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VEGETATION ECOLOGY OF THE NORTHERN KWA-ZULU-NATAL GRASSLANDS

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Vegetation ecology of the northern KwaZulu-Natal grasslands

by

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Errata

p. 68 *Helichryso hypoleucum* change to *Helichryso hypoleuci*
Podocarpodetum latifolii change to *Podocarpetum latifolii*
Panico maximum change to *Panico maximi*

p.71 *Helichryso hypoleucum* change to *Helichryso hypoleuci*
Podocarpodetum latifolii change to *Podocarpetum latifolii*

p.76 *Podocarpodetum latifolii* change to *Podocarpetum latifolii*

p.80 *Panico maximum* change to *Panico maximi*

p.166 *Sporoboletum pyramidalo* change to *Sporoboletum pyramidali*

p.170 *Sporoboletum pyramidalo* change to *Sporoboletum pyramidali*

p.171 *Sporoboletum pyramidalo* change to *Sporoboletum pyramidali*

Adopt the peace of nature.
Her secret is patience.

Meinen Eltern gewidmet, insbesondere meinem verstorbenen Vater

ABSTRACT

Vegetation ecology of the northern KwaZulu-Natal grasslands

by

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A plant-ecological study was conducted in the grasslands of northern KwaZulu-Natal to develop a better understanding of the distribution, structure and composition of the plant communities found in the area. Plant communities were identified, classified and described in terms of environmental factors, making use of the Braun-Blanquet method, the TWINSPAN-classification technique and the DECORANA ordination algorithm. Altogether 95 plant communities were identified, comprising 800 plant species. A synthesis was subsequently conducted on the complete data set consisting of all 95 plant communities, resulting in 20 vegetation types being recognized. The results will ultimately form part of a comprehensive syntaxonomical and synecological synthesis of the entire Grassland Biome of South Africa. Plant communities and other areas displaying a high degree of naturalness and/or species richness were also selected for conservation purposes. Aerial photographs, derived from different dates in the past, were analysed by means of the GIS programme IDRISI to determine the extent and rate of bush encroachment into grassland within the study area. The GIS-based analysis was further complemented by field surveys to determine the processes involved in bush encroachment. The results clearly show that a fixed pattern of succession

occurred with woody pioneer plants being the first to invade the grassland. Subsequent developments embraced the establishment of further woody plant species, being characteristic of higher seral stages, around the pioneer species until woody clusters would coalesce to form closed woodlands in the end. A brief overview and discussion of grasslands in general is also presented, dealing with issues such as origin and evolution, management, conservation and research.

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CHAPTER 1

INTRODUCTION

The Grassland Biome covers 29% or 353 800 km² of South Africa's total surface area of 1 220 000 km², of which the grasslands of northern KwaZulu-Natal occupy 4% or 14 633 km² (Low & Rebelo 1996). This is a relatively large area and even more so if expressed in terms of the total grasslands occurring to the east of the escarpment. The fact that large parts of the Grassland Biome, in particular the Highveld Region, are associated primarily with deeper, nutrient-rich soils, makes them prone to agricultural developments. Crop and livestock farming practices are extensively applied. Apart from the negative effect which agricultural practices have had on the grass layer (Tainton 1984), two other factors have become increasingly important over the last decade, posing major threats to the grasslands of South Africa. These are urbanization, which currently takes place at an alarming rate to fulfill in the present housing need, and afforestation. Afforestation takes place on a very large scale, being mainly exercised by large forestry companies. Where grasslands, experiencing high rainfall, were found most suitable for afforestation purposes until very recently, it appears that even less favourable areas are nowadays selected to be transformed into timber plantations. The reason for this is that more and more cultivars of especially *Eucalyptus* species become available which are adapted to various conditions (Bowland pers. comm.[1]). The afforestation problem is a particular point of concern for the grasslands of northern KwaZulu-Natal and definitely needs urgent attention.

All these threats facing the Grassland Biome as a whole must be seen in the light of a lack of knowledge of the ecology of grasslands as well as the low percentage (2%) of the Grassland Biome currently under conservation. Certain veld types such as the Northern Tall Grassveld (64), Southern Tall Grassveld (65) and Natal Sour Sandveld (66), classified under Natal Central Bushveld by Low & Rebelo (1996), have substantially decreased in sizes due to reasons stated earlier on (see also Eckhardt *et al.* 1996d, 1997e). Only 1.56% of the 17 370 km² which this bushveld covers are conserved (Low & Rebelo 1996). With the

[1]A.E. Bowland, Natal Parks Board, P.O. Box 662, Pietermaritzburg, 3200

implementation of the Land Redistribution Act, a further potential threat has emerged on the arena, of which the outcome is uncertain at the moment. It seems inevitable that in the case of northern KwaZulu-Natal, many local communities will enter into contracts with bigger forestry companies to increase their financial incomes. Such developments will result in further increases in the existing pressure exerted by the forestry sector.

It must be stressed here that, although certain tracts within the study area may display some savanna elements, these tracts are still part of the Grassland Biome. The grass species composition resembles very much that of grassland communities found to the west of the escarpment. Low & Rebelo's (1996) Natal Central Bushveld is, in fact, grassland, with woody plants occurring widely dispersed and mostly restricted to areas characterised by specific environmental conditions. Relatively few islands of indigenous forests and valley bushveld occur within the study area and are considered as being part of the Grassland Biome. Fire, grazing and climatic factors such as frost inhibit the distribution of the woody plants. However, where climatic conditions are more suitable for woody species, such as in lower-lying grasslands, the latter is more prone to bush encroachment and this may result in the transformation of such grasslands into woodlands and thickets (see also Chapter 5). These dynamic processes are usually triggered by changes in a combination of management and environmental factors.

The current status of and trends within the Grassland Biome were enough reason to prompt certain decision-makers in the agricultural and scientific sectors to take appropriate measures. The outcome was the Grassland Biome Project which was intended "to develop an understanding of grassland structure and functioning necessary to enable the prediction of the effects of likely perturbations to grassland ecosystems" (Mentis & Huntley 1982). The various studies emanating from this project will all contribute towards the same aim of complementing the activities of natural resource agencies, and consequently resource users such as farmers, in their management of and research on grassland resources to achieve sustainable utilization whilst applying ecological sound standards. The need for descriptive studies to form part of the overall project was clearly acknowledged. Various dissertations and theses, many of them written up in publication format, have appeared so far since the commencement of the project, having dealt with different regions of the Grassland Biome (Bredenkamp 1975; Scheepers 1975; Bezuidenhout 1988, 1993; Bloem 1988; Turner 1989; Kooij 1990; Breytenbach 1991; Du Preez 1991; Matthews 1991; Smit 1992; Coetzee 1993; Eckhardt 1993; Fuls 1993).

The value of descriptive ecological studies and inventories and the contribution they make towards the ultimate understanding of ecosystem structure and functioning has been generally recognized (Pentz 1938; Bayer 1970; Edwards 1972; Bredenkamp 1987). These studies are important for providing baseline information, enabling further detailed and specialized research. Ecological sound management and conservation of specific areas also require the important information gathered by such studies. So far, relatively few phytosociological studies were conducted in the grasslands (Smit 1992; Perkins 1997; Robbeson 1998) and other vegetation types of KwaZulu-Natal. This study consequently forms part of a comprehensive synecological and syntaxonomical synthesis of the Grassland Biome of South Africa, dealing with the vegetation ecology of northern KwaZulu-Natal grasslands. Although the whole study area has been classified as grassland (Acocks 1953, 1988), isolated patches of woodland and indigenous forest do occur and were also included in the study. However, according to the most recent vegetation map available for South Africa, Lesotho and Swaziland, the predominant part of the study area is classified as Natal Central Bushveld (Low & Rebelo 1996).

Another field of interest identified within the study area was the problem of bush encroachment in an area considered to be transitional between Lowveld (veld type 10) and Northern Tall Grassveld (veld type 64) (Acocks 1988) or between Natal Central Bushveld (25) and Natal Lowveld Bushveld (26) (Low & Rebelo 1996). After having investigated historical aerial photographs, it was clear that bush encroachment had occurred in that specific area which in turn prompted further investigation.

The aims of the study can be categorised as follows:

a. To identify, classify and describe the various plant communities found within the grasslands of northern KwaZulu-Natal. Patches of indigenous forests and woodlands as well as all types of wetlands found within the grasslands were also included in the study.

b. To produce a syntaxonomical and synecological synthesis for the vegetation of northern KwaZulu-Natal by combining the different phytosociological tables into one synoptic table and subjecting the latter to further analysis.

c. To determine the conservation value of identified plant communities and/or certain areas.

d. To investigate the processes involved in bush encroachment in selected areas.

e. To present a brief overview of certain issues regarding the grasslands of South Africa, such as origin, evolution, management, research and conservation.

This thesis consists of various manuscripts, each one representing a separate chapter. Some of the manuscripts have been published in different scientific journals, whereas others have been submitted so far. Stylistic discrepancies and repetitiveness are unavoidable due to the different layouts and styles required by the different journals. The first three chapters consist of the introduction, study area and methods respectively, followed by a series of published and unpublished manuscripts. The discussion of the methods is kept relatively brief due to it being dealt with in more detail in the various manuscripts. The results and discussion of the vegetation ecology of the different regions of the study area are presented in chapter four, starting with a comprehensive phytosociological synthesis produced from the phytosociological tables compiled for the afore-mentioned regions. A detailed description of the physical characteristics of the entire study area is also given. Subsequent to this chapter follows a study investigating the processes involved in bush encroachment as well as determining the extent and rate thereof. The next chapter is more of a philosophical nature, dealing with grassland related issues such as origin, evolution, research, management and conservation. The thesis is concluded by some final remarks, followed by a literature and species list respectively. Page numbering is consecutive throughout the thesis. A list of figures and a list of tables are presented in the front of the thesis. Figures and tables are numbered consecutive only within each specific chapter.

CHAPTER 2

STUDY AREA

The study area is situated in central-northern KwaZulu-Natal between 27° 16' and 28° 31' S latitude and 30° 00' and 31° 38' E longitude, comprising a total area of approximately 14 366 km² (Figure 1 Chapter 4.1). The geology of the area is characterized in particular by the Karoo Sequence and to a lesser extent by the Pongola Sequence. Several Formations are distinguished under these Sequences. Dolerite dykes and sills also occur widespread throughout the area, whereas alluvial deposits are mainly restricted to larger rivers and rivulets and marshes. Various physiographic regions are recognized, with basins and plains constituting the largest part. Major rivers originating here and traversing the study area include the Bivane, Blood, Mkuze, Pongolo and Black and White Mfolozi. The Buffalo River is also one of the larger rivers running through the area. The average annual rainfall for the entire area is 850 mm, varying from 700 mm in the low-lying basins to 1 200 mm for the Highlands. The variation in rainfall, which can be ascribed to the topography of northern KwaZulu-Natal, is also reflected by the widely differing temperatures experienced throughout the study area. The average annual temperatures for low-lying areas typically exceed those for high-lying areas.

CHAPTER 3

METHODS

The methods followed in this study can be divided into four different phases. The first phase consisted of a reconnaissance of the whole study area, followed by the actual vegetation surveys during which the vegetation was sampled by means of relevés. The study area was stratified according to land types (Land Type Survey Staff 1986, 1988), terrain units, aspects and slopes and altogether 601 sample plots were subjectively placed within these units. Plot sizes were fixed at 100 m² for grasslands (Scheepers 1975) and 200 m² for woodlands and forests (Bredenkamp 1982). The approach followed in this study was that of the Zürich-Montpellier School, namely the Braun-Blanquet method (Braun-Blanquet 1932). This method is widely used throughout South Africa for phytosociological studies as a means to achieve standardization within this type of ecological research (see also Bredenkamp 1975; Turner 1989; Kooij 1990; Du Preez 1991; Matthews 1991; Eckhardt 1993; Fuls 1993).

The second phase embraced data processing and analysis, resulting in the identification, classification and description of plant communities and relating the latter to environmental factors.

The third phase consisted of a synthesis of synoptic tables, which were compiled for each of the six phytosociological tables and incorporated into one comprehensive synoptic table, representing the different vegetation types of the study area (Bredenkamp & Bezuidenhout 1995).

The fourth phase involves a study in a transitional area where grassland adjoined lowveld in order to gain more insight into the processes involved in bush encroachment. Belt transects, line intercepts and the point-centered quarter technique were applied to determine the type of species which were responsible for encroachment as well as quantitative data on sizes and numbers of such species. Historical aerial photographs, derived from different periods in the past, were compared to each other to assess the extent and degree of bush encroachment which has taken place over a period of thirty years. These photographs were scanned and subsequently analysed in the Geographic Information System (GIS) package IDRISI. Statistical tests were also applied to indicate the degree of significance of the results.

This thesis consists of a number of publications, all appearing under chapter four. The above discussion of the methods applied in this study is kept briefly since more detailed descriptions are presented in the relevant publications.

CHAPTER 4

RESULTS AND DISCUSSION

CHAPTER 4.1

The vegetation types, species richness and physical environment of the grasslands of northern KwaZulu-Natal

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A comprehensive description of the physical environment and a classification and description of the vegetation types of northern KwaZulu-Natal are presented. Six phytosociological tables derived from floristic data of the area were combined into one comprehensive synoptic table. The TWINSPAN classification of this synoptic data set was subsequently refined by Braun-Blanquet procedures, resulting in the identification of 20 vegetation types which are grouped into four major vegetation types. Correlations between environmental factors and the vegetation were determined by the application of the ordination algorithm DECORANA. The floristic data of the vegetation types and of the major vegetation types were further analyzed to calculate the species richness (alpha diversity) and total number of species. Subsequent results revealed that the high-lying grasslands are the most species rich of all four major vegetation types.

Keywords: Braun-Blanquet, major vegetation type, phytosociology, species richness, syntaxon, vegetation type

Introduction

In depth ecological studies on large parts of South Africa's grasslands are scarce or even non-existent. This is especially true for phytosociological studies which were until the 1990's poorly represented among South African literature. Most ecological studies are conducted on a large scale (1:50 000 to 1:10 000), thereby increasing the necessity of extrapolating results into adjacent areas. The vegetation of KwaZulu-Natal has in the past been described by Bews (1912), Aitken (1922), Henkel (1917), Acocks (1953) and Edwards (1967). Most other ecological studies conducted in grasslands, concentrate on grazing capacities, veld condition assessments and grazing systems (Foran *et al.* 1978; Tainton 1981; Heard *et al.* 1986). The need to identify, classify and describe the many vegetation units within the Grassland Biome has been realized and some phytosociological studies, including that of Smit (1992) conducted within KwaZulu-Natal, have been undertaken, especially in the western Grassland Biome (Bredenkamp 1975; Scheepers 1975; Bezuidenhout 1988, 1993; Bloem 1988; Turner 1989; Kooij 1990; Breytenbach 1991; Du Preez 1991; Matthews 1991; Coetzee 1993; Eckhardt 1993; Fuls 1993) or are still in progress (Eckhardt *et al.* 1996a, 1996b, 1996c, 1996d, 1996e, 1997). The new vegetation map of South Africa partly results from these studies (Low *et al.* 1996).

Now that the landownership rights of this country have changed, enabling the whole population easier access to land, it is of vital importance to stress the need to conserve ecological sensitive areas (Wahl 1995). Such areas can only be identified if ecological surveys are conducted. This study, which forms part of a comprehensive syntaxonomical synthesis of the grasslands of South Africa, embraces the identification, classification and description of the vegetation types of the grasslands of northern KwaZulu-Natal. This study also aims at identifying areas of specific conservation value. To facilitate the latter, the species richness of the area was also calculated. This paper gives an overview of the major vegetation types, associated physical environment and phytodiversity of the Dundee-Utrecht-Vryheid area in the northern KwaZulu-Natal. Subsequent papers will deal with the vegetation types on a community level.

STUDY AREA

The study area represents the grassland biome in central-northern KwaZulu-Natal between 27° 16' and 28° 31' S latitude and 30° 00' and 31° 38' E longitude (Figures 1 & 2). The area comprises the central to western part of the 2730 Vryheid and the central to north-western

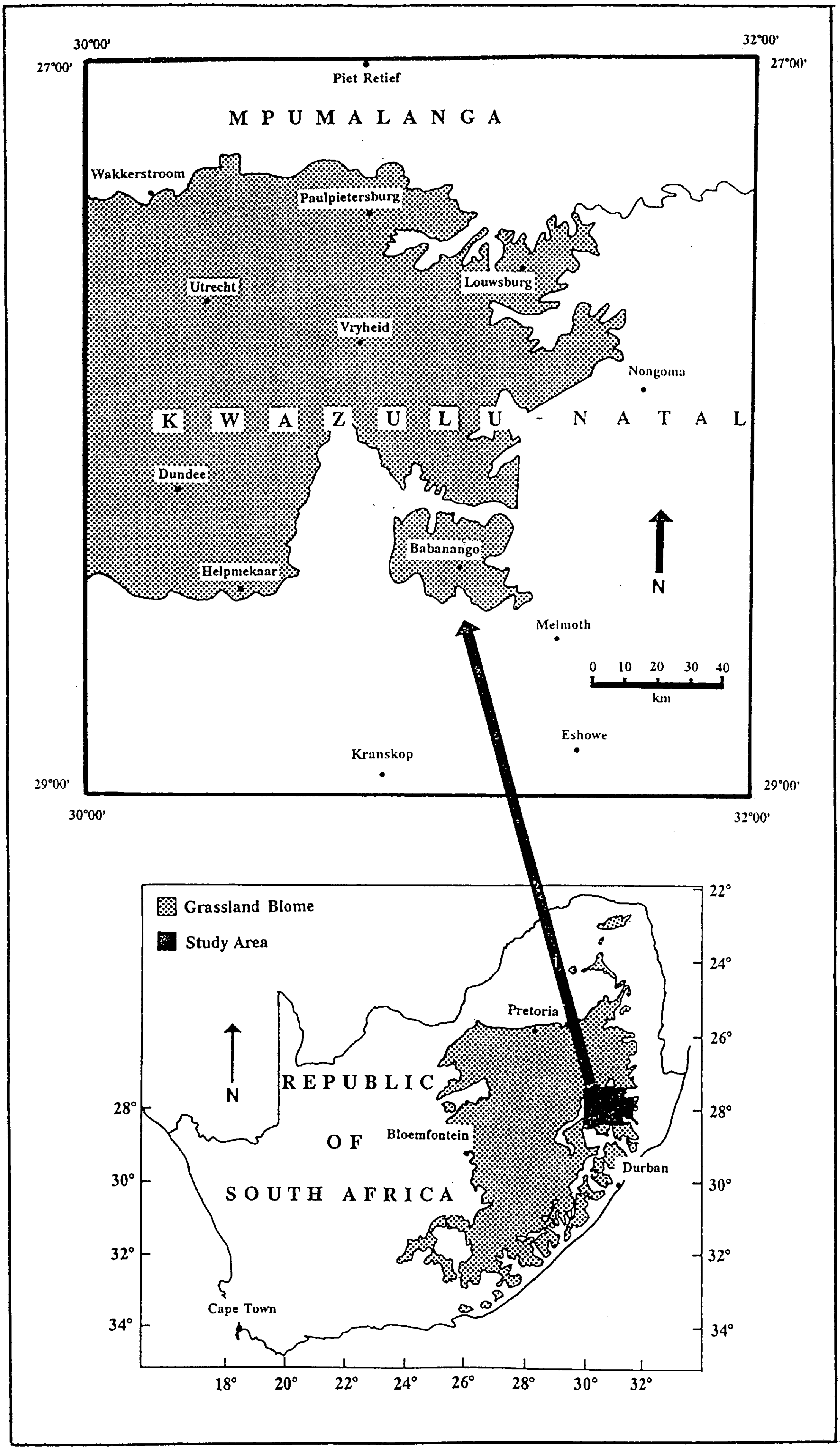

Figure 1 The study area within the Grassland Biome of South Africa.

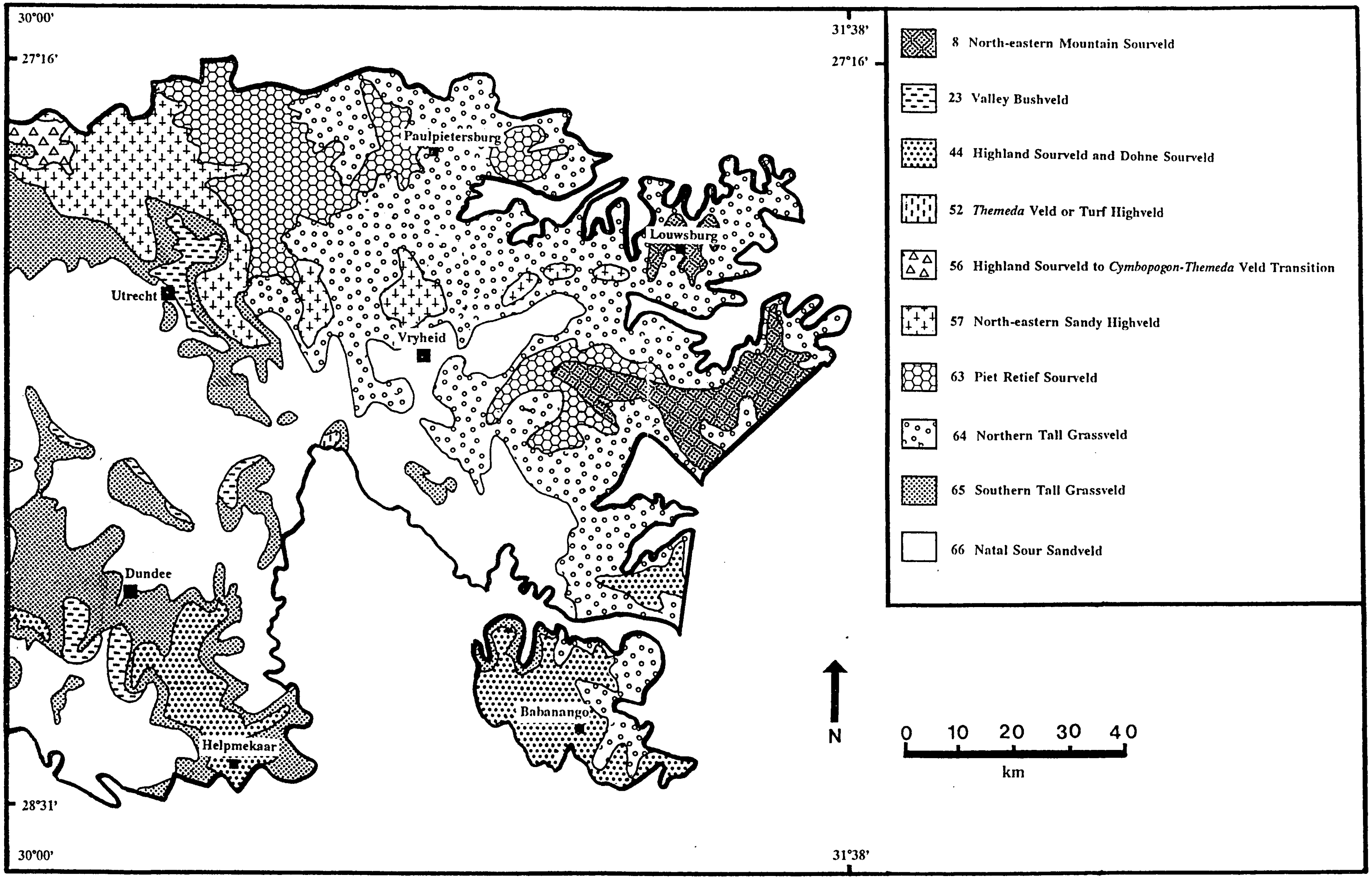

Figure 2 The 10 different veld types (Acocks 1988) occurring in the study area.

part of the 2830 Richards Bay maps (1:250 000) (Land Type Survey Staff 1986, 1988), covering an area of approximately 14 366 km². In the east and south-east the study area borders on the Natal Lowveld (Acocks 1953, 1988), while the northern limit corresponds with the southern border of Mpumalanga and the Pongolo River. Major towns included in the area are Dundee, Paulpietersburg, Utrecht and Vryheid. The area comprises 10 Veld Types with the Northern Tall Grassveld and Natal Sour Sandveld comprising more than half of the area (Figure 2) (Acocks 1953, 1988).

Physical environment

GEOLOGY

The study area is underlain by rocks varying in age from Swazian to Quaternary (4 500-1.8 million years ago). The oldest rocks are metavolcanic and metasedimentary xenoliths occurring in the Archaean granite (Linström 1987). These granites are overlain by the Pongola Sequence, which crops out at different places in the eastern and north-eastern parts of the study area (Figure 3). The Pongola Sequence, which dates from the Swazian Erathem (3 050-3 180 million years ago) and represents sedimentary, volcanic and intrusive rocks, consists of the Mozaan and Nsuze Group, both of which are subdivided into various Subgroups and Formations (SACS 1980; Linström 1987). The Nsuze Group comprises mainly volcanic rocks whilst the overlying Mozaan Group consists of rocks of predominant sedimentary origin. The Pongola Sequence is intruded by various rocks, primarily by the Usushwana Complex (2 931 million years), which comprises basic as well as acid rocks. The Karoo Sequence, being a succession of mainly sedimentary rocks and covering approximately 55% of South Africa, is dominant throughout the study area and dates from the Phanerozoic Eonothem (330-120 million years ago) (Tankard *et al.* 1982). Various Formations are distinguished under this Sequence.

Karoo Sequence

The most prominent and widespread geological grouping under this Sequence found in the

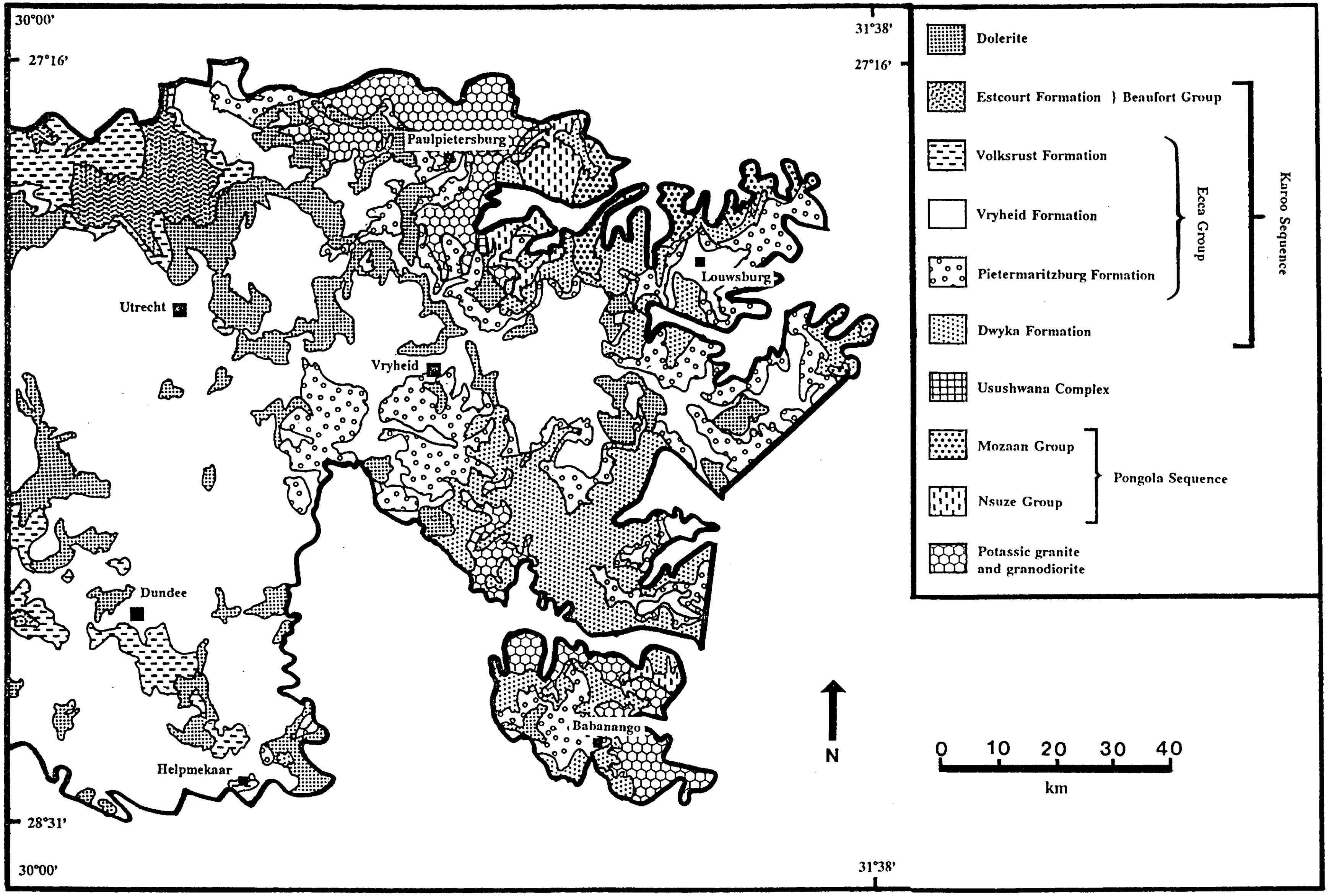

Figure 3 The geology of the study area, showing the different formations, groups and complexes.

study area, is that of the Ecca Group. This Group is further divided into three Formations and is underlain by the Dwyka Formation.

Dwyka Formation

This Formation mainly occurs east of Vryheid stretching to Louwsburg (Figure 3) and at some places can be observed as rocky outcrops. The thickness varies between a few metres up to more than 200 m. Tillite is the major component of this Formation and forms clay when in a process of weathering (Linström 1987). Sandstone is generally found in the upper parts of the Formation.

Ecca Group

Pietermaritzburg Formation

This Formation follows concordantly on the Dwyka Formation and may vary in thickness between less than 50 to more than 200 m. This variation in thickness is due to hollows and valleys, formed by Dwyka glaciers in the older rock layers, filled by the Pietermaritzburg shale. The colour of the shale varies from dark grey-blue to green-blue (Linström 1987). Thin layers of siltstone can be observed between the shale. This Formation is restricted to the eastern parts of the study area (Figure 3).

Vryheid Formation

This Formation usually lies concordantly on the shale of the Pietermaritzburg Formation and good exposures are apparent in the mountains around Vryheid. The thickness varies between 260 and 320 m. It consists of sandstone, shale and grit with coal and oil-shale beds. The Vryheid Formation can be divided into four zones according to texture and thickness of sandstone layers, sand/shale ratios and coal contents (Linström 1987). The upper zone contains the most important coal layers and is about 100 m thick. The Vryheid Formation has been deposited by fluvio- controlled deltas (Van Vuuren 1983) and is strongly represented in the central and central western parts of the study area (Figure 3).

Volksrust Formation

The Volksrust Formation follows concordantly on the Vryheid Formation and appears as outcrops at two particular places. The thickness of the outcrops are 130 and 80 m respectively. The Formation consists mainly of dark blue-grey to black shale as well as siltstone. The prevailing conditions during the sedimentation process were presumably similar to those of the Pietermaritzburg Formation (Linström 1987). The Volksrust Formation is restricted to the north-western and south-western parts of the study area (Figure 3).

Estcourt Formation

This Formation is mainly restricted to the north-western corner of the study area (Figure 3). It follows concordantly on the Volksrust Formation and reaches a minimum thickness of 90 m, although it measures more than 200 m outside the study area. The Formation is made up of sandstone, mudstone and siltstone with thin coal seams included. Indications are that this Formation has been formed by the extension of deltas in a shallow freshwater environment (Linström 1987).

Karoo Dolerite

Karoo Dolerite, in the form of dykes and sills, occurs widespread throughout the study area (Figure 3). Although found in all types of formations, it occurs more generally in the Vryheid Formation. Intrusion of the sediments of the Karoo Sequence by the dolerites dates back to the commencement of the Jurassic period (SACS 1980).

Quaternary Sediments

Masotcheni Formation

Small widely-scattered exposures of this Formation occur throughout the area but nowhere do they reach a thickness of more than five metres. These sediments are highly erodable and subsequently give rise to deeply carved dongas. The Formation consists of a basal clay layer interchanged by gravel beds. This is followed up by a layer of half-consolidated, clayey soil which makes up the largest part. Laterite and silcrete occur at the top of this zone, which in turn is overlain by a soil layer. The general colour of this Formation is a light yellow (Linström 1987). Due to the small widely-scattered occurrence of this Formation, the latter is not indicated in Figure 3.

Alluvium

Alluvium occurs only along larger rivulets and rivers as well as marshes. Large depositions occur along the Pongolo River and consist of clayey soil, gravel and smoothly-rounded rocks (Linström 1987). Alluvial depositions are not indicated in Figure 3 due to the small patchy occurrence thereof.

TOPOGRAPHY

The total study area consists of various physiographic regions of which basins and plains constitute the largest part (Turner 1967) (Figure 4). The only two distinct plateaux recognized are the Belelasberg-Skurweberg and the Helpmekaar Plateau, exceeding 1 500 m above sea-level. The highest peak is that of the Ntshele mountain, reaching a height of 2 290 m, and is situated in the far north-western corner of the study area just north of the Slang River. The lowest part, in contrast, is the Black Mfolozi River in the undulating lowlands at an altitude of only 750 m where it leaves the study area (Land Type Survey Staff 1986, 1988). The extreme differences in altitudes within the total study area have wide-ranging consequences which are reflected by clear differences in climate and vegetation.

DRAINAGE

Many of the larger, perennial rivers of KwaZulu-Natal either originate in or traverse this area. The Bivane-, Blood-, Mkuze-, Pongolo-, Black and White Mfolozi Rivers all rise in the high-lying mountainous areas which receive higher rainfall than the surrounding areas (Figure 4).

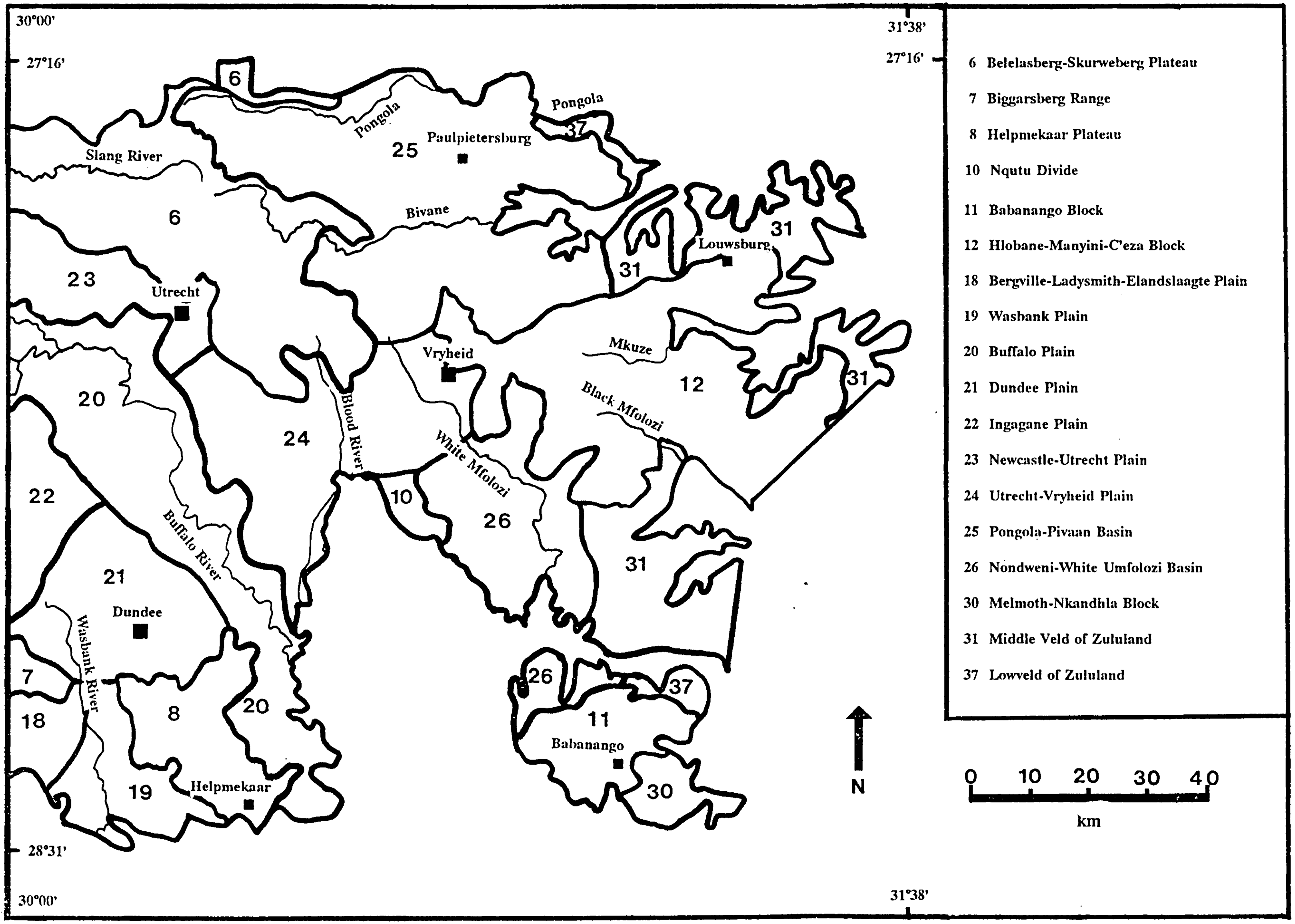

Figure 4 Distribution of physiographic regions within the study area (Turner 1967).

Although the Buffalo River only traverses the area, many important tributaries join the former within this area. The Blood River joins the Buffalo River which in turn meets up with the Tugela River further south in Zululand. The Black and White Mfolozi Rivers also join together only to form the Mfolozi River which runs into the Indian Ocean just south of the St. Lucia Estuary. The Bivane River ends up in the Pongolo River in the far eastern corner of the study area. The study area forms thus an important part of the catchment-area of some of the major rivers of northern KwaZulu-Natal.

LAND TYPES AND SOILS

The whole area consists of a mosaic of various land types with 13 different soil patterns (Land Type Survey Staff 1986, 1988). The three characteristics which define a land type, namely terrain form, soil pattern and climate, strongly correlate with the topography, and consequently can the heterogeneity in land types be ascribed to the variation in the topography. The broad soil patterns encountered in the area can be divided into seven different classes. The first class consists of red to yellow apedal, freely drained soils (map units Ab, Ac, Ad), which are restricted to high mountains and plateaux with a high rainfall. The second class is characterized by a plinthic catena with upland duplex and margalitic soils rare (map units Ba, Bb, Bd). The soils representing the catena vary from dystrophic and/or mesotrophic (map units Ba, Bb) to eutrophic (map unit Bd). The third class includes undifferentiated soils (map unit Ca) representing a plinthic catena with upland duplex and/or margalitic soils common. The forth class is characterized by soils where prismacutanic and/or pedocutanic diagnostic horizons are dominant (map units Db, Dc). Undifferentiated soils (map unit Ea) with one or more of vertic, melanic and red structured diagnostic horizons belong to the fifth class. The sixth class consists mainly of soils of the Glenrosa and/or Mispah Forms (map units Fa, Fb), although other soils may also occur. The last class consists of miscellaneous land classes which includes rock areas with miscellaneous soils.

CLIMATE

Data on rainfall and temperature were obtained from four different weather stations (Figure 5)

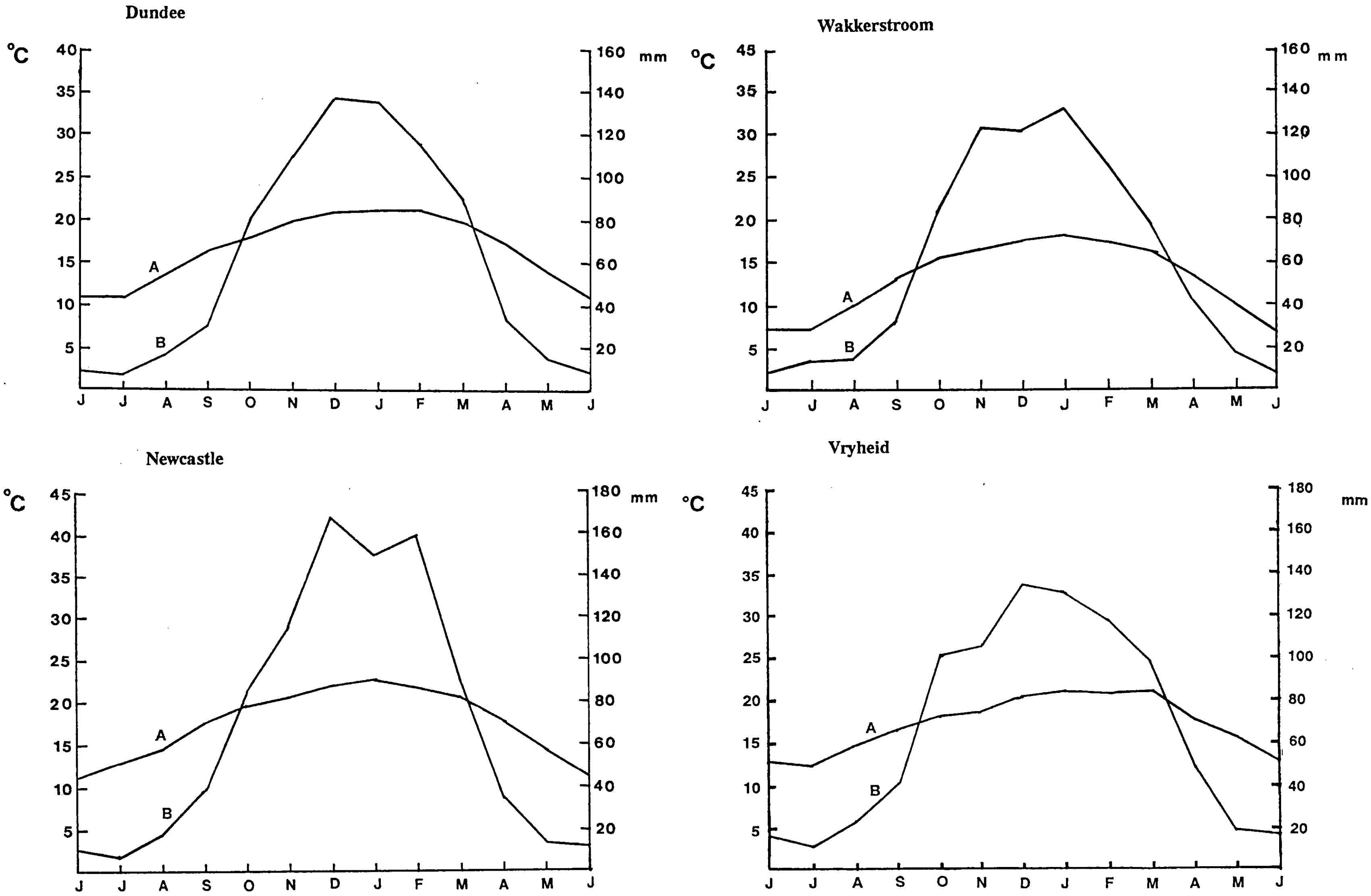

Figure 5 Climatic diagrams for four different weather stations, showing the mean monthly temperature (A) and mean monthly precipitation (B).

