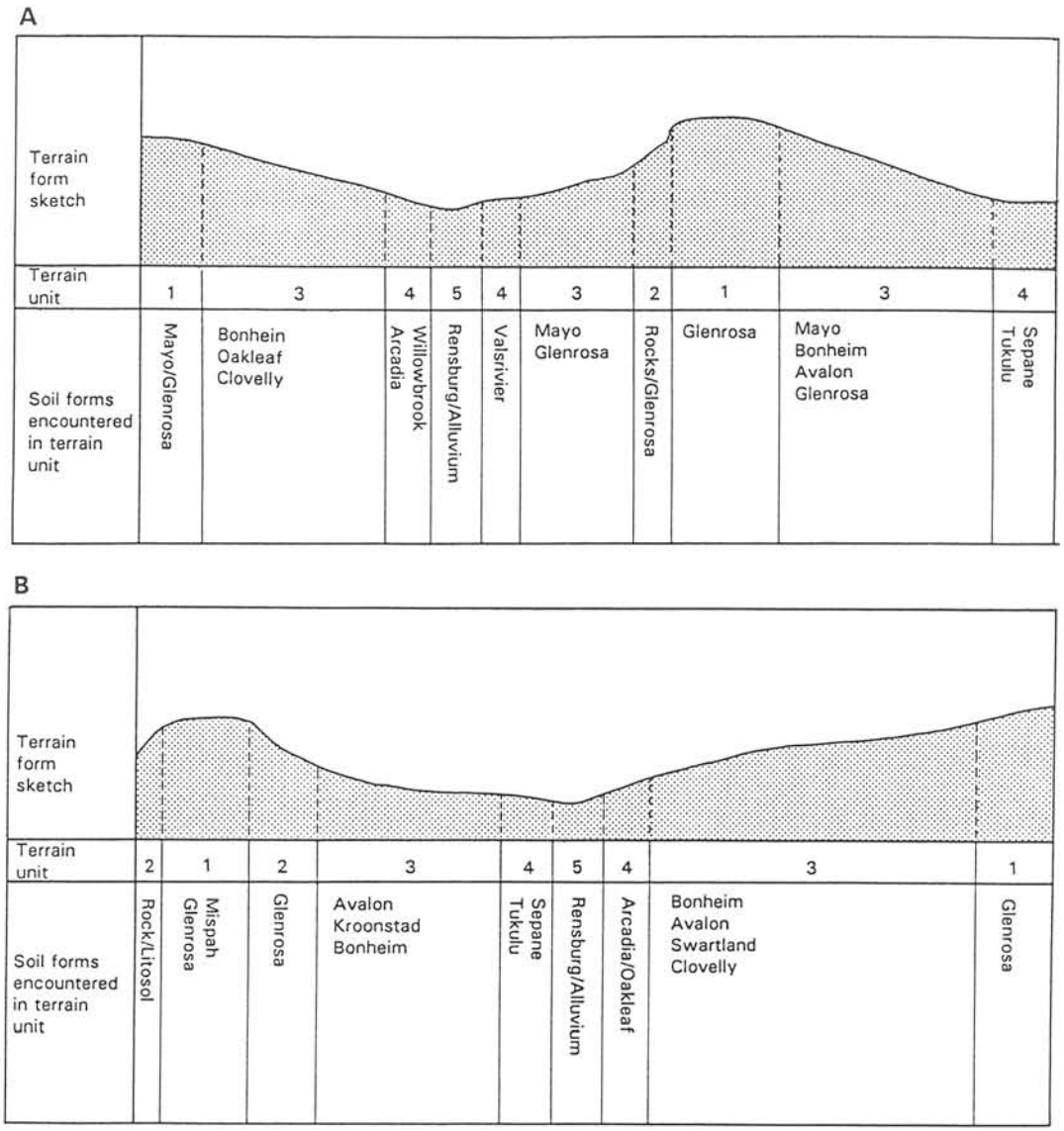

Figure 4 General terrain forms and soils encountered in the southern part of the study area.

2. *Eragrostis curvula – Themeda triandra* Grassland of the rocky outcrops and undulating plains;
3. *Mariscus congestus – Agrostis lachnantha* Wetland of the watercourses, stream-banks, vleis and pans.

The floristics and characteristic environmental attributes of each vegetation type, and its associated major plant communities, are discussed separately.

1. *Mohria caffrorum – Heteromorpha trifoliata* Low Thicket

This vegetation type is restricted to the dolerite, sandstone and mudstone rocky outcrops, covering less than 5% of the total study area. The vegetation type is generally associated with slopes in excess of 30° and shallow, litholitic soils with a high percentage of surface rock. Although the exposed rocks are predominantly doleritic, sandstone, shale, mudstone or any combinations thereof may sometimes be present. Ridges consisting exclusively of sandstone, with large sandstone boulders, were also encountered.

Signs of severe forage utilization by rock dassies (*Procavia capensis*) were obvious on many rocky slopes. The excessively large rock dassie population, due to the absence of raptors and predators in the area, is a definite threat to the conservation of the already sensitive vegetation of the rocky outcrops. Preferential livestock utilization (in some areas extremely severe utilization) of the drier northerly facing slopes was also evident where these areas were not managed separately from other grazing areas. The obvious detrimental result thereof on the vegetation threatens the survival of plant communities as well as the forage resources of this vegetation type. Owing to their present overall poor condition, restricted distribution and general species richness, all low thicket plant communities should be rendered a high conservation status.

Individual tree and shrub species were not found to be dominant in low thicket communities. In combination, trees and shrubs may become dominant, but usually graminoids remain the dominant species in the thicket communities. Shrubs seldom exceed more than 2 m in height, with the trees often being only marginally taller.