(Weather Bureau 1986, 1995). The study area receives most of its rainfall during the summer months of October to March. Most of the rain falls in the form of thunder-showers, often accompanied by hail (Schulze 1982). The average annual precipitation for the whole study area is 850 mm, but varies from as low as 700 mm for the interior low-lying basins to 1 200 mm for the highlands. Temperature patterns are closely related to the physiographic regions of the area, with the low-lying areas and major river valleys characterized by high temperatures and high-lying areas and mountains characterized by low temperatures (Schulze 1982). The average annual temperature for Dundee is 17.0°C, for Newcastle and Vryheid 17.5°C, and Wakkerstroom 13.6°C.

Methods

Field surveys were conducted over the 1993 and 1994 summer seasons and the two data sets were combined into one complete set representing the whole study area. Relevés were compiled in 601 stratified sample plots, which comes down on one sample plot per 23.9 km². Although the sample plots were subjectively placed, care was taken to include all land types with their associated terrain units, aspects and slopes. Plot sizes were fixed at 100 m² for grasslands (Scheepers 1975) and 200 m² for woodlands and forests (Bredenkamp 1982). All species occurring in a sample plot were recorded and given a value according to the Braun-Blanquet cover-abundance scale (Mueller-Dombois & Ellenberg 1974). Taxon names conform to those of Arnold & De Wet (1993). The structural classification and description of the vegetation types were based on the system of Edwards (1983). To compile a relevé the following environmental data were also recorded: geology, topography, terrain unit, aspect, slope, rockiness of the soil surface, soil types and depth, soil texture, erosion and utilization by herbivores. Soils were classified according to Department of Agricultural Development (1991).

A TWINSPAN classification (Hill 1979b) of the entire floristic data set revealed discontinuities, which were subsequently divided into six phytosociological tables. These tables were further refined to plant community level (vegetation types) by the application of Braun-Blanquet procedures (Westhoff & Van der Maarel 1978; Bredenkamp *et al.* 1989;

Kooij *et al.* 1990; Fuls *et al.* 1992; Eckhardt *et al.* 1993a) and the derived vegetation units were then identified and described by Eckhardt *et al.* (1996a, 1996b, 1996c, 1996d, 1996e, 1997). A synthesis of the entire data set was conducted by combining the synoptic tables, compiled for the six phytosociological tables, into one comprehensive synoptic table (Table 1) (Bredenkamp & Bezuidenhout 1995). Each community (vegetation unit) from each individual phytosociological table was therefore summarized as a single column (synrelevé). In this synoptic table the matrix represents the constancy of the species in each vegetation unit, described by Eckhardt *et al.* (1996a, 1996b, 1996c, 1996d, 1996e, 1997), rated on a scale of 1 to 5: 1 = <20%, 2 = 20 - 40%, 3 = 41 - 60%, 4 = 61 - 80%, 5 = >80% (Bredenkamp 1987). This table was also further refined, resulting in the identification of the vegetation types of the grasslands of northern KwaZulu-Natal, which are subsequently described in this paper.

To determine the relationship between the vegetation and environmental factors, the ordination algorithm DECORANA (Hill 1979a) was used, producing a scatter diagram (Figure 7). The data of the synoptic table, representing the different vegetation types, were used for the ordination (see also Eckhardt *et al.* 1996c).

The floristic data within each vegetation type were further analyzed to calculate alpha diversity (Figure 6) (see also Eckhardt *et al.* 1996d, 1997 for a more detailed discussion). The alpha diversity represents the species richness and is determined by the average number of species per community.

Results and discussion

Twenty vegetation types were recognized from the synoptic table (Table 1), representing 95 plant communities (vegetation units) and comprising 800 plant species. These vegetation types can be broadly classified into four major vegetation types, representing respectively woody vegetation (forests, woodlands, thickets), high-lying grasslands, low-lying grasslands and wetlands. The forests are primarily restricted to cliffs and ravines at altitudes ranging from 1 000-2 200 m, being protected against fire and frosts. The woodlands and thickets are mostly found below the altitudes at which *Leucosidea sericea* occurs and on rocky outcrops. Although the high-lying grasslands are usually associated with altitudes exceeding 1 500 m

Table 1 Synoptic table of the vegetation of northern KwaZulu-Natal

Vegetation type	1			2		3				4			5			6						7				8					9							10			11						12			
Synrelevés	001	002	003	005	008	006	007	009	010	004	011	012	013	014	015	016	017	018	019	020	021	025	026	027	032	059	060	062	063	064	054	055	056	057	058	061	065	033	049	052	028	029	030	031	050	051	034	035	036	048
Species group A																																																		
Stachys kuntzei	5	5	4							4			2	1			1	2																		2		1										1	1	1
Bromus catharticus	5	3	2																																	2														
Clutia affinis	4	5	2																			1				3		2	2	1						2														
Dioscorea sylvatica	4	3	5		3	2				2																																								
Dryopteris inaequalis	5	3	3		2			2	3																																	1								
Myrsiphyllum asparagoides	4	4	3			1				2									1							3	2	3								2														
Printzia pyrifolia	4	4	1					2														1	1					2																						
Rubia horrida	5	5	1																									2		1						2						1								
Schoenoxiphium rufum	2	4	3									2															2	2			1					2														
Helichrysum hypoleucum	5	4							3													1						4		1																				
Taraxacum officinale	4	3														1																			2															
Thalictrum rhynchocarpum	4		3		2				3		3																																							
Sparrmannia ricinocarpa	4	2				1		2		2									1																															
Species group B																																																		
Scolopia mundtii				3	2						2																																							
Dicliptera zeylanica				3	3																																													
Allophyllus africanus				3	5																																													
Hyparrhenia cymbaria				5	2							4						1				3																											2	
Species group C																																																		
Greya sutherlandii				3	2	4	5	5	5	4	5	3	1	1				1	2																															
Canthium mundianum				5	2	4	5	4	3		2	2	2	3		1	4						1																					1						
Cheilanthes virides	2			3	2	2	3	2	3		3	3	2				2					1	1	1																			1	1			1			
Carissa bispinosa				3	3	2	3	4	5	2													1																											
Apodytes dimidiata				3	4	3	3	2	3			2																																						
Aloe arborescens				3	3	4	5	5			2	2					5	1	2			1																						1						
Trimeria grandifolia			1	3	4	2	3	4	3	2			2						1																															
Tricalysia lanceolata				3	2	1		2		2		2		1			2						1	1																										
Cassinopsis ilicifolia				3	3	1			3		3		1				1							1																										
Canthium ciliatum					2			2	3	2	5													1														1				1		2						
Plectranthus madagascariensis			1			1	3	2	3			2		1				2	3				2																											
Celtis africana			1		3	1			3	2			2					1																																
Species group D																																																		
Leucosidea sericea	5	5	4	5	2	3		2	3	4	4			1												5	5	5	5	4	2	1	1	1		5		1		2										
Asplenium aethiopicum	4	3	3		4	2	5	2	5		2																																							
Rhamnus prinoides		5	5	3	4	1		4	3	4	4		1					2																		2		1												
Buddleja auriculata	2		3	3	2	4		2		5	3		1	2																																				
Myrsine africana		5	5	3		1		5	3	2	3																									2		1												
Mohria caffrorum		4	3			1	5		3	5	4		1	1			2					1	1	1		3	2	2	2	2						2		1						1						
Senecio tamoides	4	3	3	3	4	2		2					1	1		1																				2														
Scadoxus puniceus	4		1		2	2	3			4		2						1																																
Cheilanthes quadripinnata	5	4								4	2	2		2									1	1	3	3		5	2							5		2		2		1								
Species group E																																																		
Acacia caffra				3								2	5	2	3	5								1																							1			
Dombeya burgessiae												3	2	1	5																																			
Scutia myrtina			1						3				4	1	5	2																																		
Isoglossa eckloniana											2		2	1	3																																			
Species group F																																																		
Poa annua	5	5	5	3	2	1	3	2	3	2	2	2	3	2	5													2								2														
Achyranthes aspera	4	2	4	3	2	1	5	2	5	5	2	3	4		5				1									2																						
Heteromorpha trifoliata		4	2	5	2	5	3	4	5	4	3	2	1	1	3																					2														
Buddleja salviifolia	2	3	4	3	4	3		5	3	5	4		1	3	3									1	1	3	2	2		1								1				1	1	1						
Clausena anisata		1	3		5	3	5		5	5	3		4	2	3	1									1																									
Species group G																																																		
Acacia karroo													4	3	5	5		2	5	5	5	1										1					1													
Grewia occidentalis						1				2			2	3	5	3		1		4	2				1												1	2												
Bidens pilosa	2									2		2	3	3	3	2	2	1	2	4	3																							1						
Rhus pentheri										5			4	4	5	5			1		2				1													1												
Ziziphus mucronata											2	2	4	3	5	4	1	2	1		4																	1												
Species group H																																																		
Cussonia spicata				5	5	5	5	5	5	5	4	4	5	4	5	2	5	3	4		2		1		1													2						2						
Clerodendrum glabrum				3	2	1	5		3	4	3	3	5	2		2	5	1	3				1		1																									
Protasparagus virgatus			2	3	4	3		4			3	4	2	3	3	2	2	2																																
Zanthoxylum capensis					2		5		5		4	2	2	2		1	2	1						1																										1
Rhus chirindensis						1		2			4		2	2		1		2																																
Species group I																																																		
Euclea crispa		4	5	5	4	4	3	5	3	5	5	3	5	5		4	4	3	3	4	3		1		1											2		1				1								
Rhoicissus tridentata		3	2	5	2	5	3	5		4	5	3	5	4	5	3	3	4	3	5	3		1	1														2				1		2						
Rhus pyroides	5	5	3	5	4	5		5		4	5	2	3	1	5	1		2	1		3		1		1											2		1				1								
Diospyros whyteana		3	3	3	4	5		5	3	2	3	2	2	1			5	1	1	4					1													1						2						
Clematis oweniae		3	2	3	4	4		2	3	2	2	2	3	2	5	2	1	1	3																															
Dais cotinifolia		3	4	5	2	1		2	3	4	3		2	1	3	1		3	3																	2														

Vegetation type	13												14							15		16								17						18					19				20
Synrelevés	037	038	039	040	042	043	044	045	046	047	073	079	022	041	071	072	074	075	078	023	024	053	066	067	068	069	070	076	077	086	087	088	089	090	091	081	082	083	084	085	092	093	094	095	080
Species group A																																													
Stachys kuntzei			1																					1																					
Bromus catharticus																																										1			
Clutia affinis																																				1		2							
Dioscorea sylvatica																																													
Dryopteris inaequalis																																													
Myrsiphyllum asparagoides																																													
Printzia pyrifolia																																													
Rubia horrida																																													
Schoenoxiphium rufum																																													
Helichrysum hypoleucum																																													
Taraxacum officinale	1											1												1					1											1		2			
Thalictrum rhynchocarpum																																													
Sparrmannia ricinocarpa																																													
Species group B																																													
Scolopia mundtii																																													
Dicliptera zeylanica																																													
Allophyllus africanus																																													
Hyparrhenia cymbaria																															1				1										
Species group C																																													
Greya sutherlandii																																													
Canthium mundianum				1																																									
Cheilanthes virides				1								1																																	
Carissa bispinosa																																													
Apodytes dimidiata																																													
Aloe arborescens																																													
Trimeria grandifolia																																													
Tricalysia lanceolata																																													
Cassinopsis ilicifolia																																													
Canthium ciliatum																																													
Plectranthus madagascariensis		1	1																																										
Celtis africana																																													
Species group D																																													
Leucosidea sericea			1																					1									1			1		1		1					4
Asplenium aethiopicum																																													
Rhamnus prinoides			1																																										
Buddleja auriculata																																													
Myrsine africana																																													
Mohria caffrorum			1																																										
Senecio tamoides																																													
Scadoxus puniceus																																													
Cheilanthes quadripinnata																																													
Species group E																																													
Acacia caffra																																													
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Isoglossa eckloniana																																													
Species group F																																													
Poa annua																																													
Achyranthes aspera																																													
Heteromorpha trifoliata			1	1																																									
Buddleja salviifolia																																						1							
Clausena anisata																																													
Species group G																																													
Acacia karroo		1	1							1	1		4					1		5	5			1							1				1				1						
Grewia occidentalis			1																				2	1																					
Bidens pilosa													2							2											1	1						1							
Rhus pentheri																																													
Ziziphus mucronata	1												4				1	1			3										1														
Species group H																																													
Cussonia spicata				1																																									
Clerodendrum glabrum																																													
Protasparagus virgatus													2								3																								
Zanthoxylum capensis																																													
Rhus chirindensis																																													
Species group I																																													
Euclea crispa			1										4																		1														
Rhoicissus tridentata			1										2																																
Rhus pyroides																																													
Diospyros whyteana																											1																		
Clematis oweniae																																													
Dais cotinifolia																																													

Species group J												
Rhus dentata	1		2	4 3 2	4 4 5	3 5 3 3 5 4	3 2 5	2 1		4	2 1 1 2	
Melinis nerviglumis			1	2 3 2	1 1	1 2 3 3	1 3 4 4		1	3 2 5	3 4 2 4 2	2 2
Lippia javanica		3		2 2 2	4 3 5	4 4 2 3	1		1	1	1	1 2
Athrixia phylicoides			1	2 3 2	2 3	2 2 3 4	4 4 1			3	2 1 1	1 2 2
Pellaea calomelanos				4	2 2	1 4 3 1	1 2 2 2			2 2	1 3	
Cymbopogon validus			3 4	4	2 1	1 3 5 5	4 5 5 1				4 1 2 2	1 2
Cheilanthes sp.		2	2	3 2		1 4 3 2	3 2				1 1	1
Aloe marlothii				4 2	2	3 1	1 1 1 2			2		
Hippobromus pauciflorus				2	2	4 3 2 2	1					
Species group K												
Diospyros lycioides	1 1	5 2	2 3 3	4 4 5	5 5 5	4 5 4 5 5 4	1 2 4 5		2	5	4 2 1 3	1
Maytenus heterophylla	2 3		2	4 5 2	2 2 5	4 5 2 2 4 5	1 2 2			1	1	
Species group L												
Leonotis ocymifolia				4 2	1 1 5	1 2 1 1	1 1 4	3 2 2 4		2	1 1	
Species group M												
Helictotrichon turgidulum	2				1	1	1 1	2 3 5 3	1 2 1 1 5		1 2	1
Helichrysum dasycephalum	1						1	3 4 2	1 3 3 2 2 1	1 3	1 1 1	
Andropogon appendiculatus	1						1	5 5 3	2 2 1 1 1	2	1 1	1 1
Sporobolus centrifugus								3 5 3	3 1 1 1	5 3	1 1	1
Sutera sp.								2 4 2 3	2 1 1 4	2	1	
Rabdosiella calycina				2 2	1		1 1 1	3 2 2 4 1	1 2 4	3	1 1 1	1
Solanum elaeagnifolium						1 4 2		3 2 2	1 1 1 3 1	1	1	
Sutera polelensis	2 2	2	2	2	1 3			5 2 3 5 1	5	1	1 1	
Harpochloa falx	1							2 4 2	1 1 2 2		1	
Helichrysum melanacme	4						2	5 4 3 4 2	2 2	1 2	1	
Crabbea acaulis							1	3 2 2	2 3 1		1 1	
Species group N												
Eulalia villosa				4		2 2	3 5 5 3			2 3 2	5 4 4 3 1 1	1 1 5 1
Loudetia simplex							1 1 5 1		1	4 2	2 4 3 3 5 5	2
Ctenium concinnum							2 3		1 2	1 3 2	2 3 1 3 1 2	
Berkheya echinacea							2 2	2	1	1 3 2	3 3 2 3 2	1
Acalypha angustata							1 1 1 1		2 1 1 1	1 3	1 1 1 1 3	1 2
Crassula vaginata					1		1	2		1 2	1 1 2 1 2 1	
Species group O												
Panicum natalense						1 1	3 4		1 1 1	2	5 3 3 3 5 5	1 1
Eriosema kraussii									1 1	2	4 1 1 1 1 5	1
Schistostephium crataegifolium	1			2		1 1	1 3 3		2 1	1 5	2 1 1 1	2
Alepidea longifolia	1			2			2 1 1		1	1	5 1 1 1	2 1
Syncolostemon concinnum							1 3 2		1		2 2 2 2 1	
Species group P												
Alloteropsis semialata								2 2 2 1	2 3 1 1 2 1	1 4	3 1 4 5	
Pelargonium luridum					1	1 2	1	4 3 3	1 3 1 2 3 2 2	2	1 1 2 1	
Acalypha caperonioides					1	1 1	1	2 3	4 3 1 3 1	4 3	2 1 1 2	2
Dicoma anomala							2	2 3	1 1 1 1	3 2 2	1 2 2 1	2
Wahlenbergia squamifolia	1							3 4 3	1 5	1 2 2	1 1	1
Species group Q												
Helichrysum pilosellum	1						2 1 1 1	2 4 5 2	5 4 4 3 3 4 2	1 2 4	1 3 2 2 1 5	1 1 2
Tristachya leucothrix					1		4 1 2	2 4 5 3	5 3 4 4 2 4 1	1 2 3	3 3 2 3 5 2	1 1
Vernonia natalensis	1			2	1 2	1 3 2	2 4 3 3	4 4	3 2 1 3 4 5 1	3 4 5	2 3 2 3 1 4	1 1
Andropogon schirensis						3 1	2 3 1	3 2 2 4 2	5 2 2 1	2 5 5	1 2 3 1 2 4	3 1
Helichrysum cephaloideum							1 1 2	3 2 3	4 3 2 2 2 4 1	1 3	3 2 3 1 2	2 1 2
Sebaea leiostyla						1 1 1	2 2 1	3 2	2 2 2 3 2 2 1	1 2 3	2 2 2 3 2	1 1 1
Helichrysum oreophilum				2			1 1	2 1	2 2 4	2 2 5	2 5 1 4 5	
Species group R												
Melinis repens				2	1 1	1 3 3 1 5 4	1 1		1		1 1 2	1 3 1 2
Spermacoce natalensis				2			2 1		2		2 3 1	2 3 4 1
Chamaechrista stricta						3 3 1	1				1 1 1	2 2 1
Acanthospermum australe						1 3	2				1 2 1	2 1
Paspalum scrobiculatum						2			1		2 1	1 2
Sporobolus pyramidalis				2		2					1 1	1 2
Dicoma zeyheri						2	1 3 2				1 1 1	1
Species group S												
Indigofera velutina						3 1	1		1		1 2 1 1 2 3	2 1 1
Pentanisia angustifolia						1 2	1 2 1		1 1 1 2	1	3 2 3 4 3 5	3 4 1
Tephrosia natalensis						1 2	1 1 1		1		1 1 2 2 1	2 3
Species group T												
Helichrysum aureonitens							2 1 1	2	5 5 4 3	1 4 5	3 4 3 3 1 1	2 5
Monocymbium ceresiiforme						1	1 3 1		5 5 5 1 1	5 4	3 4 5 3 4	2 1 2 1
Species group U												
Berkheya setifera	1				1	2 2	4 3 4 1	3 4 2 4 3	3 3 2 3 3 2 2	3 2 5	3 4 4 4 1 5	4 4 2 2
Trachypogon spicatus					1	1 2 3 3	2 5 5 3	3 3 5 3	5 3 1 2 2 2	4 5 4	5 5 5 4 5 5	2 4 2 4
Conyza obscura	1			4 2	1	1 5 1	4 3 3 2	2	1 1 2 1	1 2	1 1 2 3	3 3 2
Species group V												
Indigofera hedyantha					1	1 2 2	2		2	2	1 1	1
Anthericum fasciculatum									1	1	1	
Geigeria aspera										1		

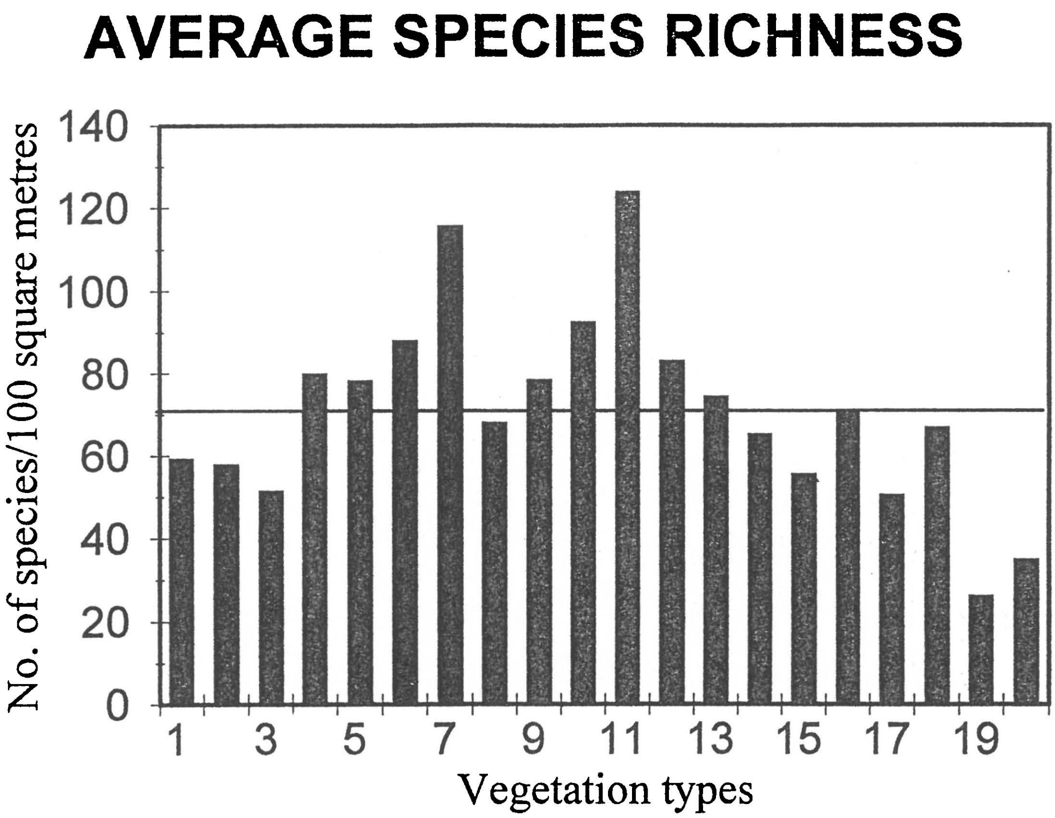
Species group J								
Rhus dentata	1	1 1	4 3	1				
Melinis nerviglumis	1 2 2		3	1		2		
Lippia javanica	1 1 2 2 1 2	4 2	2					
Athrixia phylicoides	1 1	2						
Pellaea calomelanos						2		
Cymbopogon validus	1				1			
Cheilanthes sp.		2						
Aloe marlothii		2		1				
Hippobromus pauciflorus								
Species group K								
Diospyros lycioides	1 3 2 2 1	4 2 1	4	2 2 1	1	1 1		
Maytenus heterophylla		4			1			
Species group L								
Leonotis ocymifolia	1	2	3					
Species group M								
Helictotrichon turgidulum	1 1 1			1	1	4 1 1 1	2	5
Helichrysum dasycephalum	2	1		1 1				
Andropogon appendiculatus	1			1 1		1 2	1	4
Sporobolus centrifugus								
Sutera sp.		1						
Rabdosiella calycina				1				
Solanum elaeagnifolium	1 2 1			2				
Sutera polelensis								
Harpochloa falx						1 1		
Helichrysum melanacme	1							
Crabbea acaulis	1			1 3 4 1 1				
Species group N								
Eulalia villosa	1 2 1							
Loudetia simplex	1 2 1 2							
Ctenium concinnum								
Berkheya echinacea	2 2 1 2 1 1							
Acalypha angustata	1	1	3					
Crassula vaginata								
Species group O								
Panicum natalense	1 1 2 2 2 1		3	1				
Eriosema kraussii								
Schistostephium crataegifolium			3	1				
Alepidea longifolia	1 1							
Syncolostemon concinnum	1 1 2							
Species group P								
Alloteropsis semialata	1							
Pelargonium luridum	1 1 1	1		1 2 1 1 1 2				
Acalypha caperonioides	1	1 1		1 3 1				
Dicoma anomala	1 2	1						
Wahlenbergia squamifolia								
Species group Q								
Helichrysum pilosellum	1 1 2 2	1		1		1		
Tristachya leucothrix	2 2	2 1 1	3	1 1 1				
Vernonia natalensis	2 2 2 1 1	1		1 2 1				
Andropogon schirensis	1 1 2	2 1		1		1		
Helichrysum cephaloideum	1 2 1	1 1		1				
Sebaea leiostyla	1 2 1 2 2 1			1 1				
Helichrysum oreophilum	1 1 1 2 1	1						
Species group R								
Melinis repens	1 2 3 1 5 4 4 1 1 3 2	4 1 5 5 3 5	2	1 4		1		
Spermacoce natalensis	2 4 1 1 1 3 2 2 1 4	2 1		1 1	2 1			
Chamaechrista stricta	1 1 1 3.4 4 1 4	3 4 5 4 2 1	2		2 4 1			
Acanthospermum australe	1 1 1 2 1 3 2 4 1 2	1 1 1						
Paspalum scrobiculatum	1 3 2 2 1 1	1 2 2 1		2 1	1 1	1	1	
Sporobolus pyramidalis	5 1 3 2 5 1	5 5 5 5						
Dicoma zeyheri	1 1 3 1 2	2 1 2						
Species group S								
Indigofera velutina	1 1 2 2 1 4 2 4 3	2 2 4 2 2 1		1 1				
Pentanisia angustifolia	2 1 3 2 5 3 2 4 4 3	2 3 2		1 1				
Tephrosia natalensis	1 2 2 2 1 2	2 4 1						
Species group T								
Helichrysum aureonitens	1 2 1 2 3 4 1 2	1 1 2 2	3	1	1 1	3		2
Monocymbium ceresiiforme	1 1 2 2 2 2 1 1	1 1 1		2				
Species group U								
Berkheya setifera	3 5 3 4 3 4 2 2 3 4	2 2 1 2	3	2				
Trachypogon spicatus	1 2 3 2 2 3	2 2 1 1		1 1 1				
Conyza obscura	3 4 2 4 3 5 3 2 2 4 3	3 2 5 3 2 2		1		2 1		
Species group V								
Indigofera hedyantha	1	1	4	2 3 1 2 3 1				
Anthericum fasciculatum			2 3	3 3 2 1				
Geigeria aspera				1 3 1 2 2				

Species												
Species group W												
Hermannia transvaalensis							1	2 2	1 1	1	1	
Hermannia depressa						2	2		1 1	2		1
Aristida bipartita					1	4 1 2 3	1	2	1 2 1	2		1 1
Species group X												
Aristida congesta					2	1 3 1 3	2		1	1	1 1	1 1
Cynodon dactylon						3			1 2		2	
Polygala hottentotta						2 1 1 2	1 1 1		1		1	2
Walafrida densiflora	1				1	2	1	3 2	2 1	2	1 1 1 2	1 1
Eragrostis gummiflua							1		1		1 1 2	1
Cucumis zeyheri					1		1 1 1 3		1 1		1 1	1
Abildgaardia ovata						1	1		1 1		1 1	1
Centella asiatica				2			1		2 1 1 1	1	1 1 2	2
Trichoneura grandiglumis						4					1	
Species group Y												
Chaetacanthus burchellii						1 1	1 1 2	4 3	1 2	2 3	2 3 2 2 3	3 3
Zornia capensis						2 1	1 1		1	1 2 2	2 1 3 2	2 1 2
Species group Z												
Hypoxis rigidula						1	2 1 3		2 2 1 4 1	1 2	2 2 1 2 5 5	4 3 1
Helichrysum coriaceum							1 2		1 1 1 1 2	1 2 2	1 1 1 2 1	1 1
Striga bilabiata						1 1	2	3	1 1 3	2 2	1	1 1
Species group AA												
Vernonia oligocephala								3 2 2	3 1 3 2 2 3		1 1 2	1 1
Microchloa caffra								5 2 1	1 3 4 5 2	1 3	1	1 1
Species group AB												
Anthospermum rigidum					1	1 1 1	1 3	3 4 3 1	1 4 4 3 4 2	3	2 3 1 2 3 1	2 3
Haplocarpha scaposa	1						2 1 1 1	4 5 3	4 3 2 2 3 2 3	1 2 5	2 2 2 2 1 1	1
Hypochoeris radicata	4 1					1	1 2	3 2 4 2 2	1 5 3 3 3 4 1	2 2	1 1 2 1	1 2
Felicia muricata					2	1 2	1 2	3 2 2	1 1 1 1 2	3 2	1 2 3	1 1 1
Elionurus muticus						1 1	1 1 3	4 5 2	3 3 3 4 2 3	1 4 2	2 1 4 1	3
Species group AC												
Heteropogon contortus	1				2 2	3 3 2 3	1 2 5	3 5 5 5 4	5 5 5 5 5 5 4	4 5 4	2 4 3 4 4 2	3 2 1 2
Themeda triandra	2			3	3 2	3 3 3 3 5 2	2 4 5 4	2 5 5 4	5 4 5 5 3 5 4	3 3 5	4 5 4 5 5 5	4 3 2 2
Helichrysum rugulosum				2	1 1	1 1 3 3	2 1 1 3	5 5 4 2	2 5 5 5 5 2 5	5 2 3	3 3 4 2 1	3 4 4 4
Eragrostis racemosa	1				1	2 1 2	2 3 3 4	4 3 5 2	5 5 5 5 5 4 5	3 5 5	1 5 5 4 5 5	4 4 3 1
Eragrostis capensis	1				1	1 1 1	1 1	3 4 4 5 5	5 5 5 5 5 2 3	2 2 3	1 2 3 3 3 2	2 4 2
Cymbopogon excavatus				2	2 2 3	3 5 4 4 4	1 4 4 4	3 2 5 1	4	4	1 2 2 2 1	4 5 2 2
Aristida junciformis					2	1 1 1 2	2 2 3	3 4 3 4 1	2 4 2 2 5 2 3	4 5	3 3 5 2 1	1 1 3 5
Helichrysum nudifolium				2	1	1 3 3	2 1 2	2 4 3	3 2 2 4 2 1	1 2 3	3 2 3 2 3	4 3 1
Scabiosa columbaria	1				1	1 1	1 2 4	3 4 2 5 1	1 1 1 3 5 2	3 4	2 1 2 1 2	2 2
Diheteropogon amplectens	1			2	1 1	3 4 3 1 2	2 5 5 3		1 1 2 1	2 2 3	5 4 4 3 2 3	3 3 1 1
Berkheya onopordifolia					1	1 1 1 2 3	1 5	3 2 1	3 2 3 2 3	4	1	1
Setaria sphacelata					2 1 3	3 1 5 3	1 2 1 1		1 1 1	1 2	2 2 1 2 3	3 2
Commelina africana	1 1		1	2 2	4 3	1 1 1 4	1 1 3	3 2 2 1	2 3 3 3 3 1	3 2	3	2 1
Conyza podocephala					1	2 1 1 2		3 4 2	1 3 1 2 3 4 1	2	1	1 1
Rhynchosia totta					2	1 2	1 1	5 2 4	1 1 2 2 1	2	1 2	
Monsonia angustifolia					1	1 1 2		2 2 1		1	1 1	1 1
Ipomoea ommaneyi					2 2	1 1 1	1 3	2		2 4	1 1 1 1	1 1
Species group AD												
Conyza brasiliensis												
Typha capensis												
Paspalum urvillei				2								
Species group AE												
Conyza albida												
Juncus inflexus												
Mariscus congestus												
Digitaria sanguinalis				2		2						
Fuirena pubescens												
Schizostylis coccinea								1				
Juncus punctorius												
Cyperus marginatus												
Gunnera perpensa								1				
Senecio affinis								1				
Cliffortia linearifolia	1							1	1		1	
Species group AF												
Arundinella nepalensis				2 2								
Hyparrhenia dregeana		3	2 2	4 4		1 1 2 3	5 1 1				1	1 1 1
Phragmites australis												
Andropogon eucomus							1					
Fimbristylis ferruginea												
Ischaemum fasciculatum								1				
Miscanthus junceus												
Hemarthria altissima												
Imperata cylindrica						1			1			
Species group AG												
Hyparrhenia hirta			2	2 3 3	1 2	4 4 5 4 2 4	5 5 5 5	3 2 3	1 2 2 4 5	5 4 4	1 5 5 4 2 4	5 5 5 3
Eragrostis curvula	2			2 2	5 5 5	4 5 4 4 4 5	3 4 4 4	5 5 5 5 4	2 5 5 5 5 5 5	5 4 4	1 4 3 5 4 1	4 5 3 4
Sporobolus africanus				3 2	3 1 3	3 2 2 3	2 1 2 3	2	5 1 4 4	3 2	2 2 2 1	3 4 5 2

Species group W																																													
Hermannia transvaalensis	1					2					3		2	2		2	2	2		2			3	3	1	2	1	2	1																
Hermannia depressa		1											4	3	2	5	1	1	1	2	3	1		2	5	4	1		2																
Aristida bipartita	1		1		1		2							3	2			1	1	4			3	4	2	4	4		2																
Species group X																																													
Aristida congesta	1	1	1	2		2		2	1		1	1	3	2	2	5	3	3	1	4	5	2	5	1	5	3		4	2									1							
Cynodon dactylon	2	1		2	1	2	2		1	1	3	1	2	1	4	2	2	4	1	2		1	3		1	2		5	3	2	1	1						1							
Polygala hottentotta	2	1	1	1	1	2	2			1				5	2	5	1	1			5	3	4	2	2	1	3		2										1						
Walafrida densiflora		2	1	2		4	5	5			1		2	2			2	2	1	2		1	3	2	3	3		4	1									1							
Eragrostis gummiflua	2			1	1	3	2	2			3	1	2	1		2	4	5		2		3	2	2	1			4	2		1								1						
Cucumis zeyheri	2	1		1	3	2		2			2	1		1		2	1	2		2	3		2	2	1			2	1																
Abildgaardia ovata	1	1		1	3				1		2	1		2	2	2	2	2				1		3	2		3	2	1																
Centella asiatica	1	1			2	2	2	5		1	2			2				1	1			1	3	2			1	2	3		1				1			2		1					2
Trichoneura grandiglumis	1					2	2		2		1	1	3			4	3	4				1	2		1	1		2	1																
Species group Y																																													
Chaetacanthus burchellii	2	2		2	4	2	2	4			1		2	4			2	1	1	4	3	1	4	2	3		2		1																
Zornia capensis	1	3	1		3	4	3	2	2		2		2	3	4	4	1	3	1						2	3	2	4	1																
Species group Z																																													
Hypoxis rigidula	1		1	1	3	2	2	4				1		2					1	2		1			2	1	2																		
Helichrysum coriaceum	1	2	2	1		2	2		1			1		1				1	1	2				1				2	1																
Striga bilabiata		1		2	3	2			1					2						2	5	1	2	3	3	2																			
Species group AA																																													
Vernonia oligocephala		1	1		2	2	2				1		2	2				1	1	2				2	1			2	1																
Microchloa caffra		1									2					4		2	2	2	3		3	1		2	2	2	3																
Species group AB																																													
Anthospermum rigidum	1	1	1	1	4	4	4		1		1	1		4			1	1	3	2	3	2	2	2	4	2	4	2	2																
Haplocarpha scaposa		2	1	1	2	2		4			3	1	2	4				1	1				3	2		2	3		1										2	1					
Hypochoeris radicata		3		1	2	4		5	1		2	2						1	1				2	2		1	1		3		1					4	2	2				1	1		5
Felicia muricata	1		2	1	3	3	3	2	3				2	2			1	1					2		5	2		2	2																
Elionurus muticus		1			2											2				2			3	3	1	3	4	2	1																
Species group AC																																													
Heteropogon contortus	1	1	3	1	3	2	4	4		1	3	1	3	3	5	5	3	4	3	2	3	4	4	3	5	4	4	4	3																
Themeda triandra	2	4	5	2	5	3	2	2	3	1	3	1	3	5	2	4	2		2	5	5	5	4	5	5	3	5		4							1					3				
Helichrysum rugulosum	3	3	5	4	3	4	5	5	3	2	3	2	5	2	2	4	3	4	5	4	5	5	4	4	4	3	3	4	4							1		1	1			1			
Eragrostis racemosa	3	2	4	2	5	4	5	4	5	1	3		2	4	2	4	1	3	3		5	4	3	4	5	2	3	4	2																
Eragrostis capensis	2	2	3	1	3	3	5	4	4	1	3		2	3		4	2	2	3		3	3	3	5	4	4	5	2	5		1														
Cymbopogon excavatus	3	3	5	4	5	5	5	4	5	5	5		5	5	4	5	3	2	2	4	5	1	3	2	5	5	4		2	2	1								1	1					
Aristida junciformis	1	1	3	1	1	4			1			2					1	3	3					2	2	1	1	2	3			1		1			2		1			1	1		
Helichrysum nudifolium	1			3	2	4	4	2	3		2		2	2			1	2	1		3	1	2	1			1	4			1														
Scabiosa columbaria	2	1	3		3		2		1		2		2	4				1	1	2	3			2	2	3	3	2	1							1									
Diheteropogon amplectens	1	1	1	2	4		2		4		1			3							3			2	1	1	3												2						
Berkheya onopordifolia		1	2		2	2	2	4	1		2	1		3			1	2	2	4	5	2	5	5	5	4	4	2	3	2									1	1					
Setaria sphacelata	1	1	2		5		2		1		2	2	2	2	2						5	2		3	1	2	3		2					1		2			2	1		1			
Commelina africana	1	1		1	1	2		2			2	1							1	2	5	2	3	2			1	4	2											1					
Conyza podocephala		2	2						2			1	2	1			1		1	2		1	3		2		1		1		1					2		2							
Rhynchosia totta				1	1	2								1						2		1		2	1	1	1																		
Monsonia angustifolia						2				1			2	1			1	2	1	4			4	1	2	5																			
Ipomoea ommaneyi			2						1												3	1		3	5				1																
Species group AD																																													
Conyza brasiliensis	1													1																4	2	2	2	2	1										
Typha capensis																														3	3	1	3	1	4								1		
Paspalum urvillei												1																			5	4	5	4	5			1		1					
Species group AE																																													
Conyza albida			1															1											1							4	4	3	3	4		1	1		
Juncus inflexus																															1					3		3	3	3					
Mariscus congestus																													1	5	1			1			2	2	4	3			1	2	
Digitaria sanguinalis				1																			2							2						1	2	1	2	1		1			2
Fuirena pubescens												1																		2	1					1		1	1	3			2		
Schizostylis coccinea																																				1	2	1	1	1					
Juncus punctorius																															1					2	3	2	2				1		
Cyperus marginatus																															1				1	1	2	1	1						
Gunnera perpensa																																				4	3		1						5
Senecio affinis																																				4	2	1					1		2
Cliffortia linearifolia																																				2	4	1							
Species group AF																																													
Arundinella nepalensis																													1	2	4	2	2	5	2	5	5	3	4	4			1		
Hyparrhenia dregeana		1	1	1					2	1			2								3									4	2	3	1	1	3	2	2	3	3	4					
Phragmites australis																														2	3	3	3	2	4		2	2	2	3	3				
Andropogon eucomus	1					2					2			1			1	1											1	5	3						2		4	2					
Fimbristylis ferruginea											1			1															1	5	4	4	1	2	1	2		3	5	3					
Ischaemum fasciculatum																															2	1	3	3	1	4	4	1	2	3					
Miscanthus junceus																															4	4	4	3	3	1	3	2	2	3					
Hemarthria altissima																														3	3	5	4	3	5				3	3					
Imperata cylindrica	1									2			1			1	1				1							1	5	5								5	5					
Species group AG																																													
Hyparrhenia hirta	4	5	5		5	5	5	5	5	5	5	4	5	5	5	5	4	5	5	5	5	5	5	5	5	5	4	5	5	5	4	2			1	1	2	3	5	4					
Eragrostis curvula	5	5	5	5	5	5	5	5	5	5	5	5	4	5	5	5	5	5	4	5	5	4	5	5	5	5	3	5	5	5	2	1			1	4	2	2	1	3		1			
Sporobolus africanus	4	4	3	4	3	4	3	4	4	5	5	4	5	3	4	4	4	3	2	2	3	1		1	1	2	2	2	2	2	3	1	2	3	5	3		1	1	2					

Species group AH												
Eragrostis planiculmis											1	
Panicum schinzii												
Stiburus alopecuroides									1		1	
Species group AI												
Paspalum dilatatum						1 2			1 1			1
Leersia hexandra												
Setaria pallide-fusca							1					1
Species group AJ												
Limosella grandiflora												
Wahlenbergia banksiana	1						2		1		1 1	1
Juncus dregeanus												
Agrostis barbuligera												
Kyllinga erecta									1			
Isolepis fluitans												
Prunella vulgaris	2											
Epilobium salignum												
Hypericum lalandii												
Species group AK												
Pycreus betschuanus												
Schoenoplectus corymbosus												
Pennisetum sphacelatum								2 2	1			
Persicaria serrulata												
Agrostis lachnantha												
Pseudognaphalium oligandrum												
Species group AL												
Eragrostis plana	1			3		1 1 4	2 1	5 4 4 4	1 5 5 5 5 4 3	3 4 3	2 2 2 1	3 1 4 1

Species group AH																																													
Eragrostis planiculmis																													1		1						2	1	3	3	5	4	3		2
Panicum schinzii																													1								3	2		1		2	2	5	2
Stiburus alopecuroides																																				3	3				3	1		3	
Species group AI																																													
Paspalum dilatatum	1	2								1	1	3		1				1				2		2			1	2	2	5	5	5	3	3	5	5	3	5	5	5	5	4	2	3	
Leersia hexandra																														2	4	3	3	3	5	2	4	3	2	2	3	1	3	3	
Setaria pallide-fusca																							2					2			1	1	1			2	2	3		1	3	3	2		
Species group AJ																																													
Limosella grandiflora																																													5
Wahlenbergia banksiana		1	1							1								1	1										1		1					3									5
Juncus dregeanus																																													4
Agrostis barbuligera																																													4
Kyllinga erecta											1																				2	3				1				1		1			4
Isolepis fluitans																																					2							5	4
Prunella vulgaris																																													4
Epilobium salignum																																													2
Hypericum lalandii																																													2
Species group AK																																													
Pycreus betschuanus																														2	3	2	1	1	1	2	2	2	1	1		1	1		2
Schoenoplectus corymbosus																														3		1		2	1	1	3	2	3	2		2	3	3	2
Pennisetum sphacelatum																															1	2			1		4	2	1	3	5	4	2		5
Persicaria serrulata																															1			1	1	1	3	2	1		3	1	4		4
Agrostis lachnantha																														4	2				2	3	3	2	4	4		1	3		5
Pseudognaphalium oligandrum											1																		1		1			1		1	2	3	1	2		4	3	3	4
Species group AL																																													
Eragrostis plana	2	4	3	2	4	2		4	3	3	4	4	3	4	2	2	2	2	3	4		2	5	5		3	4	4	5	5	4	3	3	4	4	5	3	4	3	4	5	5			5



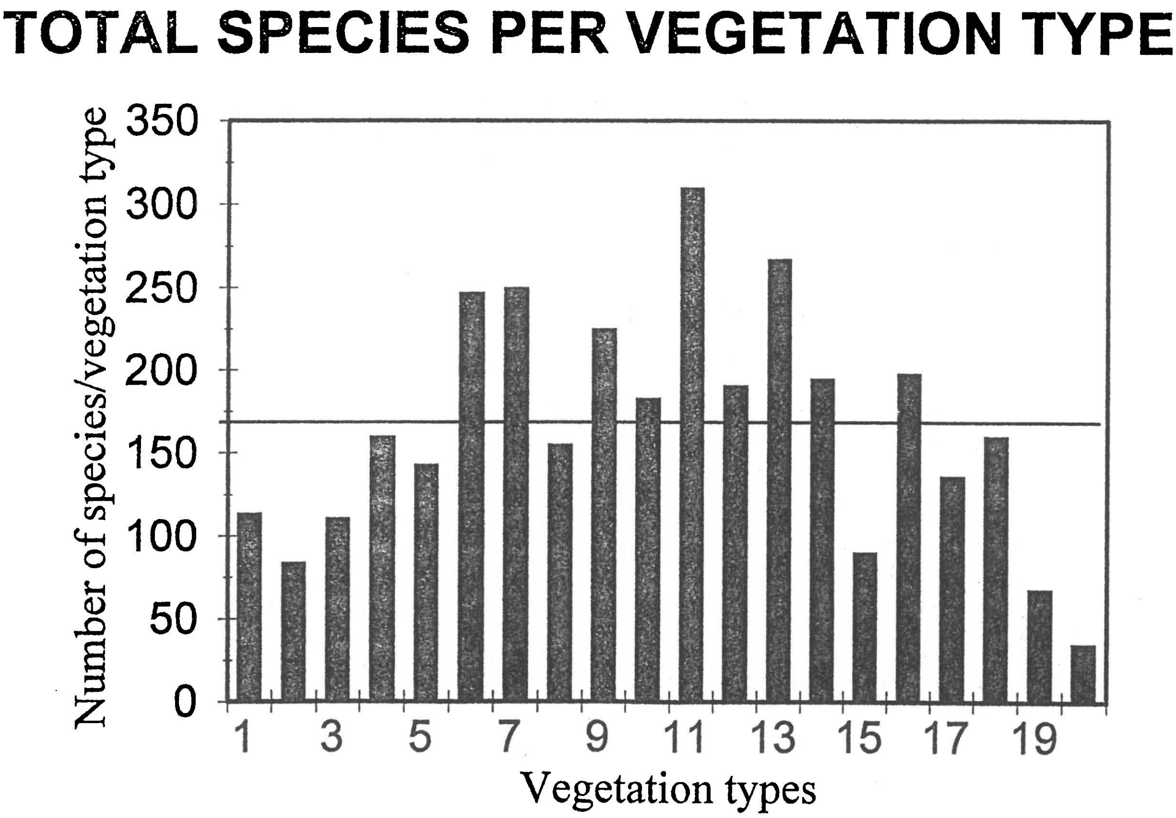


Figure 6 The average species richness and total number of species per vegetation type. The respective averages calculated from the values of all 20 vegetation types are indicated by horizontal lines.