Although the distribution pattern of the woody species along the slopes may vary considerably, the trees and shrubs often occur in patch-like pockets, or bush-clumps, on the slopes. It would appear as if the establishment of one woody species creates a favourable niche for another woody species to follow suit. Certain shrub species, such as *Protasparagus*

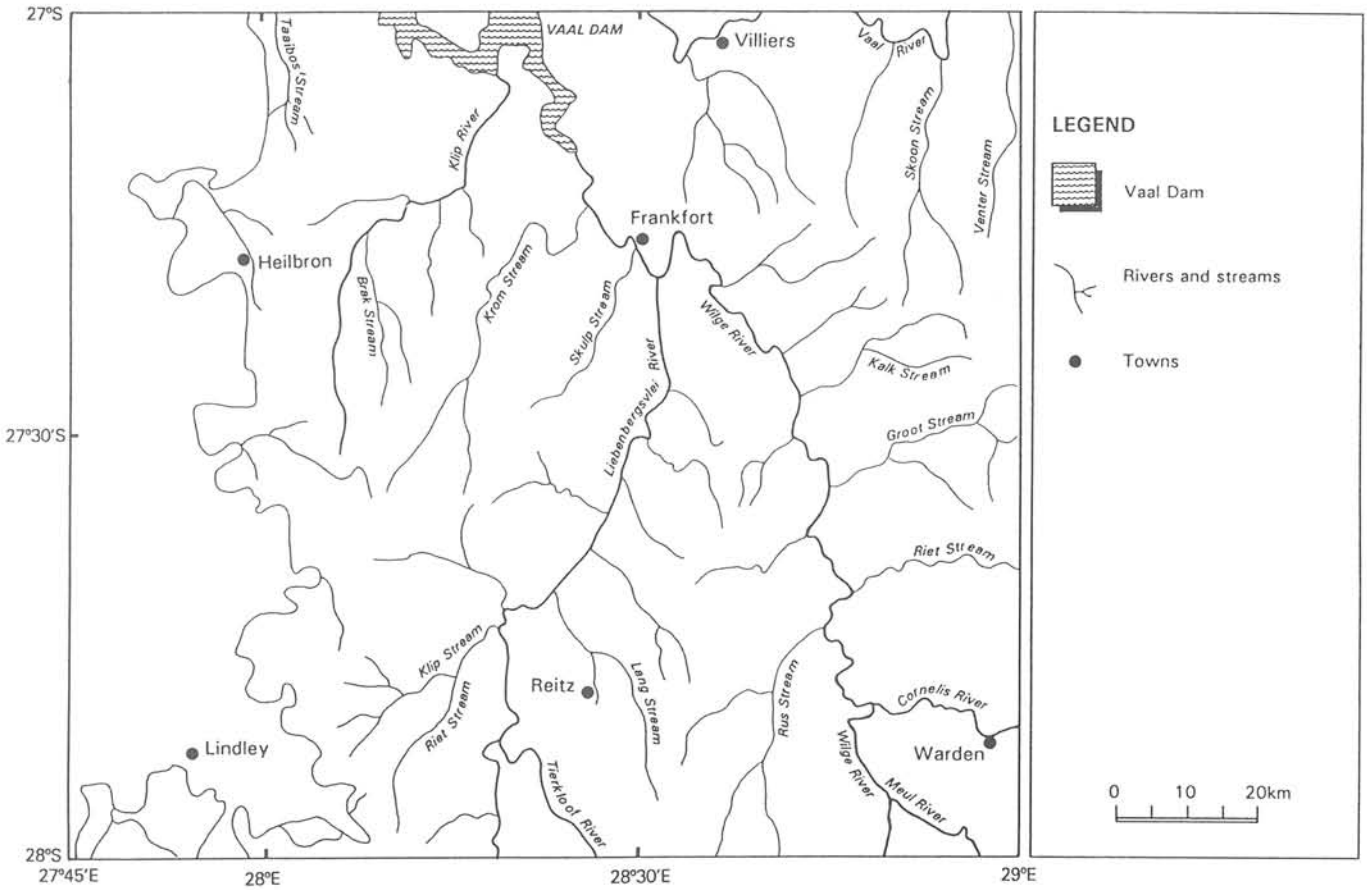

Figure 5 The main rivers and streams of the study area [adapted from Department of Agriculture (1979)].

laricinus and *P. setaceus* (species group C, Table 1) are mostly associated with larger trees and shrubs.

Diagnostic tree species (often appearing more shrub-like) of the low thicket vegetation include *Kiggelaria africana, Rhus pyroides* and *Euclea crispa* (species group C, Table 1). The small shrubs *Diospyros austro-africana* (species group F) and *Rhus discolor* (species group C) are often associated with low-thicket vegetation (Table 1).

Most graminoids with a high constancy and/or canopy cover in low thicket communities, such as *Eragrostis curvula* (species group T), *Cymbopogon plurinodis* (species group N), *Elionurus muticus* (species group M), *Harpochloa falx* (species group G) and *Koeleria capensis* (species group F), are not exclusive to these communities (Table 1).

Forbs often found on the rocky outcrops are *Salvia repens, Physalis viscosa, Commelina africana, Leonotis dysophylla, Senecio hastatus* and *Archyranthes aspera* (species group C, Table 1). *Mohria caffrorum* and *Cheilanthes eckloniana* are mesic ferns which are often associated with rock-crevices and sheltered micro-habitats on the steep rocky slopes (species group C, Table 1).

The low thicket vegetation can be subdivided into two major plant communities: 1.1, *Artemisia afra – Kiggelaria africana* Low Thicket; and 1.2, *Hyparrhenia hirta – Diospyros lycioides* Low Thicket.

1.1 *Artemisia afra – Kiggelaria africana* Low Thicket

This plant community is associated with the cool, moist, southerly facing, steep, rocky slopes. The aspect may vary from west-south-west to south to east-south-east. The diagnostic species of this plant community are adapted to colonize the specific niches created by the reduced sun insolation on southern slopes.

The only diagnostic tree species of this plant community is *Leucosidea sericea* (species group A, Table 1). However, this species was found to be exclusive to steep slopes along the banks of the Wilge River. *Kiggelaria africana* has a noteworthy higher constancy in this plant community than in other plant communities (species group C, Table 1). Diagnostic shrubs encountered in this plant community are *Artemisia afra, Rhus dentata, Clutia affinis* and *Rubus ludwigii* (species group A, Table 1). *Ehrharta erecta*, a diagnostic, loosely tufted or rambling, perennial graminoid, increases in shady and moist areas which are disturbed. This species was characteristically found underneath trees and shrubs, or areas shaded by rocks, wherever rock dassies overutilize the herbaceous vegetation. Other graminoids frequently associated with southerly facing slopes are *Harpochloa falx, Tristachya leucothrix* (species group G), *Koeleria capensis* (species group F) and the hydrophilic *Andropogon appendiculatus* and *Helictotrichon turgidulum* (species group T) (Table 1).

Diagnostic forbs which are often associated with rock fissures in shaded areas, are *Crassula lanceolata* and *Haemanthus humilis*. Other diagnostic forbs of this plant community include *Myrsiphyllum asparagoides, Cineraria alchemilloides, Helichrysum cephaloideum* and *Galium thunbergianum* (species group A, Table 1). The ferns *Asplenium aethiopicum* and *Cheilanthes viridis* are often encountered in moist, shaded patches on the steep, southerly facing slopes (species group A, Table 1).

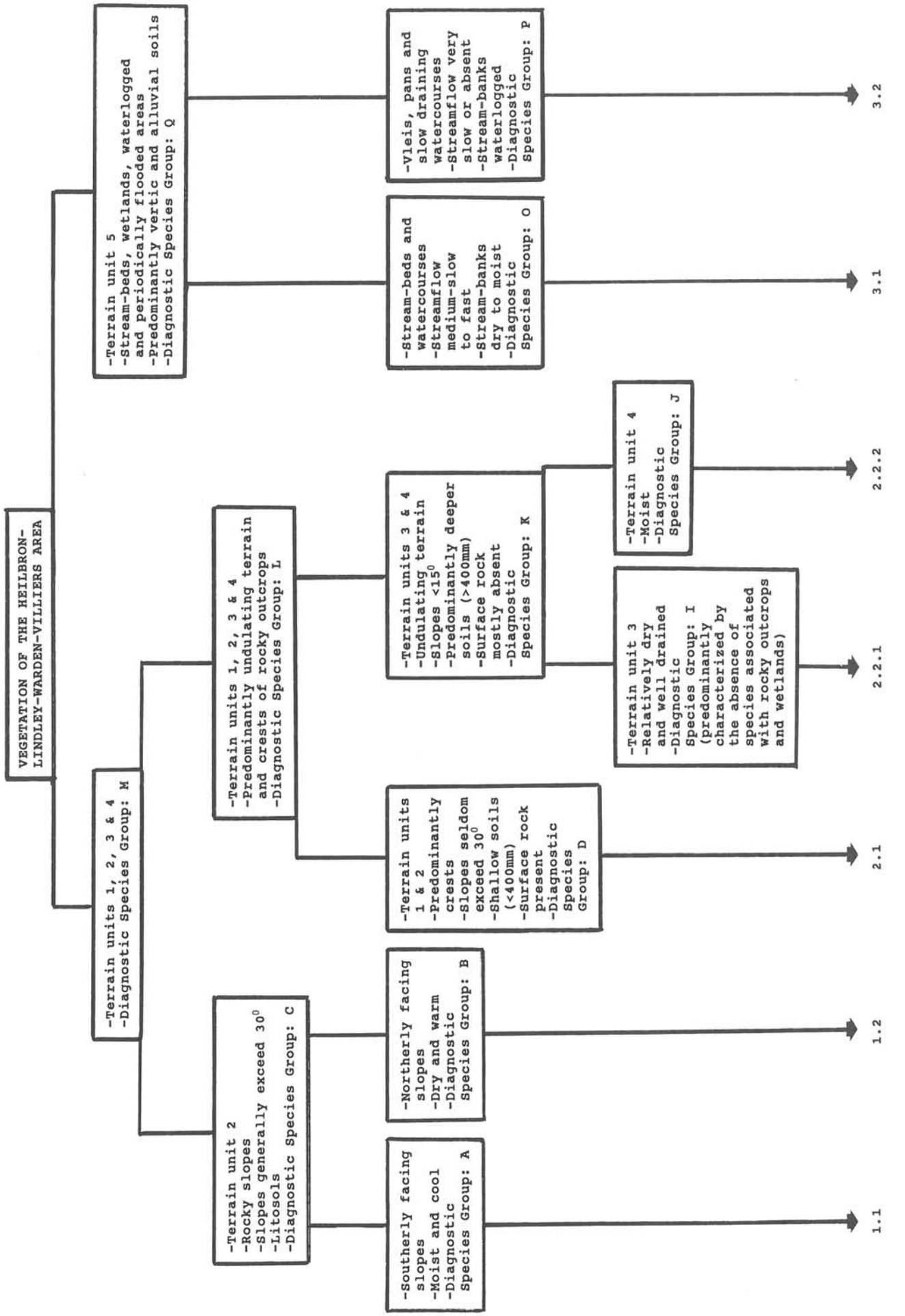

Figure 6 The hierarchical classification and habitat interpretation of the seven major plant communities of the study area. Community numbers correspond to plant community descriptions in text.