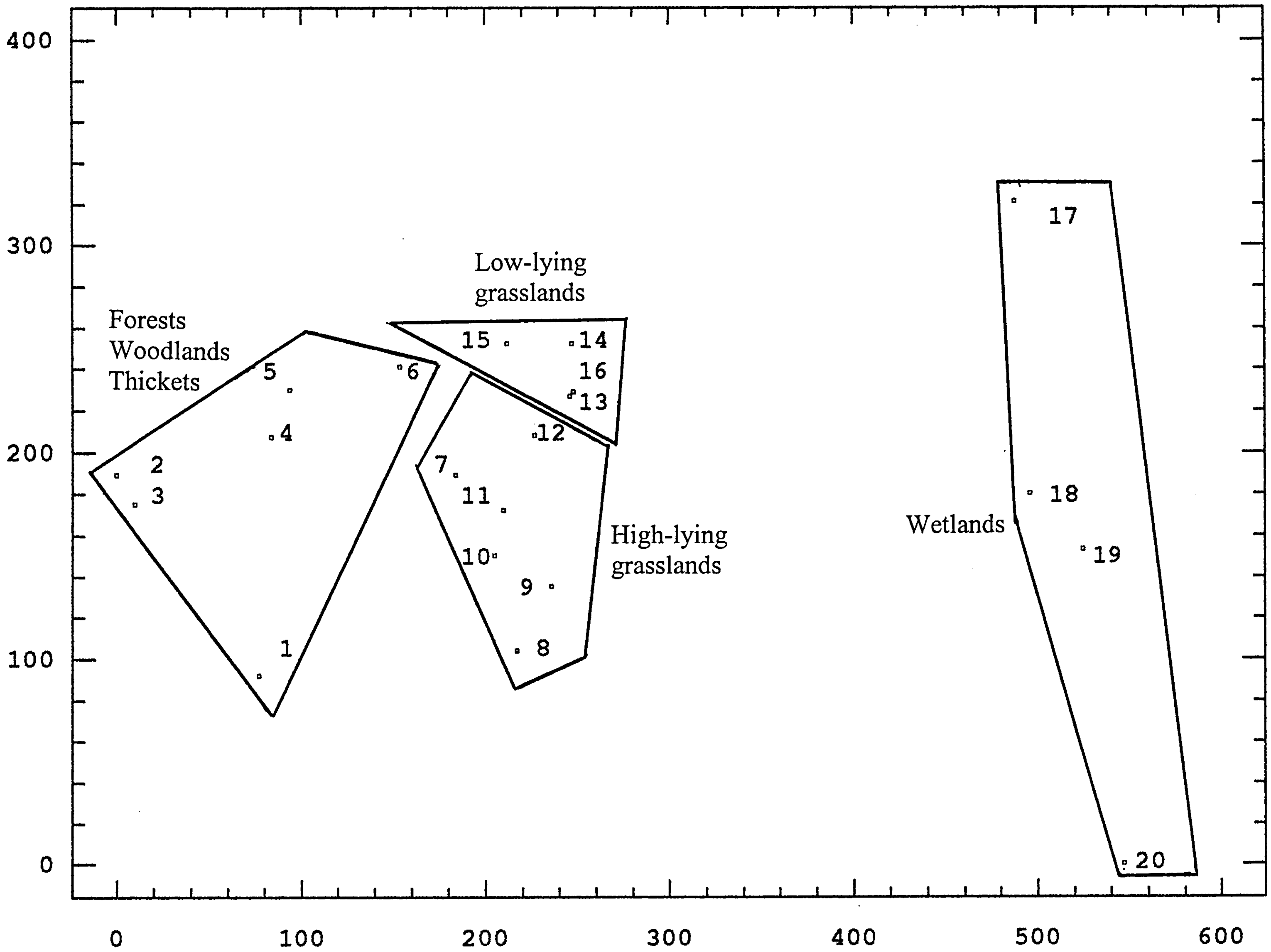


Figure 7 The distribution of synrelevés on a two-dimensional level, using the values of the first and second axis (Eigen values: axis 1 = 0.71, axis 2 = 0.21).

and a high rainfall, certain communities of these grasslands may sometimes be found at elevations below 1 500 m. The low-lying grasslands are mostly encountered at altitudes below 1 500 m with a concomittant low rainfall. The wetlands include springs, vlei-areas, pans, rivers and streams and may be found throughout the study area. The four major vegetation types are as follows:

1. *Euclea crispa-Diospyros lycioides* Forest/Woodland/Thicket
2. *Helichrysum pilosellum-Trachypogon spicatus* Low/Short Closed Grassland/Low Thicket
3. *Aristida congesta* ssp. *barbicollis-Hyparrhenia hirta* Short/Tall Closed Grassland/Low Open/Closed Woodland
4. *Agrostis lachnantha-Eragrostis plana* Wetland

The four major vegetation types are represented by 20 vegetation types (numbers between brackets). The hierarchical classification of the vegetation of northern KwaZulu-Natal is presented in Table 2.

Description of the vegetation types

1. *Euclea crispa-Diospyros lycioides* Forest/Woodland/Thicket

In principal, this major vegetation type represents all the communities dominated by woody species within the northern KwaZulu-Natal grasslands. This includes forests, primarily restricted to high altitudes (1 000- 2 200 m), and woodlands and thickets, occurring at moderate to low altitudes (<1 650 m). These woody communities are largely restricted to steep (20° - 90°) slopes, with surface rocks mostly covering more than 20% of the area. The predominant soils are of the Glenrosa-Mispah complex, being 200-300 mm deep and relatively low (15-20%) in clay content.

The diagnostic species for this major vegetation type are the trees and climbers listed under species group I (Table 1).

This major vegetation type has an average species richness of 69 species per community, which is the second highest value of the four major vegetation types described in this paper,

Table 2 Hierarchical classification of the vegetation of northern KwaZulu-Natal.

1. *Euclea crispa-Diospyros lycioides* Forest/Woodland/Thicket
    - 1.1 *Leucosidea sericea-Poa annua* Low to Tall Forest/Short Closed Woodland/Short Thicket
        - 1.1.1 *Stachys kuntzei-Rhus pyroides* Low to Tall Forest/Short Closed Woodland (1)
        - 1.1.2 *Allophylus africanus-Dais cotinifolia* Low to Tall Forest (2)
        - 1.1.3 *Greya sutherlandii-Cussonia spicata* Low to Tall Forest (3)
        - 1.1.4 *Clerodendrum glabrum-Hyparrhenia hirta* Short Forest/Short Thicket (4)
    - 1.2 *Acacia karroo-Eragrostis curvula* Low to Short Closed Woodland/Low Thicket
        - 1.2.1 *Acacia caffra-Rhus pentheri* Low to Short Closed Woodland (5)
        - 1.2.2 *Diospyros lycioides-Eragrostis curvula* Low to Short Closed Woodland/Low Thicket (6)
2. *Helichrysum pilosellum-Trachypogon spicatus* Low to High Closed Grassland/Low Thicket
    - 2.1 *Diospyros lycioides-Cymbopogon validus* Tall/High Closed Grassland/Low Thicket (7)
    - 2.2 *Helichrysum dasycephalum-Heteropogon contortus* Short/Tall Closed Grassland/Tall/High Open/Closed Shrubland
        - 2.2.1 *Leucosidea sericea-Aristida junciformis* Tall/High Open/Closed Shrubland (8)
        - 2.2.2 *Helichrysum rugulosum-Tristachya leucothrix* Short/Tall Closed Grassland (9)
    - 2.3 *Loudetia simplex-Trachypogon spicatus* Short/Tall Closed Grassland
        - 2.3.1 *Vernonia natalensis-Trachypogon spicatus* Short/Tall Closed Grassland (10)
        - 2.3.2 *Berkheya echinacea-Panicum natalense* Short/Tall Closed Grassland (11)
    - 2.4 *Berkheya setifera-Hyparrhenia hirta* Short/Tall Closed Grassland (12)
3. *Aristida congesta* ssp. *barbicollis-Hyparrhenia hirta* Short/Tall Closed Grassland/Low Thicket
    - 3.1 *Conyza obscura-Sporobolus africanus* Short/Tall Closed Grassland (13)
    - 3.2 *Hermannia depressa-Aristida bipartita* Short/Tall Closed Grassland/Low Thicket
        - 3.2.1 *Melinis repens-Cymbopogon excavatus* Short/Tall Closed Grassland/Low Thicket (14)
        - 3.2.2 *Acacia karroo-Themeda triandra* Low Thicket (15)
        - 3.2.3 *Indigofera hedyantha-Elionurus muticus* Short/Tall Closed Grassland (16)
4. *Agrostis lachnantha-Eragrostis plana* Wetland
    - 4.1 *Schoenoplectus corymbosus-Paspalum dilatatum* Wetland
        - 4.1.1 *Fimbristylis ferruginea-Arundinella nepalensis* Wetland
            - 4.1.1.1 *Paspalum urvillei-Hemarthria altissima* Wetland (17)
            - 4.1.1.2 *Conyza albida-Ischaemum fasciculatum* Wetland (18)
        - 4.1.2 *Eragrostis planiculmis-Pennisetum sphacelatum* Wetland (19)
    - 4.2 *Limosella grandiflora-Agrostis lachnantha* Wetland (20)

and an average total number of 143 species per vegetation type, which is the third highest value (Table 3).
A total of 21 plant communities were distinguished under this major vegetation type and were described by Eckhardt *et al.* (1997).

1.1 *Leucosidea sericea-Poa annua* Low to Tall Forest/Short Closed Woodland/Short Thicket

This syntaxon represents forests, woodlands and thickets and represents the *Leucosideetalia sericeae* described by Eckhardt *et al.* (1997). The diagnostic species for this syntaxon include trees, pteridophytes, a forb and a climber listed under species group D (Table 1). The presence of the pteridophytes in particular suggests moist and shady conditions.

It seems that this syntaxon resembles the *Poa annua-Leucosidea sericea* Woodland of the north-eastern Orange Free State (Eckhardt *et al.* 1993a) and most probably falls under the *Scolopietea mundii* described by Du Preez *et al.* (1991).

Four vegetation types are distinguished under this syntaxon:

1.1.1 Vegetation type 1: *Stachys kuntzei-Rhus pyroides* Low to Tall Forest/Short Closed Woodland

This vegetation type represents the *Stachyo kuntzei-Leucosidion sericeae* (Eckhardt *et al.* 1997) and is a transition from precursor forest or woodland to initial forest types. It is found at altitudes exceeding 1 800 m, being primarily restricted to the Highland Sourveld to *Cymbopogon-Themeda* Veld Transition (56) and North-eastern Sandy Highveld (57) (Acocks 1953, 1988) (Figure 2) of the Belelasberg-Skurweberg Plateau (Figure 4). This vegetation type occurs on 20°- 45° slopes with a predominant southerly aspect. The soils are less than 200 mm deep and have a clay content varying from 15-20%. Surface rocks cover 2-20% of the area.
The diagnostic species for this vegetation type are included in species group A (Table 1).

Table 3 The species richness, expressed as the average of the total number of species of all communities (synrelevés), and the total number of species of each vegetation type.

Vegetation type	Species richness	Total number of species
1	59	114
2	58	84
3	52	111
4	80	160
5	78	143
6	88	247
Average	**69**	**143**
7	116	250
8	68	155
9	79	225
10	93	183
11	124	310
12	83	191
Average	**94**	**219**
13	74	267
14	65	195
15	56	90
16	71	198
Average	**67**	**188**
17	51	136
18	67	160
19	26	68
20	35	35
Average	**45**	**100**
Total average	**71**	**166**
p-value	**0.0035**	**0.0363**

The average number of species per community is 59 (Figure 6a), with the total number of species for this vegetation type being 114 (Figure 6b), both values being far below their respective averages.

The following three plant communities are classified under this vegetation type (Eckhardt *et al.* 1997):

1. *Helichryso hypoleuci-Leucosideetum sericeae solanetosum retroflexum*
2. *Helichryso hypoleuci-Leucosideetum sericeae stachyetosum kuntzei*
3. *Rhamno prinoidis-Podocarpetum latifolii*

1.1.2 Vegetation type 2: *Allophylus africanus-Dais cotinifolia* Low to Tall Forest

This vegetation type represents low to tall tropical forest types, being primarily restricted to south-facing slopes (20°- 90°) of the North-eastern Mountain Sourveld (8) (Acocks 1953, 1988) (Figure 2) which are characterized by moist cool conditions. The altitudinal range varies from 1 300-1 500 m. The Glenrosa-Mispah complex is the predominant soil form, being less than 200 mm deep and containing less than 15% clay. Surface rocks generally cover more than 20% of the area.

Diagnostic species are included in species group B (Table 1). The tall grass *Hyparrhenia cymbaria* is mostly found on the margins of forests.

The average number of species recorded per community was 58 (Figure 6a), the total number for this vegetation type being 84 (Figure 6b), which is only half the average.

The following two plant communities are classified under this vegetation type (Eckhardt *et al.* 1997):

1. *Plectrantho grallati-Dalbergietum obovatae*
2. *Plectrantho fruticosi-Trimerietum grandifoliae*

1.1.3 Vegetation type 3: *Greya sutherlandii-Cussonia spicata* Low to Tall Forest

This vegetation type represents low to tall forest types found on moderate to steep (25°- 90°) slopes in the Northern Tall Grassveld (64) (Acocks 1953, 1988) (Figure 2) at altitudes ranging from 1 200-1 600 m. The slopes are facing into all possible directions. The predominant soil types are the Glenrosa-Mispah complex, being less than 200 mm deep and containing less than 15% clay. More than 20% of the surface area is covered by rocks.
No diagnostic species were recognized for this vegetation type (Table 1). However, species with a constancy value of more than 40% include *Greya sutherlandii, Canthium mundianum, Heteromorpha trifoliata, Cussonia spicata* and *Euclea crispa* (Table 1).
A low species richness of only 52 species per community was recorded (Figure 6a), with the total number of species for this vegetation type being 111 (Figure 6b).

The four plant communities representing this vegetation type, are the following (Eckhardt *et al.* 1997):

1. *Plectrantho grallati-Canthietum mundianum*
2. *Combreto kraussianae-Greyietum sutherlandii*
3. *Rapano melanophloei-Greyietum sutherlandii*
4. *Clauseno anisatae-Greyietum sutherlandii*

1.1.4 Vegetation type 4: *Clerodendrum glabrum-Hyparrhenia hirta* Short Forest/Short Thicket

This vegetation type represents temperate short forests at altitudes of 1 400-1 650 m in the Southern Tall Grassveld (65) (Acocks 1953, 1988) and short closed thicket or isolated bushclumps at altitudes of 1 000-1 650 m in the Northern Tall Grassveld (64) (Acocks 1953, 1988) (Figure 2). The steepness of the slopes varies from 30°- 90°, facing mainly into a northerly direction. The Glenrosa-Mispah complex soils are generally encountered, being 200-500 mm deep and containing 15-25% clay. Surface rocks usually cover more than 20% of the area.

No diagnostic species were identified within this vegetation type (Table 1). Species with a constancy value of more than 40% include *Greya sutherlandii, Cussonia spicata, Clerodendrum glabrum, Euclea crispa, Rhoicissus tridentata* and *Diospyros lycioides* (Table 1).
An above-average species richness of 80 species per community was recorded (Figure 6a), with the total number of species for this vegetation type being slightly below the average (160) (Figure 6b).

The three plant communities classified under this vegetation type, include (Eckhardt *et al.* 1997):

1. *Buddlejo salviifoliae-Podocarpetum latifolii*
2. *Hyparrhenio dregeanae-Dombeyetum rotundifoliae*
3. *Hyparrhenio cymbariae-Diospyretum lycioidis*

1.2 *Acacia karroo-Eragrostis curvula* Low to Short Closed Woodland/Low Thicket

This syntaxon represents woodlands and thickets and represents the *Acacietalia karroo* described by Eckhardt *et al.* (1997). The diagnostic species are listed under species group G (Table 1), being clear indicators of relatively warm and dry conditions.

This syntaxon shows close resemblance to the *Acacia karroo* riparian thicket of the Orange Free State described by Du Preez *et al.* (1991).
Two vegetation types are distinguished under this syntaxon:

1.2.1 Vegetation type 5: *Acacia caffra-Rhus pentheri* Low to Short Closed Woodland

This vegetation type occurs at altitudes ranging from 1 100-1 500 m and is primarily associated with the Valley Bushveld (23) (Acocks 1953, 1988) (Figure 2), which has a very patchy distribution. The Glenrosa Form is the predominant soil type, being 200-300 mm deep and containing 15-20% clay. The steepness of the slopes varies from 8°- 30°, with the latter facing into all possible directions. Surface rocks may cover from 2% to more than 20% of the area.

The diagnostic species are listed under species group E (Table 1).

An average number of 78 species was recorded per community (Figure 6a), the total number of species for this vegetation type being 143 (Figure 6b).

The three plant communities classified under this vegetation type, are the following (Eckhardt *et al.* 1997):

1. *Panico maximi-Clerodendretum glabrum*
2. *Aloo maculatae-Rhoetum pentherii*
3. *Stipo dregeanae-Rhoetum pyroidis*

1.2.2 Vegetation type 6: *Diospyros lycioides-Eragrostis curvula* Low to Short Closed Woodland/Low Thicket

This vegetation type is primarily associated with Valley Bushveld (23) and Northern Tall Grassveld (64) (Acocks 1953, 1988) (Figure 2) at an altitudinal range of 1 100-1 500 m, displaying the widest distribution of all woody vegetation types. The Glenrosa-Mispah complex is the predominant soil type, being 200-300 mm deep and the clay content varying from 15-20%. The steepness of the slopes varies from 8°-30°. Surface rocks generally cover more than 20% of the area.

No diagnostic species were identified within this vegetation type (Table 1). Species with a constancy value exceeding 40% are *Euclea crispa, Rhoicissus tridentata, Rhus dentata, Diospyros lycioides* and *Eragrostis curvula* (Table 1).

This woodland/thicket has the highest species richness (88) (Figure 6a) and total number of species (247) (Figure 6b) of all vegetation types classified under this major vegetation type.

The following six plant communities are classified under this vegetation type (Eckhardt *et al.* 1997):

1. *Rhoo pentherii-Acacietum caffrae*
2. *Trichoneuro grandiglumis-Canthietum mundianum*
3. *Conyzo bonariensis-Cymbopogonetum validi*
4. *Cymbopogono validi-Acacietum karroo*
5. *Brachiario eruciformis-Acacietum karroo themedetosum triandrae*
6. *Brachiario eruciformis-Acacietum karroo bothriochloetosum insculptae*

2. *Helichrysum pilosellum-Trachypogon spicatus* Low to High Closed Grassland/Low Thicket

This major vegetation type broadly represents the grasslands of high (>1 200 m) altitudes, although it is primarily found at altitudes exceeding 1 500 m. It includes the *Alepidea longifolia-Monocymbium ceresiiforme* Grassland (Eckhardt *et al.* 1996c), the *Helichrysum pilosellum-Heteropogon contortus* Grassland (Eckhardt *et al.* 1996e) and the high-lying parts of the *Panicum natalense-Eragrostis curvula* Grassland (Eckhardt *et al.* 1996d). This major vegetation type shows a close affinity with the *Tristachya leucothrix-Trachypogon spicatus* grassland of moist mountain slopes and plateaux of the Orange Free State described by Du Preez *et al.* (1991). It is a typical low to short grassland, being often found invaded by *Leucosidea sericea* shrubs and trees at relatively high altitudes and under mismanagement conditions. Therefore, low thickets are encountered within these high-lying grasslands, originating from adjacent sheltered areas. The diagnostic species include grasses and forbs listed under species group Q (Table 1).

This major vegetation type displays the highest average species richness (94) and average total number of species (219) of all major vegetation types dealt with in this paper (Table 3).

Altogether 29 plant communities, classified under six vegetation types, were distinguished under this major vegetation type.

2.1 Vegetation type 7: *Diospyros lycioides-Cymbopogon validus* Tall/High Closed Grassland/Low Thicket

This vegetation type occurs at altitudes of 1 200-1 700 m, being mainly associated with rocky outcrops and 5°-45° slopes, facing mainly northerly. The predominant soils are of the Glenrosa-Mispah complex, being less than 200 mm deep and containing 15-20% clay. Surface rocks usually cover more than 20% of the area.

No diagnostic species are recognized under this vegetation type (Table 1). Species with a constancy value of more than 40% are *Eulalia villosa, Hyparrhenia hirta* and *Eragrostis curvula* (Table 1). Noteworthy is the relatively strong presence of woody species, suggesting a close affinity between this vegetation type and the *Euclea crispa-Diospyros lycioides* major vegetation type.

This vegetation type has the second highest species richness (116) (Figure 6a) and third highest total number of species (250) (Figure 6b) of all vegetation types described in this paper.

The following four plant communities are classified under this vegetation type (Eckhardt *et al.* 1996c):

1. *Hyparrhenio dregeanae-Hyparrhenietum hirtae*
2. *Digitario diagonalis-Trachypogonetum spicati athrixietosum phylicoidis*
3. *Digitario diagonalis-Trachypogonetum spicati loudetietosum simplicis*
4. *Berkheyo onopordifoliae-Diospyretum lycioidis hyparrhenietosum hirtae*

2.2 *Helichrysum dasycephalum-Heteropogon contortus* Short/Tall Closed Grassland/Tall/High Open/Closed Shrubland

This syntaxon represents the *Helichrysum pilosellum-Heteropogon contortus* Grassland described by Eckhardt *et al.* (1996e) and closely resembles the *Monocymbium ceresiiforme-Tristachya leucothrix* Grassland of the north-eastern Orange Free State described by Eckhardt *et al.* (1993b). It is primarily restricted to altitudes exceeding 1 500 m. Areas which were subjected to mismanagement, are invaded by *Leucosidea sericea*, changing the grassland to shrubland.

The diagnostic species which characterize this syntaxon are included in species group M (Table 1).

Two vegetation types are recognized under this syntaxon:

2.2.1 Vegetation type 8: *Leucosidea sericea-Aristida junciformis* Tall/High Open/Closed Shrubland

This vegetation type represents the *Leucosideo sericeae-Eragrostietum curvulae* described by Eckhardt *et al.* (1996e) and is generally associated with the North-eastern Sandy Highveld (57) (Acocks 1953, 1988) (Figure 2) in the area around Groenvlei, at altitudes exceeding 1 700 m. Although this vegetation type is mainly found on slopes (20°-45°), with a predominant southerly aspect, it may also occur on mountain plateaux and rocky outcrops. The Glenrosa Form constitutes the major part of the soils, being less than 300 mm deep and containing less than 20% clay. Surface rocks usually cover more than 20% of the area.

This vegetation type consists of a well-developed grass layer which has been invaded to varying degrees by *Leucosidea sericea* shrubs. The imbalance between the woody and the herbaceous component has mainly been caused by overutilization of the grass layer and wrong burning practices (Edwards 1967). Although no diagnostic species were identified within this vegetation type, most prominent species, displaying a constancy value of more than 40%, include *Heteropogon contortus, Eragrostis capensis* and *E. curvula* (Table 1).

This vegetation type has the lowest species richness (68) (Figure 6a) and total number of species (155) (Figure 6b) of all the vegetation types constituting the high-lying *Helichrysum pilosellum-Trachypogon spicatus* major vegetation type.

The following six plant communities are classified under this vegetation type (Eckhardt *et al.* 1996e):

1. *Leucosideo sericeae-Eragrostietosum curvulo-planae*

2. *Leucosideo sericeae-Eragrostietum curvulae rhoetosum discolor*
3. *Leucosideo sericeae-Eragrostietum curvulae cheilanthetosum quadripinnatae*
4. *Leucosideo sericeae-Eragrostietum curvulae helichrysetosum hypoleucum*
5. *Leucosideo sericeae-Eragrostietum curvulae tristachyetosum leucothricis*
6. *Leucosideo sericeae-Eragrostietosum curvulo-caesiae*

2.2.2 Vegetation type 9: *Helichrysum rugulosum-Tristachya leucothrix* Short/Tall Closed Grassland

This vegetation type represents plant communities which occur predominantly at altitudes exceeding 1 500 m, with one community restricted to altitudes below 1 500 m. The high-lying plant communities are primarily associated with the North-eastern Sandy Highveld (57) (Acocks 1953, 1988) (Figure 2). Various types of soils are encountered, the depths of which vary from 200 to more than 500 mm and the clay percentages from 15-35%. Surface rocks may be present but occur widely scattered.

No diagnostic species were identified which characterize this vegetation type (Table 1). However, this vegetation type is distinguished from the *Leucosidea sericea-Aristida junciformis* Shrubland by the absence of species group L and the species *Leucosidea sericea* and the presence of species groups T and Z (Table 1). Species with a constancy value of more than 40% include *Heteropogon contortus, Themeda triandra* and *Eragrostis racemosa* (Table 1).

The average number of species recorded per community is 79 (Figure 6a), the total number of species for this vegetation type being 225 (Figure 6b).

The six plant communities classified under this vegetation type, are the following (Eckhardt *et al.* 1996e):

1. *Monocymbio ceresiiformis-Themedetum triandrae trachypogonetosum spicati*
2. *Monocymbio ceresiiformis-Themedetum triandrae sporoboletosum africani*
3. *Monocymbio ceresiiformis-Themedetum triandrae eragrostietosum planae*
4. *Microchloa caffra-Themeda triandra* Grassland

5. *Microchloa caffra-Aristida junciformis* Grassland
6. *Hyparrhenio hirtae-Eragrostietum curvulae*

2.3 *Loudetia simplex-Trachypogon spicatus* Short/Tall Closed Grassland

This syntaxon represents plant communities which are classified under the *Alepidea longifolia-Monocymbium ceresiiforme* Grassland (Eckhardt *et al.* 1996c) and the *Panicum natalense-Eragrostis curvula* Grassland (Eckhardt *et al.* 1996d). These communities generally occur at altitudes exceeding 1 200 m, but mostly, however, exceeding 1 500 m.
The diagnostic species which characterize this syntaxon are listed under species group N (Table 1).

Two vegetation types are recognized under this syntaxon:

2.3.1 Vegetation type 10: *Vernonia natalensis-Trachypogon spicatus* Short/Tall Closed Grassland

This vegetation type is primarily restricted to altitudes exceeding 1 500 m, occurring on plateaux and slopes of the Belelasberg-Skurweberg Plateau (Figure 4). The slopes are 25°-35° steep, facing into various directions. The predominant soils belong to the Glenrosa-Mispah complex, being less than 300 mm deep and containing less than 20% clay. Surface rocks usually cover more than 20% of the area.
No diagnostic species were identified, but species with a constancy value of more than 40% include *Vernonia natalensis, Trachypogon spicatus, Heteropogon contortus, Themeda triandra, Eragrostis racemosa, E. curvula, E. plana* and *Hyparrhenia hirta* (Table 1). The shrub *Diospyros lycioides* is often associated with this vegetation type, occurring widely scattered on the slopes.
An average number of 93 species was recorded per community (Figure 6a), with the total number of species for this vegetation type being 183 (Figure 6b).

The following three plant communities are classified under this vegetation type (Eckhardt *et* *al.* 1996c, 1996d):

1. *Berkheyo onopordifoliae-Diospyretum lycioidis acalyphetosum caperonioidis*
2. *Sporobolo centrifugi-Alloteropsidetum semialatae*
3. *Melino nerviglumis-Heteropogonetum contorti*

2.3.2 Vegetation type 11: *Berkheya echinacea-Panicum natalense* Short/Tall Closed Grassland

This vegetation type is found at altitudes of 1 200 m and higher, occurring on plateaux, midslopes and rocky outcrops within the Northern Tall Grassveld (64) (Acocks 1953, 1988) (Figure 2). Various soil types are encountered, the depths of which may vary from 200 to more than 500 mm and the clay contents from 15-25%. Where surface rocks are present, these may cover up to more than 20% of the area.

The diagnostic species of this vegetation type are listed under species group O (Table 1). This grassland is further distinguished from vegetation type 10 by the presence of species group S (Table 1).

This vegetation type has the highest species richness (124) (Figure 6a) and total number of species (310) (Figure 6b) of all vegetation types identified and described within the study area of northern KwaZulu-Natal.

The following six plant communities are recognized under this vegetation type (Eckhardt *et al.* 1996c, 1996d):

1. *Alepideo longifoliae-Eulalietum villosae*
2. *Helichryso oreophili-Themedetum triandrae*
3. *Monocymbio ceresiiformis-Aristidetum junciformis*
4. *Hyparrhenia hirta-Aristida junciformis* Grassland
5. *Panico natalensis-Loudetietum simplicis urelytretosum agropyroidis*
6. *Panico natalensis-Loudetietum simplicis eriosemetosum kraussianae*

2.4 Vegetation type 12: *Berkheya setifera-Hyparrhenia hirta* Short/Tall Closed Grassland

This vegetation type occurs on plateaux and midslopes at altitudes varying from 1 000-1 800 m, being generally associated with the Northern Tall Grassveld (64) (Acocks 1953, 1988) (Figure 2). Various types of soils are encountered, being 200 to more than 500 mm deep and containing 15-30% clay. Surface rocks predominantly cover less than 5% of the area, although a cover percentage of more than 20% may be reached at some places.

No diagnostic species were identified within this vegetation type (Table 1). Species with a constancy value of more than 40% include *Helichrysum rugulosum, Hyparrhenia hirta* and *Eragrostis curvula* (Table 1).

The average number of species recorded per community was 83 (Figure 6a), with the total number of species for this vegetation type being 191 (Figure 6b).

The four plant communities classified under this vegetation type include the following (Eckhardt *et al.* 1996c, 1996d):

1. *Helichrysum nudifolium-Hyparrhenia hirta* Grassland
2. *Cymbopogon excavatus-Hyparrhenia hirta* Grassland
3. *Helichrysum aureonitens-Eulalia villosa* Grassland
4. *Aristida junciformis* Grassland

3. *Aristida congesta* ssp. *barbicollis-Hyparrhenia hirta* Short/Tall Closed Grassland/Low Thicket

This major vegetation type represents the low-lying grasslands, occurring at altitudes between 750-1 500 m, with low thickets often encountered on specific habitat types. The distribution of this major vegetation type corresponds primarily with the Southern Tall Grassveld (65) and the Natal Sour Sandveld (66) (Acocks 1953, 1988) (Figure 2), although it may also be found in lower-lying areas of the Northern Tall Grassveld (64). Due to a lower annual rainfall and higher prevailing temperatures, drought conditions may sometimes be experienced, and together with overgrazing conditions, often results in this grassland being dominated by annual pioneer species.

The diagnostic species which characterize this major vegetation type are included in species group X (Table 1).

This major vegetation type has the third highest average species richness (67) and the second highest average total number of species (188) of all four major vegetation types described in this paper (Table 3).

A total of 29 plant communities, classified under four vegetation types, were distinguished under this major vegetation type.

3.1 Vegetation type 13: *Conyza obscura-Sporobolus africanus* Short/Tall Closed Grassland

This vegetation type is primarily restricted to midslopes at altitudes ranging from 900-1 500 m, although it may sometimes be found at altitudes reaching 1 800 m. Various types of soils are encountered, the depth of which may vary from 200 to more than 500 mm and the clay content from 15-35%. Surface rocks are mostly absent, but may sometimes cover as much as 5-20% of the area.

No diagnostic species were identified within this vegetation type (Table 1). However, the most prominent species with a constancy value of more than 40% include *Eragrostis curvula* and *Sporobolus africanus*, whereas other also relatively prominent species include *Helichrysum rugulosum, Cymbopogon excavatus* and *Hyparrhenia hirta* (Table 1).

This vegetation type displays the highest species richness (74) (Figure 6a) within this major vegetation type and the second highest total number of species (267) (Figure 6b) of all vegetation types described in this paper.

The following twelve plant communities are recognized under this vegetation type (Eckhardt *et al.* 1996a, 1996c, 1996d):

1. *Sporobolo pyramidalis-Hyparrhenietum hirtae*

2. *Spermacoce natalensis-Eragrostis plana* Grassland
3. *Helichrysum rugulosum-Hyparrhenia hirta* Grassland
4. *Hyparrhenio filipendulae-Sporoboletum africani*
5. *Setario sphacelatae-Eragrostietum planae*
6. *Walafrido densiflorae-Hyparrhenietum hirtae cymbopogonetosum excavati*
7. *Walafrido densiflorae-Hyparrhenietum hirtae heteropogonetosum contorti*
8. *Walafrido densiflorae-Hyparrhenietum hirtae hypochoeretosum radicatae*
9. *Indigofera velutina-Hyparrhenia hirta* Grassland
10. *Cymbopogon excavatus-Eragrostis curvula* Grassland
11. *Sporoboletum pyramidali-africani berkheyetosum setiferae*
12. *Eragrostis plana-Sporobolus africanus* Grassland

3.2 *Hermannia depressa-Aristida bipartita* Short/Tall Closed Grassland/Low Thicket

This syntaxon represents short/tall closed grassland and low thickets at altitudes of 750-1 500 m. Plant communities of the thickets (Eckhardt *et al.* 1997), of the *Panicum natalense-Eragrostis curvula* Grassland (Eckhardt *et al.* 1996d) and of the *Helichrysum rugulosum-Hyparrhenia hirta* Grassland (Eckhardt *et al.* 1996a) are included under this syntaxon.
The diagnostic species which characterize this syntaxon are included in species group W (Table 1).

Three vegetation types are classified under this syntaxon:

3.2.1 Vegetation type 14: *Melinis repens-Cymbopogon excavatus* Short/Tall Closed Grassland/Low Thicket

This vegetation type occurs predominantly at altitudes of 800-1 500 m, although one community is found at altitudes exceeding 1 500 m. The thickets are found on rocky ridges with surface rocks covering more than 20% of the area as well as on midslopes, at altitudes of 800-1 250 m. The soils vary largely in depth (200 to more than 500 mm) and clay content (15 to more than 35%). Where surface rocks are encountered, these may cover up to 20% of the area.

No diagnostic species were distinguished, the most prominent species, with a constancy value of more than 40%, being *Heteropogon contortus, Hyparrhenia hirta, Eragrostis curvula* and *Sporobolus africanus* (Table 1).

The average number of species recorded per community was 65 (Figure 6a), with the total number of species for this vegetation type being 195 (Figure 6b).

The following seven plant communities are recognized under this vegetation type (Eckhardt *et al.* 1996a, 1996d, 1996e):

1. *Sporobolo pyramidalis-Acacietum sieberianae*
2. *Polygalo hottentottae-Cymbopogonetum excavati*
3. *Brachiaria brizantha* Variant
4. *Conyza obscura* Variant
5. *Sporoboletum pyramidali-africani pogonarthrietosum squarrosae*
6. *Aristido congestae-Eragrostietum gummifluae*
7. *Heteropogon contortus-Aristida junciformis* Grassland

3.2.2 Vegetation type 15: *Acacia karroo-Themeda triandra* Low Thicket

This vegetation type is found at altitudes of 1 000-1 250 m, being restricted to midslopes and mostly being associated with the Southern Tall Grassveld (65) and the Natal Sour Sandveld (66) (Acocks 1953, 1988) (Figure 2). Soil depth may vary from 200 to more than 500 mm and the clay content from 15 to more than 35%. Where surface rocks are present, these may cover more than 20% of the area.

Although no diagnostic species were identified, this vegetation type is nevertheless distinguished from vegetation type 14 by the absence of species groups R, S, T and U and by the presence of species group V (Table 1). Species with a constancy value exceeding 40% include the tree *Acacia karroo* (species group G, Table 1), the grasses *Aristida congesta* ssp. *barbicollis, Themeda triandra, Cymbopogon excavatus, Hyparrhenia hirta, Eragrostis curvula* and the forbs *Chaetacanthus burchellii, Helichrysum rugulosum* and *Berkheya*

onopordifolia (Table 1). The vegetation is principally dominated by *Acacia karroo*.
This vegetation type is relatively species poor, containing only 56 species per community (Figure 6a) and a total number of 90 species (Figure 6b), both values being the lowest to be recorded within this major vegetation type.

The two plant communities classified under this vegetation type, include the following (Eckhardt *et al.* 1997):

1. *Eragrostis plana-Acacia karroo* Thicket
2. *Setaria sphacelata-Acacia karroo* Thicket

3.2.3 Vegetation type 16: *Indigofera hedyantha-Elionurus muticus* Short/Tall Closed Grassland

This vegetation type is primarily restricted to midslopes, but may also be found on crests and footslopes. It is mostly found at altitudes below 1 300 m, although some communities within this vegetation type may also occur up to an altitude of 1 800 m. Various types of soils may be encountered, being usually 300 to more than 500 mm deep and containing from 15 to more than 35% clay. Surface rocks are mostly absent.
No diagnostic species were identified for this vegetation type (Table 1). However, this vegetation type is distinguished from vegetation type 15 by the absence of the tree *Acacia karroo* (species group G, Table 1). Species with a constancy value of more than 40% include the grasses *Heteropogon contortus, Eragrostis curvula, Hyparrhenia hirta* and the forb *Helichrysum rugulosum* (Table 1).
An average number of 71 species was recorded per community (Figure 6a), with the total number of species for this vegetation type being 198 (Figure 6b).