Table 1 Synoptic table of the major plant communities of the Heilbron–Lindley–Warden–Villiers area

Vegetation type:	1		2			3	
Community number:	1.1	1.2	2.1	2.2		3.1	3.2
				2.2.1	2.2.2		
Species Group A (Diagnostic species of the *Artemisia afra – Kiggelaria africana* Low Thicket)							
Artemisia afra	5	2				1	
Crassula lanceolata	5	2	1				
Ehrharta erecta	4	2					
Rhus dentata	3	1	1				
Clutia affinis	3	1				1	
Leucosidea sericea	2						
Myrsiphyllum asparagoides	2	1	1				
Cineraria alchemilloides	2	1					
Asplenium aethiopicum	2	1	1				
Cheilanthes virides	2	1					
Rubus ludwigii	2	1					
Pelargonium ranunculophyllum	2	1					
Helichrysum cephaloidium	2		1	1		1	
Vernonia natalensis	2	1	1	1			
Haemanthus humilis	2	1	1				
Galium thunbergianum	2	1					
Oxalis obliquitera	2	1	1				
Arundinella nepalensis	2				1		
Species Group B (Diagnostic species of the *Hyparrhenia hirta – Diospyros lycioides* Low Thicket)							
Hyparrhenia hirta	1	5	2	1		2	
Diospyros lycioides	2	4	1				
Lantana rugosa	1	4	1				
Melinis nerviglumis	2	4	1				
Aristida congesta	1	3	1	1	1		
Celtis africana	1	3					
Grewia occidentalis		3	1				
Pollichia campestris	1	3	1	1	1		
Bidens bipinnata	1	3	1		1	1	
Pellaea calomelanos	1	2					
Pavonia burchellii		2					
Hemizygia pretoriae	1	2					
Opuntia ficus-indica		2					
Species Group C (Species occurring generally in the Low Thicket communities of the rocky outcrops)							
Mohria caffrorum	5	4	1				
Heteromorpha trifoliata	3	3					
Kiggelaria africana	3	2					
Salvia repens	3	2	1				
Maytenus heterophylla	2	3					
Protasparagus setaceus	2	3	1			1	
Protasparagus laricinus	2	3	1			1	
Physalis viscosa	2	3	1				
Commelina africana	2	3	1	1	1	1	
Rhus pyroides	2	2	1			1	
Euclea crispa	2	2					
Rhus discolor	2	2	1	1			
Clematis brachiata	2	2					
Cheilanthes eckloniana	2	2					
Leonotis dysophylla	2	2	1				
Senecio hastatus	2	2	1			1	
Achyranthes aspera	2	2				1	1

Table 1 Continued

Vegetation type:	1		2			3	
Community number:	1.1	1.2	2.1	2.2		3.1	3.2
				2.2.1	2.2.2		
Species Group D (Diagnostic species of the *Digitaria tricholaenoides – Aristida diffusa* Grassland)							
Pachycarpus schinzianus	1	1	4	1			
Digitaria tricholaenoides	1	1	3	1			
Dicoma anomala		1	3	1			
Cymbopogon excavatus	1	1	2	1	1	1	
Ziziphus zeyheriana		1	2	1			
Diheteropogon amplectens	1		2				
Microchloa caffra	1	1	2	1	1		
Acalypha angustata	1	1	2	1	1	1	
Ajuga ophrydis	1	1	2	1	1		
Cyanotis speciosa		1	2	1			
Hibiscus aethiopicus	1	1	2	1	1		
Cephalaria zeyheriana		1	2	1	1	1	
Indigofera hedyantha		1	2	1			
Polygala hottentottica	1	1	2	1	1		
Tephrosia capensis	1	1	2	1	1	1	
Rhynchosia totta	1	1	2	1			
Filicia muricata		1	2	1	1	1	
Rhynchosia adenodes	1	1	2	1	1	1	
Species Group E							
Aristida diffusa	1	3	4	1			
Vernonia oligocephala	1	2	3	1			
Aristida canescens	1	2	2				
Rhus rigida	1	2	2				
Argyrolobium pauciflorum		2	2	1			
Solanum panduriforme		2	2	1			
Turbina oblongata	1	2	2	1	1	1	
Species Group F (Species occurring generally on rocky outcrops)							
Diospyros austro-africana	4	3	2	1			
Koeleria capensis	4	2	2	1	1		
Trachypogon spicatus	2	2	3	1			
Dianthus mooiensis	2	1	2				
Helichrysum nudifolium	2	1	2	1	1		
Species Group G (Species occurring generally on rocky outcrops and higher lying Grassland)							
Harpochloa falx	5	2	4	2	1	1	
Brachiaria serrata	2	3	5	3	1		
Tristachya leucothrix	3	1	4	3	1		
Species Group H							
Scabiosa columbaria		1	3	2	1		
Hypoxis rigidula	1	1	3	2	1	1	1
Species Group I							
Asclepias eminens			1	2	1		
Ahthericum fasciculatum		1	1	2			
Stoebe vulgaris	1		1	2	1		
Species Group J (Diagnostic species of the *Andropogon appendiculatus – Eragrostis plana* Grassland of the lower lying areas)							
Panicum stapfianum			1	1	3	1	2
Digitaria eriantha	1	1	1	1	2	1	1

Table 1 Continued

Vegetation type:	1		2			3	
Community number:	1.1	1.2	2.1	2.2		3.1	3.2
				2.2.1	2.2.2		
Senecio erubescens			1	1	2		1
Falkia oblongia				1	2	1	1
Scirpus burkei				1	2		
Oenothera stricta	1	1	1	1	2	1	
Sutera aurantiaca		1	1	1	2	1	
Arctotis arctotoides	1	1	1	1	2	1	
Geigeria aspera		1	1	1	2	1	
Salvia runcinata	1	1	1	1	2	1	
Euphorbia striata	1		1	1	2	1	
Sonchus dregeanus	1	1	1	1	2		
Hermannia oblongifolia	1	1		1	2	1	
Species Group K							
Berkheya pinnatifida		1	1	2	3		1
Walafrida densiflora		1	1	2	3	1	
Species Group L (Species occurring generally in Grassland communities)							
Helichrysum rugulosum	1	1	3	4	3		
Anthospermum hispidulum	1	1	3	3	2	1	
Eragrostis racemosa	1	1	3	3	2		
Eragrostis capensis	1	1	3	3	2		
Crabbea acaulis	1	1	2	3	2		
Species Group M (Species occurring generally in Low Thicket and Grassland communities)							
Elionurus muticus	4	3	4	5	2		
Setaria sphacelata	3	4	3	4	4	1	1
Heteropogon contortus	1	4	5	3	2		
Aristida junciformis	3	3	4	2	2		
Setaria nigrirostris	2	3	3	2	2	1	
Hermannia depressa	1	2	3	3	1		
Species Group N							
Themeda triandra	3	3	5	5	5	2	1
Cymbopogon plurinodis	4	4	5	5	3	2	1
Conyza podocephala	1	2	2	1	2	2	
Species Group O (Diagnostic species of the *Cyperus longus* – *Cyperus fastigiatus* Wetland)							
Oenothera rosea	2	1		1	1	5	1
Cyperus fastigiatus						4	2
Cyperus longus					1	4	1
Juncus exsertus						4	2
Ciclospermum leptophyllum			1		1	4	1
Pulicaria scabra						4	1
Gallium capense	1	1		1	1	4	1
Conyza bonariensis				1	1	4	2
Phragmites australis						3	
Salix babylonica						3	1
Cyperus marginatus						3	1
Veronica anagallis-aquatica					1	3	1
Mentha longifolia					1	3	
Salix fragilis						2	
Typha capensis						2	
Imperata cylindrica	1				1	2	
Crinum bulbispermum						2	
Rumex crispus					1	2	

Table 1 Continued

Vegetation type:	1		2			3	
Community number:	1.1	1.2	2.1	2.2		3.1	3.2
				2.2.1	2.2.2		
Verbena brasiliensis				1	1	2	1
Gerbera ambigua					1	2	1
Senecio inornatus					1	2	
Asclepias fruticosa					1	2	
Bromus catharticus	1				1	2	
Melolobium burchelli						2	
Berula erecta						2	1
Digitaria ternata						2	1
Setaria pallide-fusca						2	1
Gomphostigma virgatum						2	
Species Group P (Diagnostic species of the *Schoenoplectus decipiens – Leersia hexandra* Wetland)							
Leersia hexandra						1	4
Schoenoplectus decipiens						1	4
Cynodon bradleyi							3
Eleocharis palustris							3
Fuirena coerulescens					1	1	2
Cyperus rigidifolius					1		2
Lotononis listii							2
Species Group Q (Diagnostic species of the Wetland)							
Agrostis lachnantha	1				1	5	4
Hemarthria altissima					1	5	3
Mariscus congestus					1	4	4
Polygonum lapathifolium						4	4
Pseudognaphalium luteo-album				1	1	4	4
Paspalum distichum					1	2	3
Aster squamatus						3	2
Cineraria lyrata		1			1	3	2
Fingerhuthia sesleriiformis					1	2	2
Panicum schinzii					1	2	2
Ranunculus multifidus					1	2	2
Rumex lanceolata		1			1	2	2
Species Group R (Species associated with lower lying Grasslands and Wetlands)							
Paspalum dilatatum				1	2	5	4
Pennisetum sphacelatum	2	1	1	1	4	2	3
Cirsium vulgare	1				2	4	2
Trifolium africanum	1		1	1	2	2	2
Species Group S (Species associated with undulating Grassland and Wetland)							
Eragrostis plana	1	1	1	4	5	4	3
Cynodon dactylon	1	1	1	2	3	3	3
Haplocarpha scaposa		1	1	2	3	3	2
Species Group T (Species occurring generally in all plant communities)							
Eragrostis curvula	5	5	4	5	5	4	3
Andropogon appendiculatus	4	1	2	1	5	4	3
Helictotrichon turgidulum	3	1	1	2	3	2	2
Berkheya radula	1	1	1	1	3	2	1

1.2 *Hyparrhenia hirta – Diospyros lycioides* Low Thicket

This plant community is associated with steep, northerly facing slopes. The aspect varies from west to north to east. The slopes are dry and warm owing to direct sun insolation. These areas were often found to be overgrazed and disturbed. The preferential utilization of these areas by livestock is ascribed to the higher palatability of vegetation in more arid environments (Bosch 1989). Diagnostic species encountered in this plant community are generally more xeric than those characteristic of the *Artemisia afra – Kiggelaria africana* Low Thicket.

The small to medium-sized, deciduous tree *Celtis africana* is the only diagnostic tree species of this plant community (species group B, Table 1). Diagnostic small shrubs often encountered within this community are *Lantana rugosa, Grewia occidentalis, Pollichia campestris* and *Hemizygia pretoriae* (species group B, Table 1). The larger, conspicuous, evergreen shrub *Diospyros lycioides* often is the dominant woody species of this plant community (species group B, Table 1).

Diagnostic graminoids are the often dominant, large, tufted perennial *Hyparrhenia hirta*, the medium to small, tufted, perennial *Melinis nerviglumis*, as well as the small, annual (or biannual), tufted *Aristida congesta* subsp. *congesta* (species group B, Table 1). This pioneer grass species was often found in overgrazed and disturbed areas. *Aristida diffusa* (species group E), a medium-sized, weak perennial, tufted graminoid was also encountered frequently on northerly facing slopes.

The exotic, weedy forb *Bidens bipinnata* characteristically occurs in disturbed areas underneath the larger woody species. *Opuntia ficus-indica*, a large, exotic succulent, has invaded some disturbed areas (species group B, Table 1).