Eight plant communities are classified under this vegetation type (Eckhardt *et al.* 1996a, 1996d):

1. *Themeda triandra-Heteropogon contortus* Grassland

2. *Aristido bipartitae-Themedetum triandrae phyllanthetosum burchellii*
3. *Aristido bipartitae-Themedetum triandrae brachiarietosum serratae*
4. *Aristido bipartitae-Themedetum triandrae felicietosum muricatae*
5. *Aristido bipartitae-Themedetum triandrae monsonietosum angustifoliae*
6. *Aristido bipartitae-Themedetum triandrae elionuretosum mutici*
7. *Centello asiaticae-Eragrostietum planae melinetosum repens*
8. *Centello asiaticae-Eragrostietum planae themedetosum triandrae*

4. *Agrostis lachnantha-Eragrostis plana* Wetland

This major vegetation type represents all the wetland plant communities associated with rivers, streams, springs, vleis and pans, but may also be encountered on some footslopes. These wetlands closely resemble the *Eragrostis plana-Agrostis lachnantha* Wetland of the north-eastern Orange Free State described by Eckhardt *et al.* (1993c). The substrate associated with these wetlands may vary from rocks covered with alluvial sands to humic, anaerobic, clayey, water-saturated soils, reaching depths of up to more than 500 mm.
The diagnostic species which characterize this major vegetation type are included in species group AK (Table 1).
This wetland major vegetation type has the lowest average species richness (45) and average total number of species (100) of all four major vegetation types dealt with in this paper, stressing the general species poorness of wetlands (Table 3).

A total of 16 plant communities, classified under four vegetation types, are recognized under this major wetland vegetation type.

4.1 *Schoenoplectus corymbosus-Paspalum dilatatum* Wetland

This syntaxon represents all wetland plant communities excluding those associated with springs. The diagnostic species for this syntaxon are listed under species group AI (Table 1).

Altogether 15 plant communities, classified under three vegetation types, are distinguished under this syntaxon.

4.1.1 *Fimbristylis ferruginea-Arundinella nepalensis* Wetland

This syntaxon represents all the wetland plant communities associated with rivers and streams, occurring at various altitudes. The diagnostic species which characterize this syntaxon are included in species group AF (Table 1).

Two vegetation types, representing 11 plant communities, are classified under this syntaxon:

4.1.1.1 Vegetation type 17: *Paspalum urvillei-Hemarthria altissima* Wetland

This vegetation type represents primarily the *Paspalo urvillei-Leersietum hexandrae* described by Eckhardt *et al.* (1996b) and is generally restricted to rivers and streams at an altitudinal range of 750-1 300 m. The substrate consists predominantly of the Dundee Form and of alluvial sand covering relatively large rocks. The clay content may vary from as little as less than 15% in the sand layers to more than 35% in clay rich sedimentations. Soil depth also varies strongly, but usually exceeds 500 mm.

This vegetation type is characterized by the diagnostic species listed under species group AD (Table 1).

Although being relatively species poor compared to the vegetation types of the grasslands, this vegetation type has the second highest species richness (51) (Figure 6a) and total number of species (136) (Figure 6b) of all wetland vegetation types described in this paper.

The following six plant communities are classified under this vegetation type (Eckhardt *et al.* 1996b):

1. *Imperato cylindricae-Fimbristylidetum ferrugineae eragrostietosum curvulae*
2. *Paspalo urvillei-Leersietum hexandrae pycreetosum betschuani*
3. *Paspalo urvillei-Leersietum hexandrae chamaechristetosum strictae*
4. *Paspalo urvillei-Leersietum hexandrae senecionetosum isatidei*

5. *Paspalo urvillei-Leersietum hexandrae verbenetosum brasiliensis*
6. *Paspalo urvillei-Leersietum hexandrae phragmitetosum australis*

4.1.1.2 Vegetation type 18: *Conyza albida-Ischaemum fasciculatum* Wetland

This vegetation type represents plant communities associated with mountain streams, rivers and to a lesser extent vlei-areas at altitudes exceeding 1 500 m as well as plant communities of rivers and streams at altitudes of 900-1 400 m. The substrate in the high-lying areas consists of clayey (>35%) deep (>500 mm) soils, whereas in the low-lying areas the substrate is mainly constituted of alluvial sand and rocks, with clay rich soils being less frequently encountered.

The diagnostic species which characterize this vegetation type are listed under species group AE (Table 1). This vegetation type is further distinguished from vegetation type 17 by the presence of species group AH (Table 1).

This vegetation type has the highest species richness (67) (Figure 6a) and total number of species (160) (Figure 6b) within this major vegetation type.

Five plant communities are recognized under this vegetation type (Eckhardt *et al.* 1996b):

1. *Arundinello nepalensis-Eragrostietum planae*
2. *Pycnostachys reticulata-Arundinella nepalensis* Wetland
3. *Mariscus congestus-Setaria pallide-fusca* Wetland
4. *Imperato cylindricae-Fimbristylidetum ferrugineae senecionetosum achilleifolii*
5. *Imperato cylindricae-Fimbristylidetum ferrugineae paspaletosum dilatati*

4.1.2 Vegetation type 19: *Eragrostis planiculmis-Pennisetum sphacelatum* Wetland

This vegetation type represents vlei-areas and pans occurring at altitudes exceeding 1 500 m. The soils are mostly deeper than 500 mm, being humic, clayey (>35%) and waterlogged. Surface rocks may sometimes be found, but are generally absent. Pans occurring on mountain plateaux are usually characterized by shallow (200-300 mm) soils.

Although no diagnostic species were identified, this vegetation type is distinguished from the other wetland vegetation types by the absence of species groups AD, AE, AF, AG, AJ and by the presence of species groups AH and AI (Table 1). Species mostly displaying a constancy value of more than 40% include *Eragrostis planiculmis, Paspalum dilatatum, Leersia hexandra* and *Pseudognaphalium oligandrum* (Table 1).

An extremely low species richness of only 26 (Figure 6a) species per community was recorded, which is the lowest average number of species recorded per community for the whole of the study area. The total number of species for this vegetation type is also an extremely low 68 (Figure 6b).

The following four plant communities are recognized under this vegetation type (Eckhardt *et al.* 1996b):

1. *Schoenoplecto decipientis-Eragrostietum planiculmis*
2. *Eragrostietum plano-planiculmis*
3. *Eleocharito palustris-Schoenoplectetum corymbosi*
4. *Isolepido fluitantis-Panicetum schinzii*

4.2 Vegetation type 20: *Limosella grandiflora-Agrostis lachnantha* Wetland

This vegetation type is associated with springs occurring at altitudes exceeding 1 500 m. The soils are waterlogged, being rich in clay deposits (>35%) and are generally deeper than 500 mm. Surface rocks may be encountered, but are usually absent.

This vegetation type is characterized by diagnostic species which are included species group AJ (Table 1). The woody species *Leucosidea sericea* (species group D, Table 1) is very prominent, often forming clusters around wet areas.

Since this vegetation type represents only one community, the average number of species per community (35) (Figure 6a) and the total number of species (35) (Figure 6b) for this vegetation type are the same.

The only plant community classified under this vegetation type, is the following (Eckhardt *et al.* 1996b):

1. *Limosello grandiflorae-Leucosideetum sericeae*

Ordination

A scatter diagram, indicating the distribution of synrelevés, which represent the different vegetation types, along the first and second axis, is presented (Figure 7). Four relatively distinct discontinuous groups can be observed, each group representing a major vegetation type. Synrelevés 1-6 represent forests, woodlands and thickets, synrelevés 7-12 represent the high-lying grasslands, synrelevés 13-16 represent the low-lying grasslands and synrelevés 17-20 the wetlands. The distribution of the synrelevés cannot be strictly correlated with specific environmental factors, since these factors also vary considerably within the vegetation types. However, the occurrence of the wetlands to the far right of the diagram, being associated with a water regime, suggests the obvious differences between the species compositions of the wetland vegetation types and those of the other vegetation types. The close occurrence of the synrelevés representing the high-lying grasslands and those representing the low-lying grasslands emphasizes the close relationship between the two grassland types concerning their species compositions and environmental conditions under which they are found. The gradual change from vegetation types dominated by grasses to those dominated by trees and forbs is clearly shown by the diagram, with synrelevés representing woodlands and thickets occurring to the immediate left of the grasslands and synrelevés representing forests occurring to the far left.

Concluding remarks

The processing of the entire floristic data, embracing several steps to be followed, starting with the compilation of six different synoptic tables, classifying by means of the TWINSPAN classification technique, refining by Braun-Blanquet procedures and ending up with a single comprehensive synoptic table, revealed 20 vegetation types. These vegetation types were subsequently identified and described. To determine the correspondence between the different vegetation types as well as the relationship between the latter and the environment, the ordination algorithm DECORANA was used.

After the species richness and total number of species had been determined for each vegetation type, the data were further analyzed to compare the four major vegetation types with each other. From the results it can be inferred that the high-lying grasslands, represented by the *Helichrysum pilosellum-Trachypogon spicatus* major vegetation type, have the highest average species richness and average total number of species (Table 3). In strong contrast to this, the wetlands, represented by the *Agrostis lachnantha-Eragrostis plana* major vegetation type, were found to be the least diverse and species rich (Table 3). These calculations were statistically tested and at a level of $a = 0.05$ there was a significant difference ($p < 0.05$) between the four major vegetation types. This clearly emphasizes the need to concentrate more intensely on the high-lying grasslands when it comes to preserving species richness and probably also species diversity. This does not imply, however, that wetlands are to be neglected due to being extremely species poor. In fact, the wetland vegetation is unique, extremely sensitive and plays an important ecological role in the purification and regulation of water. Therefore, wetlands must necessarily receive special attention. A point of great concern is the large-scale expansion of exotic plantations intended for the timber industry, placing heavy pressure on the high-lying grasslands and wetlands, with extensive grassland areas already being replaced by plantations. Indigenous forests, restricted to sheltered ravines and cliffs, are also endangered by the afforestation of high-lying grasslands because the aggressive exotics tend to penetrate the forests from adjacent areas, thereby replacing indigenous forest species.

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CHAPTER 4.2

Plant communities of the forests, woodlands and thickets in northern KwaZulu-Natal

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Plant communities of the forests, woodlands and thickets in northern KwaZulu-Natal

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An analysis of the woody vegetation of northern KwaZulu-Natal is presented. Relevés were compiled in 102 stratified random sample plots. A TWINSPAN classification, refined by Braun-Blanquet procedures, revealed 24 plant communities, also referred to as vegetation units. For each of these vegetation units, the species richness was determined. Four associations were identified which have a conservation importance. An ordination (DECORANA), based on floristic data, revealed the position of the syntaxa on environmental gradients.

Key words: classification, community, conservation, new syntaxa, species richness, vegetation unit.

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Introduction

Although several studies have been conducted on various forest and woodland types of South Africa (Bews 1917; Killick 1963; Edwards 1967; Moll 1968; Acocks 1953, 1975, 1988) there are still areas which remain to be classified and described in more detail. The mountainous areas of the Paulpietersburg-Vryheid-Louwsburg region display relics of indigenous forests, woodlands and/or thickets which still need to be described. These isolated vegetation patches are usually restricted to specific topographical positions. It is believed that large areas, which are presently grassland, were originally covered by forests and woodlands, but due to the increased use of fire, these forests and woodlands have been reduced in size and restricted to areas that are more protected against fires (Moll 1968; White 1983; Acocks 1988). However, this notion is refuted nowadays, with strong archaeological evidence suggesting that the grasslands must have been the long-standing component (Meadows & Linder 1989). This is also manifested in the higher levels of endemism in grassland species. Edwards (1967) distinguished various woody vegetation types in the Tugela River Basin, which includes a portion of the western part of this study area. The forests and woodlands are classified by Edwards (1967) under 'Uplands Vegetation'. Acocks (1988) used the label 'Inland Tropical Forest Types', and 'Temperate and Transitional Forest and Scrub Types' for the relevant forests and woodlands found in the area. The woody vegetation which will be described here will subsequently include forests and woodlands described by Edwards (1967).

This paper forms part of an investigation on the vegetation of northern KwaZulu-Natal. It is envisaged that descriptions, formal classifications, and a syntaxonomy of the various vegetation units will result from this investigation. The vegetation units will be described as newly derived syntaxa which will make an important contribution to the knowledge on the vegetation of KwaZulu-Natal. The alpha diversity was also determined for each vegetation unit, which assisted the identification of potential conservation areas. Eventually, a synthesis in the form of a synoptic table, will be presented as a summa-

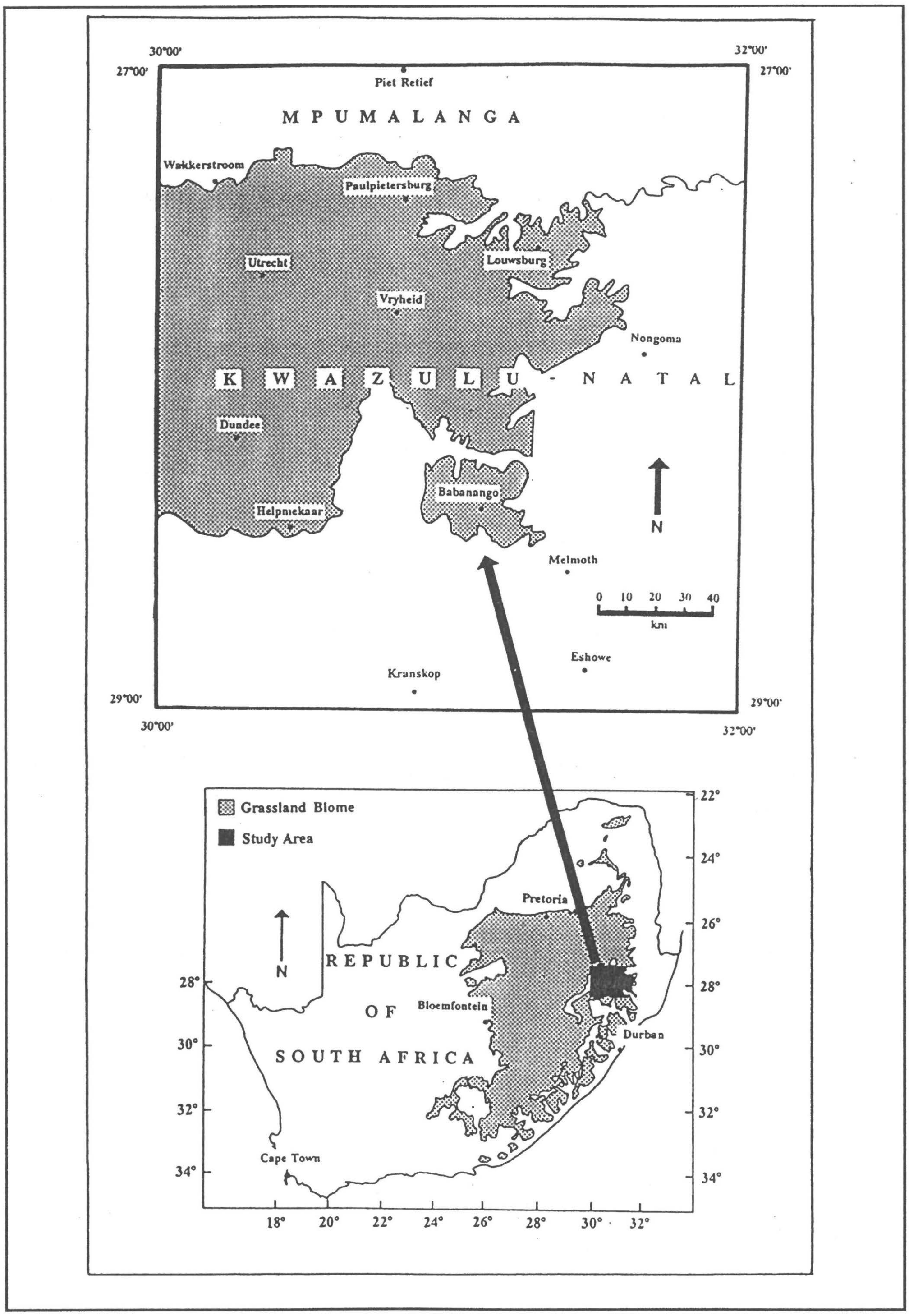

Fig. 1. Map indicating the location of the study area within the Grassland Biome.

ry of the major vegetation types found in the entire northern KwaZulu-Natal.

Finally, the results of this study are to be incorporated into a comprehensive synecological and syntaxonomical synthesis of the Grassland Biome of South Africa (see also Bredenkamp *et al.* 1989; Bezuidenhout & Bredenkamp 1990; Kooij 1990; Du Preez 1991; Matthews 1991; Smit 1992; Eckhardt 1993; Fuls 1993).

Study area

The study area is situated in central-northern KwaZulu-Natal (Land Type Survey Staff 1986, 1988) between latitude 27°16'S– 28°31'S and longitude 30°00'E–31°38'E (Fig. 1). The area covers 14 366 km² and comprises a variety of physiographic regions (Turner 1967). The predominant characteristic regions are basins, plains, plateaux and slopes. The difference in altitude between the two most extreme locations is approximately 1 500 m. The study area lies in the summer rainfall region, with the annual precipitation averaging about 850 mm. The rainfall pattern is strongly influenced by the topography of the area, varying from 700 mm in the low-lying river basins to 1 200 mm per annum in the highlands (Schulze 1982). The average annual temperature varies from 13 °C to 19 °C at different localities within the area, also correlating strongly with the physiographic regions, being higher for lower-lying river basins and plains, and lower for high-lying plateaux and mountains. Minimum temperatures of below freezing point are usually reached in the high-lying areas. The geology roughly consists of the Pongola and Karoo Sequences, the latter comprising more than three quarters of the total area (SACS 1980; Linström 1987). Sandstone and shale of the Vryheid Formation, as well as scattered occurrences of post-Karoo dolerite, constitute a large part of the geology.

Methods

The data on the forests, woodlands and thickets have been derived from 102 stratified random sample plots. Stratification was based on terrain units and aspect. Plot sizes were fixed at 200 m² (Bredenkamp 1982) in contrast to the 100 m² for grassveld (Scheepers 1975). Within each sample plot, all species were recorded and a cover-abundance value assigned to each according to the Braun-Blanquet scale (Mueller-Dombois & Ellenberg 1974). Taxon names conform to those of Arnold & De Wet (1993).

Although not strictly adhered to, the structural classification system of Edwards (1983) has been used as a criterion for an approximation of the structure of the woody vegetation. Environmental data recorded in a sample plot include terrain unit, aspect, slope, geology, soil type and depth, soil texture, rockiness of the soil surface and degree of erosion.

The first approximation of a vegetation classification, based on the total floristic data set was obtained by the application of the default Two-Way Indicator Species Analysis (TWINSPAN) (Hill 1979b). This first step of a classification procedure identified six different vegetation types. This output was then used to subdivide the data set into six phytosociological tables, each one of which was again subjected to TWINSPAN. The resultant classifications were then further refined by using Braun-Blanquet procedures (Westhoff & Van der Maarel 1978; Behr & Bredenkamp 1988; Bredenkamp & Bezuidenhout 1994). One of the phytosociological tables (Table 1) produced by this classification technique, represents the woody vegetation, described in this paper. The other tables represent grassland and wetland communities which will be dealt with separately.

The ordination algorithm DECORANA (Hill 1979a) (Fig. 3) was applied to determine gradients in vegetation and possibly the relationship between these plant communities and the physical environment.

In order to facilitate the identification of potential conservation areas, the alpha diversity of the different plant communities was determined. The alpha diversity (species richness) is defined as the number of species per unit area within a homogeneous community or the total number of species per community (Whittaker 1977). The 100 m² sample plots were taken as the unit area within a homogeneous community.

Results and discussion

The woody vegetation can be classified into forests, woodlands and thickets (Edwards 1983). Two orders were clearly distinguished, namely the *Leucosideetalia sericeae* (Order 1) and the *Acacietalia karroo* (Order 2). The former order is generally restricted to steep slopes (>20°–90°) at higher altitudes, which are characterised by moister conditions and lower temperatures. The forests of the North-eastern Mountain Sourveld, Highland Sourveld and Dohne Sourveld (Acocks 1953, 1975, 1988) fall under this order (Order 1). Although not strongly present throughout the order, *Leucosidea sericea* is considered the diagnostic species because of its restriction to and best characterisation of this order (Table 1). Grasses are virtually absent and are replaced by a well-developed forb-layer. The *Acacietalia karroo* is restricted to lower-lying areas, which are characterised by hotter and drier conditions, and more clayey soils. The diagnostic species for this order is *Acacia karroo*. The grass stratum is well represented by prominent species such as *Eragrostis curvula*, *Hyparrhenia hirta*, *Cymbopogon excavatus*, *Themeda triandra* and *Heteropogon contortus* (Table 1). This order most probably belongs to the *Acacia karroo* Class, described by Du Preez & Bredenkamp (1991).

It is very interesting to find that the average number of species per sample plot for both orders is very similar (29.1:30.7) (Fig. 2, horizontal lines represent the respective averages for the two orders). However, the total number of species for the *Acacietalia karroo* (79.1) strongly exceeds that of the *Leucosideetalia sericeae* (59) (Fig. 2).

Classification

The analysis resulted in the following hierarchical classification of the *Leucosideetalia sericeae* and the *Acacietalia karroo*:

1. *Leucosideetalia sericeae*
 1.1 *Stachyo kuntzei-Leucosidion sericeae*
  1.1.1 *Helichryso hypoleucum-Leucosideetum sericeae*
   1.1.1.1 *Helichryso hypoleucum-Leucosideetum sericeae solanetosum retroflexum* (vegetation unit 1)
   1.1.1.2 *Helichryso hypoleucum-Leucosideetum sericeae stachyetosum kuntzei* (vegetation unit 2)
  1.1.2 *Rhamno prinoidis-Podocarpodetum latifolii* (vegetation unit 3)
 1.2 *Trimerio grandifoliae-Greyion sutherlandii*
  1.2.1 *Buddlejo salviifoliae-Podocarpodetum latifolii* (vegetation unit 4)
  1.2.2 *Plectrantho grallati-Dalbergietum obovatae* (vegetation unit 5)
  1.2.3 *Plectrantho grallati-Canthietum mundianum* (vegetation unit 6)
  1.2.4 *Combreto kraussianae-Greyietum sutherlandii* (vegetation unit 7)
  1.2.5 *Plectrantho fruticosi-Trimerietum grandifoliae* (vegetation unit 8)
  1.2.6 *Rapano melanophloei-Greyietum sutherlandii* (vegetation unit 9)
  1.2.7 *Clauseno anisatae-Greyietum sutherlandii* (vegetation unit 10)
 1.3 *Maeso lanceolatae-Euclion crispae*
  1.3.1 *Hyparrhenio dregeanae-Dombeyetum rotundifoliae* (vegetation unit 11)
  1.3.2 *Hyparrhenio cymbariae-Diospyretum lycioidis* (vegetation unit 12)

2. *Acacietalia karroo*
 2.1 *Eragrostio curvulae-Acacion caffrae*
  2.1.1 *Panico maximum-Clerodendretum glabrum* (vegetation unit 13)
  2.1.2 *Aloo maculatae-Rhoetum pentherii* (vegetation unit 14)
  2.1.3 *Stipo dregeanae-Rhoetum pyroidis* (vegetation unit 15)
  2.1.4 *Rhoo pentherii-Acacietum caffrae* (vegetation unit 16)
 2.2 *Trachypogo spicati-Diospyrion lycioidis*
  2.2.1 *Trichoneuro grandiglumis-Canthietum mundianum* (vegetation unit 17)
  2.2.2 *Conyzo bonariensis-Cymbopogonetum validi* (vegetation unit 18)
  2.2.3 *Cymbopogono validi-Acacietum karroo* (vegetation unit 19)
 2.3 *Brachiario eruciformis-Acacietum karroo*
  2.3.1 *Brachiario eruciformis-Acacietum karroo themedetosum triandrae* (vegetation unit 20)
  2.3.2 *Brachiario eruciformis-Acacietum karroo bothriochloetosum insculptae* (vegetation unit 21)

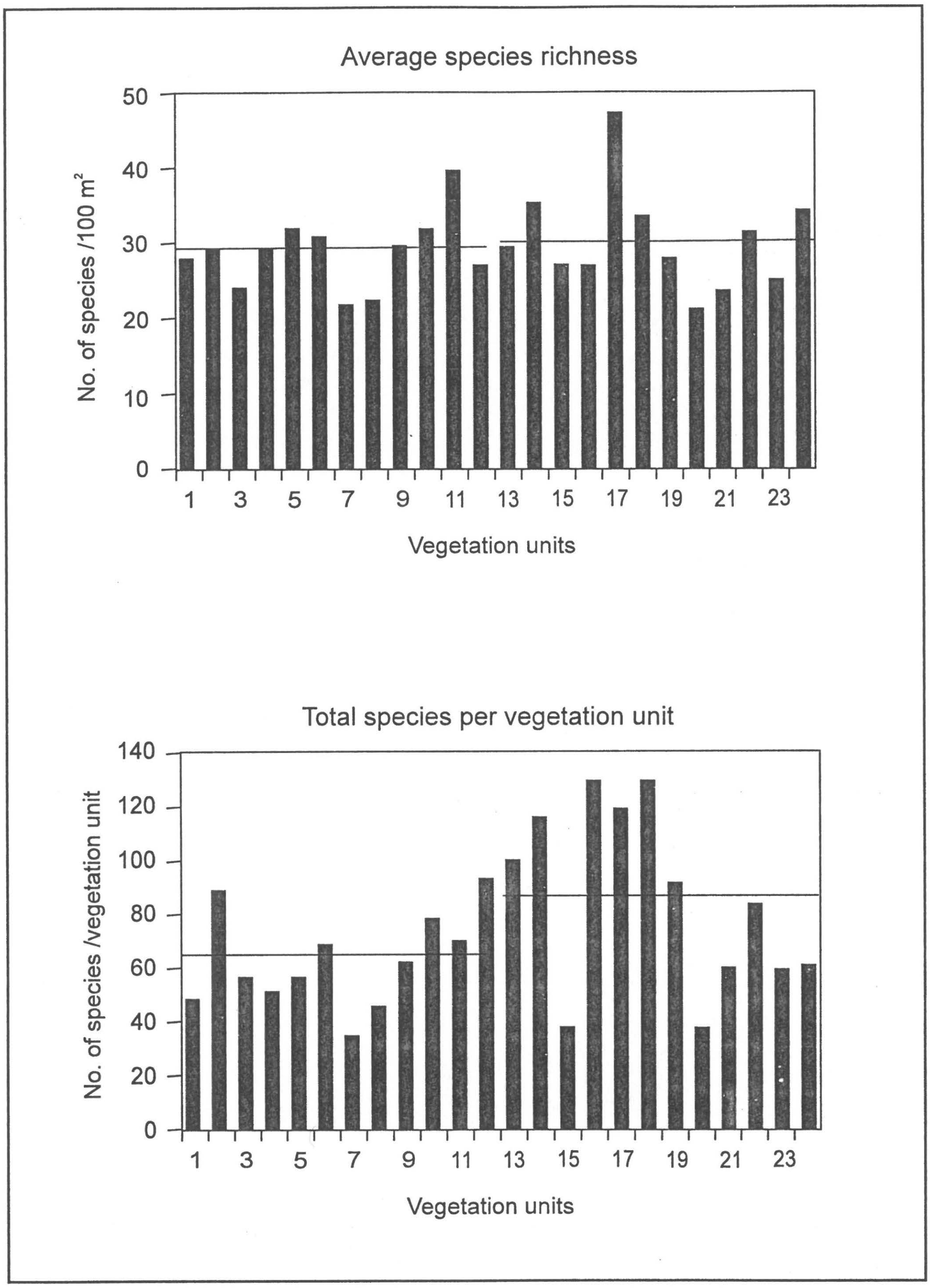

Fig. 2. Average species richness and total number of species of each vegetation unit. Horizontal lines represent the averages for the two respective orders: *Leucosideetalia sericeae* and *Acacietalia karroo*.

2.4 *Sporobolo pyramidalis-Acacietum sieberianae* (vegetation unit 22)
2.5 *Eragrostis plana-Acacia karroo* Thicket (vegetation unit 23)
2.6 *Setaria sphacelata-Acacia karroo* Thicket (vegetation unit 24)

Description of the plant communities

1. *Leucosideetalia sericeae* order nov.

Nomenclatural type: *Stachyo kuntzei-Leucosidion sericeae* (holotypus)

This order represents forests, woodlands and thickets of high altitudes, usually restricted to protected ravines and steep (20°-90°) mainly south-facing slopes. Cool, moist, high rainfall conditions prevail, with mist clouds often enfolding the mountains. These isolated patches of woody vegetation, surrounded by grassland, are considered by some ecologists as relics of woody vegetation which has originally covered larger areas (Edwards 1967; see also Moll 1968). However, as mentioned earlier on, this notion has been refuted now (Meadows & Linder 1989). This order is related to the *Podocarpetalia latifolii* described by Du Preez *et al.* (1991), but only a syntaxonomical synthesis will confirm this. Generally shallow (<200 mm) soils of the Glenrosa-Mispah complex, often covered by a humus layer, are typical of these slopes. These soils display a relatively low clay content of 15-20 %.

Tropical forest types within the study area are confined to the mountains between Nongoma and Vryheid and to the Louwsburg area, at altitudes between 1 000-1 500 m, receiving an annual rainfall of 900-1 950 mm. These forests are a component of North-eastern Mountain Sourveld (Acocks 1953, 1975, 1988). Temperate and transitional forest and woodland types found in the study area are outliers of similar physiognomic units which extend from the Upper Plateau of the Drakensberg between Mont-Aux-Sources and Volksrust down to the eastern slopes and foothills (Acocks 1953, 1975, 1988). Altitude varies from 1 500-2 200 m, and heavy frosts occur during the winter months. Mean annual rainfall varies between 750 mm and 1 500 mm.

Although absent from the tropical forest and woodland types, *Leucosidea sericea* is considered a character species for this order for reasons mentioned earlier on (species group M, Table 1). Both *Leucosidea sericea* and *Buddleja salviifolia* are important precursors to Upland Forests (Edwards 1967). These species will tolerate very frequent fires and in the absence of burning, conditions become favourable for initial forest species, gradually replacing the heliophytic species. Principal initial (early successional) (Edwards 1967) forest species are *Podocarpus latifolius*, *Dalbergia obovata*, *Combretum kraussii*, *Cryptocarya woodii*, *Allophylus africanus*, *Xymalos monospora*, *Heteropyxis natalensis*, *Rapanea melanophloeos*, *Scolopia oreophila*, *Trimeria grandifolia* and *Apodytes dimidiata*. Species of wider occurrence are listed under species group AE (Table 1).

1.1 *Stachyo kuntzei-Leucosidion sericeae* all. nov.

Nomenclatural type: *Helichryso hypoleucum-Leucosideetum sericeae* (holotypus)

This alliance represents a transition from precursor forest or woodland to initial forest types and would be classified as seral woody forest communities according to Moll (1968). It occurs on relatively moderate to steep slopes (20°-45°) with a predominant southerly aspect. The clay content of the soils varies from 15-20 %. Larger rocks are scattered on the slopes, covering from 2-20 % of the surface.

Species group C contains diagnostic species, which are dominated by the forb *Stachys kuntzei* (Table 1). The graminoid *Poa annua* (species group T, Table 1) is very prominent and often forms a dense ground cover. The absence of heliophytic species (species groups AA and AO) is very evident.

1.1.1 *Helichryso hypoleucum-Leucosideetum sericeae* ass. nov.

Nomenclatural type: relevé 165 (holotypus)

Although it is not clear to what extent geology influences the vegetation, it is interesting to note that this short closed woodland (Edwards 1983) association occurs only on sandstone, shale and mudstone of the Estcourt Formation.

Diagnostic species are represented by species group A (Table 1).

Two sub-associations are recognised under this association:

1.1.1.1 *Helichryso hypoleucum-Leucosideetum sericeae solanetosum retroflexum* sub-ass. nov.

Nomenclatural type: relevé 122 (holotypus)

This sub-association occurs on relatively deep (200-500 mm) soils of the Glenrosa Form.

It is characterised by the diagnostic species group B (Table 1).

The average number of species encountered per sample plot is 28.3, with the total number of species for this sub-association being 44 (Fig. 2).

1.1.1.2 *Helichryso hypoleucum-Leucosideetum sericeae stachyetosum kuntzei* sub-ass. nov.

Nomenclatural type: relevé 165 (holotypus)

The soils of this sub-association are of the Glenrosa-Mispah complex and between 200 and 300 mm deep.

There are no diagnostic species which characterise this sub-association. It is distinguished from the former sub-association by the presence of species groups L, S, AB and AI, and by the absence of species group B (Table 1). Prominent species are *Stachys kuntzei*, *Rhamnus prinoides*, *Leucosidea sericea*, *Poa annua* and *Euclea crispa*.

Although a total of 82 species was encountered, the average species richness is only 29.7 (Fig. 2), indicating a high degree of variation in the species composition of this sub-association.

1.1.2 *Rhamno prinoidis-Podocarpodetum latifolii* ass. nov.

Nomenclatural type: relevé 237 (holotypus)

According to Moll (1968), this association would be included under climax forest. *Podocarpus latifolius* is the character species (species group D, Table 1), which clearly distinguishes this association from the *Helichryso hypoleucum-Leucosideetum sericeae*. These two associations are, however, related to each other by species group C (Table 1). This association represents an initial tall forest type, with *Leucosidea sericea* being gradually replaced or forced to forest margins by typical forest species as succession progresses. Frequent fires can reverse the succession process, thereby enhancing the establishment of *Leucosidea sericea* and the disappearance of subclimax or climax forest species. Prominent species are *Stachys kuntzei*, *Podocarpus latifolius*, *Rhamnus prinoides*, *Leucosidea sericea* and *Buddleja salviifolia* (Table 1). The forb species *Watsonia latifolia* was found in relevé 226 and is classified as rare by Hall *et al.* (1980).

A total of 52 species was found, with the average number per sample plot being as low as 24.2 (Fig. 2).

1.2 *Trimerio grandifoliae-Greyion sutherlandii* all. nov.

Nomenclatural type: *Rapano melanophloei-Greyietum sutherlandii* (holotypus)

This alliance represents the typical initial forest and true forest types (Edwards 1967) encountered in the whole of the study area. This includes tropical and temperate forests

Table 1

Synoptic table of the forests, woodlands and thickets of northern KwaZulu-Natal, South Africa

Order	1												2											
Alliance	1.1		1.2								1.3		2.1				2.2							
Association	1.1.1		1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2.3		2		
			1	2	2	2	2	2	2	2	3	3	1	1	1	1	2	2	2			4		
			2	1	2	3	4	5	6	7	1	2	1	2	3	4	1	2	3					
Subassociation	1	1																		2	2			
	1	1																		3	3			
	1	1																		1	2			
	1	2																						
Community																							2	2
																							5	6
Species group A																								
Helichrysum hypoleucum	5	4								3														
Cheilanthes quadripinnata	5	4		4							2	2		2										
Printzia pyrifolia	4	4	1						2															
Taraxacum officinale	4	3														1								
Sparrmannia ricinocarpa	4	2		2		1			2										1					
Cliffortia nitidula	2	3			3				2		2													
Helichrysum melanacme		4																						
Helichrysum splendidum	2	2																						
Species group B																								
Solanum retroflexum	5			2							2			1										
Phalaris arundinacea	4	1																						
Solanum aculeatissimum	4	1																						
Galinsoga parviflora	4																							
Dioscorea retusa	4											2												
Species group C																								
Stachys kuntzei	5	5	4	4									2	1			1	2						
Dryopteris inaequalis	5	3	3					2	2	3														
Clutia affinis	4	5	2																					
Rubia horrida	5	5	1																					
Myrsiphyllum asparagoides	4	4	3	2		1													1					
Bromus catharticus	5	3	2																					
Schoenoxiphium rufum	2	4	3									2												
Thalictrum rhynchocarpum	4		3					2		3	3													
Species group D																								
Podocarpus latifolius				3	5																			
Species group E																								
Dalbergia obovata					5											1								
Species group F																								
Plectranthus grallatus					5	5																		
Species group G																								
Combretum kraussii					3		5			3			1											
Cryptocarya woodii				2			5																	
Hypoestes aristata							3			3														
Species group H																								
Plectranthus fruticosus								5	2															
Allophylus africanus					3			5																
Xymalos monospora								4																
Heteropyxis natalensis								2																
Dicliptera zeylanica					3			3																
Species group I																								
Usnea trichoides						2			5															
Rapanea melanophloeos						1			5								2							

Table 1 (continued)

Cephalanthus natalensis									5			2							1					
Pterocelastrus echinatus						1			4		2						2							
Scolopia oreophila									4															
Species group J																								
Trimeria grandifolia			1	2	3	2	3	4	4	3			2						1					
Carissa bispinosa				2	3	2	3	3	4	5														
Apodytes dimidiata					3	3	3	4	2	3		2												
Species group K																								
Asplenium aethiopicum	4	3	3			2	5	4	2	5	2													
Dioscorea sylvatica	4	3	5	2		2		3																
Senecio tamoides	4	3	3		3	2		4	2				1	1		1								
Scadoxus puniceus	4		1	4		2	3	2				2						1						
Zantedeschia albomaculata	4		1			3		2	2															
Species group L																								
Rhamnus prinoides		5	5	4	3	1		4	4	3	4		1					2						
Myrsine africana		5	5	2	3	1			5	3	3													
Mohria caffrorum		4	3	5		1	5			3	4		1	1			2							
Maytenus mossambicensis		1	2				3	3			3		1			1	1							
Species group M																								
Leucosidea sericea	5	5	4	4	5	3		2	2	3	4			1										
Species group N																								
Greya sutherlandii				4	3	4	5	2	5	5	5	3	1	1				1	2					
Cheilanthes viridis	2				3	2	3	2	2	3	3	3	2				2							
Cassinopsis ilicifolia					3	1		3		3	3		1				1							
Species group O																								
Maesa lanceolata					3	1					4	3						1						
Canthium ciliatum				2				2	2	3	5													
Hyparrhenia cymbaria					5			2				4						1						
Halleria lucida								2	2		2	3												
Species group P																								
Panicum maximum					3							2	4			1	2							
Vepris lanceolata													2											
Ficus abutilifolia													2											
Hypoestes forskaolii													2			1								
Isoglossa eckloniana											2		2	1	3									
Species group Q																								
Commelina africana		1	1	2		1					2		4	3		1	1		1	4			2	5
Aloe maculata			1								2		2	4		1					2			3
Dombeya burgessiae												3	2	1	5									
Species group R																								
Rhus chirindensis						1			2		4		2	2		1		2						
Stipa dregeana										3	3				5									
Species group S																								
Buddleja salviifolia	2	3	4	5	3	3		4	5	3	4		1	3	3									
Clausena anisatha		1	3	5		3	5	5		5	3		4	2	3	1								
Heteromorpha trifoliata		4	2	4	5	5	3	2	4	5	3	2	1	1	3									

Table 1 (continued)

Species group T																								
Poa annua	5	5	5	2	3	1	3	2	2	3	2	2	3	2	5									
Achyranthes aspera	4	2	4	5	3	1	5	2	2	5	2	3	4		5				1					
Buddleja auriculata	2		3	5	3	4		2	2		3		1	2										
Protasparagus setaceus	2	1	1	4			5			5		2	2	1					1					
Celtis africana			1	2		1		3		3			2					1						
Species group U																								
Acacia caffra					3							2	5	2	3	5								
Rhus pentheri				5									4	4	5	5			1		2			
Scutia myrtina			1							3			4	1	5	2								
Grewia occidentalis				2		1							2	3	5	3		1		4	2			
Aloe marlothii				4							2		2			3		1				2		
Olea europaea													2	1		2								
Ipomoea ommaneyi													2	2		1		1	1					3
Species group V																								
Trichoneura grandiglumis																	4					3		
Indigofera velutina																	3	1				2		
Felicia mossamedensis																	3							
Hypoxis iridifolia																	3							
Ficus ingens												2					3		1			2		
Andropogon schirensis																	3		1					
Barleria obtusa																	3			2				
Pavetta edentula								2									3							
Hyparrhenia filipendula																	2							
Erythrina latissima																	2							
Hyperthelia dissoluta																	2	1						
Erythrina lysistemon																1	2		1					
Species group W																								
Canthium mundianum					5	4	5	2	4	3	2	2	2	3		1	4							
Zanthoxylum capensis							5	2		5	4	2	2	2		1	2	1						
Species group X																								
Conyza obscura		1									4	2		1		1		5	1			3		
Species group Y																								
Cheilanthes sp.						2		2			3	2				1	4	3	2			2		
Hippobromus pauciflorus				2									2				4	3	2	2				
Trachypogon spicatus														1		1	2	3	3					
Pellaea calomelanos				4									2	2		1	4	3	1					
Helichrysum nudifolium												2		1			1	3	3			2		3
Chamaecrista stricta																	3	3	1			3	2	
Tapiphyllum parvifolium						1		2									4	1	1					
Brachiaria deflexa												2		1			3	1	2					
Aloe zebrina																	1	3	1			2		
Tetraselago natalensis																	2	1	2					
Species group Z																								
Athrixia phylicoides				2		1					3	2	2		3	2	2	3	4			2		
Melinus nerviglumis				2		1					3	2	1	1		1	2	3	3					3
Leonotis ocymifolia				4								2	1	1	5	1	2	1	1			2		3
Species group AA																								
Cussonia spicata				5	5	5	5	5	5	5	4	4	5	4	5	2	5	3	4		2			
Clerodendrum glabrum				4	3	1	5	2		3	3	3	5	2		2	5	1	3					

Table 1 (continued)

Protasparagus virgatus		2		3	3		4	4		3	4	2	3	3	2	2	2				2			3
Cymbopogon validus						3			4		4		2	1		1	3	5	5					
Aloe arborescens					3	4	5	3	5		2	2					5	1	2					
Plectranthus madagascariensis			1			1	3		2	3		2		1				2	3					
Dombeya rotundifolia						2					4	2				1		1				2		
Species group AB																								
Clematis oweniae		3	2	2	3	4		4	2	3	2	2	3	2	5	2	1	1	3					
Dais cotinifolia		3	4	4	5	1		2	2	3	3		2	1	3	1		3	3					
Species group AC																								
Brachiaria eruciformis													1							5	4		2	
Zinnia peruviana													2			1	1			5	3		2	
Stachys natalensis																1				2	3			3
Urochloa panicoides																				4	2			
Species group AD																								
Diheteropogon amplectens		1									2		1	1		3	4	3	1		2			3
Species group AE																								
Rhus pyroides	5	5	3	4	5	5		4	5		5	2	3	1	5	1		2	1		3			
Diospyros whyteana		3	3	2	3	5		4	5	3	3	2	2	1			5	1	1	4				
Species group AF																								
Sporobolus pyramidalis												2									2	5		
Acacia sieberiana								2										1	1			5		3
Hermannia depressa																2						4	2	3
Species group AG																								
Bothriochloa insculpta																	1	1			4	3		
Species group AH																								
Lippia javanica				2	3						2	2	4	3	5	4	4	2	3			4	2	
Ziziphus mucronata											2	2	4	3	5	4	1	2	1		4	4		3
Sporobolus africanus											3	2	3	1	3	3	2	2			3	5	2	3
Hyparrhenia dregeana					3	2			2		4	4				1	1	2	3			2		3
Vangueria infausta											2	2	2	1		1	2		1			3		
Species group AI																								
Euclea crispa		4	5	5	5	4	3	4	5	3	5	3	5	5		4	4	3	3	4	3	4		
Rhoicissus tridentata		3	2	4	5	5	3	2	5		5	3	5	4	5	3	3	4	3	5	3	2		
Maytenus heterophylla		2	3	4					2		5	2	2	2	5	4	5	2	2	4	5	4		
Species group AJ																								
Eragrostis plana		1									3							1	1		4	3	4	
Schkuhria pinnata													2	1		1	1	1			3	4	4	
Cynodon dactylon																					3	2	2	
Species group AK																								
Melinis repens												2	1	1		1	3	3	1	5	4	4	2	
Eragrostis pseudosclerantha																	1	3	1		3	3	2	
Species group AL																								
Helichrysum rugulosum											2		1	1		1	1	3	3			5	4	5
Aristida congesta													2			1	3	1			3	3	4	5
Berkheya onopordifolia														1		1	1	1	2		3		4	5

Table 1 (continued)

Species group AM	
Acacia karroo	I I I I I I I I I I I I I4 I3 I5 I5I I2 I5 I5 I5 I4 I5 I5I
Bidens tilosa	I2 I I I2I I I I I I I I2 I3 I3 I3 I2 I2 I1 I2 I4 I3 I2 I2I I
Setaria sphacelata	I I I I I I I I I I I I2 I1 I3 I3 I I I1 I5 I3 I2I I5I I
Aristida bipartita	I I I I I I I I I I I I I I1I I4 I1 I I I2 I3I I4I I
Species group AN	
Eragrostis curvula	I I2 I I I I I I I I I2 I2 I5 I5 I5 I4 I5 I4 I4 I4 I5 I4 I5 I5I
Hyparrhenia hirta	I I I I2I I2 I I I I I3 I3 I1 I2 I I4 I4 I5 I4 I2 I4 I5 I5 I5I
Cymbopogon excavatus	I I I I2I I I I I I I I I2 I2 I3 I3 I5 I4 I4I I4 I5 I4 I5I
Themeda triandra	I I2 I I I I I I I I I I3 I3 I2I I3 I3 I3 I3 I5 I2 I3 I5 I5I
Heteropogon contortus	I I1 I I I I I I I I I I I2 I2I I3 I3 I I I2 I3 I3 I2 I3I
Species group AO	
Diospyros lycioides	I I1 I1 I4 I5 I2 I3 I2I I3 I4 I5 I5 I5 I5 I4 I5 I4 I5 I5 I4 I4 I4I I
Rhus dentata	I I1 I I4I I2 I I I I I3 I2 I4 I4 I5 I3 I5 I3 I3 I5 I4I I4 I3I

(Acocks 1988). Soils are of the Glenrosa-Mispah complex and generally <200 mm deep, with a clay content usually less than 15 %. Large surface rocks are often present, covering more than 20 % of the surface area. Slopes are steep to very steep (20°-90°) and facing mainly southward.