2. *Eragrostis curvula – Themeda triandra* Grassland

This vegetation type is principally associated with flat to undulating terrain (slopes less than 10°) where surface rocks are absent and the soil depth exceeds 400 mm. All areas classified as terrain units 3 and 4, covering approximately 70 – 75% of the total study area, form part of this vegetation type. Grassland communities were only rarely encountered on steeper slopes (exceeding 30°), the only exception being a few southerly facing slopes. However, grassland communities are common on the more gradual slopes (10 – 30°) as well as the crests of the hills and ridges (together comprising approximately 15 – 20% of the total study area).

Of the 25 graminoids frequently encountered in the major grassland communities (see species groups D, E, F, G, J, L, M, N, R, S & T), only the mostly small, tufted, perennials *Eragrostis racemosa* and *Eragrostis capensis* were found to be diagnostic (species group L) (Table 1). This is ascribed to the generally wide ecological amplitudes of the common grasses of the study area. The extremely variable *Eragrostis curvula*, a small to large, perennial, tufted graminoid, was found to have the widest ecological amplitude of all species encountered. The most dominant grasses, with high canopy covers, are *Themeda triandra* and *Cymbopogon plurinodis* (species group N, Table 1). Others, such as *Eragrostis plana* (species group S), *Elionurus muticus* and *Aristida junciformis* (species group M) may occasionally be dominant or co-dominant, depending on specific environmental conditions.

Trees and larger shrubs are absent from the grassland communities. Diagnostic forbs found in these communities are *Helichrysum rugulosum, Anthospermum hispidulum* and *Crabbea acaulis* (species group L, Table 1). Other forbs occurring frequently in grassland communities are *Hermannia depressa* (species group M), *Scabiosa columbaria, Hypoxis rigidula* (species group H), *Berkheya pinnatifida* and *Walafrida densiflora* (species group K) (Table 1). Whenever the vegetation was visibly overutilized, increases in the number and abundance of both forb and grass species were noted. This is ascribed to a greater variation of ecological niches created as the vegetation is 'opened' by overutilization (Fuls 1992a). Pristine grassland vegetation in the study area is characterized by the total dominance of a few dominant perennial graminoids, with very few forbs and species.

The grassland vegetation generally has a patchy appearance, with dominant and diagnostic species associated with small to large patches, varying from a few square metres to a few hectares. The patchiness is primarily ascribed to the wide range of grazing regimes, on a macro-scale, and the micro-scale patch-overgrazing within grazing units in the area (Fuls 1992b). The changes in vegetation due to livestock utilization, especially on a micro-scale, complicate the identification and confinement of grassland communities on the ground.

The grassland vegetation type can be divided into two distinct major plant communities: 2.1, *Digitaria tricholaenoides – Aristida diffusa* Grassland of the rocky outcrops; and 2.2, *Eragrostis curvula – Themeda triandra* Grassland of the undulating plains.

2.1 *Digitaria tricholaenoides – Aristida diffusa* Grassland

This plant community is predominantly restricted to the crests of hills and ridges, only occasionally occurring on medium to steep slopes (rarely exceeding 30°) where surface rock is present. Diagnostic grass species are the perennial, small to medium-sized, rhizomatous and tufted *Digitaria tricholaenoides*, the perennial, medium to large, tufted *Cymbopogon excavatus*, the perennial, medium to large, rhizomatous *Diheteropogon amplectens* and the small, perennial, densely tufted *Microchloa caffra* (species group D, Table 1). *Aristida diffusa* characteristically has a higher abundance and cover within this plant community, relative to other plant communities of the area (species group E, Table 1). Graminoids often encountered and sometimes dominant, but not diagnostic, include *Aristida canescens* (species group E), *Trachypogon spicatus* (species group F), *Brachiaria serrata, Harpochloa falx* and *Tristachya leucothrix* (species group G) (Table 1).

The diagnostic shrubs of the grassland of the rocky outcrops are dwarfed, always being less than 500 mm in height. These include the thorny *Ziziphus zeyheriana* which often occurs in dense patches, the densely branched, foliose *Indigofera hedyantha*, the often decumbent *Rhynchosia adenodes* as well as the karroid *Felicia muricata* which is often associated with disturbed areas (species group D, Table 1). The slightly larger shrubs which were also found,

but are not diagnostic, in this plant community are *Rhus rigida* (species group E) and *Diospyros austro-africana* (species group F) (Table 1).

The grassland of the rocky outcrops was found to be the most species-rich of all grassland communities, often containing a variety of grasses, shrubs and forbs. Nine diagnostic forbs are listed in species group D, Table 1. The most abundant and conspicuous forb is *Pachycarpus schinzianus*. Other prominent forbs frequently encountered are *Dicoma anomala, Acalypha angustata, Cyanotis speciosa* and *Cephalaria zeyheriana*.

2.2 *Eragrostis curvula – Themeda triandra* Grassland

Graminoids with a wide ecological amplitude and consequently wide distribution are particularly dominant in this plant community, often comprising more than 95% of the total canopy cover. The grassland of the undulating plains has virtually no diagnostic species, the only exception being the forbs *Berkheya pinnatifida* and *Walafrida densiflora* (species group K, Table 1). All other species which are abundant or dominant in this grassland community are also often found in other plant communities. Subsequently, this grassland vegetation is principally characterized by the absence of species which are diagnostic of the rocky outcrops (species groups A – F) and wetlands (species groups O – Q) (Table 1).

The grassland vegetation of the undulating plains was further subdivided into two plant communities: 2.2.1, *Elionurus muticus – Themeda triandra* Grassland of the higher lying areas (terrain unit 3); and 2.2.2, *Andropogon appendiculatus – Eragrostis plana* Grassland of the lower lying areas (terrain unit 4).

2.2.1 *Elionurus muticus – Themeda triandra* Grassland

This plant community is associated with the higher lying areas of the undulating plains, classified as terrain unit 3 (Land Type Survey Staff 1984) (see also Figures 3 & 4). Surface rock is mostly absent, soils are generally well drained and deeper than 400 mm. The terrain morphology varies from flat to high undulating, being predominantly mildly undulating.

All dominant graminoids within this grassland community are medium-sized to large, perennial and tufted. These include, ranked according to overall abundance within this plant community, *Themeda triandra, Cymbopogon plurinodis* (species group N), *Eragrostis curvula* (species group T), *Elionurus muticus, Heteropogon contortus, Setaria sphacelata, Aristida junciformis* (species group M), *Tristachya leucothrix, Brachiaria serrata* (species group G) and *Setaria nigrirostris* (species group M) (Table 1). These grass species are not diagnostic, but individually or collectively have a characteristically high abundance and canopy cover within this plant community. The wiry, medium-sized, tufted, perennial graminoid *Eragrostis plana* was often encountered on disturbed areas, sometimes becoming dominant, especially in moist, poorly drained situations.

The only species which are slightly diagnostic of this plant community are the forbs *Asclepias eminens* and *Anthericum fasciculatum* as well as the karroid shrub *Stoebe vulgaris* which is often indicative of degradation (species group I, Table 1). Other forbs which are encountered frequently are *Helichrysum rugulosum, Anthospermum hispidulum* and *Crabbea acaulis* (species group L, Table 1).

2.2.2 *Andropogon appendiculatus – Eragrostis plana* Grassland

This plant community is exclusively found on the lower lying areas of the undulating plains, classified as terrain unit 4 (Land Type Survey Staff 1984) (see Figures 3 & 4). The soils are generally deeper than 400 mm, moist, clayey and often poorly drained. Preferential utilization of this plant community was often noted, especially on the upper parts of the lower lying areas where an increased inclination towards the watercourse occurs.

The medium-sized, perennial, tufted *Panicum stapfianum* and the variable, mostly medium-sized, perennial, tufted or rhizomatous *Digitaria eriantha* are diagnostic graminoids associated with this plant community (species group J, Table 1). *Andropogon appendiculatus* (species group T) and *Eragrostis plana* (species group S) have a characteristically high cover and abundance within this plant community (Table 1).

Many of the graminoids frequently encountered in this plant community, sometimes being dominant or co-dominant, are more hydrophilic than those typically associated with other plant communities in the area. These include the densely tufted *Andropogon appendiculatus* (species group T) and *Pennisetum sphacelatum* (species group R), the medium-sized, loosely tufted, perennial *Helictotrichon turgidulum* (species group T), the wiry *Eragrostis plana* and the mat-forming, stoloniferous and rhizomatous *Cynodon dactylon* (species group S) (Table 1). The latter two, in combination with notable increases in the number and abundance of forb species such as *Oenothera stricta, Arctotis arctotoides, Geigeria aspera, Euphorbia striata* and *Sonchus dregeanus* (species group J, Table 1), are often indicators of disturbance. Other graminoids often associated with the lower lying grassland are *Themeda triandra* (species group N), *Eragrostis curvula* (species group S) and *Setaria sphacelata* (species group M) (Table 1).

Diagnostic forb species of this plant community include *Senecio erubescens, Falkia oblonga, Sutera aurantiaca* and *Salvia runcinata* (species group J, Table 1). All these forbs are typically associated with moist areas. Similarly, the strong rhizomatous sedge *Juncus punctoris*, often forming dense patch-like stands, is indicative of a moist habitat. Other forbs often associated with lower lying areas are *Berkheya pinnatifida, Walafrida densiflora* (species group K), *Helichrysum rugulosum* (species group L), *Haplocarpha scaposa* (species group S) and *Berkheya radula* (species group T) (Table 1).

3. *Mariscus congestus – Agrostis lachnantha* Wetland

This vegetation type is restricted to seasonally or permanently waterlogged soils and/or seasonally or periodically flooded areas, including rivers, streams, pans, vleis and stream-beds, covering less than 5% of the total study area. The diagnostic and dominant species are all typically hydrophilic, depending on excessive soil moisture and/or standing water to complete their life cycles. Relevés compiled in wetlands and stream-beds always included the vegetation

within the stream-bed/pan/vlei as well as the vegetation of the immediately adjacent areas (mostly stream-banks) directly influenced by the stream/pan/vlei.

Diagnostic graminoids of the wetland are the medium-sized, loosely tufted, short-lived perennial or annual *Agrostis lachnantha*, the mat-forming, stoloniferous and rhizomatous perennials *Hemarthria altissima* and *Paspalum distichum*, the medium to large, tufted, perennial *Fingerhuthia sesleriiformis* and the medium to large, loosely tufted, annual *Panicum schinzii* (species group Q, Table 1). Other grass species commonly encountered in wetland communities are *Paspalum dilatatum, Pennisetum sphacelatum* (species group R), *Eragrostis plana, Cynodon dactylon* (species group S), *Eragrostis curvula, Andropogon appendiculatus* and *Helictotrichon turgidulum* (species group T) (Table 1). *Mariscus congestus* is the only sedge which is associated with all major wetland communities (species group Q, Table 1). Diagnostic forbs frequently encountered in wetland communities are *Polygonum lapathifolium, Pseudognaphalium luteo-album, Aster squamatus* and *Cineraria lyrata* (species group Q, Table 1).

Many of the species encountered in wetland communities are exclusive to these specific communities, indicating the unique floristic composition and subsequent higher need for conservation of this vegetation type.

Two major plant communities were identified within the hydrophilic vegetation type. The different plant communities are not restricted to specific rivers/streams and may alternate along the passageway of a particular river/stream, depending on variations in topography, stream-bed incision and drainage tempo.

The two major plant communities are: 3.1, *Cyperus longus – Cyperus fastigiatus* Wetland; and 3.2, *Schoenoplectus decipiens – Leersia hexandra* Wetland.