Diagnostic species are included in species group J (Table 1). Other prominent species include: *Greyia sutherlandii*, *Canthium mundianum*, *Cussonia spicata*, *Rhus pyroides* and *Euclea crispa*. Altogether seven forest associations are recognised under this alliance.

1.2.1 *Buddlejo salviifoliae-Podocarpodetum latifolii* ass. nov.

Nomenclatural type: relevé 299 (holotypus)

This association is a temperate initial, short forest type (Edwards 1967) and is sometimes exposed to fires. It is suspected that the mixed woody communities referred to by Moll (1968), are similar to this association but as he did not use Braun-Blanquet procedures, this could not be confirmed. This association occurs on shale and sandstone of the Volksrust Formation. Huge boulders cover more than 20 % of the surface area of the slopes.

This association is characterised by *Podocarpus latifolius* (species group D, Table 1). Other prominent species are *Leucosidea sericea*, *Buddleja salviifolia*, *Clausena anisata* and *Heteromorpha trifoliata*.

The average number of species per sample plot is 29.5 (Fig. 2), which is nearly the average for the *Leucosideetalia sericeae*. The total number of species are 47 (Fig. 2), which is well below the average.

1.2.2 *Plectrantho grallati-Dalbergietum obovatae* ass. nov.

Nomenclatural type: relevé 591 (holotypus)

This association occurs on relatively sandy soils (<15 % clay), derived from sandstones, shales and mudstones of the Vryheid Formation. Although the two sample plots, which represent this association, are situated on a north and a south-facing slope, the species compositions suggest a tropical element in both relevés. This unit is subsequently classified as a low to short tropical forest type (Edwards 1983; Acocks 1988).

Two character species are recognised (species group E & F, Table 1). Other sometimes prominent species include *Apodytes dimidiata*, *Rhamnus prinoides*, *Cassinopsis ilicifolia*, *Canthium mundianum*, *Dais cotinifolia*, *Rhus pyroides* and *Euclea crispa*.

This association has 32 species per sample plot (Fig. 2), which is well above the average (29.1). The total number of species is 52, which is below the average of 59 (Fig. 2).

1.2.3 *Plectrantho grallati-Canthietum mundianum* ass. nov.

Nomenclatural type: relevé 544 (holotypus)

This low to short forest type (Edwards 1983) occurs on very steep (30°-90°), northerly, easterly and west-facing slopes. Surface rocks cover more than 20 % of the soil surface. Drier conditions are prevalent due to direct and relatively long exposure to sunlight, creating more suitable conditions for the establishment of heliophytic grasses. Even east-facing slopes receive more radiation than southerly-facing slopes.

This association is characterised by the diagnostic species *Plectranthus grallatus* (species group F, Table 1), through which it is related to the *Plectrantho grallati-Dalbergietum obovatae*. Conspicuous and dominant species are *Greyia sutherlandii*, *Canthium mundianum*, *Rhus pyroides* and *Diospyros whyteana*. Also very prominent are the tall grass *Cymbopogon validus* and the succulent shrub *Aloe arborescens*.

A total of 64 species was recorded within this association, with an average of 31 species per sample plot (Fig. 2).

1.2.4 *Combreto kraussianae-Greyietum sutherlandii* ass. nov.

Nomenclatural type: relevé 469 (holotypus)

This association occurs on dolerite and mainly sandstone of the Vryheid Formation. The soils are very rocky (>20 %), have a low clay content (<15 %) and are mainly of the Mispah Form. Much organic material has accumulated, transforming gradually to humus. The gradients of the slopes vary from 25°-45°, facing southerly.

This short forest type (Edwards 1983) has a strong tropical element and is characterised by species group G (Table 1). A clear feature of this association is the absence of *Leucosidea sericea*, *Rhus pyroides* and *Diospyros whyteana*. Because *Leucosidea sericea* is considered a precursor species which disappears under climax conditions, it can be assumed that this species was present in an earlier successional stage. Other prominent species are *Greyia sutherlandii*, *Apodytes dimidiata*, *Canthium mundianum* and *Cussonia spicata*.

Only 22 species per sample plot were recorded on average, the total for the whole vegetation unit being 31 (Fig. 2).

1.2.5 *Plectrantho fruticosi-Trimerietum grandifoliae* ass. nov.

Nomenclatural type: relevé 563 (holotypus)

This short to tall tropical forest type (Edwards 1983; Acocks 1988) falls within the North-eastern Mountain Sourveld (Acocks 1953, 1975, 1988), where extensive patches of it still occur. These patches are usually restricted to south-facing slopes with cool moist prevailing conditions. It is especially this association, as well as the *Plectrantho grallati-Dalbergietum obovatae*, which are seriously threatened by exotic plantations of mainly *Eucalyptus* spp. and wattles (*Acacia mearnsii*).

The diagnostic species occur within species group H (Table 1). Other prominent species include *Trimeria grandifolia*, *Apodytes dimidiata*, *Celtis africana* and sometimes *Rhamnus prinoides* and *Euclea crispa*. These forests also lack *Leucosidea sericea* and *Greyia sutherlandii*.

Only 42 species were recorded in this relatively species poor forest type, the average number of species per sample plot being 22.7 (Fig. 2).

1.2.6 *Rapano melanophloei-Greyietum sutherlandii* ass. nov.

Nomenclatural type: relevé 600 (holotypus)

This low to short forest type (Edwards 1983), also characterised by a strong tropical element, occurs on very steep (30°-90°) slopes, facing all major aspects.

Diagnostic species are listed under species group I (Table 1) and include the moss *Usnea trichodeoides*. *Scolopia oreophila* is a rare species which is endemic to northern KwaZulu-Natal (Hall *et al.* 1980). Other prominent species include: *Rhamnus prinoides*, *Leucosidea sericea*, *Greyia sutherlandii*, *Buddleja salviifolia*, *Rhus pyroides*, *Diospyros whyteana* and *Euclea crispa*.

The average number of species per sample plot is 30, with the total number for the whole vegetation unit being 56 (Fig. 2), which is slightly less than the average of 79.1.

1.2.7 *Clauseno anisatae-Greyietum sutherlandii* ass. nov.

Nomenclatural type: relevé 462 (holotypus)

This short to tall forest type (Edwards 1983), which occurs only on south-facing slopes, has a temperate to tropical nature. It is assumed that it is closely related to the *Plectrantho fruticosi-Trimerietum grandifoliae* because of the very similar habitat conditions. It is also possible that not all species of this association have been recorded, thus causing these two forest types to be separated in this study. The association has no diagnostic species group and is therefore considered a separate type. Prominent species are: *Trimeria grandifolia*, *Apodytes dimidiata*, *Greyia sutherlandii*, *Buddleja salviifolia*, *Celtis africana*, *Canthium mundianum*, *Cussonia spicata* and the graminoid *Poa annua*.

This vegetation unit has a high species richness (32.3) and a total of 72 species (Fig. 2).

1.3 *Maeso lanceolatae-Euclion crispae* all. nov.

Nomenclatural type: *Hyparrhenio dregeanae-Dombeyetum rotundifoliae* (holotypus)

This alliance represents short thicket (Edwards 1983) or isolated bush clumps at an altitude above the *Acacia caffra* zone (1 200-1 600 m), above which *Acacia caffra* is absent (Edwards 1967). These thickets are widely scattered, usually occurring as isolated islands throughout the grassland and are not restricted exclusively to steep slopes (3°-90°). Soils are shallow (200-300 mm) and have a clay content of 15-25 %. Superficial rocks cover 5 % to more than 20 % of the soil surface.

The diagnostic species are listed under species group O (Table 1), including the tall grass *Hyparrhenia cymbaria* which is very conspicuous and indicative of more suitable conditions for the grass stratum. Other grasses also very prominent are *Cymbopogon validus*, *Hyparrhenia dregeana*, *H. hirta* and *Eragrostis curvula*. This alliance was often found to have been invaded by silver wattle (*Acacia dealbata*) and black wattle (*A. mearnsii*).

Two associations are recognised under this alliance:

1.3.1 *Hyparrhenio dregeanae-Dombeyetum rotundifoliae* ass. nov.

Nomenclatural type: relevé 516 (holotypus)

This association occurs mainly on north-facing slopes with gradients of between 30° and 90°. It can be considered equivalent to the forests on the southern slopes but, due to different climatical conditions, species composition and structure are different. The vegetation is dominated by a short (Edwards 1983) woody stratum with a well-developed substratum grass cover. Sandstone of the Vryheid Formation and dolerite are the predominant geological components underlying the soils of these slopes.

No diagnostic species are characteristic for this thicket, but nevertheless it is constituted of several prominent and sometimes dominant species such as *Rhamnus prinoides*, *Leucosidea sericea*, *Canthium ciliatum*, *Dombeya rotundifolia*, *Euclea crispa* and the tall grass species *Cymbopogon validus* and *Hyparrhenia dregeana* (Table 1).

A very high species richness of 39.7 species per sample plot was recorded, with 72 species in total for the association (Fig. 2).

1.3.2 *Hyparrhenio cymbariae-Diospyretum lycioidis* ass. nov.

Nomenclatural type: relevé 416 (holotypus)

This association has a patchy distribution, being generally restricted to small ravines and rocky outcrops.

No diagnostic species are recognised, but the most prominent are *Greyia sutherlandii*, *Maesa lanceolata*, *Clerodendrum glabrum*, *Ziziphus mucronata*, *Diospyros lycioides* and the tall grasses *Hyparrhenia cymbaria* and *Hyparrhenia dregeana* (Table 1).

This association is clearly distinguished from the *Hyparrhenio dregeanae-Dombeyetum rotundifoliae* by the absence of species groups L and M.

Despite the large number (87) of species found in this vegetation unit, the species richness (27.5) is even below the average of 29.1 (Fig. 2).

2. *Acacietalia karroo* order nov.

Nomenclatural type: *Eragrostio curvulae-Acacion caffrae* (holotypus).

The *Acacietalia karroo* occurs at altitudes lower than the *Leucosideetalia sericeae*, characterised by higher average annual temperatures and milder winters. These are woodlands and thickets (Edwards 1983) with a patchy distribution, mostly restricted to slopes and midslopes with widely differing gradients (3°-35°). They are mainly associated with the Northern and Southern Tall Grassveld and the Natal Sour Sandveld (Acocks 1953, 1975, 1988). The most frequent soil encountered is the Glenrosa Form, being 300 mm deep on average, but which sometimes reaches depths of up to 500 mm. Clay content varies from 15-35 %, but on average is between 15-20 %. Although surface rocks are absent in some cases, they usually cover more than 20 % of the surface area, with rock size generally exceeding 500 mm in diameter. The geology is characterised by sandstone of the Vryheid Formation, and post Karoo dolerite. The more clayey soils are derived mainly from dolerite.

The diagnostic species is *Acacia karroo* (species group AM, Table 1), but other character species closely associated with this species, are the alien weed *Bidens pilosa*, and the grasses *Setaria sphacelata* and *Aristida bipartita*. Other species which are very prominent and often dominant according to their cover-abundance values, include the grasses *Eragrostis curvula*, *Hyparrhenia hirta*, *Cymbopogon excavatus*, and the woody species *Diospyros lycioides* and *Rhus dentata*. Overgrazed grasslands adjoining these woodlands or thickets, are often found to be invaded by shrubs and trees of *Acacia karroo*.

2.1 *Eragrostio curvulae-Acacion caffrae* all. nov.

Nomenclatural type: *Rhoo pentheri-Acacietum caffrae* (holotypus)

This vegetation unit is found in the area around Dundee, Utrecht and directly north of Vryheid. Around Dundee it covers smaller koppies, whereas in the Utrecht area, it is restricted to the slopes of the Belelasberg, representing Valley Bushveld (Acocks (1953, 1975, 1988).

The character species for this alliance are listed under species group U (Table 1). Other prominent, and often dominant, species are the woody *Ziziphus mucronata*, *Euclea crispa*, *Acacia karroo*, *Diospyros lycioides*, *Rhus dentata*, and the graminoids *Eragrostis curvula* and *Cymbopogon excavatus*.

2.1.1 *Panico maximum-Clerodendretum glabrum* ass. nov.

Nomenclatural type: relevé 179 (holotypus)

This association can be classified as short closed woodland (Edwards 1983) with a well-developed grass layer. It occurs exclusively on sandstone of the Vryheid Formation, and dolerite. The predominant soil type is the Glenrosa Form, although a combination of the latter and the Mispah Form are occasionally encountered.

Diagnostic species are listed under species group P (Table 1). Other important species include *Clausena anisatha*, *Acacia caffra*, *Rhus pentheri*, *Scutia myrtina*, *Clerodendrum glabrum*, *Rhus pyroides*, *Acacia karroo*, *Diospyros lycioides* and *Eragrostis curvula*.

The average number of species recorded per sample plot is 30.4, with the total number for the whole vegetation unit being 94 (Fig. 2).

2.1.2 *Aloo maculatae-Rhoetum pentheri* ass. nov.

Nomenclatural type: relevé 54 (holotypus)

This association of a low to short closed woodland (Edwards 1983) occurs on moderate (3°-20°) slopes as well as on crests of smaller koppies. Aspect seems to play no role in determining the occurrence of this vegetation. No diagnostic species are recognised, but conspicuous and often dominant species include *Rhus pentheri*, *Ziziphus mucronata*, *Euclea crispa*, *Acacia karroo*, *Rhus dentata* and the grass *Eragrostis curvula* (Table 1). This association is closely related to the *Panico maximum-Clerodendretum glabrum* and is only distinguished from the latter by the absence of species group P.

The total 107 species recorded in this woodland type is very high, with an equally high species richness of 35.4 (Fig. 2), which is the second highest for all vegetation units of the forests, woodlands and thickets found in this study area. These high values are ascribed to the heterogeneous nature of the koppies.

2.1.3 *Stipo dregeanae-Rhoetum pyroidis* ass. nov.

Nomenclatural type: relevé 262 (holotypus)

This low to short closed woodland (Edwards 1983) occurs on southern slopes, with gradients of between 15°-20°. Rock cover is less than 2 %.

No character species are distinguished (Table 1). The most dominant and conspicuous species are *Acacia caffra*, *Rhus pentheri*, *Rhus pyroides*, *Ziziphus mucronata*, *Maytenus heterophylla*, *Acacia karroo*, *Diospyros lycioides*, the forb *Achyranthes aspera*, and the grasses *Stipa dregeana*, *Poa annua*, *Sporobolus africanus*, *Eragrostis curvula* and *Cymbopogon excavatus*. The species *Poa annua*, *Sporobolus africanus* and *Eragrostis curvula* are indicators of disturbance, the causes for which are not known. This association is closely related to the *Aloo maculatae-Rhoetum pentheri* and is only distinguished from the latter by the absence of species group Q.

Only 34 species were recorded within this woodland type, with the species richness being only 27 (Fig. 2).

2.1.4 *Rhoo pentheri-Acacietum caffrae* ass. nov.

Nomenclatural type: relevé 185 (holotypus)

This low to short closed woodland (Edwards 1983) occurs in a variety of habitats, ranging from dongas to relatively steep (30°) slopes. Such slopes are mainly south-facing, but sometimes face west- or eastward.

No diagnostic species could be identified, but nevertheless prominent species are *Acacia caffra*, *Rhus pentheri*, *Ziziphus mucronata*, *Euclea crispa*, *Acacia karroo*, *Diospyros lycioides*, *Rhus dentata*, and the grasses *Eragrostis curvula*, *Hyparrhenia hirta*, *Cymbopogon excavatus* and *Themeda triandra* (Table 1). The more disturbed parts of this community are recognised by higher cover-abundance values of *Eragrostis curvula* and lower values or even absence of *Themeda triandra*. Although related to the three previously described associations, the absence of species groups R, S and T is very eminent. This clearly indicates somewhat warmer and drier prevailing conditions.

An exceptionally large total number of 120 species was recorded, with the average number of species per sample plot being 26.8 (Fig. 2).

2.2 *Trachypogo spicati-Diospyrion lycioidis* all. nov.

Nomenclatural type: *Trichoneuro grandiglumis-Canthietum mundianum* (holotypus)

This alliance occurs at 1 250-1 500 m above sealevel and shows wide differences in structure and species composition. Although it generally occurs as a low thicket, at some places the structure and composition of the vegetation are such that these situations can be classified as low to short closed woodland (Edwards 1983).

Character species for this alliance are listed under species group Y (Table 1). These diagnostic species, however, display only low cover-abundance values, in contrast to the high values of species such as *Diospyros lycioides*, *Cymbopogon validus*, *Eragrostis curvula* and *Hyparrhenia hirta*.

2.2.1 *Trichoneuro grandiglumis-Canthietum mundianum* ass. nov.

Nomenclatural type: relevé 392 (holotypus)

This thicket is restricted to granitic outcrops. Soils are shallow (200-300 mm) and clay contents low (15-20 %). Soils are predominantly of the Glenrosa-Mispah complex. Surface rocks cover more than 20 % of the area, with granite sills, appearing above the ground, constituting a large part of this cover.

The character species are included within species group V (Table 1). Other prominent and sometimes dominant species are *Canthium mundianum*, *Clerodendrum glabrum*, *Diospyros lycioides*, *Eragrostis curvula* and *Hyparrhenia hirta*. This thicket type is distinguished from the following two associations by the presence of species group W (Table 1). Although *Acacia karroo* was absent from the sample plots, widely distributed individuals may be observed.

Of all the vegetation units described in this paper, this association has the highest species richness (47.8), with the total number of species being 110 (Fig. 2).

2.2.2 *Conyso bonariensis-Cymbopogonetum validi* ass. nov.

Nomenclatural type: relevé 421 (holotypus)

This low thicket (Edwards 1983) occurs on moderate to relatively steep (10°-30°) slopes, facing all four aspects.

The only character species is the forb *Conyza obscura* (species group X, Table 1), which displays low cover-abundance values and is consequently difficult to be observed. The most dominant species are: *Diospyros lycioides*, *Cymbopogon validus* and *Hyparrhenia hirta*. As already mentioned in the *Trichoneuro grandiglumis-Canthietum mundianum*, *Acacia karroo* is very sparsely distributed and has consequently only sometimes been recorded. In these cases low cover-abundance values were recorded for *Acacia karroo*.

A total number of 121 (Fig. 2) species was recorded for this association, which is the highest of all vegetation units described in this paper. The species richness (33.4) (Fig. 2) is also well above the average of 30.7.

2.2.3 *Cymbopogono validi-Acacietum karroo* ass. nov.

Nomenclatural type: relevé 400 (holotypus)

This low thicket (Edwards 1983) is generally restricted to slopes of between 5° and 35° and at some places is of such a nature that it could be classified as low closed woodland (Edwards 1983).

No diagnostic species are identified, but nevertheless prominent and often dominant species include: *Acacia karroo*, *Diospyros lycioides*, *Cymbopogon validus*, *Eragrostis curvula*, *Hyparrhenia hirta* and *Cymbopogon excavatus* (Table 1).

An average number of 28.8 species was recorded per sample plot, with the total number being 85 (Fig. 2).

2.3 *Brachiario eruciformis-Acacietum karroo* ass. nov.

Nomenclatural type: relevé 48 (holotypus)

This low thicket (Edwards 1983) occurs on terrain units 2 and 3 with slopes ranging from 3°-25°. Soils are rich in clay (>35 %) and relatively deep (>300 mm).

The diagnostic species are listed under species group AC (Table 1). Although the two grass species *Brachiaria eruciformis* and *Urochloa panicoides* are indicative of heavy (clayey) soils, all four character species suggest a relatively high degree of disturbance. The woody stratum is dominated totally by *Acacia karroo*, with species such as *Eragrostis curvula*, *Themeda triandra* and *Bidens pilosa* very prominent and often dominant in the herbaceous stratum. Both *Eragrostis curvula* and *Bidens pilosa* are further indicators of disturbance.

Two sub-associations are recognised under this association:

2.3.1 *Brachiario eruciformis-Acacietum karroo themedetosum triandrae* sub-ass. nov.

Nomenclatural type: relevé 48 (holotypus)

This sub-association occurs on the slopes and crests of smaller koppies. The predominant soil type is the Mayo Form, with clay percentages well exceeding 35 %.

There are no diagnostic species, but species which are conspicuous and often dominant include: *Acacia karroo*, *Euclea crispa*, *Rhoicissus tridentata*, *Diospyros lycioides*, *Brachiaria eruciformis*, *Urochloa panicoides*, *Melinis repens*, *Themeda triandra* and *Bidens pilosa* (Table 1). *Melinis repens* and *Bidens pilosa* are both indicators of disturbance.

An average number of only 22 species was recorded per sample plot, the total number being only 35 (Fig. 2).

2.3.2 *Brachiario eruciformis-Acacietum karroo bothriochloetosum insculptae* sub-ass. nov.

Nomenclatural type: relevé 375 (holotypus)

This low thicket (Edwards 1983) occurs mainly on terrain unit 3 and is usually restricted to deep (>500 mm), clayey (>35 %) soils. Surface rocks are generally absent. This unit is an extension of the thickets of the slopes described earlier (2.3.1) in this order, with the woody component being represented mainly by *Acacia karroo*.

The diagnostic species which distinguish this sub-association from the *Brachiario eruciformis-Acacietum karroo themedetosum triandrae*, are listed under species group AG and AJ (Table 1), all indicators of disturbance, whereas the two sub-associations are related to each other through species group AC (Table 1). Predominant species are *Acacia karroo*, *Aristida congesta* subsp. *barbicollis*, *Setaria sphacelata*, *Eragrostis curvula* and *Hyparrhenia hirta*.

An average number of 24.5 species was recorded per sample plot, the total being 55 species (Fig. 2).

2.4 *Sporobolo pyramidalis-Acacietum sieberianae* ass. nov.

Nomenclatural type: relevé 507 (holotypus)

This low thicket (Edwards 1983) sometimes occurs on rocky ridges, where the percentage surface rock cover normally exceeds 20 %, but is usually found on terrain unit 3 at lower altitudes, where the percentage surface rock cover is lower than 5 %. Soil depths vary from 200-500 mm and clay percentages from 15-35 %.

The character species are the densely tufted grass *Sporobolus pyramidalis*, the small inconspicuous forb *Hermannia depressa* and *Acacia sieberiana* which can occur as a large tree (species group AF, Table 1). Other prominent and often dominant species include: *Acacia karroo*, *Bothriochloa insculpta*, *Eragrostis curvula* and *Hyparrhenia hirta*.

A total number of 77 species was recorded, the average number per sample plot being 31.8 (Fig. 2).

2.5 *Eragrostis plana-Acacia karroo* Thicket

This low thicket (Edwards 1983) is restricted exclusively to flat to gently sloping (0°-8°) midslopes with deep (>500 mm), clayey (>35 %) soils, derived mainly from dolerite but also from sandstone of the Vryheid Formation. Surface rocks are virtually absent.

This community has no diagnostic species (Table 1). The only woody species is *Acacia karroo* which, together with *Eragrostis plana*, *Eragrostis curvula*, *Hyparrhenia hirta* and *Themeda triandra*, largely constitutes this vegetation unit. This community has a strong affinity with grassland and can be considered a transition from thicket to grassland.

A total number of 55 species was recorded, with an average of 25.3 per sample plot (Fig. 2).

2.6 *Setaria sphacelata-Acacia karroo* Thicket

This low thicket (Edwards 1983) occurs on shallow (200-300 mm) soils of the Glenrosa Form with clay content varying from 15-20 %. Surface rocks cover more than 20 % of the area. The slopes are moderate (3°-10°), facing mainly eastward.

This community is closely related to the *Eragrostis plana-Acacia karroo* Community, displaying a very similar species composition, except for the absence of species groups AJ and AK (Table 1). The dominant species include: *Acacia karroo*, *Setaria sphacelata*, *Eragrostis curvula* and *Hyparrhenia hirta*. Smaller clusters of *Acacia sieberiana* are sometimes encountered.

The average species richness is 35 species per sample plot, with the total number of species being 56 (Fig. 2).

Ordination

The scatter diagram displays the distribution of the relevés along the first and fourth axes (Fig. 3). The vegetation units are represented as groups, their distribution on the diagram corresponding with certain physical environmental conditions. The three gradients which are described by the first axis, are altitude, moisture regime and slope. These gradients correlate closely with each other and have a strong influence on the vegetation. Forests and woodlands of high altitudes, accompanied by a relatively high soil moisture content and steep slopes, occur to the right of the diagram. The high soil moisture content associated with high-lying steep slopes can be ascribed to the simultaneous effect of high rainfall and low evaporation figures. Low-lying woodlands and thickets, associated with a lower soil moisture content and less steep slopes, appear in the left hand side of the diagram. No clear gradient can be observed along the fourth axis which can explain the distribution of the relevés, yet this diagram gives a clearer presentation of the gradients than those diagrams displaying axes 2 and 3.

Concluding remarks

The TWINSPAN classification and its subsequent refinement by Braun-Blanquet procedures resulted in the delineation of 24 communities. These communities can be related to certain environmental factors the gradi-

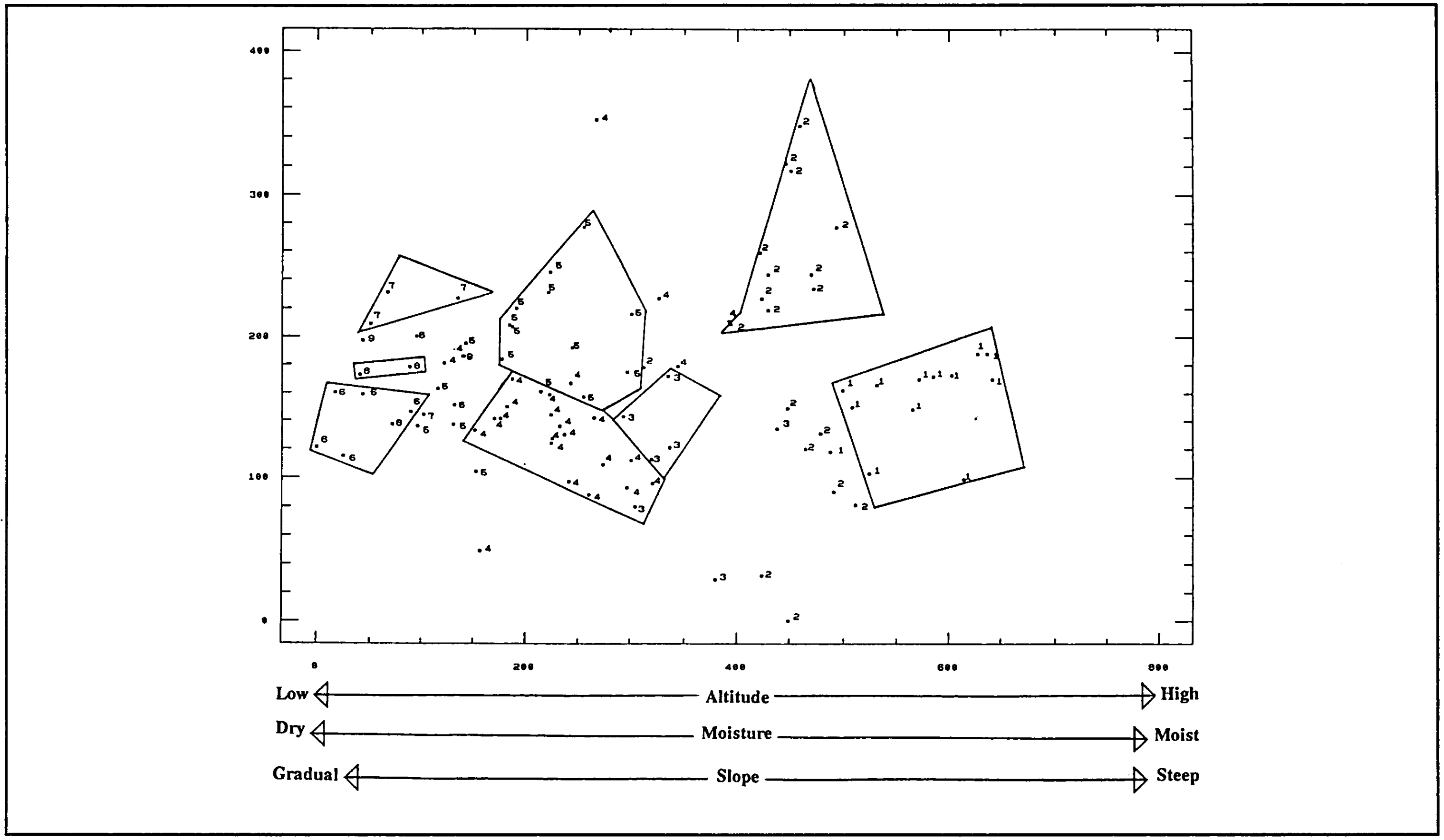

Fig. 3. The distribution of the relevés along the first and fourth axes of the ordination based on floristic data. 1. *Stachyo kuntzei-Leucosidion sericeae*. 2. *Trimerio grandifoliae-Greyion sutherlandii*. 3. *Maeso lanceolatae-Euclion crispae*. 4. *Eragrostio curvulae-Acacion caffrae*. 5. *Trachypogo spicati-Diospyrion lycioidis*. 6. *Brachiario eruciformis-Acacietum karroo*. 7. *Sporobolo pyramidalis-Acacietum sieberianae*. 8. *Eragrostis plana-Acacia karroo*. 9. *Setaria sphacelata-Acacia karroo*.

ents of which are illustrated in the DECORANA scatter diagram.

There are certain vegetation units or areas which need special attention and should be considered for conservational purposes. The *Rhamno prinoidis-Podocarpodetum latifolii* has conservation value in that the rare *Watsonia latifolia* (Hall *et al.* 1980) was found in relevé 226. The *Plectrantho grallati-Dalbergietum obovatae* of the Ntabankulu mountain north of Glückstadt and the *Plectrantho fruticosi-Trimerietum grandifoliae* of the mountain range north of Black Mfolozi are two associations which are not only in danger of being destroyed through replacement by eucalyptus and wattle plantations, but seed dispersal from adjacent plantations also holds a serious threat to these indigenous associations. The *Rapano melanophloei-Greyietum sutherlandii* is a community of conservation importance because of the presence of the rare and endemic woody species *Scolopia oreophila* (Hall *et al.* 1980). The *Hyparrhenio dregeanae-Dombeyetum rotundifoliae* of the northerly-facing slopes of the Ngcaka mountain at Lüneburg is also of conservation importance due to its high species richness. This association is however threatened in that it is often exposed to the destructive effect of veld fires. The *Trichoneuro grandiglumis-Canthietum mundianum* of the granitic outcrops on the farm Toggekry near Lenjane Drift with its exceptionally high species richness, makes this association worthy of conservation.

It is hoped that the descriptions of the different vegetation units will make a significant contribution towards the understanding of these units but also of the vegetation of northern KwaZulu-Natal as a whole. Hopefully, the information can be meaningfully applied in the management and conservation of the respective areas with particular emphasis, however, on the forests and woodlands of higher altitudes which are threatened by exotic plantations. Proper and sound assessment of the woody vegetation, including aspects such as species richness, is a prerequisite before suggestions concerning conservation can be made. The high-lying woodlands and forests, although not extremely rich in species, are to be considered for inclusion in the Natural Heritage Programme because of certain potential factors which threaten to destruct these woodlands and forests.

Acknowledgement

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CHAPTER 4.3

The plant communities and species richness of the *Alepidea longifolia-Monocymbium ceresiiforme* High-altitude Grassland of northern KwaZulu-Natal

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The plant communities and species richness of the *Alepidea longifolia-Monocymbium ceresiiforme* High-altitude Grassland of northern KwaZulu-Natal

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Eckhardt, H.C., N. Van Rooyen and G.J. Bredenkamp. 1996. The plant communities and species richness of the *Alepidea longifolia-Monocymbium ceresiiforme* High-altitude Grassland of northern KwaZulu-Natal. *Koedoe* 39(2): 53-68. Pretoria. ISSN 0075-6458.

As part of a vegetation survey of the grasslands of northern KwaZulu-Natal, this survey was conducted within the *Alepidea longifolia-Monocymbium ceresiiforme* grassland of high altitudes. Relevés were compiled in 156 stratified random sample plots. The data set was classified using TWINSPAN. Subsequent refinement by Braun-Blanquet procedures produced 15 plant communities. Species richness was determined for each community. According to naturalness and species richness two communities were selected as being of conservation importance. An ordination algorithm (DECORANA) was also applied to describe the relationships between the vegetation units and the physical environment.

Keywords: Braun-Blanquet method, classification, diagnostic species, grassland, species richness.

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Introduction

The grasslands of South Africa constitute one of the country's most important renewable natural resource regions. Many livestock farming enterprises depend entirely on the forage production of the grass layer. Yet, a closer look at the floristic composition of the grasslands as a whole, reveals a gradual degradation (Tainton 1981). Signs of degradation usually differ from one area to another. In the eastern higher rainfall areas of the country, retrogressive change in species composition takes place from subclimax/climax stages towards earlier successional stages, whereas a decline in cover and productivity of the grass layer can be witnessed mainly in the drier western parts of the grassland biome (Tainton 1981). In addition to this, large parts of the grassland have been destroyed to make place for the development of urban areas, afforestation, agriculture and mining (Mentis & Huntley 1982). Degradation of the natural environment, and the grasslands in particular, must be considered in the context of food production, which, for Africa as a whole, will have to be tripled during the next three decades, if predicted demands are to be met (Agricultural News 1995). Therefore, it is necessary to manage and conserve the remaining grasslands carefully if sustainable production is to be maintained. This, however, cannot be achieved without proper knowledge of the ecology of the various vegetation assemblages and of ecosystems at large (Pentz 1938; Bayer 1970; Edwards 1972; Bredenkamp & Theron 1991).

This paper forms part of an investigation of the vegetation of northern KwaZulu-Natal and deals in particular with the high-lying (>1 200 m above sea-level) grasslands of northern KwaZulu-Natal (see also Eckhardt *et al.* 1996). Considerable progress has been made with the syntaxonomy of South African grasslands (e.g. Bezuidenhout *et al.*

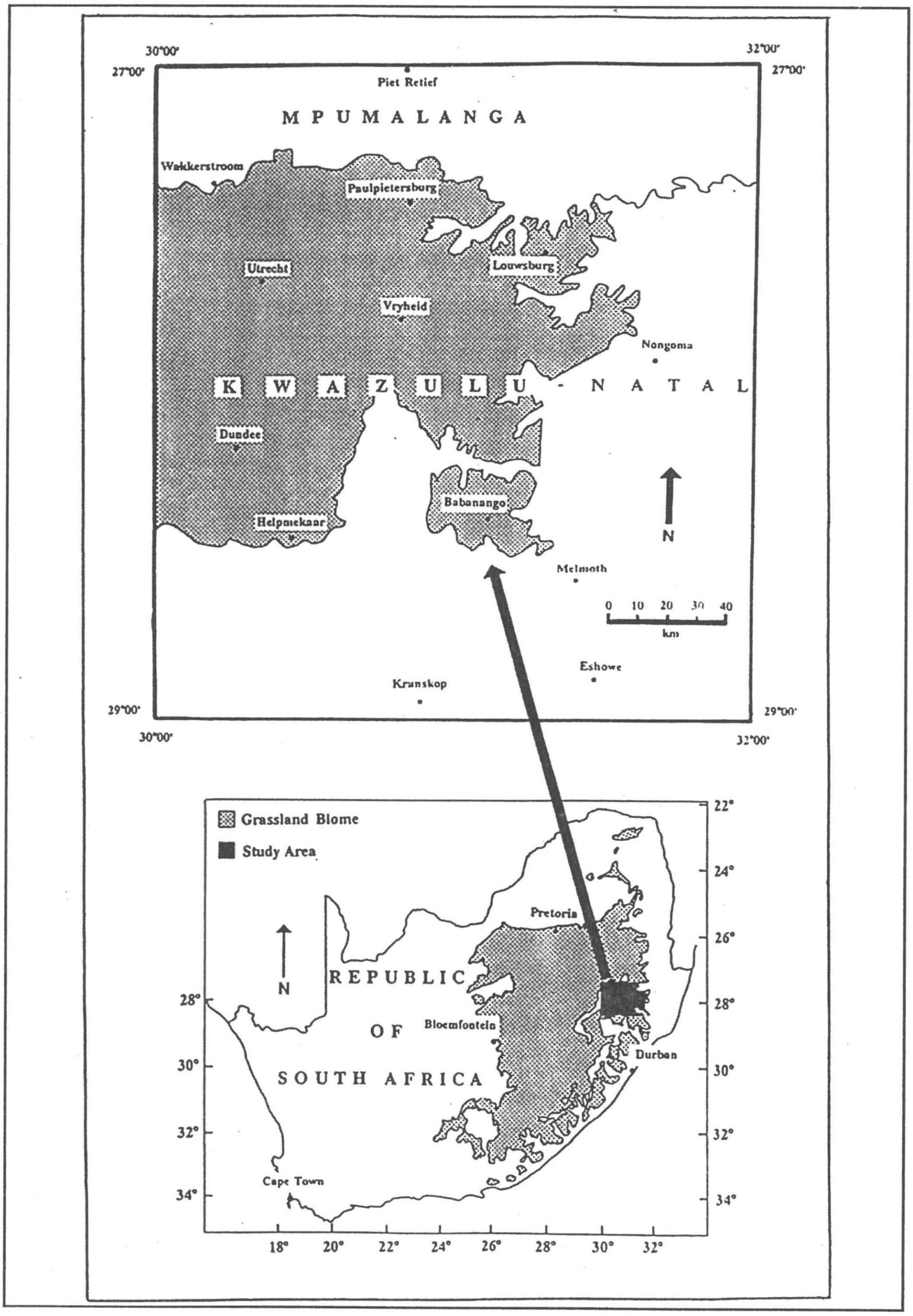

Fig. 1. Map indicating the location of the study area within the Grassland Biome.

1994), but little is known of the syntaxonomy of KwaZulu-Natal grasslands. The floristic data and phytosociological analysis from this region allows the compilation of a syntaxonomy, which is a major contribution to the phytosociological knowledge of South African grasslands.