3.1 *Cyperus longus – Cyperus fastigiatus* Wetland

This very distinct plant community is associated with medium-slow to fast draining streams and rivers. Their stream-banks are often wet but are not waterlogged for long periods, occasionally being only moist or even relatively dry. Stream-bed incision is generally medium to deep.

The diagnostic tree species *Salix babylonica* (usually 6 – 8 m tall) is relatively common throughout this wetland community with *Salix fragilis* (usually 3 – 5 m tall) occurring occasionally (species group O, Table 1).

Diagnostic and often co-dominant sedges are *Cyperus fastigiatus, Cyperus longus, Juncus exsertus* and *Cyperus marginatus*, and diagnostic reeds are *Phragmites australis* and *Typha capensis* (species group O, Table 1).These sedges and reeds characteristically have a patch-like distribution. They are often exclusively dominant within alternating patches which seldom comprise more than a few square metres. Their distribution and dominance depend on a variety of interactive environmental factors such as stream-flow, presence and depth of standing water, soil texture and soil depth.

Oenothera rosea, Ciclospermum leptophyllum, Pulicaria scabra, Galium capense and *Conyza bonariensis* are diagnostic forbs with a noteworthy high constancy within this plant community (species group O, Table 1). Other conspicuous and diagnostic forbs include *Senecio inornatus, Rumex crispus* and *Mentha longifolia*. Small (seldom exceeding 1 m in height), diagnostic shrubs occasionally encountered within this wetland community are *Asclepias fruticosa* and *Melolobium burchelli*. These shrubs are often associated with drier, alluvial stream-banks which are periodically flooded for short periods of time (species group O, Table 1). By contrast, the hygrophilous shrub *Gomphostigma virgatum* is found within stream-beds, characteristically associated with rocks and flowing water (species group O, Table 1).

With the exception of the reed *Phragmites australis*, all diagnostic and other grass species encountered in this wetland community are restricted to the stream-banks. These include the rhizomatous, sward-forming, perennial *Imperata cylindrica* which is associated with wet stream-banks, the medium-sized, weak perennial or annual, loosely tufted *Bromus catharticus*, the small, annual, loosely tufted *Digitaria ternata* and the medium-sized, annual, loosely tufted *Setaria pallide-fusca* (species group O, Table 1). The latter three are all characteristically associated with damp and disturbed stream-banks, with *Bromus catharticus* and *Setaria pallide-fusca* often occurring in disturbed areas shaded by *Salix babylonica* and *S. fragilis*. Other dominant or co-dominant graminoids encountered within this plant community, but with no diagnostic value, are listed in species groups Q – T, Table 1.

3.2 *Schoenoplectus decipiens – Leersia hexandra* Wetland

This plant community is restricted to pans, vleis and slow-draining watercourses. Where this plant community is associated with streams, stream incision is shallow, streamflow is slow to very slow and the stream-banks are moist to very wet, sometimes being waterlogged for the major part of the rainy season. Trees and shrubs are generally absent from this plant community, probably owing to the poor aeration of the soils.

Diagnostic and often dominant graminoids are the perennial, rhizomatous, hydrophyte *Leersia hexandra*, characteristically forming a dense sward in vlei-like areas as well as in water at the edges of pools associated with slow-draining streams; and the very small, mat-forming, stoloniferous, perennial *Cynodon bradleyi* (species group P, Table 1). This mat-forming species often occurs as a continuous band, a few metres or more wide, all around the edges of pans, adjacent to the water. If the pans dry up during the growing season, *C. bradleyi* quickly colonizes the newly exposed and drained areas. The forb *Lotononis listii* often occurs intermittently within the *C. bradleyi* mat. The sedge *Cyperus rigidifolius* frequently occurs in numbers at the outer edge of the *C. bradleyi* dominant band. Other sedges which are diagnostic for this plant community are *Schoenoplectus decipiens, Eleocharis palustris* (mainly restricted to vlei-like areas) and *Fuirena coerulescens* (species group P) (Table 1).

Other graminoids, sedges and forbs which are frequently encountered within this plant community are listed in species groups Q – T, Table 1.

Concluding remarks

On a regional scale, the seven major plant communities described here could all be related to distinct, specific

environmental attributes and conditions. Subsequently, these plant communities can be readily distinguished in the field.

The substantial plant community variations recorded within this relatively homogeneous area has important management and conservation implications. Each of these major plant communities should be managed and conserved separately, as different, unique ecologic units. Only if ecological boundaries are incorporated first and foremost into land-use planning and management on all scales, will optimal resource utilization and conservation be attained.

At present the obvious ecological boundaries between the different plant communities and their associated environmental attributes are mostly ignored by the landowners and land-managers, with clearly detrimental effects on the vegetation and forage resource base. Preferential utilization and/or retrogression of especially the northerly facing slopes and lower-lying grassland is evident throughout. Certain plant communities are therefore threatened: species disappear from the sward; some species increase markedly at the expense of others; large, tufted graminoids are replaced by less productive, smaller graminoids; and sheet erosion and severe crusting occur. These are but a few obvious consequences of land management which is generally out of step with nature.

There are clear similarities between the major plant communities of the study area and those found in adjacent areas, both with regard to the species encountered therein and the plant communities described [see Eckhardt *et al.* (1993) and Fuls *et al.* (1992)]. A detailed comparison between all the plant communities hitherto described in the study area and all adjacent areas will be presented in the envisaged synthesis of the vegetation of the northern Orange Free State (including all areas north of the 28°S latitude).

On a farm level scale, each major plant community discussed here can be subdivided into smaller, yet distinctive, plant communities which are all associated with specific environmental conditions. To permit a more detailed classification and mapping of the vegetation of the study area, separate analyses and descriptions of the minor plant communities, encompassed by the presented major plant communities, will be undertaken.

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