Study area

The study area is situated in central-northern KwaZulu-Natal (Land Type Survey Staff 1986, 1988) between latitude 27°16'S– 28°31'S and longitude 30°00'E–31°38'E (Fig. 1). The area covers approximately 14 366 km² and lies at an altitude of between 750 m and 2 290 m above sea-level. Mean annual rainfall is 850 mm, although it may vary markedly within the area due to physiographic heterogeneity (Schulze 1982). The area consists of irregular undulating lowlands in the central and south-western parts, undulating mountains and lowlands in the north-western and eastern parts, and low mountains in the south-eastern part (Kruger 1983). Parts of the vegetation are equivalent to the *Themeda-Tristachya-Digitaria* Northern Highlands Grassland described by Edwards (1967) which are predominantly fire-maintained grasslands with islands of woody vegetation scattered through-out the area (see also Eckhardt *et al.* 1996). The specific area covered by the *Alepidea longifolia-Monocymbium ceresiiforme* Grassland encompasses the high-lying central-northern parts of the study area.

Methods

Relevés were compiled in 156 sample plots, which were randomly distributed throughout the study area on the basis of terrain units and aspect. Care was taken as to cover all variations within the vegetation. All plots were circular and fixed at 100 m² (Scheepers 1975). All plant species occurring in the plots were recorded and given a value according to the Braun-Blanquet cover-abundance scale (Mueller-Dombois & Ellenberg 1974). Taxon names conform to those of Arnold & De Wet (1993). The structural classification system of Edwards (1983) was used to classify the different grassland types according to their structural properties. Environmental data recorded for each relevé included: terrain unit, aspect, slope, geology, soil type and depth, soil texture, rockiness of soil surface and degree of erosion.

Two-Way Indicator Species Analysis (TWINSPAN) (Hill 1979b) was performed on the floristic data set of 156 relevés. This classification was further refined by Braun-Blanquet procedures (Westhoff & Van der Maarel 1978; Kooij 1990; Bredenkamp & Bezuidenhout 1995; Fuls 1993). The results are presented in a phytosociological table (Table 1).

The ordination algorithm DECORANA (Hill 1979a) (Fig. 4) was also applied to the floristic data set to illustrate relationships between the vegetation units and the environmental factors recorded. For practical reasons the large data set has been transformed into a synoptic table to simplify the interpretation of possible gradients. If each relevé had to be indicated on the scatter diagram, the numbers representing the relevés would often overlap each other, thereby making them illegible.

The floristic data within each identified plant community were analysed further to determine species richness (see Eckhardt *et al.* 1996 for a more detailed discussion and definition).

Results and discussion

The different vegetation units which constitute Table 1 are generally classified together as moist, high-lying grasslands. These grasslands occur mainly on plateaux and mid-slopes, but are also often found on scarps. Tall (1-2 m) to high (>2 m) grassland (Edwards 1983) usually covers the steeper slopes and scarps with rocky conditions prevalent and woody vegetation being absent. Gradual slopes and undulating plains of the higher altitudes are covered by short (0.5-1 m) to tall grassland on deeper soils.

The most common and often physiognomically dominant species include *Hyparrhenia hirta*, *Eragrostis curvula*, *E. plana* and *Sporobolus africanus*, represented by species group R, as well as *Themeda triandra*, *Trachypogon spicatus* and *Cymbopogon excavatus* (species group S, Table 1). The species which comprise group R are the most widely

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Table 1

Phytosociological table of the Alepidea longifolia - Monocymbium ceresiiforme *High-altitude Grassland of northern KwaZulu-Natal*

Alliance	1				2			4							
Association	1.1	1.2		1.3	2.1	2.2							8		
Subassociation		1.2.1	1.2.2					4.1	4.2						
Community							3			5	6	7		9	10
Releves	45555555	4445444440	44544335455	01533	00112544550014	35335255444013433455555555	113330355	3102202	122212220111	3334453545	45333	05545645	3345503533	44454344334534	2534343
	72447889	4663866267	60478899924	73388	67233949266632	81852090559333966077788926	345154306	3947848	979987037957	0590713083	32609	77659081	5887803747	98152161549404	6165120
	94155587	3363447855	85779676762	32223	81690358262373	73595281285054259206834415	455441608	9224049	431866559016	5746505876	09605	67450129	8489253278	31917302654977	7437801
Species group A															
Hyparrhenia dregeana	311A+1A1	+ +	A				1			+	A	1		+	+
Hyparrhenia cymbaria	B3 1 1											+ +			
Species group B															
Digitaria diagonalis	1+	+1BA 1++	1++ ++	1	+	+ 1			+						
Berkheya zeyheri		++ +++ +	+1++ + +	11		+ + +	+					+			+
Schistostephium crataegifolium	+	+1+1 + +	+ 1 +R1	1+	1	+ + + +	+		+			1 +			
Cheilanthes sp.		++1 ++ 1	1+ 1+	+	+						+				
Leonotis ocymifolia	+	++	R++R++ +			+ +	+		+ 1 1 +						1
Dicoma zeyheri	+	+ + 1+ +	++ +			+ + R +	R			R					+
Species group C															
Berkheya speciosa		1++1+1+++	1	+	+	+ +		1			+				+
Rhus discolor		++++ ++ 1	1	R		R	+		+ ++						
Hypoxis galpinii		+++ 1 +	+		+1			+	+ 1						
Plectranthus madagascariensis		+++ +												+	+
Species group D															
Athrixia phylicoides	1 ++1+	+++++ 1R	1	+R		R	1		+++1 +	+	+ R	+ R			1
Species group E															
Alepidea longifolia	1+	1	++	111R1	+	1+ + 1+	1		+	+	R R				R
Eriosema kraussianum				+1+ +	+	+ +	+								
Pearsonia sessilifolia			+ +1	++1	+	1 1	+						+		
Schizachyrium sanguineum		+		111		1 11									
Gnidia capitata				+ +1		+	+				R		+		
Species group F															
Cymbopogon validus	4AB+1 +	+A33145++B	31A++3++A1A	+ +1+	+	+ + R + + +	+ 1	1			+	1 1			
Species group G															
Helichrysum oreophilum			+	1 1	1+A11+1++1+11R		+	+	1 +1				1	+	
Alloteropsis semialata					A 31A A 1	1 1			1						
Species group H															
Monocymbium ceresiiforme		+ 1	1 +++ A 1	+1 +	11 +A11A A+	+1AA3A+1+A111111+++A1B+1BB		+		++ 1+	+	1 +	1	+ +	
Species group I															
Panicum natalense		11+1 + +	+1 1111 11	+1A1B	11 A1 + B 1A	1 1 + + A1 B 1A A + +	1 11 A			1			+		
Loudetia simplex	1	1	11 34A +ABA	34	1 31+ 11+B1 B	A+A B++ 1A1333 3 + 1	+ A 11 3	+					1		
Tristachya leucothrix		11 1+A11B	+3	131	B1 1 11 A	+B A + 11A 1 A A	131 1 A	1 1	+ 1	1	1				1 1
Berkheya echinacea		+ 1 +	1 1 +	1 11	+ ++ 1+ 1+1	1 1 + 11 +1 1	1+1 1 +		+1			+		+++	+ 1
Ctenium concinnum		1+1 +	1 1 R + +	AB	1 1+ +A 11	+ 1 B	1++ +		1						
Syncolostemon concinnus	+	+++ + +	1 + +	+1	+ + +	+++ ++ + +	1 1 +						+		+
Sebaea leiostyla	+ +	+ +1	+	1 +	+ + + +	+1+ 1+ + ++1	+1++		+ +	+	+	+	+	+1 +	+
Haplocarpha scaposa	11	+1	+	11	1 + + 1	+ + 1+11+ +	+ 1+	+	1			+		+ 11	+
Tetraselago natalensis	1 +		1 +	R	+ + 1	1 1 1+1	1+ 1								R
Species group J															
Berkheya onopordifolia	+					+		++1++1	+ 1++++++1		+ +			+ +	+ +
Commelina africana		+	+				1 ++1	+ 1+1	11 1 111		+ +	+	+ +	+	
Dicoma anomala				1	1 1 + 1			1 +	1 11 1 1+				+		
Ipomoea ommaneyi		1		1		1+	+	+ 1 1+	1 1 1	+R	+				1 +
Indigofera hedyantha					+			1 +	1 + + 1	+ 1					
Species group K															
Acalypha caperonioides		1		1 +	1	1 +	1		11 1 1111 11						
Rabdosiella calycina	+	+	R		1		1 1		1++11 1 +			+			
Species group L															
Melinis nerviglumis	1	1++11	1+ 111A	1A1111	111 11++ +1 1	+1 + + 1 + ++	1+ 111 1	A 11++1	1+1+ 11 A			+ 1	+		++
Vernonia natalensis	1++	1111 +A ++	A 1R	+ 11 1+	1++ 1+1 + 1	+ 1+ 1 + +1+	1 R+1 +	1++ 1 +	11 + 1+ +			+		+ R+	
Diospyros lycioides	+	RRR +	+R+	+++	++R+ + +	R +	+ + R+	A+AAA++	+++ ++R +++A	+				R	+R R
Rhus dentata		R+ + +	+ + +	+ R	+	+		++A+++	1+++R+ +1						
Pellaea calomelanos	+	+ ++	1 1	11		++1	+ 1 1+1	+	1 + 1+						
Protasparagus setaceus		R R	R	R	+ +	R	R+	+	+ +R R						

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Table 1 *(continued)*

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Species group M

Helichrysum nudifolium     | 1   1 |          |      +     |     |  + ++ +1  1 |1+ 1+  +  +  +   ++      1| 111  1 |  + 1 |      +    | 1+ ++1+1 |     | 1+++ |+    R  |          |       |
Elionurus muticus          |      1| +        |            |     |+    +  +1  |      1 1  A   1         |        | +11 1| +   1     |B +B +   A|     |      |        |    +     |       |

Species group N

Diheteropogon amplectens   |1  +    |AAA11A111B|A1+1A  1  +A1|BA111|1 11++1111    1| 111   A+++ A111 +11+ +   | 1 + 1 +|+  1 1 | 1 + A    1| 11111    |++ + | 1    |  +     |     +   +|    +|
Heteropogon contortus      |        |   1      | 1 +  +  +  |  + +|31A13B       111| + 1+1     1 1+1 +  ++ 1 | 113B11 |1B1 111|A 1 1B 131BB|3 AA A1  1|   1+|A     | 1   1  |  +      +|+ B 1 |
Pentanisia angustifolia    |        |        ++| +   +  +   |+  1+|+        ++1+  |1 111  + ++ +111  1+1   |+  11+1+1|1     |   1        | +  +11 + |++11 |  +   |    1R1  |  +   1   |  + + 1|
Andropogon schirensis      |        |11  +   + |111   A   1 |   1 |   1  1 1A  1 |1 B   A1+A+1  1    11 11AA|   A    |   1   |+1   1  1  | 11+1+    |     |      |  +     |          |       |
Chaetacanthus burchellii   |      + |11        |     + 1 +  | 1 + |1      11+ 11  |+ 11          1   1 +++1 | 1   1  |       |1 1  1      |+  +++1+  |+11  |      | ++ +   |  + +  1 +|       |
Anthospermum rigidum       |        | +      + |            |1  + | 1  1+1    11 | + 1           1+  +     |  +1 1  |11 1 1 |1 1 11  1   |     +1+ +| + 1+|      |   +    |      +   |  1    |
Scabiosa columbaria        |        |        + | +  1    1  |     |      +  + ++  |  +          +  ++       |  1  +  |+++1 1 |  1 11 1 +1 |1    +1+  |   1 +|     |+ +  1  |  +       |+ 1  +|
Hypoxis rigidula           |        |R     + 1 |          + | 1+  |   1      11+  |           +  + R +      | ++     |+ +  1 |     +      | 1+1++ 11 | +11 |      |  +     |          |      +|
Helichrysum cephaloideum   |        |+    +    |      R     | +1+ | ++      +      | + +   ++  +++  + 1+  +  |   1    |+    + |+     1     |    ++ +  | +   | 1 +  |        |+    1    |       |
Setaria sphacelata         |    1   |1++       |      +     | + 1 |1  +      13    |          ++  +          |   + 1  | +     |           +|1++1 +A   |  1 1|      |    +   |        +|  1 + |
Moraea natalensis          |        |  +    +  |           +|     |      R         |         +  +R           | R+     |+      |            |++++RR    |+ +  |      |R       | +R  + +  |  + + |

Species group O

Eulalia villosa            | 311    1|ABAA+1A1AB|1BB  +1  R111|B3BBA|11    +++B1 1 A|+AA 3  3  1A3+B    +3AAA1 |A 1A  1 |+A 1  |11  +   1  |   +     |+  |ABA1 1RA|        |          |      |
Helichrysum aureonitens    |+1   +  |+          |      1    +|1  +1| 1 1+1++ +1+  |1 1 11 +++1 1+      ++1  11| +++ 1 + |      |    1   +  |  + +R +|   |+1+111+1|  +    + |1+    ++  | 1    |
Pteridium aquilinum        | + 11++1|          1+   +|1      1 + |     |  +             |1 1 + +          +  ++ + ++|  1   1 |      |            |         |   |1 1 +   |        |    1 1   |      |
Helichrysum pilosellum     | + 1     |          1|  1        | 1   |1 1111    1 1+ |   1        1         +1+ + |11      | 1    |   1    1   |1        | 1 |11      |        |          |      |

Species group P

Sporobolus pyramidalis     |        |          |           |     |               |                 1      |      B |      |            |      1 | 3 1|        |B111+ 4+14|          |     1|

Species group Q

Spermacoce natalensis      |+      1 |          |       +    |     |              |1       +11  +   +  +11 | +++ 1  |      |       ,    | 1  + + |1 + 1| + ++1+ | ++     1 |+  1+11 1R++ +|  +  |
Zornia capensis            |         |1          |           |     |11 1      11 |  1        +1        +  | 1111   |    1 |     1      | + 1    ++|    +|1+1   |   +  +  | +1 11 + +  1 |    1 |
Hypochoeris radicata       |          |          |       + + |     |  1  +        |+         +         +  | 11   + |   1 +| +  +   1   | +    +|       |   + +   |+++  1 R +  +|      |

Species group R

Hyparrhenia hirta          |4B4B5435|11A11 +3BA| 1A31A35331| 1   |B1 1A334341A A|3B43A143A43A13A  4 B+B3 3B|314 3AB3 |4134444|334413341333|A35153344+|44B35|B54A554 |33453  54 |555B43B34A5545|413355A|
Eragrostis curvula         |1  +  ++|31 ++++1+ |  +1 1+ +1+|  A |1B 13A11  +A1B|A+ 1 1  B11A1A+  A +      | 11111311|111+A |1AB33 3+AABA| BA A13BAA|B1331|B    +B+|B3B+ 33+33|+AA3BAABBA 1B1|A AB1A4|
Sporobolus africanus       |      +11|++        |   +      +++|     |      + +     +| +   ++ A1A  + ,       1|       11 |1   1 1|+1A 1     +  | 1  1 1+1 | +11+|A11+111 | 1111 1+A1|1+ 1+1BA A1+ | 3 1 +1|
Eragrostis plana           |      ++ |          |          +|     |+3   +    1 + |4  +    +13           1| 1A   B  |      | + 4   1111|11  1  ++A|  1 |B1B. + A | 1 1    1A|11  A3AA 411 | 31  R |

Species group S

Themeda triandra           | 1 1 +  | +11++ BBB|B1ABA11+ 1 |33B +|BA13B+3BBABB3 | ++1 1 1 +1AA111 + 1+31  B|3+11AB++ |1B3 AA |A   1B AB 33|A113+A1 1 |A1 A |A  +  1 |1 A+ B   |+AAA  311 1  +|A ++111|
Trachypogon spicatus       |   1    1|111B41+BBA|AB31AA3+1+4|A1B1B|11311BBAA 1 1A|+B11 +A +A +1331 +3B3135+A|+4  +B1 3| 311   |+1+  A111  +|    1+B   |1+ ++|   1  ++| +        |  +    +    1|1 +1  +|
Eragrostis racemosa        | +     ++|1+  1 1 1 |1 11  1   1|+    |1111111 11 111|111A+11+ +1111  +1+1111A11| 111111 |111  11|1   11  11 1|+ 1 111+1 | 1111|1+  1+ |1 1+ 1 + |+    +1+    +| +1+1 1|
Berkheya setifera          |  +111 1|1  1+ + +1|  111 1+11 |1A1  |11111 1+11 1  |1111   1+11 111+   1111 |11 11111 |1      |11111   11  | 11 11111 |+1 1+|1+   + |         |  1++11 1 +  |1 +1+11|
Cymbopogon excavatus       |      1 |AA1 AA111 |1A 1+ B 11 |   1 |++    +A +    | + 1   11 1  A11 A      |B    +1 |B 1A11 |1BA1 B1   1A| A1A11A11 |1BBBA| +    + |BAA 1  1 | + 3A 1 A  BA |B 1A1+1|
Helichrysum rugulosum      |     +1+|+         1|      1     |     |11   1+   +  1| 1 11 +1 1+  +   11 1 1 1 1| 11+  11+|   1 11|1+1111 11 11| 1  +11+ 1|111 +|1+ +11 +|11++ + +  | ++ 11+   +++|11++ 1+|
Eragrostis capensis        |        |   +  1  | +        1|   + |  11 +1    1 | 111 1  +1 1 1   + ++11  1| 111 1  |       | 1       1 11|A  1 11  | 1111|1  ++ | 1 + 1  1| 1  11 +      |  + 1 1|
Aristida junciformis       |     1BA |          |        +R +|     |1B  1 +   +  3|+A   B  4A A   14113 +1 + |+B+A 11 1| +1  13|3   +1A+BB 1|      +  4|    +| 1 51  4|   A3     |       +      |  3B R |
Conyza obscura             | 1+ ++ 1| 1  + + +1|  +    ++++|   + |     +         |  +++ ++     1           |1 1 + 1+ |1  1  | +          +|   ++1++ |++1 | +  ++ |+11++    + |+R 1 ++ + +++ | 1  +  |
Tephrosia natalensis       |    +   | +         | +    R    |   + |1         1    | ++            + +   ++   |   1  1 |       |             |  + +11  |  +1+|       |          |        +  + | +   +|
Helichrysum coriaceum      |1        |++    +   |            |   1 |         1     | 1        +1             |    + 1 |       |+            | +       |     |  +    | 1         |1+   + 1 +  |+ +   |
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distributed and often most prominent species encountered in this and other plant communities throughout the study area and are therefore included in one separate species group.

A diagrammatic presentation of the hierarchical classification and associated environmental interpretation of the different vegetation units is presented in Fig. 2.

The average species richness of the communities is 27.9 species per 100 m² and the average total number is 117.9 (Fig. 3). In contrast to these values the species richness for the two orders *Leucosideetalia sericeae* and *Acacietalia karroo*, described by Eckhardt *et al.* (1996), are 29.1 and 30.7 respectively, and the total number of species 59 and 79.1.

Classification

The analysis resulted in the following hierarchical classification:

1. *Cymbopogono validi-Eulalion villosae*
   - 1.1 *Hyparrhenio dregeanae-Hyparrhenietum hirtae* (vegetation unit 1)
   - 1.2 *Digitario diagonalis-Trachypogonetum spicati*
     - 1.2.1 *Digitario diagonalis-Trachypogonetum spicati athrixietosum phylicoidis* (vegetation unit 2)
     - 1.2.2 *Digitario diagonalis-Trachypogonetum spicati loudetietosum simplicis* (vegetation unit 3)
   - 1.3 *Alepideo longifoliae-Eulalietum villosae* (vegetation unit 4)

2. *Monocymbio ceresiiformis-Trachypogonion spicati*
   - 2.1 *Helichryso oreophilum-Themedetum triandrae* (vegetation unit 5)
   - 2.2 *Monocymbio ceresiiformis-Aristidetum junciformis* (vegetation unit 6)

3. *Hyparrhenia hirta - Aristida junciformis* Grassland (vegetation unit 7)

4. *Berkheyo onopordifoliae-Diospyretum lycioidis*
   - 4.1 *Berkheyo onopordifoliae-Diospyretum lycioidis hyparrhenietosum hirtae* (vegetation unit 8)
   - 4.2 *Berkheyo onopordifoliae-Diospyretum lycioidis acalyphetosum caperonioidis* (vegetation unit 9)

5. *Helichrysum nudifolium - Hyparrhenia hirta* Grassland (vegetation unit 10)

6. *Cymbopogon excavatus - Hyparrhenia hirta* Grassland (vegetation unit 11)

7. *Helichrysum aureonitens-Eulalia villosa* Grassland (vegetation unit 12)

8. *Sporobolo pyramidalis-Hyparrhenietum hirtae* (vegetation unit 13)

9. *Spermacoce natalensis-Eragrostis plana* Grassland (vegetation unit 14)

10. *Helichrysum rugulosum-Hyparrhenia hirta* Grassland (vegetation unit 15)

Description of the plant communities

1. *Cymbopogono validi-Eulalion villosae* all. nov.

Nomenclatural type: *Digitario diagonalis-Trachypogonetum spicati* (holotypus)

This alliance occurs on flat to steeply undulating topography at an altitude of more than 1 200 m, with slopes often being as steep as 25°- 35°, facing mainly north (Fig. 2). Soils are generally of the Glenrosa-Mispah complex, depth being less than 200 mm and clay percentages varying from 15-20%. Percentage surface rock cover usually exceeds 20%.

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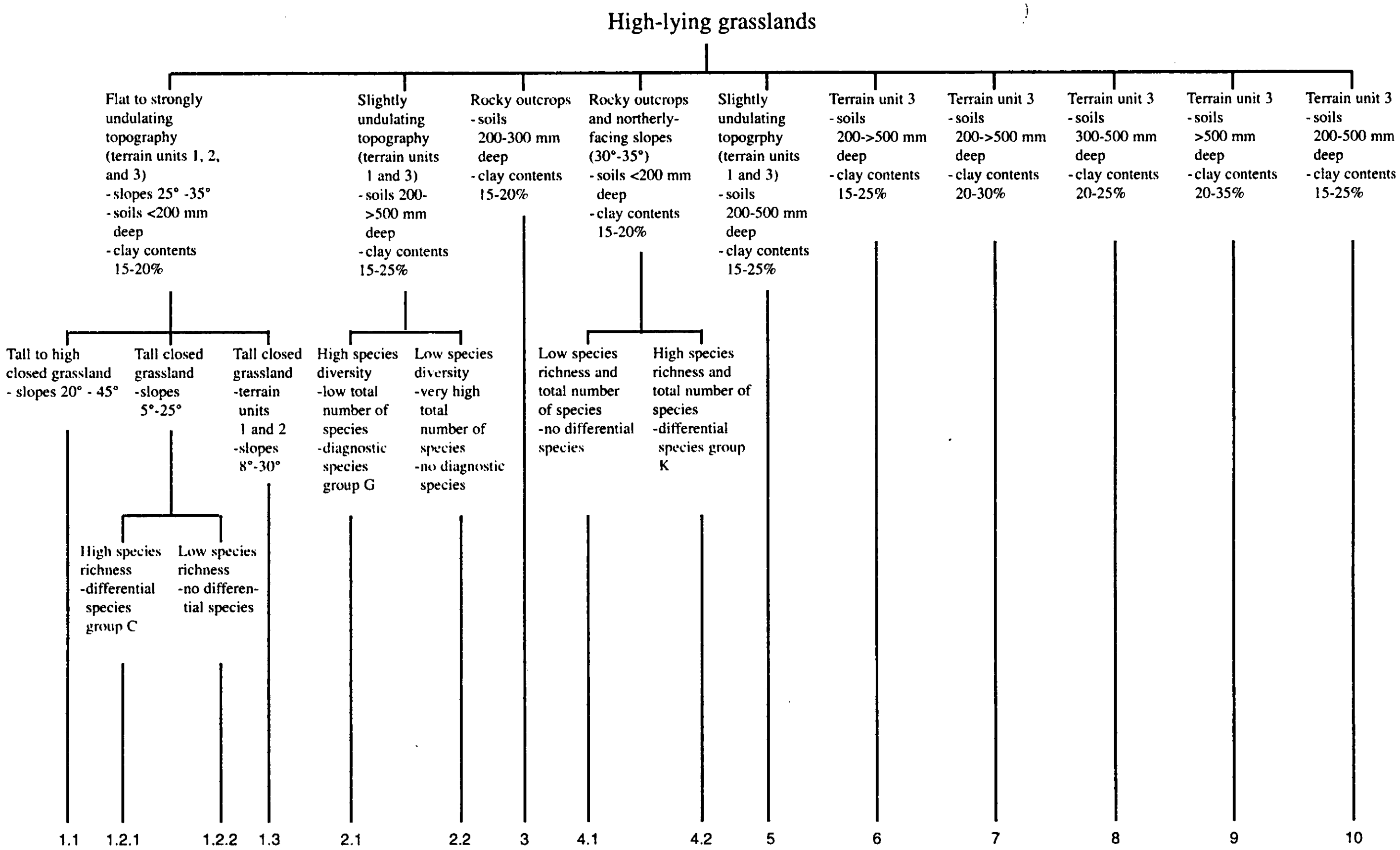
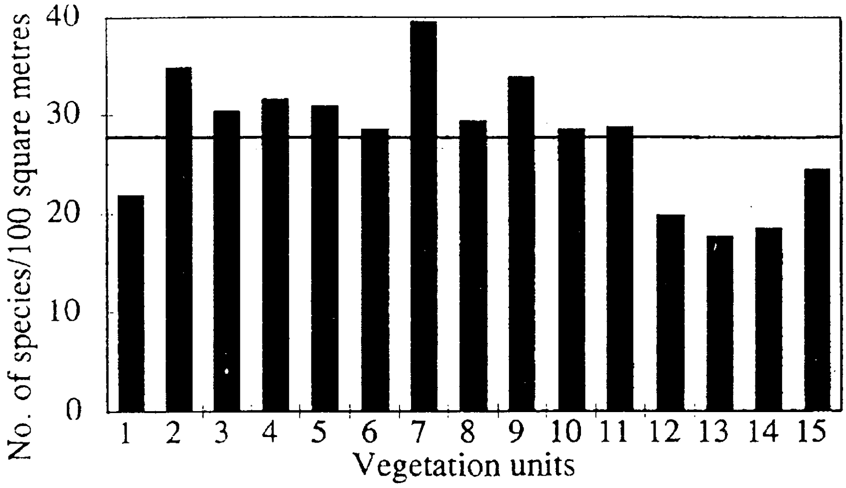


Fig. 2. The hierarchical classification and associated environmental characteristics of the 15 vegetation units.

AVERAGE SPECIES RICHNESS



TOTAL SPECIES PER VEGETATION UNIT

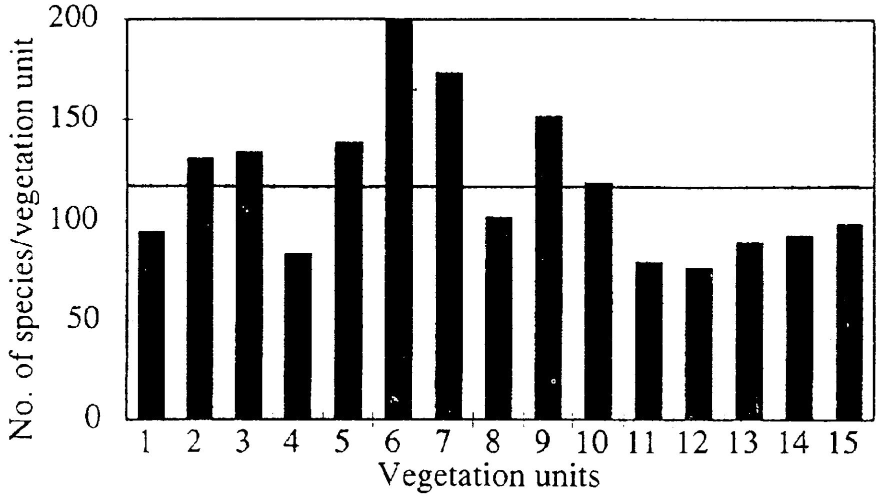


Fig. 3. Average species richness and total number of species calculated for each vegetation unit. Horizontal lines represent the respective averages for the *Alepidea longifolia-Monocymbium ceresiiforme* major vegetation type.

The only diagnostic species is the tall grass *Cymbopogon validus* (species group F, Table 1). Other prominent and often dominant species include *Eulalia villosa*, *Hyparrhenia hirta*, *Themeda triandra*, *Trachypogon spicatus* and *Cymbopogon excavatus*.

1.1 *Hyparrhenio dregeanae-Hyparrhenietum hirtae* ass. nov.

Nomenclatural type: relevé 545 (holotypus)

This tall to high closed grassland (Edwards 1983) association occurs on steep (20°- 45°), north-facing slopes (Fig. 2). Soils of the Glenrosa-Mispah complex predominate, the depth being less than 200 mm while clay percentages vary from 15-20%. Surface rocks cover more than 20% of the area, while the size of the rocks generally exceeds 500 mm.

Diagnostic species characteristic of this association are listed under species group A (Table 1). Other physiognomically conspicuous and dominant species are *Cymbopogon validus* and *Hyparrhenia hirta*.

The average number of species per sample plot (species richness) is 21.9 and the total number of species recorded is 95, both values being well below the respective averages (Fig. 3).

1.2 *Digitario diagonalis-Trachypogonetum spicati* ass. nov.

Nomenclatural type: relevé 466 (holotypus)

In comparison to the previous community this tall closed grassland (Edwards 1983) association occurs on less steeper (5°- 25°) slopes and more gently undulating terrain and is often associated with rocky outcrops (Fig. 2). The Glenrosa-Mispah complex soils are principally associated with this terrain type, soil depth being <200 mm. Clay percentages (15-20%) are very low. Surface rocks generally exceed 500 mm in diameter and cover more than 20% of the area.

Character species are listed under species group B (Table 1). Other prominent and often dominant species include *Cymbopogon validus, Loudetia simplex, Diheteropogon amplectens, Eulalia villosa*, *Hyparrhenia hirta*, *Themeda triandra*, *Trachypogon spicatus* and *Cymbopogon excavatus*. Although present in low numbers, the shrubs *Diospyros lycioides* and *Rhus dentata* are very conspicuous and associated mostly with rocky outcrops.

This association is the type for the *Cymbopogono validi-Eulalion villosae*. Two sub-associations are recognised within this association:

1.2.1 *Digitario diagonalis-Trachypogonetum spicati athrixietosum phylicoidis* subass. nov.

Nomenclatural type: relevé 466 (holotypus)

This grassland is characterised by the diagnostic species listed under species group C (Table 1). This sub-association is related to the *Hyparrhenio dregeanae-Hyparrhenietum hirtae* by the presence of the shrub *Athrixia phylicoides* (species group D, Table 1).

Both species richness (34.9) and the total number of species (131) are well above the respective averages (Fig. 3). In fact, the species richness is the second highest encountered within the vegetation units reported on in this paper.

1.2.2 *Digitario diagonalis-Trachypogonetum spicati loudetietosum simplicis* subass. nov.

Nomenclatural type: relevé 386 (holotypus)

This sub-association is found mainly on rocky outcrops (Fig. 2).

There are no diagnostic species which characterise this vegetation unit, but the latter is nevertheless distinguished from the *Digitario diagonalis-Trachypogonetum spicati athrixi-*

etosum phylicoidis by the absence of species groups C and D (Table 1).

The average number of species recorded per sample plot is 30.4, with the total number of species being 134 (Fig. 3).

1.3 *Alepideo longifoliae-Eulalietum villosae* ass. nov.

Nomenclatural type: relevé 73 (holotypus)

This tall closed grassland (Edwards 1983) association is found on strongly to moderately undulating terrain (Fig. 2). Soils of the Glenrosa-Mispah complex predominate, being between 200-300 mm in depth. Clay content varies between 15-20%. Surface rocks cover more than 20% of the area and are up to 500 mm in diameter. Among the character species, which are listed under species group E (Table 1), is the physiognomically conspicuous forb *Alepidea longifolia.* Other prominent species are *Cymbopogon validus*, *Eulalia villosa*, *Themeda triandra* and *Trachypogon spicatus*. The absence of *Hyparrhenia hirta* is noticeable and appears to be linked to the relatively undisturbed condition of the grassland. It seems that grassland becomes invaded by *Hyparrhenia hirta* if it is overutilised. This substantiates Edwards's (1967) finding that *Hyparrhenia hirta* was prominent in *Themeda-Trachypogon* Highlands Grassland where the primary grass cover had been disturbed by persistant overgrazing. This association is related to the *Hyparrhenio dregeanae-Hyparrhenietum hirtae* and the *Digitario diagonalis-Trachypogonetum spicati* by the presence of *Cymbopogon validus* (species goup F, Table 1).

The species richness is 31.6 and the total number of species recorded is only 84 which is well below the average (Fig. 3). The relative naturalness and high species richness lend this community conservation value.

2. *Monocymbio ceresiiforme-Trachypogonion spicati* all. nov.

Nomenclatural type: *Helichryso oreophilum-Themedetum triandrae* (holotypus)

This alliance occurs on slightly undulating topography, i.e. on plateaux and midslopes, at altitudes >1 200 m (Fig. 2). Major soil types encountered are the Glenrosa, Mispah and Clovelly Form. Soil depths vary from 200-500 mm and clay percentages from 15-25%. The percentage surface rock cover is mostly less than 5% but sometimes exceeds 20%.

This short to tall closed grassland (Edwards 1983) is clearly distinguished from the *Cymbopogono validi-Eulalion villosae* by the absence of the tall grass *Cymbopogon validus* (species group F, Table 1) and the presence of *Monocymbium ceresiiforme* (species group H, Table 1), which is also the only character species. Other physiognomically prominent species are *Hyparrhenia hirta*, *Themeda triandra* and *Trachypogon spicatus*. This vegetation unit resembles the *Themeda-Trachypogon* Highlands Grassland described by Edwards (1967).

Two associations are distinguished within this alliance:

2.1 *Helichryso oreophilum-Themedetum triandrae* ass. nov.

Nomenclatural type: relevé 230 (holotypus)

This association is the type of the *Monocymbio ceresiiformis-Trachypogonion spicati*. It occurs often on small rocky outcrops which are usually underutilised as a result of their inaccessibility for livestock caused by the high percentage (>20%) of large surface rocks (Fig. 2).

The character species are the forb *Helichrysum oreophilum* and the grass *Alloteropsis semialata* (species group G, Table 1). Other physiognomically prominent species which largely constitute this community are the grasses *Monocymbium ceresiiforme, Loudetia simplex, Heteropogon contortus, Hyparrhenia hirta, Eragrostis curvula, Themeda triandra* and *Trachypogon spicatus* (Table 1).

A species richness of 30.9 and a total of 139 species were recorded (Fig. 3). High degree of naturalness and relatively high species richness lend this community conservation importance.

2.2 *Monocymbio ceresiiformis-Aristidetum junciformis* ass. nov.

Nomenclatural type: relevé 359 (holotypus)

This grassland has no diagnostic species and is distinguished from the *Helichryso oreophilum-Themedetum triandrae* by the absence of species group G and the presence of species group Q (Table 1). Conspicuous and dominant species include *Monocymbium ceresiiforme, Loudetia simplex, Eulalia villosa, Hyparrhenia hirta, Eragrostis curvula, Trachypogon spicatus* and *Aristida junciformis* (Table 1). Noteworthy is the presence of the latter species which suggests degradation as a result of ill-managed burning practices and selective grazing (Edwards 1967; Moll 1968). The grass *Aristida junciformis* causes a problem in certain high rainfall mountainous areas, gradually replacing more palatable species and thereby reducing the grazing capacity of the veld.

Although an average number of only 28.5 species was recorded per sample plot, an exceptionally large total number of 199 species was found (Fig. 3). This is the largest number of species found in any vegetation unit described in this paper.

3. *Hyparrhenia hirta-Aristida junciformis* Grassland

This short to tall closed grassland (Edwards 1983) community is generally restricted to rocky outcrops with surface rocks covering more than 20% (Fig. 2). The predominant soil type is the Glenrosa-Mispah complex, with depths varying from 200-300 mm and clay contents of between 15 and 20%.

The syntaxonomic position of this grassland community is unclear since no diagnostic species are recognised. Prominent species are *Hyparrhenia hirta, Themeda triandra, Trachypogon spicatus* and the unpalatable *Aristida junciformis* (Table 1).

An exceptionally high average number of 39.7 species was recorded per sample plot, which is the highest number recorded for all vegetation units described (Fig. 3). The total number of species is also very high (174) (Fig. 3).

4. *Berkheyo onopordifoliae-Diospyretum lycioidis* ass. nov.

Nomenclatural type: relevé 176 (holotypus)

This tall sparse to open shrubland (Edwards 1983) occurs on steep (30°- 35°) north-facing slopes and rocky outcrops (Fig.2). Glenrosa Form is the predominant soil type, with depths being less than 200 mm and clay contents varying from 15-20%. Surface rocks cover more than 20% of the area and were usually more than 500 mm in diameter.

Diagnostic species are listed under species group J (Table 1). The most prominent species is the shrub *Diospyros lycioides* which is closely associated with this type of terrain. Other conspicuous and often dominant species include *Hyparrhenia hirta, Eragrostis curvula, Themeda triandra, Cymbopogon excavatus* and *Aristida junciformis* (Table 1). The presence of *Aristida junciformis* indicates some degree of disturbance caused by selective grazing and ecological unsound burning practices (Edwards 1967; Moll 1968).

Two sub-associations are recognised within this association:

4.1 *Berkheyo onopordifoliae-Diospyretum lycioidis hyparrhenietosum hirtae* subass. nov.

Nomenclatural type: relevé 42 (holotypus)

This sub-association has no diagnostic species, but contains prominent species such as *Diospyros lycioides*, *Hyparrhenia hirta*, *Themeda triandra* and *Cymbopogon excavatus* (Table 1).

The total number of species recorded is 102, whereas the average number recorded per sample plot is 29.4 (Fig. 3).

4.2 *Berkheyo onopordifoliae-Diospyretum lycioidis acalyphetosum caperonioidis* subass. nov.

Nomenclatural type: relevé 176 (holotypus)

This sub-association is the type of the association and is distinguished from the *Berkheyo onopordifoliae-Diospyretum lycioidis hyparrhenietosum hirtae* by the presence of the diagnostic species group K (Table 1). Other prominent and often dominant species are *Diospyros lycioides*, *Heteropogon contortus*, *Hyparrhenia hirta*, *Eragrostis curvula*, *Themeda triandra*, *Cymbopogon excavatus* and *Aristida junciformis* (Table 1). The strong presence of the latter species confirms the extent to which this vegetation unit is degraded, which can mainly be ascribed to selective grazing by sheep.

A relatively high species richness of 33.9 and large total number of 152 species were recorded (Fig. 3).

5. *Helichrysum nudifolium-Hyparrhenia hirta* Grassland

This short to tall closed grassland (Edwards 1983) community occurs on slightly undulating topography, i.e. terrain unit 1 and 3 (Fig. 2). Although various soil types may be encountered, the Glenrosa, Mispah and Clovelly Forms are the most predominant. Soil depths vary from 200 to more than 500 mm, while percentage clay varies from 15-25%. Surface rocks are generally absent, but sometimes cover as much as 5% of the area.

The syntaxonomic position of this grassland community is unclear. It contains no diagnostic species but is distinguished by the absence of certain species groups. Physiognomically conspicuous and often dominant species include *Heteropogon contortus*, *Hyparrhenia hirta*, *Eragrostis curvula*, *Themeda triandra* and *Cymbopogon excavatus* (Table 1).

An average number of 28.5 species was recorded per sample plot, with the total number of species being 119 (Fig. 3).

6. *Cymbopogon excavatus-Hyparrhenia hirta* Grassland

This short to tall closed grassland (Edwards 1983) community occurs predominantly on midslopes (Fig. 2), and soils of the Glenrosa and Mispah Form are most frequently encountered. Soil depths vary from 200 to more than 500 mm and clay content from 15-25%. Surface rocks usually cover less than 5% of the area.

The syntaxonomic position of this community is unclear since no diagnostic species are recognised. Prominent and often dominant species include *Hyparrhenia hirta*, *Eragrostis curvula*, *Themeda triandra* and *Cymbopogon excavatus* (Table 1).

The community as a whole is relatively species poor, consisting of only 80 species, although the species richness of 28.8 is slightly above average (Fig. 3).

7. *Helichrysum aureonitens-Eulalia villosa* Grassland

This short to tall closed grassland (Edwards 1983) occurs on flat to undulating midslopes (Fig. 2). The predominant soil types are

Glenrosa, Mispah and Clovelly Forms, with depths varying from 200 to more than 500 mm and clay contents from 20-30%. Surface rock was sometimes present, covering between 5-20% of the area.

The syntaxonomic position of this grassland is unclear. Character species are absent, but the most prominent are *Eulalia villosa*, *Hyparrhenia hirta*, *Eragrostis plana* and *Aristida junciformis* (Table 1). The high cover-abundance values recorded for *Aristida junciformis* are ascribed to selective grazing (Tainton 1981) and a long history of regular autumn, or early winter, burning (Moll 1968).

The species richness (19.9) and the total number of species (77) recorded are very low (Fig. 3). Although certain parts of this community are disturbed, as manifested by the strong presence of *Aristida junciformis*, the low values reported may indeed be an indication of the actual number of species which the habitat can maintain.

8. *Sporobolo pyramidalis-Hyparrhenietum hirtae* ass. nov.

Nomenclatural type: relevé 358 (holotypus)

This short to tall closed grassland (Edwards 1983) occurs on relatively flat topography, i.e. mainly on terrain unit 3 (Fig. 2). Different soil types are encountered, the most common including Clovelly, Mispah and Griffin Forms. Soil depths vary from 300-500 mm but usually exceed 500 mm, with clay contents varying from 20-25%. Surface rocks are generally absent. This association is characterised by the diagnostic species *Sporobolus pyramidalis* (species group P, Table 1), which is a tough and unpalatable species and an indicator of overgrazed and trampled areas (Tainton 1981; Van Oudtshoorn 1991). This vegetation unit has a low grazing potential, consisting mainly of old field grassland species *Hyparrhenia hirta* and *Eragrostis curvula* (Table 1). From an ecological and agricultural point of view this vegetation unit is in a poor condition as can be inferred from the low presence of *Themeda triandra*. This grassland can be considered as Secondary Grassland, which arises from mismanagement, burning and from other forms of human activity (Edwards 1967). These grasslands are thus in a disturbed state.

An exceptionally low number of only 17.7 species per sample plot was recorded, with the total number of species (90) being also far below the average (Fig. 3).

9. *Spermacoce natalensis-Eragrostis plana* Grassland

This short to tall closed grassland (Edwards 1983) is found on terrain unit 3, which has a flat to undulating topography (Fig. 2). The predominant soils are the Glenrosa, Mispah, Clovelly and Hutton Forms. The soil depths usually exceed 500 mm, with clay percentages varying from 20-35%. Surface rocks are virtually absent throughout.

The syntaxonomic position of this grassland is unclear. Diagnostic species are absent, but physiognomically conspicuous and often dominant species are *Hyparrhenia hirta*, *Eragrostis curvula*, *E. plana* and *Cymbopogon excavatus* (Table 1). These species and the simultaneous low cover-abundance values or total absence of species of more advanced successional stages typically indicate the disturbed state of this community, caused by overgrazing and ecological unsound burning practices.

An average number of 18.5 species was recorded per sample plot, the total number of species being 93 (Fig. 3).

10. *Helichrysum rugulosum-Hyparrhenia hirta* Grassland

This short to tall closed grassland (Edwards 1983) occurs on flat to undulating midslopes (Fig. 2). Major soils encountered include Glenrosa, Mispah and Clovelly Forms.

Although soils may be deeper than 500 mm, the usual depth varies from 200-500 mm and the clay contents from 15-25%. Surface rocks are usually present, covering from 5 to more than 20% of the area.

The syntaxonomic position of this community is unclear due to the absence of diagnostic species. The most prominent species are limited in numbers, including only *Hyparrhenia hirta* and *Eragrostis curvula* (Table 1). This community is distinguished from other communities by the absence of all species groups with the exception of species groups R and S (Table 1). The predominance of a few species is again very apparent, causing especially the forb species to be present in low numbers. The disturbance factor, caused by overgrazing and ecological unsound burning practices, is clearly observable in the species composition.

The species richness of 24.4 and the total number of 99 species recorded, indicate the relative species poorness of this community (Fig. 3).

Ordination

The scatter diagram displays the distribution of the synrelevés, representing the different vegetation units, along the first and second axes (Fig. 4). The relationships among the communities, and not within each community, are expressed by this diagram. The different vegetation units show some degree of coherence but do not display a distinct discontinuity. The distribution of the synrelevés is related to particular environmental factors. A disturbance gradient is described by the first axis, with the undisturbed vegetation units occurring to the left of the diagram. The synrelevés to the right of the diagram represent informal communities with the primary grass cover disturbed and therefore dominated by *Hyparrhenia hirta*. The second axis represents a gradient displaying the change in percentage surface rock cover. Vegetation units occurring at the top of the diagram are associated with rocky conditions, whereas those at the bottom of the diagram are associated with a low percentage surface rock cover. A third and fourth gradient occur along the same diagonal line running from the bottom right corner of the diagram. Vegetation units at the bottom right of the diagram are associated with deep clayey soils, whereas those further to the top left are associated with shallow sandy soils.

Concluding remarks

The successful delineation of 15 communities was obtained from TWINSPAN classification and subsequent refinement there-of by Braun-Blanquet procedures. These communities are related to certain environmental gradients as indicated on the DECORANA scatter diagram.

High species richness, high total number of species and naturalness lend the *Helichryso oreophilum-Themedetum triandrae* conservational value. The high cover-abundances of *Themeda triandra*, *Trachypogon spicatus* and *Alloteropsis semialata*, which are indicators of relatively undisturbed veld, confirm the ecological well-preserved condition of this vegetation unit.

High species richness and naturalness also lend the *Alepideo longifoliae-Eulalietum villosae* conservational value. The *Hyparrhenia hirta-Aristida junciformis* Grassland appears to be a disturbed vegetation unit, with the optimal species composition assumed to be represented by relevé 314 which is situated on the farm Waterval on the northern slopes of the Ntabankulu mountain. The absence of *Hyparrhenia hirta* is evident and this species is suspected of invading this grassland type if managed incorrectly. The vegetation represented by relevé 314 is unfortunately endangered by everexpanding *Eucalyptus* plantations, thereby destroying important islands of high species diversity and species richness.

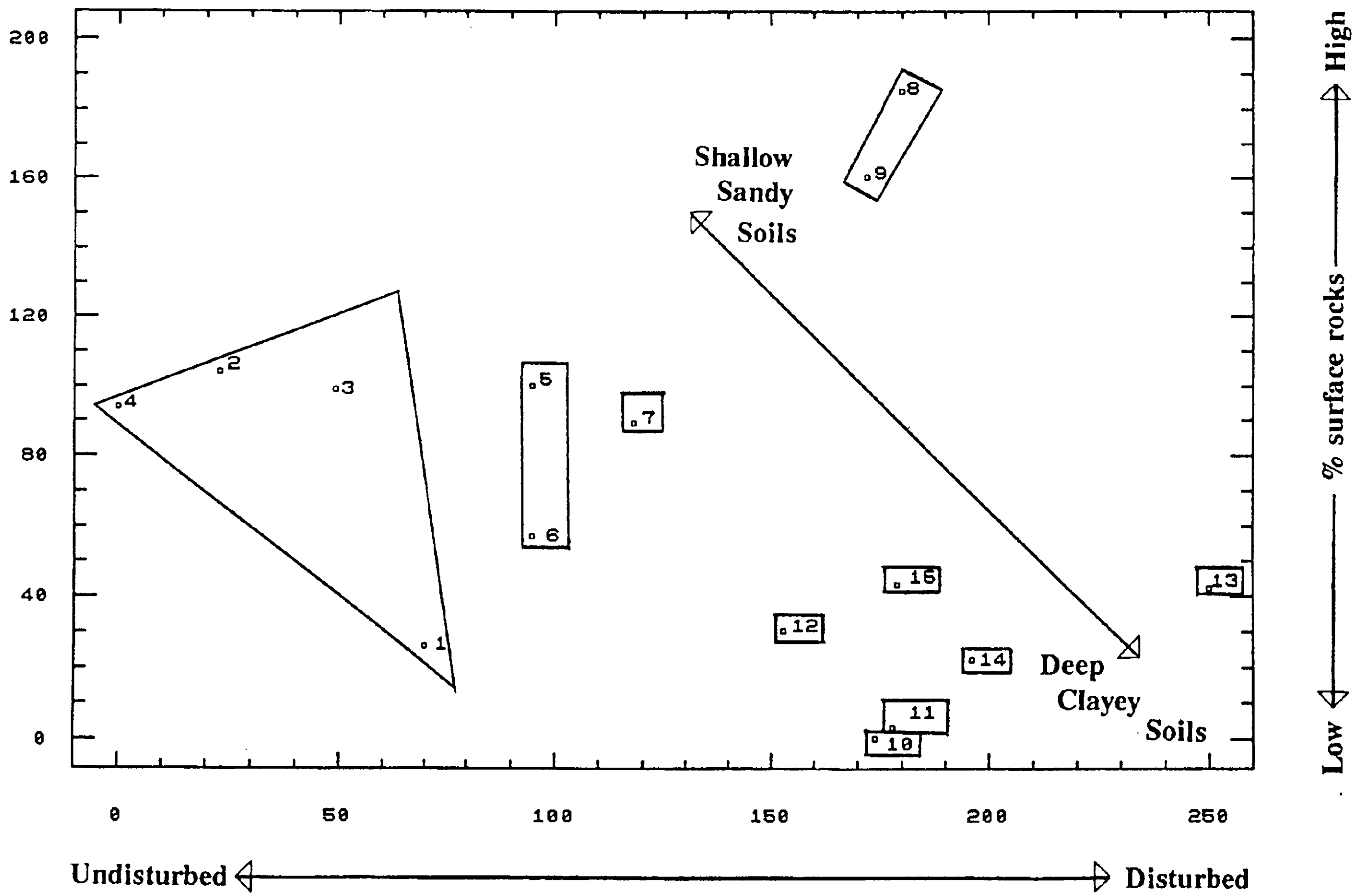


Fig. 4. DECORANA ordination to illustrate the distribution of the synrelevés along the first and second axes. The synrelevés represent the vegetation units.

In general, grasslands at altitudes of 1 500 m and higher are found suitable for afforestation purposes due to the high rainfall experienced in such regions. These mountainous regions are the origin and catchment of various rivers and smaller streams. Consequently, if these high-lying grasslands are converted into plantations, not only will areas with high species richnesses and diversity disappear, but water shortages caused by these plantations will adversely affect the environment and many people further downstream.

Acknowledgement

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CHAPTER 4.4

Plant communities of the *Panicum natalense-Eragrostis curvula* Grassland of northern KwaZulu-Natal

To be submitted

Plant communities of the *Panicum natalense-Eragrostis curvula* Grassland of northern KwaZulu-Natal

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The aim of the study was to produce a phytosociological description and classification of the vegetation of northern KwaZulu-Natal. The floristic data, which have been derived from 76 stratified sample plots, were subsequently subjected to TWINSPAN, followed by refinement by Braun-Blanquet procedures. DECORANA was applied to determine the relation between the vegetation and principal environmental factors. The whole of the floristic data set was classified as *Panicum natalense-Eragrostis curvula* Grassland. A total of 14 communities were identified which were subsequently related to environmental gradients. Species richness was also determined for each vegetation unit. Consideration of conservation sites was based on species richness and naturalness which could be inferred from the floristic data. Two plant communities of conservation importance were identified.

Keywords: classification, conservation, grasslands, species richness, TWINSPAN, vegetation units

Introduction

An estimated 11% of the grasslands of the mountains and higher-lying (usually >1 500 m above sea-level) parts of South Africa are already afforested (Department of Water Affairs and Forestry 1995). Many of these areas have not been floristically surveyed and described before being converted to plantations. The high-altitude grasslands are in general species rich and usually display a relatively large number of endemic species (Matthews *et al.* 1993). It is also known that the diversity of habitats in the mountainous areas results in great plant community diversity (Deall *et al.* 1989; Matthews *et al.* 1993; Smit *et al.* 1995; Burgoyne 1995; Eckhardt *et al.* 1996a). The effect of biodiversity on population dynamics and ecosystem functioning is clearly stated by Tilman & Downing (1994), who proved that the primary productivity in more diverse plant communities is more resistant to and recovers more fully from a major drought.

The poor knowledge of the composition and functioning of South African grasslands leaves a gap in the management of this important natural resource. In a comprehensive study on the grassland vegetation of northern KwaZulu-Natal, the *Panicum natalense-Eragrostis curvula* Grassland was identified as a major vegetation type. This major vegetation type correlates strongly with Acocks' (1988) Northern Tall Grassveld and Natal Sour Sandveld veld types (Figure 1 & 2) and is predominantly encountered at altitudes of 900-1 500 m above sea-level, although sometimes also found on mountain plateaux at altitudes ranging from 1 700-1 800 m. It is exactly the higher-lying grassland which is in desperate need to be phytosociologically described, since it is most affected by afforestation. This study comprises a phytosociological survey and aims at determining the floristic composition of the different communities identified. This information will allow the compilation of a syntaxonomy which is considered a major contribution to the phytosociological knowledge of South African grasslands (Bezuidenhout & Bredenkamp 1990; Kooij 1990; Du Preez 1991; Matthews 1991; Smit 1992; Coetzee 1993; Eckhardt 1993; Fuls 1993). Although various criteria can be used to determine the conservation potential of an area (Rapoport *et al.* 1986; Anderson 1991; Götmark 1992; Keel *et al.* 1992), no specific attempt was made to achieve this by way of scientifically based methods. In this study, however, the selection of areas of conservation importance was principally based on subjective decisions after having considered species richness, rarity of species and naturalness. The term `naturalness' is used here to indicate relatively undisturbed areas or communities. The results of

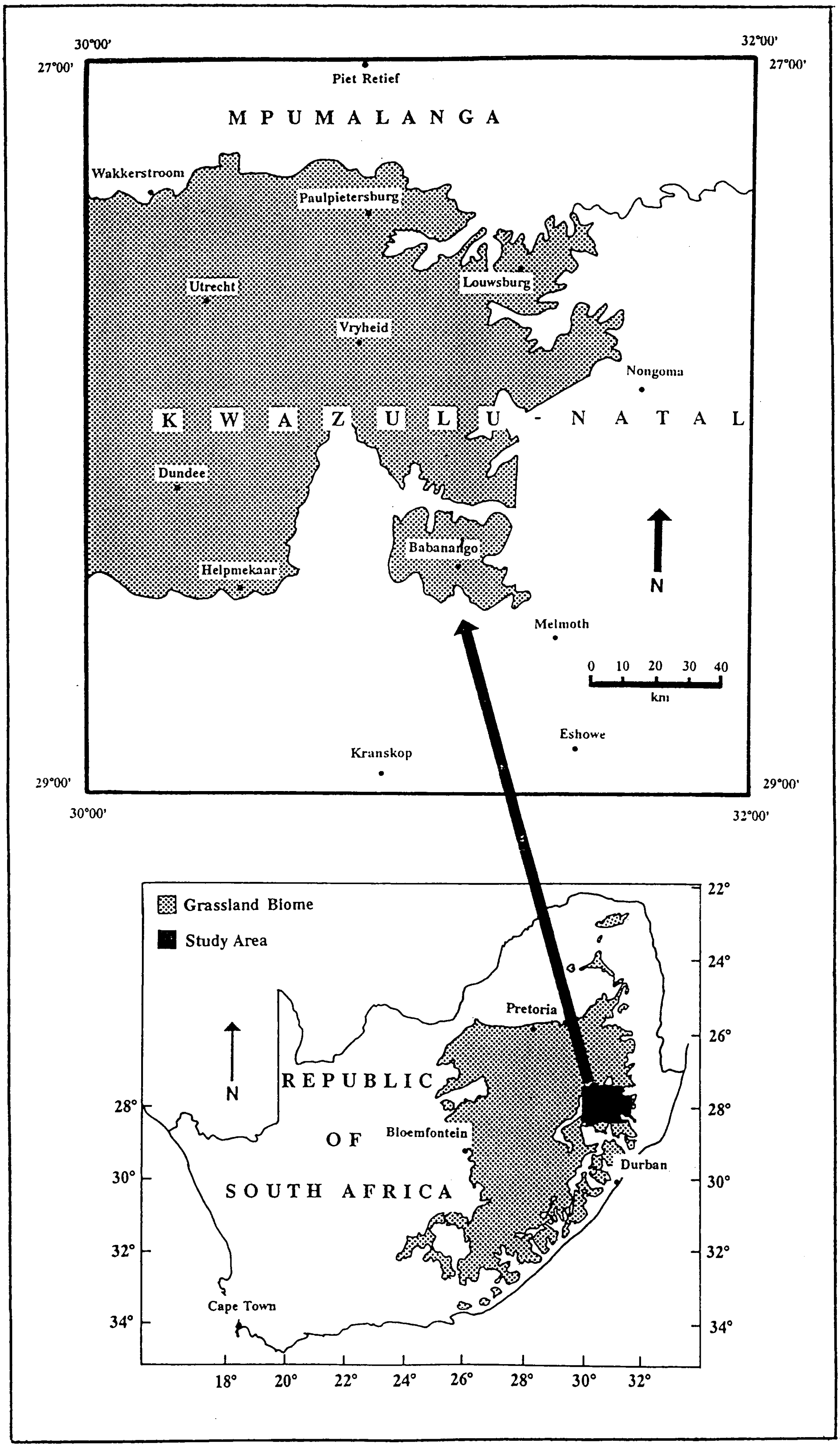

Figure 1 Location of the study area within the Grassland Biome of South Africa.

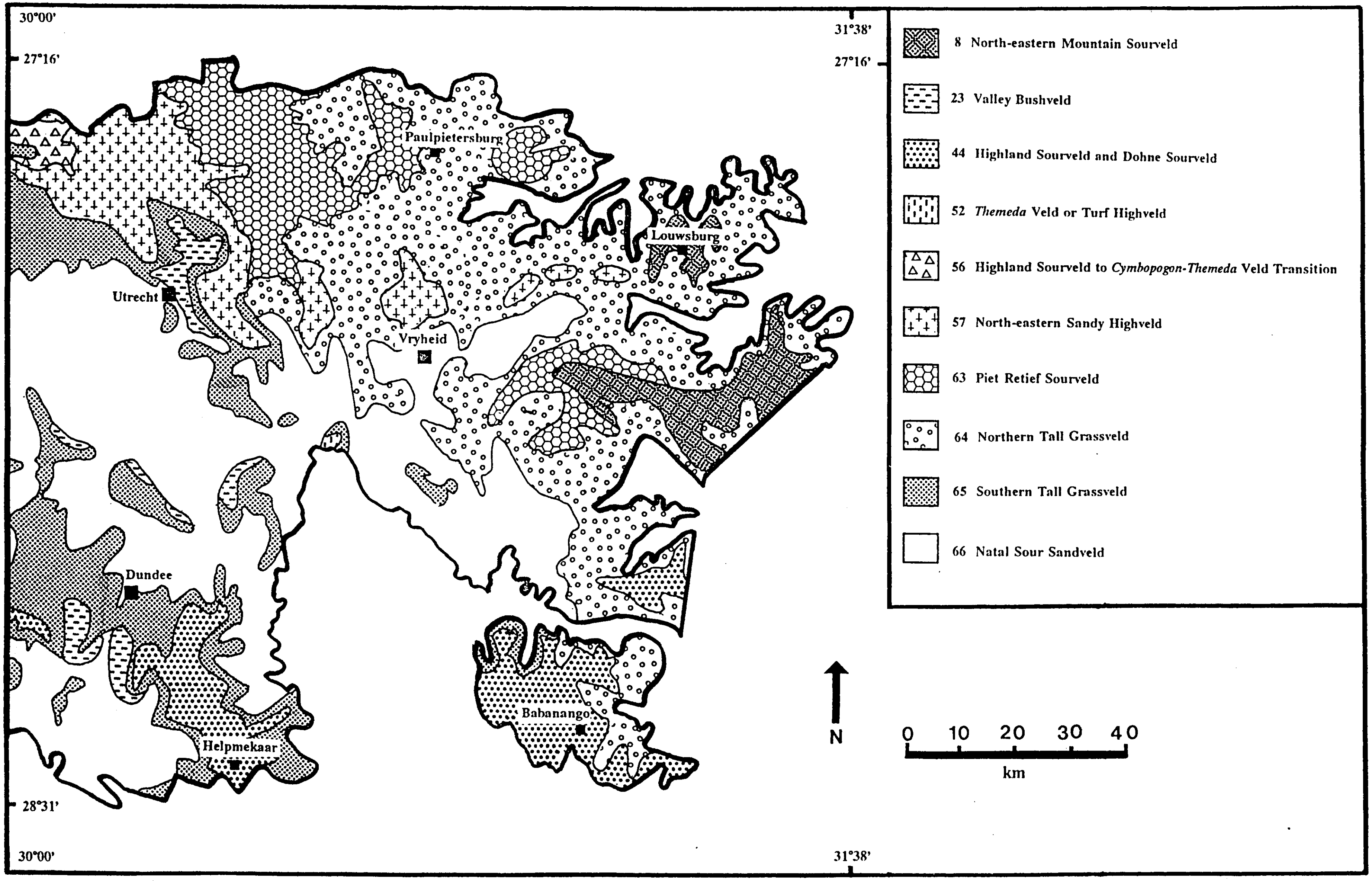

Figure 2 Distribution of veld types within the study area according to Acocks (1988).

this study should be incorporated into management plans to encourage scientifically based management decisions.

Study area

The area of central-northern KwaZulu-Natal (Land Type Survey Staff 1986, 1988), between 27° 16' and 28° 31' S latitude and 30° 00' and 31° 38' E longitude (Figure 1), consists of irregular undulating lowlands in the central and south-western parts, undulating mountains and lowlands in the north-western and eastern parts, and low mountains in the south-eastern part (Kruger 1983). Islands of woody vegetation are widely scattered throughout the entire area, being mainly restricted to areas which are relatively protected against fires and harsh climatic conditions. These remaining islands of woody vegetation suggest the fire climax status of the grasslands of northern KwaZulu-Natal (Tainton 1981). The *Panicum natalense-Eragrostis curvula* Grassland occurs mainly in the undulating lowlands and on mountains in the central part of the study area (see also Eckhardt *et al.* 1996a). The whole of the study area covers approximately 14 366 km^2 and lies at an altitude of 750 to 2 290 m. The average annual rainfall is 850 mm, although it may differ widely within the area due to the diversity in physiographic regions (Schulze 1982).

Methods

Relevés were compiled in 76 sample plots, which were stratified on the basis of terrain units and aspect within the *Panicum natalense-Eragrostis curvula* Grassland. Plot sizes were fixed at 100 m^2 (Scheepers 1975). All species within the sample plots were recorded and given a value according to the Braun-Blanquet cover-abundance scale (Mueller-Dombois & Ellenberg 1974). Taxon names conform to those of Arnold & De Wet (1993). The structural classification system of Edwards (1983) was used to classify the different grassland types. Environmental data recorded for each relevé include geology, terrain unit, aspect, slope, soil type and depth, soil texture, rockiness of soil surface and erosion. Soil types are described according to the Department of Agricultural Development (1991).

The first approximation of the floristic data set was obtained by the application of the Two-Way Indicator Species Analysis (TWINSPAN) (Hill 1979b) (see also Eckhardt *et al.* 1996a, 1996b).

The classification was further refined by Braun-Blanquet procedures (Westhoff & Van der Maarel 1978; Kooij *et al.* 1990; Bredenkamp & Bezuidenhout 1995; Eckhardt *et al.* 1993; Fuls *et al.* 1993) to identify the different communities, which are subsequently presented in a phytosociological table.

Terrain form sketches are presented to indicate the terrain units with which the different communities are associated. To illustrate the relationships between the vegetation units and environmental factors, the ordination algorithm DECORANA (Detrended Correspondance Analysis) (Hill 1979a) was applied. The synoptic data from the synoptic table, which represents the different vegetation units, were used for the ordination (see also Eckhardt *et al.* 1996a). Each vegetation unit is subsequently represented by a synrelevé, the latter being a synoptic vector showing the constancy value per species in a community.

The floristic data within each plant community were analyzed further to determine alpha diversity (see Eckhardt *et al.* 1996b for a more detailed discussion).

The nomenclatural type for each syntaxon was selected according to the one type which best represents the specific syntaxon, with special emphasis on the diagnostic species.

Results and discussion

The *Panicum natalense-Eragrostis curvula* Grassland is restricted to midslopes (undulating areas), with altitudes ranging from 900-1 500 m, although it sometimes also occurs on mountain plateaux at altitudes of 700-1 800 m (Figure 3). The slopes rarely exceed gradients of 3°. Surface rocks are mostly absent and restricted to crests, steeper (25°- 30°) slopes and rocky outcrops where this grassland may be encountered. Various soil types are found, being mostly deeper than 300 mm and containing 15-35% clay.

The most common, and often physiographically dominant, grass species are *Eragrostis curvula, Hyparrhenia hirta, Sporobolus africanus* and *Eragrostis plana* (species group X, Table 1), which are constantly present in most plant communities found throughout the entire study area. Other prominent species include the grasses *Eragrostis racemosa, E. capensis, Themeda triandra* and *Heteropogon contortus* and the forb *Helichrysum rugulosum* (species group W, Table 1).

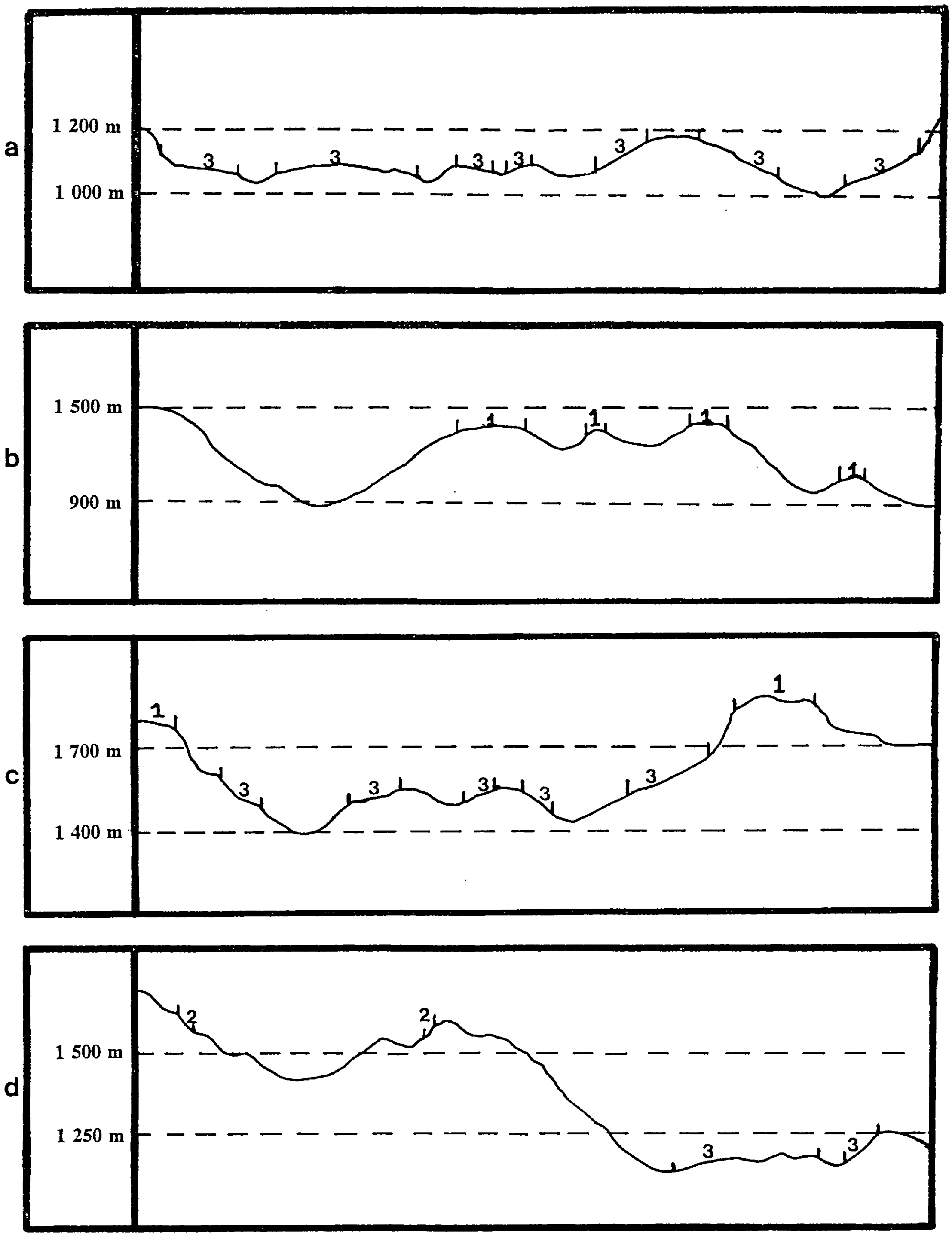

Figure 3 Schematic illustration of the distribution of the vegetation units along the terrain form. Numbers indicate the terrain units at various altitudes. Each sketch represents different vegetation units: a = *Cymbopogono excavati-Eragrostion curvulae*, b = *Aristida junciformis* Grassland, c = *Loudetio simplicis-Trachypogonion spicati* and d = *Melino nerviglumis-Heteropogonetum contorti* and *Themeda triandra-Heteropogon contortus* Grassland.

Table 1 Phytosociological table of the *Panicum natalense-Eragrostis curvula* Grassland of northern KwaZulu-Natal

Alliance	1																																													
Association	1.1								1.2									1.3							1.4																					
Subassociation																									1.4.1				1.4.2				1.4.3													
Community																																				1.5						1.6				
Relevés	473	552	567	471	476	528	553	472	173	329	371	028	425	426	431	433	439	338	340	558	560	376	069	409	319	398	555	346	315	330	341	351	074	342	435	441	444	408	483	505	403	491	580	414	309	581
Species group A																																														
Hyparrhenia filipendula	4	5	5	4	5	5	4	4																																						
Sporobolus pyramidalis	A		+		1		1																																				A			1
Thunbergia atriplicifolia	R	+	1	+										R	1																						+									
Species group B																																														
Polygala hottentotta								+	+	+	+	1	R	+	+	+	+		+								R				+													R		
Hermannia depressa									1			1	1	1	1																															
Aristida bipartita									1	1				1		1						+									+															
Species group C																																														
Setaria sphacelata									1	+								1	1	+	+	B	A	B								+					+									
Species group D																																														
Chaetacanthus burchellii				+	+			+	1			1	+		1	+	+	+	1		+	+		+				+	+				+	+												
Scabiosa columbaria									+		+	1			1	1	+	+	+	+			+						+												+					
Species group E																																														
Walafrida densiflora	+	1								+	+														1		+	+	1	+	+	+	1	+	1											
Melinis repens	+		+			+		+							+							1			1	1	+	+	1	1	+			1	1						+				+	
Hypochoeris radicata					R														+					R	1		+	+					1	+	+			+								
Species group F																																														
Anthospermum rigidum								+			+	1	1	+	+	1	1	1	1	+	+			1	1		+	1	1	+		1				+										
Chamaechrista stricta								+		+	+		+	+	+		+	+	+		+				+	+	+			+	1	1													1	
Species group G																																														
Indigofera velutina	+			1				+					1				1	1												A	+	1			+	+		+		1	+					
Acanthospermum australe	1	1						+					+											+					1			1		+			+	1	+	+		1				
Species group H																																														
Felicia muricata		1							+					+				+	+				1	+	1			1	1			1	1					1		+	+					
Species group I																																														
Pentanisia angustifolia							+	+	+				+		+		+	1	1	1		1	1	1	+			+				+	+		1	+		1	+	+						
Zornia capensis										+		1	1	1				1	1				1	1		+	+	1	1		+		1				+	1								

Alliance													3																	
Association						3.1				3.2												4								
Subassociation										3.2.1						3.2.2														
Community	2																									5				
Relevés	587	247	296	453	569	518	520	535	538	144	146	320	438	531	561	067	070	131	141	546	548	072	115	129	130	001	002	007	065	449
Species group A																														
Hyparrhenia filipendula																														
Sporobolus pyramidalis																														
Thunbergia atriplicifolia																														
Species group B																														
Polygala hottentotta																										+	+	1		
Hermannia depressa																										1				
Aristida bipartita																														
Species group C																														
Setaria sphacelata																1	B				1	1							1	+
Species group D																														
Chaetacanthus burchellii																1	+				+		1		1				1	
Scabiosa columbaria												+				1					+	1	+	+						
Species group E																														
Walafrida densiflora																											+			
Melinis repens	+			+																										
Hypochoeris radicata									+							+														
Species group F																														
Anthospermum rigidum										+	+		+			1										+		1		
Chamaechrista stricta																														
Species group G																														
Indigofera velutina					1								+		R	+	1		1											
Acanthospermum australe				+																										
Species group H																														
Felicia muricata		1								1		1	+										+							
Species group I																														
Pentanisia angustifolia													1	1	+	1	+		+	1	+									
Zornia capensis									+							1	1					1								

Species group J	
Cymbopogon excavatus	¦1 B 1 1 1¦A 1 B 1 A 1 1 1 A¦1 A + 1 1 A¦A B + A¦B 1 + A¦ + B¦+ 1 1 1 1¦3 A A A 1¦+ +¦ ¦ + ¦ ¦ ¦1 ¦
Conyza obscura	¦+ 1 + + +¦ + + ¦ + + +¦+ 1 + +¦+ + ¦1 ¦ 1 R ¦1 1 + 1¦ ¦ ¦ ¦1 ¦ 1 ¦
Species group K	
Aristida junciformis	¦ + ¦ ¦ + ¦A R +¦ ¦ ¦ +¦ ¦3 + 4 5 3¦B A 4 A¦ + + ¦ + ¦ ¦ ¦
Species group L	
Sporobolus centrifugus	¦ ¦ ¦ ¦ ¦ ¦ ¦ ¦ + ¦A A A B¦ ¦ ¦ + 1 ¦ ¦
Species group M	
Panicum natalense	¦ + ¦ ¦+ 1 ¦+ +¦ ¦ +¦ ¦ A ¦ ¦A 1 A A A A¦A 1 A + +¦ 1 ¦ + ¦
Species group N	
Urelytrum agropyroides	¦ ¦ ¦ + ¦ ¦ ¦ ¦ ¦ + ¦ ¦1 + + 1 +¦ + ¦ ¦ ¦
Species group O	
Elionurus muticus	¦ ¦ ¦1 + ¦ ¦ ¦ ¦ ¦ ¦A 1 1¦1 1 1 +¦ + ¦1 ¦ ¦
Species group P	
Eriosema kraussiana	¦ ¦ ¦ ¦ ¦ ¦ ¦ ¦ ¦ ¦1 ¦1 1 1 1 + +¦ 1¦ ¦
Hemizygia pretoriae	¦ ¦ ¦1 ¦ ¦ ¦ ¦ ¦ + R¦ ¦1 ¦B 1 1 ¦+ ¦ ¦
Species group Q	
Loudetia simplex	¦+ +¦ ¦ + ¦+ ¦ ¦ ¦ ¦ ¦ + +¦1 + +¦3 A 3 1 B 4¦1 A + B 1 ¦ + ¦ ¦
Alloteropsis semialata	¦ ¦ ¦ + ¦ ¦ ¦ ¦ ¦ ¦3 3 3¦1 A + A¦1 1 1 1 A 1¦ ¦ ¦
Species group R	
Schistostephium crataegifoliu	¦ ¦ ¦ ¦ ¦ ¦ ¦ ¦ ¦ ¦ ¦ ¦1 1 + 1¦ ¦
Melinis nerviglumis	¦ ¦ ¦ 1 1 ¦ ¦ ¦ ¦ ¦ + +¦ 1 ¦ ¦ + 1¦1 + 1 1¦ ¦
Sebaea grandis	¦ ¦ ¦ ¦ ¦ ¦ ¦ + ¦ ¦ ¦ ¦ ¦1 + +¦ ¦
Ipomoea ommaneyi	¦ ¦ ¦ ¦ ¦ ¦ ¦ + ¦ ¦ ¦ ¦+ ¦1 1 1 ¦ + ¦
Satyrium longicauda	¦ ¦ ¦ ¦ ¦ ¦ ¦ ¦ ¦ ¦ ¦ + ¦ + +¦ ¦
Bulbostylis oritrephes	¦ ¦ ¦ ¦ ¦ ¦ ¦ ¦ ¦ ¦ ¦ ¦ + 1 ¦ ¦
Indigofera dregeana	¦ ¦ ¦ 1 ¦ ¦ ¦ ¦ ¦ + ¦ ¦ ¦ 1 1 ¦ ¦
Species group S	
Helichrysum pilosellum	¦+ ¦ ¦ 1 ¦ ¦ +¦1 ¦ ¦ ¦ 1¦ 1 ¦1 1 1 1 1¦ 1 1 1¦ ¦
Acalypha angustata	¦ ¦ ¦ ¦ ¦ ¦ ¦ ¦ ¦ ¦ + ¦ + + +¦ 1 1¦ ¦
Species group T	
Helichrysum oreophilum	¦ ¦ ¦ 1 ¦ ¦+ ¦ ¦ ¦ ¦ +¦A 1 1 1 ¦1 1 1 + 1 1¦1 + 1 +¦ ¦
Tristachya leucothrix	¦ ¦1 ¦ ¦ ¦ ¦ ¦ ¦ ¦ 1¦A B 3 A B B¦ 1 B ¦ B B ¦ 1 ¦
Brachiaria serrata	¦ ¦A ¦1 ¦ ¦ ¦ ¦ ¦ ¦ ¦ 1 1 1¦1 A 1 ¦A ¦ ¦

Species group U

Andropogon schirensis		+ 1					+ A		1	1 1 + 1	1 +	A A A A	+ 3 1 1	A
Monocymbium ceresiiforme	1 1	+	1 +	+	1		+		+	1 1 + 1	1 1 1	A 1 A A	1 1 B	1 +
Vernonia natalensis			+ R		R		+		+	+ + +	+	+ + + +	1 + 1 1	+
Helichrysum aureonitens		+	1 1	+ +	+ + +		1			1 1 1	1	1	1 + 1 +	
Ctenium concinnum										1 +	1	A 1	1	
Species group V														
Berkheya setifera	+ 1 1 +	1 1 +	+ 1 + 1 1	1 1	1 1 +	1	1 1	1 1 +	+ +	+	+	+ 1 1 1 1	1 1 1 1	
Trachypogon spicatus	1 1 1	1 1	+ B				+ 4 +		1 1 1 1	1 1 + A	3 B 3 3 1	A A 1 1 B 3	+ B 4	A
Diheteropogon amplectens	1 + +	1 + 1 + 1	+ + + + 1		+		+ + + +		+	+	1 A	A 1 1	+ 1	
Helichrysum nudifolium	+ 1 + +	1 +	+ +	+ + +	1 + +	1	+ + +		1	+	+ +	+ + +	1 +	+
Hypoxis rigidula	+	1 R	+ 1 + +	R	+	+ +			R		1 1 + + R	1 1 1 1 1 +	+	+
Haplocarpha scaposa	+	1 1 1 1 + + +	+ 1	+		1 +				+	+	1	1 + + 1	
Species group W														
Eragrostis racemosa	1 + +	1 A 1 1 1 1	A + 1 + 1 1	1 1 +	1 + 1 1	1 +	1 1 1 1 +	1	+	1 1 + 1	1 B A A 1 1	1 1 A A 1	1 1 1 1	A 1 A 1
Themeda triandra	1 A	3 1 + A 1 + + + 1	B B + + 3 1	1 +	1	A	+ A +	+	+ +	+ +	1 A A 1 1	3 B 4 3 B 3	1 A 1 A	A A 3 1 +
Helichrysum rugulosum	1 1 + + +	1 1 1	+ 1 1	1 1 1	1 1 1 1	1 + +	1 1 +	+ +	1 1 + +	1	+ +	+	1 1	+ + 1 1 +
Heteropogon contortus	+	3 1 + +	3 + 1 A	1	A A A	+ 1		1	+ A	1 1 1 A	1 3 1 B	1 1	A A A	B A A A
Eragrostis capensis	+	1 + + A 1	1 + 1	1 +	1 + 1 1	1 +	1 1 + +	+	.	+	1 + +	1 1	1 1	1 1 1
Species group X														
Eragrostis curvula	1 1 1 A 1 B A	1 3 B B B 3 B A 1	1 A B 3 + B 1	B 1 B 1	3 A 1 A	A 1 3	A 1 B B + A	1 A B B A	1 + + 1	A A A	+ + 1 1	1	1 1 1	B 3 1 B
Hyparrhenia hirta		3 4 4 4 3 4 4 3 5	3 4 3 3 4 3 3	A 4 4 4	B 4 5 4	4 5 3	5 4 B 4 5 1	4 4 5 4 3	3 A 1	+ A +	+ +	1 A 1 1	3 1 4	A + 3 A +
Sporobolus africanus	1 1 1 + 1 B	1 1 + 1 1	+ 1 1	1 1 +	1 +	+ 1	+ + 1 +	1 1 1 1 A	1 +	+	+			A
Eragrostis plana	1 1 1	B 1 + 1 3 +	1 3 B A +	3		B 1	+ 1 +	+ 1 3	+	1 + +	+		A +	3 5

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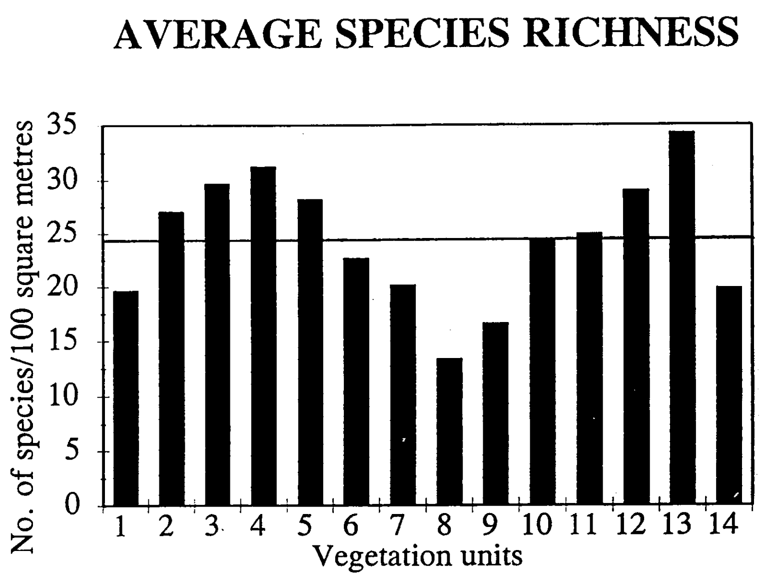
The average species richness for this major vegetation type is 24 (Figure 4) which is somewhat below the average recorded for the *Alepidea longifolia-Monocymbium ceresiiforme* major vegetation type, occurring at higher altitudes (>1 200 m) (Eckhardt *et al.* 1996a). The relative species poorness of this grassland type is further emphasized by the low average total number of 68 species compared to the 118 of the *Alepidea longifolia-Monocymbium ceresiiforme* Grassland (Figure 4).

Classification

The data analysis resulted in the identification of 14 plant communities which are subsequently hierarchically classified. The Code of Phytosociological Nomenclature (Barkman *et al.* 1986) is also used here:

1. *Cymbopogono excavati-Eragrostion curvulae*
 1.1 *Hyparrhenio filipendulae-Sporoboletum africani* (vegetation unit 1)
 1.2 *Polygalo hottentottae-Cymbopogonetum excavati* (vegetation unit 2)
 1.3 *Setario sphacelatae-Eragrostietum planae* (vegetation unit 3)
 1.4 *Walafrido densiflorae-Hyparrhenietum hirtae*
  1.4.1 *Walafrido densiflorae-Hyparrhenietum hirtae cymbopogonetosum excavati* (vegetation unit 4)
  1.4.2 *Walafrido densiflorae-Hyparrhenietum hirtae heteropogonetosum contorti* (vegetation unit 5)
  1.4.3 *Walafrido densiflorae-Hyparrhenietum hirtae hypochoeretosum radicatae* (vegetation unit 6)
 1.5 *Indigofera velutina-Hyparrhenia hirta* Grassland (vegetation unit 7)
 1.6 *Cymbopogon excavatus-Eragrostis curvula* Grassland (vegetation unit 8)
2. *Aristida junciformis* Grassland (vegetation unit 9)
3. *Loudetio simplicis-Trachypogonion spicati*
 3.1 *Sporobolo centrifugi-Alloteropsidetum semialatae* (vegetation unit 10)
 3.2 *Panico natalensis-Loudetietum simplicis*
  3.2.1 *Panico natalensis-Loudetietum simplicis urelytretosum agropyroidis* (vegetation unit 11)



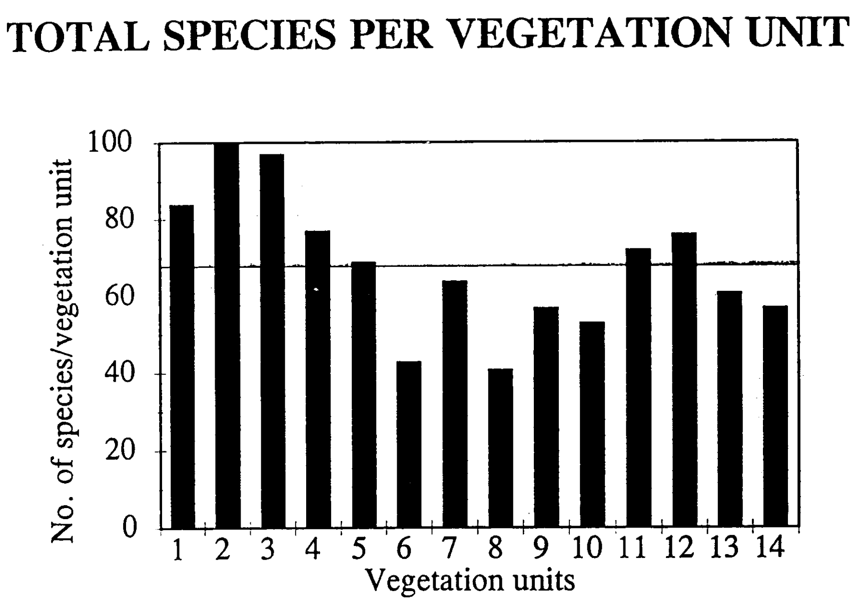


Figure 4 Illustration of the average species richness and total number of species of each vegetation unit. Horizontal lines represent the respective averages of the *Panicum natalense-Eragrostis curvula* Major vegetation type.

3.2.2 *Panico natalensis-Loudetietum simplicis eriosemetosum kraussianae* (vegetation unit 12)

4. *Melino nerviglumis-Heteropogonetum contorti* (vegetation unit 13)
5. *Themeda triandra-Heteropogon contortus* Grassland (vegetation unit 14)

Description of the plant communities

1. *Cymbopogono excavati-Eragrostion curvulae* all. nov.

Nomenclatural type: Walafrido densiflorae-Hyparrhenietum hirtae (holotypus)

This alliance is found on terrain unit 3, with a flat to slightly undulating topography (Figure 3a). Various soil types are encountered, varying in depth from 200 to more than 500 mm, with clay percentage varying from less than 15% to more than 35%. Surface rocks are virtually absent, being generally restricted to rocky outcrops.

The diagnostic species are listed under species group J (Table 1). Other prominent species include *Themeda triandra, Eragrostis curvula, Hyparrhenia hirta* and *Eragrostis plana* (Table 1).

Four associations are distinguished, occurring as mosaic within this alliance rather than being geographically distinct entities.

1.1 *Hyparrhenio filipendulae-Sporoboletum africani* ass. nov.

Nomenclatural type: relevé 552 (holotypus)

This short to tall closed grassland occurs on slightly undulating midslopes below the 1 200 m altitude (Figure 3a). Different soil types are encountered, varying in depth from 200 to more than 500 mm and clay contents varying between 15-25%. Surface rocks are generally absent.

The characteristic species are listed under species group A (Table 1). Common, and sometimes conspicuous, species include *Cymbopogon excavatus* and *Eragrostis curvula.* Noteworthy is the absence of *Hyparrhenia hirta*, but is replaced by the related, tall growing and prominent *Hyparrhenia filipendula*.

This grassland has a considerably low average species richness of 20, but displays one of the highest total number of species (84) within the *Panicum natalense-Eragrostis curvula* Grassland (Figure 4).

1.2 *Polygalo hottentottae-Cymbopogonetum excavati* ass. nov.

Nomenclatural type: relevé 371 (holotypus)

This short to tall closed grassland is usually found on midslopes of relatively lower altitudes (<1 200 m) which are characterized by warmer conditions (Figure 3a). The different soil types encountered vary in depth from 300 to more than 500 mm, with clay contents varying from 25% to more than 35%. Surface rocks are absent.

The diagnostic species which characterize this grassland are listed under species group B (Table 1). Other prominent, and sometimes dominant, species are *Cymbopogon excavatus, Themeda triandra, Eragrostis curvula, E. plana* and *Hyparrhenia hirta* (Table 1).

The average number of species recorded per sample plot is 27, with the total number being 100 for the community, which is the highest total recorded for a community in this major vegetation type (Figure 4).

1.3 *Setario sphacelatae-Eragrostietum planae* ass. nov.

Nomenclatural type: relevé 560 (holotypus)

This short to tall closed grassland occurs mainly on midslopes of relatively lower altitudes (<1 200 m) (Figure 3a). The predominant soil type is the Hutton Form, being generally more than 500 mm deep, with clay percentages varying from 20-30%. Surface rocks are virtually absent throughout.

The diagnostic species is *Setaria sphacelata* (species group C, Table 1) which may sometimes be dominant. Other conspicuous, and sometimes dominant, species include *Themeda triandra,* *Hyparrhenia hirta, Eragrostis curvula* and *E. plana* (Table 1). This community is related to the *Polygalo hottentotta-Cymbopogonetum excavati* by the presence of species group D (Table 1). Both the average species richness (29) and the total number of species (97) recorded for this community clearly exceed the respective averages calculated for the major vegetation type (Figure 4).

1.4 *Walafrido densiflorae-Hyparrhenietum hirtae* ass. nov.

Nomenclatural type: relevé 319 (holotypus)

This short to tall closed grassland is generally restricted to midslopes of relatively lower (<1 200 m) altitudes (Figure 3a). Major soil types are Glenrosa and Avalon Forms. Soil depths usually exceed 500 mm, with clay contents varying from 15-25%. Surface rocks are generally absent. The diagnostic species which characterize this association are listed under species group E (Table 1). The most dominant species are *Cymbopogon excavatus, Eragrostis curvula* and *Hyparrhenia hirta* (Table 1). The high cover-abundance values displayed by *Eragrostis curvula* and more specifically *Hyparrhenia hirta,* are clear indicators of past disturbance. The dominating effect of the latter species, which is ascribed to poor management practices, results in the suppression of other species and reduces their competitive potential (Edwards 1967).

Three sub-associations are recognized under this association:

1.4.1 *Walafrido densiflorae-Hyparrhenietum hirtae cymbopogonetosum excavati* sub-ass. nov.

Nomenclatural type: relevé 319 (holotypus)

This is the typical sub-association of the association. No diagnostic species were recorded for this grassland. This sub-association is distinguished by the presence of species groups E and F and by the absence of species group G (Table 1). The most conspicuous and dominant species are *Cymbopogon excavatus, Eragrostis curvula* and *Hyparrhenia hirta* (Table 1).

The average species richness of 31 is relatively high if compared to the total number of species (77) recorded for the entire sub-association (Figure 4).

1.4.2 ***Walafrido densiflorae-Hyparrhenietum hirtae heteropogonetosum contorti*** **sub-ass. nov.**

Nomenclatural type: relevé 315 (holotypus)

This sub-association contains no diagnostic species, but is nevertheless distinguished from the *Walafrido densiflorae-Hyparrhenietum hirtae cymbopogonetosum excavati* by the presence of species group G (Table 1). The physiographic most conspicuous and dominant species are *Cymbopogon excavatus, Heteropogon contortus, Eragrostis curvula* and *Hyparrhenia hirta* (Table 1).

The average number of species recorded per sample plot is 28 and the total number of species for the entire community is 69 (Figure 4).

1.4.3 ***Walafrido densiflorae-Hyparrhenietum hirtae hypochoeretosum radicatae*** **sub-ass. nov.**

Nomenclatural type: relevé 435 (holotypus)

Although no diagnostic species are recognized under this sub-association, it is distinguished from the *Walafrido densiflorae-Hyparrhenietum hirtae cymbopogonetosum excavati* and the *Walafrido densiflorae-Hyparrhenietum hirtae heteropogonetosum contorti* by the absence of species group F (Table 1). The most prominent, and usually dominant, species are *Cymbopogon excavatus, Hyparrhenia hirta, Eragrostis curvula* and *E. plana* (Table 1).

This sub-association is relatively species poor compared to the two above-mentioned sub-associations. The average species richness is 23 and the total number of species recorded for the community is 43 which is far below the average (Figure 4).

1.5 *Indigofera velutina-Hyparrhenia hirta* Grassland

This short to tall closed grassland occurs on midslopes of varying altitudes (Figure 3a). Different soil types are found, the depths of which generally exceed 500 mm. Clay contents vary from 20% to more than 35%. No surface rocks are present.

This community is distinguished by the presence of species groups G, H and I and contains no diagnostic species (Table 1). The only two species which dominate the grass layer are *Eragrostis curvula* and *Hyparrhenia hirta* (Table 1).

An average number of 20 species was recorded per sample plot, with the total number for the community being 64 (Figure 4).

1.6 *Cymbopogon excavatus-Eragrostis curvula* Grassland

This short to tall closed grassland is found on midslopes of different altitudes (Figure 3a). Various soil types are encountered, the depths of which generally vary from 300 to more than 500 mm and clay percentages from 20-35%. No surface rocks are present.

Although no diagnostic species were recorded, this community is distinguished from the *Indigofera velutina-Hyparrhenia hirta* Grassland by the absence of the inconspicuous forbs listed under species groups G, H and I (Table 1). The most prominent and dominant species are *Cymbopogon excavatus, Eragrostis curvula* and *Hyparrhenia hirta* (Table 1).

This is an extremely species poor community, with an average species richness of 13 and a total number of 41 species. These are the lowest values to be recorded within this major vegetation type (Figure 4).

2. Aristida junciformis Grassland

This short closed grassland is mostly found on terrain unit 1 at lower altitudes (<1 500 m) (Figure 3b). The predominant soil types are Glenrosa and Mispah Forms, being shallow (<300 mm) and low (<20%) in clay content. Surface rocks cover more than 20% of the area and are usually more than 500 mm in diameter.

The physiographical most prominent and dominant species is the unpalatable and wiry-leaved *Aristida junciformis*, which completely dominates the grass layer in certain parts of the grassland. Another less often conspicuous species is *Hyparrhenia hirta*. This grassland appears to be closely related to the Secondary *Aristida junciformis* Grassland described by Edwards (1967), which is equivalent to the Ngongoni Veld of Acocks (1988) and also shows some affinity with the *Aristida junciformis* subsp. *junciformis-Sporobolus centrifugus* Grassland identified and described by Smit *et al.* (1993). Selective overgrazing, especially by sheep, as well as autumn burning are the principal factors causing *Aristida junciformis* to oust other more palatable species (Edwards 1967; Tainton 1981).

This grassland displays a low average species richness (17) and low total number of species (57) (Figure 4).

3. *Loudetio simplicis-Trachypogonion spicati* all. nov.

Nomenclatural type: Panico natalensis-Loudetietum simplicis (holotypus)

This short closed grassland occurs on terrain units 1 and 3 at relatively high altitudes (Figure 3c).

The diagnostic species are the two grasses listed under species group Q (Table 1). Other prominent, and often dominant, species include *Trachypogon spicatus* and *Themeda triandra* (Table 1). The low cover-abundance values and infrequent occurrences of *Hyparrhenia hirta* are noteworthy. This has an indirect effect on the species diversity of the communities recognized under this alliance. Considering the species composition, this grassland appears to be in a relatively good condition seen from an ecological point of view.

Two associations are recognized under this alliance:

3.1 *Sporobolo centrifugi-Alloteretum semialatae* ass. nov.

Nomenclatural type: relevé 538 (holotypus)

This grassland is found on the plateaux of mountains at higher altitudes (>1 700 m) (Figure 3c). The typical soil type is the Mispah Form, although rock-beds are sometimes observed emerging above the soil surface. Soils are consequently shallow (<200 mm) and low in clay content (<20%). Surface rocks, including rock-beds, cover more than 20% of the area.

The diagnostic species is *Sporobolus centrifugus* (species group L, Table 1), which is a typical species for high mountainveld. Other prominent, and often dominant, species include *Aristida junciformis, Elionurus muticus, Alloteropsis semialata* and *Eragrostis curvula* (Table 1). The strong presence of *Aristida junciformis* can be partly ascribed to shallow rocky soils but also to overutilization due to non-rotational grazing systems (see also Edwards 1967).

An average number of 25 species was recorded per sample plot, although a total number of only 53 species was recorded in this community (Figure 4).

3.2 *Panico natalensis-Loudetietum simplicis* ass. nov.

Nomenclatural type: relevé 144 (holotypus)

This grassland is generally found on midslopes of higher altitudes (>1 400 m) (Figure 3c) and is closely associated with deep (>500 mm) sandy (<15% clay) soils derived from dolerites and sandstone and shale of the Vryheid Formation. The predominant soil types are Clovelly, Avalon and Glenrosa Forms. Surface rocks are mostly absent.

The diagnostic species for this association is *Panicum natalense* (species group M, Table 1). Other prominent, and often dominant, species include *Loudetia simplex, Alloteropsis semialata, Tristachya leucothrix, Trachypogon spicatus, Eragrostis racemosa* and *Themeda triandra* (Table 1). The strong presence of *Loudetia simplex* and *Trachypogon spicatus* clearly indicates the sandy nature of the soils.

Two sub-associations are distinguished under this association:

3.2.1 *Panico natalensis-Loudetietum simplicis urelytretosum agropyroidis* sub-ass. nov.

Nomenclatural type: relevé 144 (holotypus)

The diagnostic species for this sub-association is *Urelytrum agropyroides* (species group N, Table 1), which is common but not abundant. Prominent, and often dominant, species are *Panicum natalense, Loudetia simplex, Alloteropsis semialata, Tristachya leucothrix, Trachypogon spicatus, Eragrostis racemosa, Themeda triandra* and *Heteropogon contortus* (Table 1).

The average species richness (25) slightly exceeds the average of this major vegetation type, with the total number being 72 (Figure 4).

3.2.2 *Panico natalensis-Loudetietum simplicis eriosemetosum kraussianae* sub-ass. nov.

Nomenclatural type: relevé 141 (holotypus)

The diagnostic species for this sub-association are listed under species group P (Table 1). This community is distinguished from the *Panico natalensis-Loudetietum simplicis eriosemetosum kraussianae* by the presence of species groups P and S and the absence of species groups N and O (Table 1). The most prominent, and often dominant, species are *Panicum natalense, Loudetia simplex, Andropogon schirensis, Monocymbium ceresiiforme, Trachypogon spicatus* and *Themeda triandra* (Table 1).

The average number of species recorded per sample plot is 29, with the total number of species being 76 (Figure 4).

4. *Melino nerviglumis-Heteropogonetum contorti* ass. nov.

Nomenclatural type: relevé 129 (holotypus)

This short to tall closed grassland occurs on steep (25°- 30°) slopes at high altitudes (>1 500 m) (Figure 3d), with the aspect apparently having no clear influence on the vegetation. The

Glenrosa Form is the predominant soil type, the depths being usually <300 mm and clay content varying from 15-20%. Surface rocks often cover more than 20% of the area, being 250-500 mm in diameter.

Diagnostic species are listed under species group R (Table 1). Other prominent, and sometimes dominant, species are *Tristachya leucothrix, Trachypogon spicatus, Themeda triandra, Heteropogon contortus* and *Hyparrhenia hirta* (Table 1).

This community has the highest mean species richness (34) of all plant communities recorded in this major vegetation type, although the total number of species is only 61 (Figure 4).

5. *Themeda triandra-Heteropogon contortus* Grassland

This short to tall grassland occurs on lower-lying (<1 250 m) plains and midslopes of high altitudes (1 400 m) (Figure 3d). Various soil types are encountered, being generally deeper than 500 mm. Clay content varies considerably from less than 15% to more than 35%. No surface rocks are present.

This community contains no diagnostic species, but includes the prominent species *Eragrostis racemosa, E. curvula, E. plana, Themeda triandra, Heteropogon contortus* and *Hyparrhenia hirta* (Table 1). The high cover-abundance values for *Heteropogon contortus* and *Eragrostis curvula* suggest that this grassland has been overutilized in the past (Van Oudtshoorn 1991), the vegetation being dominated by a few, mostly unpalatable, species only. Forb species are limited in numbers, giving rise to the relatively low average number of species recorded per sample plot (20) and low total number of species (57) (Figure 4).

Ordination

The scatter diagram shows the distribution of the synrelevés along the first and second axes (Figure 5). The entire diagram represents gradients of various environmental factors. The distribution of the synrelevés shows a relatively distinct discontinuity and gives a clear reflection of the prevailing environmental conditions. Four gradients can be observed on the first axis and one gradient on the second axis. Vegetation units occurring to the left of the

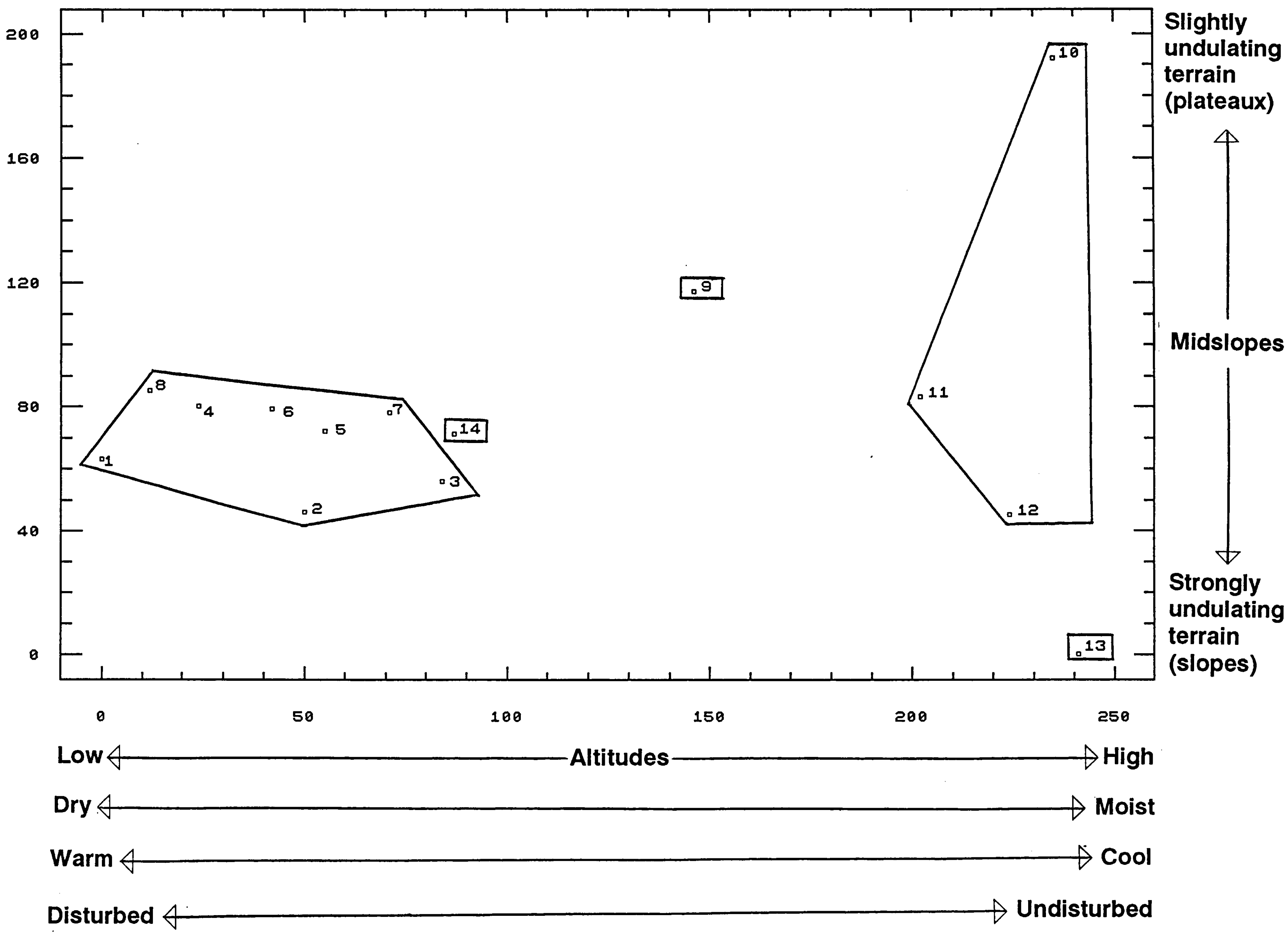


Figure 5 Ordination diagram indicating the distribution of the synrelevés along the first and second axes.

diagram are associated with low altitudes, dry warm conditions and a high degree of disturbance. Vegetation units to the right are associated with high altitudes, moist cool conditions and a low degree of disturbance. Vegetation units occurring at the top of the diagram are generally restricted to flat to slightly undulating terrain (terrain unit 1). Vegetation units at the bottom of the diagram are associated with strongly undulating terrain (slopes), whereas those appearing half-way up the gradient are associated with midslopes.

Concluding remarks

The TWINSPAN classification and subsequent refinement there-of by Braun-Blanquet procedures resulted in the delineation of 14 communities. These communities are related to certain environmental factors the gradients of which are illustrated in the DECORANA scatter diagram.

Due to their relatively undisturbed condition or naturalness the high-lying *Loudetio simplicis-Trachypogonion spicati* and the *Melino nerviglumis-Heteropogonetum contorti* should be considered for conservational purposes. Besides this, these two syntaxa are also in danger of being replaced by eucalyptus and wattle plantations. Although the species composition of these grasslands reflects a relatively natural condition, long-term mismanagement could result in palatable species being replaced by unpalatable, strong competitors such as *Aristida junciformis, Eragrostis plana, Sporobolus africanus, S. pyramidalis* and *Hyparrhenia hirta* (Edwards 1967; Tainton 1981; Van Oudtshoorn 1991). The grasslands of mountain plateaux are especially subjected to high grazing pressure, as witnessed during field surveys. The shallow soils and sensitive grass layer are easily disturbed if subjected to too long grazing periods. No rare or endemic species were found within this major vegetation type. Both the Northern Tall Grassveld and the Natal Sour Sandveld veld types cover large areas within the entire study area and extend even beyond the borders of the study area. It is, however, not known whether any parts of the two veld types are currently conserved and therefore no recommendations can be made, except for the two above-mentioned communities which ought to be conserved.

The environmental conditions under which the different communities within the *Panicum natalense-Eragrostis curvula* Grassland are found, often appear to be relatively similar. It seems as if the absence and presence of forbs is the main reason for distinguishing between different vegetation units and that the species composition is not so much the product of the environment but that of management. The different communities identified and described here should serve as management units on a farm-scale level to maintain the natural species composition and facilitate ecological sound planning.

Acknowledgement

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CHAPTER 4.5

The plant communities and alpha diversity of the *Helichrysum pilosellum-Heteropogon contortus* High-altitude grassland of northern KwaZulu-Natal

To be submitted

The plant communities and alpha diversity of the *Helichrysum pilosellum-Heteropogon contortus* High-altitude grassland of northern KwaZulu-Natal

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A vegetation analysis of the high-altitude *Helichrysum pilosellum-Heteropogon contortus* Grassland of northern KwaZulu-Natal is presented. Relevés were compiled in 79 stratified sample plots. A TWINSPAN classification of the floristic data set and subsequent refinement by Braun-Blanquet procedures resulted in the identification of 12 plant communities (vegetation units) which were hierarchically classified and described. Species richness, rarity of species and naturalness were used as criteria to determine conservation potential of each vegetation unit. Two syntaxa were selected being of conservation importance. The ordination algorithm DECORANA, based on the floristic data, gave an indication of the relationship between vegetation units and physical environment.

Keywords: conservation, Grassland Biome, plant communities, species richness, syntaxonomy, vegetation units

Introduction

This study forms part of a formal syntaxonomical classification of the grasslands of northern KwaZulu-Natal (see also Eckhardt *et al.* 1996a, 1996b, 1996c & 1997). The aim of the study is to refine Acocks' Veld Types (1953, 1975, 1988) of the study area to a community level. This could contribute to ecological sound management of the vegetation. The ultimate refinement will subsequently be incorporated into a syntaxonomical synthesis of the entire Grassland Biome (Kooij 1990; Du Preez 1991; Matthews 1991; Smit 1992; Coetzee 1993; Eckhardt 1993; Fuls 1993; Burgoyne 1995). Furthermore, an attempt was made to identify natural areas or vegetation units with conservation potential. The conservation potential was based on species richness, rarity of species and naturalness (Götmark 1992; Rapoport *et al.* 1986), the latter term being used to indicate areas of relatively undisturbed condition. The *Helichrysum pilosellum-Heteropogon contortus* Grassland has been identified as a major vegetation type which generally occurs at an altitude of more than 1 500 m above sea-level. It covers a small part compared to the rest of the study area. Due to this grassland's occurrence at high altitudes with a concomittant high rainfall, it could be regarded as a potential area for afforestation, resulting in the destruction of this vegetation (Department of Water Affairs and Forestry 1995). It is therefore necessary to determine the conservation potential of the communities within the *Helichrysum pilosellum-Heteropogon contortus* Grassland before any transformations into exotic plantations take place. This could contribute to the ecologically based land-use planning for the area concerned.

Study area

The entire study area is situated in central-northern KwaZulu-Natal (Land Type Survey Staff 1986, 1988) between 27° 16' and 28° 31' S latitude and 30° 00' and 31° 38' E longitude (Figure 1). The area covers approximately 14 366 km² and lies at an altitude of 750 to 2 290 m above sea-level. The average annual rainfall is 850 mm, although differences may occur within the area due to variations in physiography (Schulze 1982). The area consists of irregular undulating lowlands in the central and south-western parts, undulating mountains and lowlands in the north-western and eastern parts, and low mountains in the south-eastern part (Kruger 1983). The

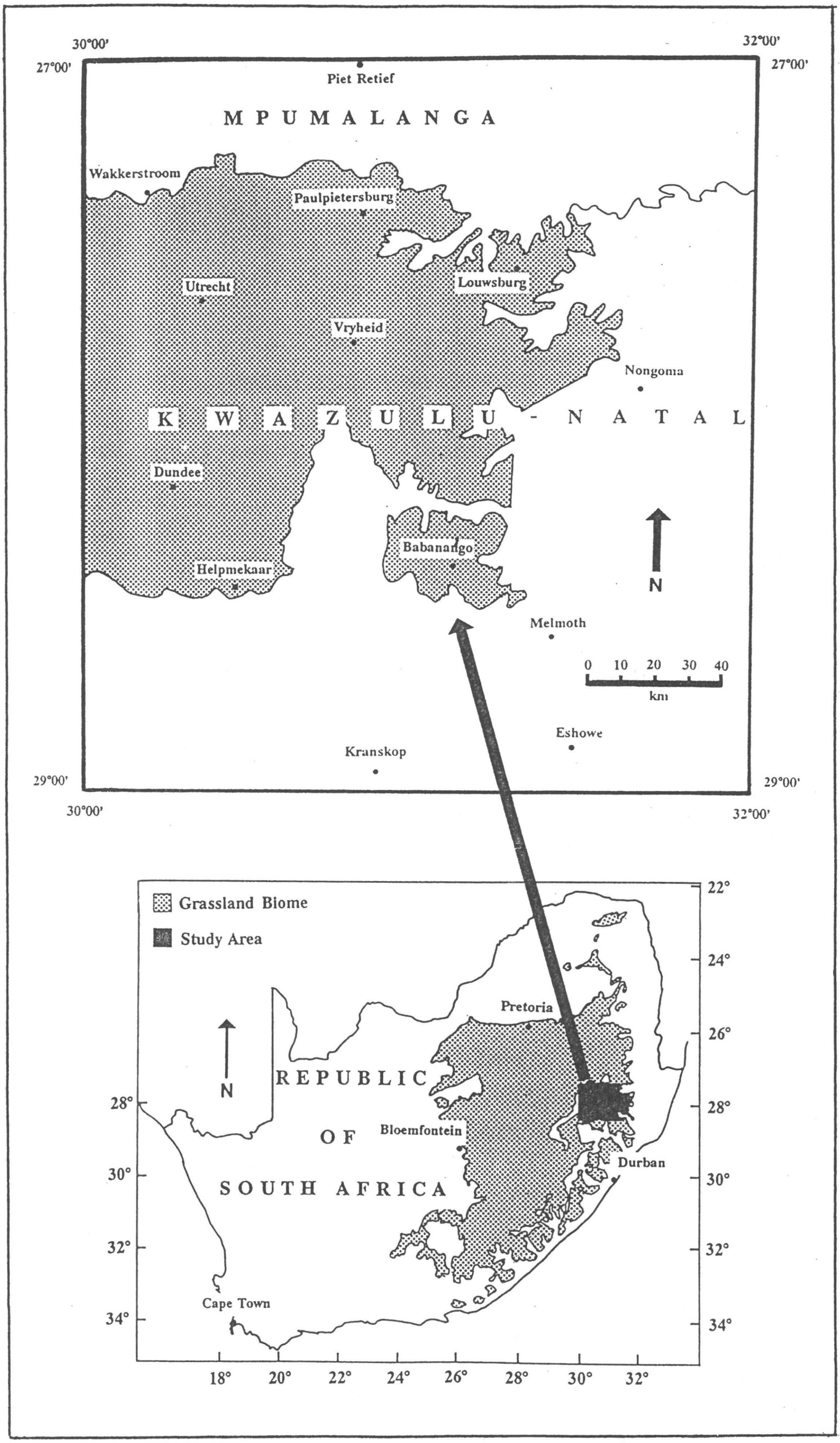


Figure 1 Location of the study area within the Grassland Biome of South Africa.

Helichrysum pilosellum-Heteropogon contortus Grassland is mainly restricted to high-lying (>1 500 m above sea-level) areas of the north-western (mainly Belelasberg-Skurweberg Plateau) and south-western (mainly Helpmekaar Plateau) parts of the study area and partly to low-lying (<1 500 m above sea-level) areas (mainly Buffalo and Dundee Plain) in the southern part of the study area (Figure 2) (see also Eckhardt *et al.* 1996b, 1996c), corresponding mainly with Acocks' (1988) North-eastern Sandy Highveld (veld type 57) and Highland Sourveld and Dohne Sourveld (veld type 44) in the north-western and south-western parts of the study area (Figure 3). This grassland type is considered as fire climax grassland of potential forest areas at high elevations with moderate summers and cold winters (Tainton 1981). This vegetation is virtually throughout an uniform dense, short grassland.

Methods

Relevés were compiled in 79 sample plots, which were stratified on the basis of terrain units (Land Type Survey Staff 1986) and aspect within the *Helichrysum pilosellum-Heteropogon contortus* Grassland. Plot sizes were fixed at 100 m² (Scheepers 1975). All species within a sample plot were recorded and given a value according to the Braun-Blanquet cover-abundance scale (Mueller-Dombois & Ellenberg 1974). Taxon names conform to those of Arnold & De Wet (1993). The structure of the different grassland types was described and classified according to the structural classification system of Edwards (1983). The following environmental data were recorded at each relevé: geology, terrain unit, aspect, slope, soil type and depth, soil texture, rockiness of soil surface and erosion. Soil types were identified according to the Department of Agricultural Development (1991).

Two-Way Indicator Species Analysis (TWINSPAN) (Hill 1979b) was applied to derive a first approximation of the floristic variation within the data set (see also Eckhardt *et al.* 1996c). The classification was further refined by Braun-Blanquet procedures (Westhoff & Van der Maarel 1978; Kooij *et al.* 1990; Coetzee *et al.* 1993; Eckhardt *et al.* 1993; Fuls *et al.* 1993; Smit *et al.* 1993; Matthews *et al.* 1994; Bredenkamp & Bezuidenhout 1995; Visser *et al.* 1996) to identify the different plant communities presented in a phytosociological table.

A hierarchical classification of the 12 plant communities and their associated characteristics is also given. The ordination algorithm DECORANA (Hill 1979a) was used for this floristic data

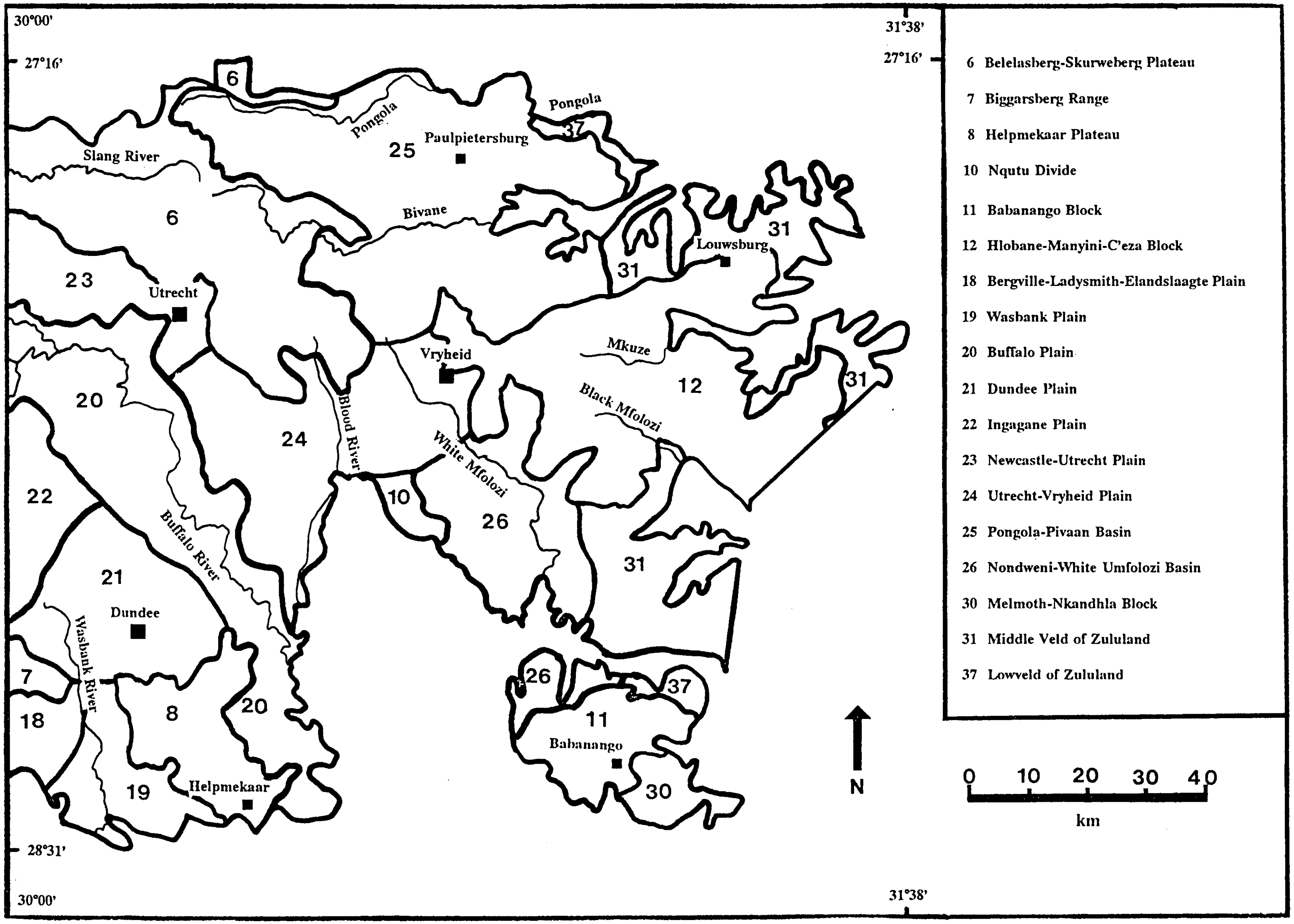


Figure 2 Different physiographic regions (Turner 1967) found within the study area, with major rivers also indicated.

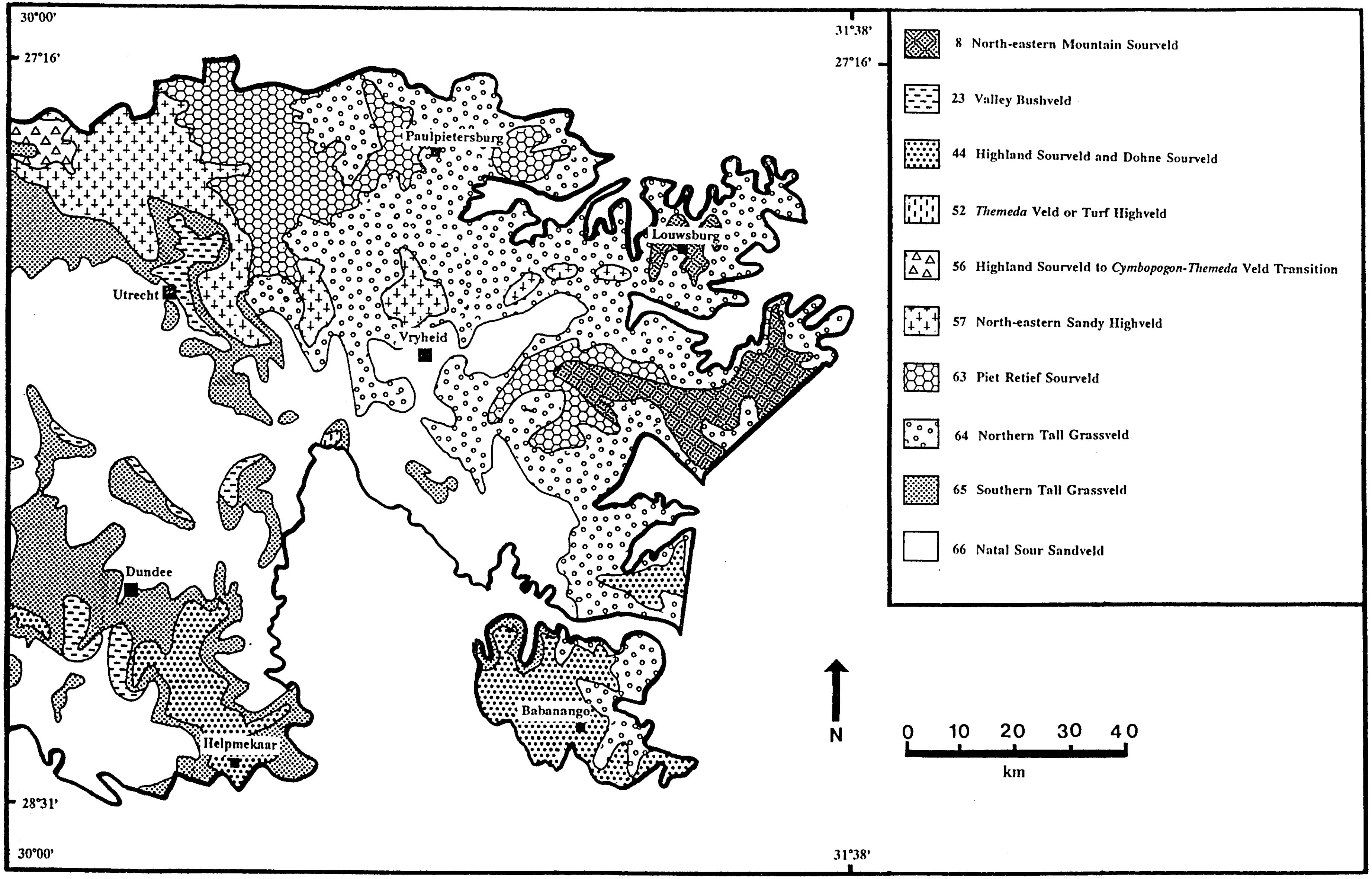


Figure 3 The distribution of veld types (Acocks 1988) within the study area.

set to illustrate gradients in vegetation and relationships between vegetation and the environment. The synoptic data obtained from the synoptic table, were used in the ordination, with the vegetation units being represented by synrelevés (see also Eckhardt *et al.* 1996c).

The floristic data within each identified plant community were analyzed further by calculating species richness (see also Eckhardt *et al.* 1997 for a more detailed discussion).

Results and discussion

The *Helichrysum pilosellum-Heteropogon contortus* Grassland is generally found on midslopes and scarps at high altitudes exceeding 1 500 m, but is sometimes also encountered on midslopes at altitudes lower than 1 500 m (Figure 4). The steepness of midslopes varies from 0°- 15°, whereas scarps may be as steep as 20°- 45°. Surface rocks are usually associated with scarps, covering more than 20% of the surface area in most cases. The predominant soils are Glenrosa and Avalon Forms, being less than 200 mm deep on steep slopes and exceeding 500 mm on midslopes. Soil texture is generally sandy. The geology is mainly characterized by dolerite, and sandstone, shale and mudstone of the Beaufort Group.

The most common and physiognomically prominent species are the grasses *Heteropogon contortus* and *Themeda triandra* (species group Q, Table 1). Other less common but prominent species include *Eragrostis curvula* and *E. plana* (species group P, Table 1). The latter two species, as well as *Hyparrhenia hirta* and *Sporobolus africanus* (species group O, Table 1), are not as frequent within the *Helichrysum pilosellum-Heteropogon contortus* Grassland as they are throughout the rest of the grasslands of the entire study area with the exception of the wetlands.

Compared to the *Alepidea longifolia-Monocymbium ceresiiforme* Grassland (Eckhardt *et al.* 1996b) and the *Panicum natalense-Eragrostis curvula* Grassland (Eckhardt *et al.* 1996c), this grassland displays the highest species richness (29 species per 100 m^2) and the second highest total number of species (74) (Figure 5).

Classification

The analysis resulted in the identification of 12 communities which are subsequently hierarchically classified:

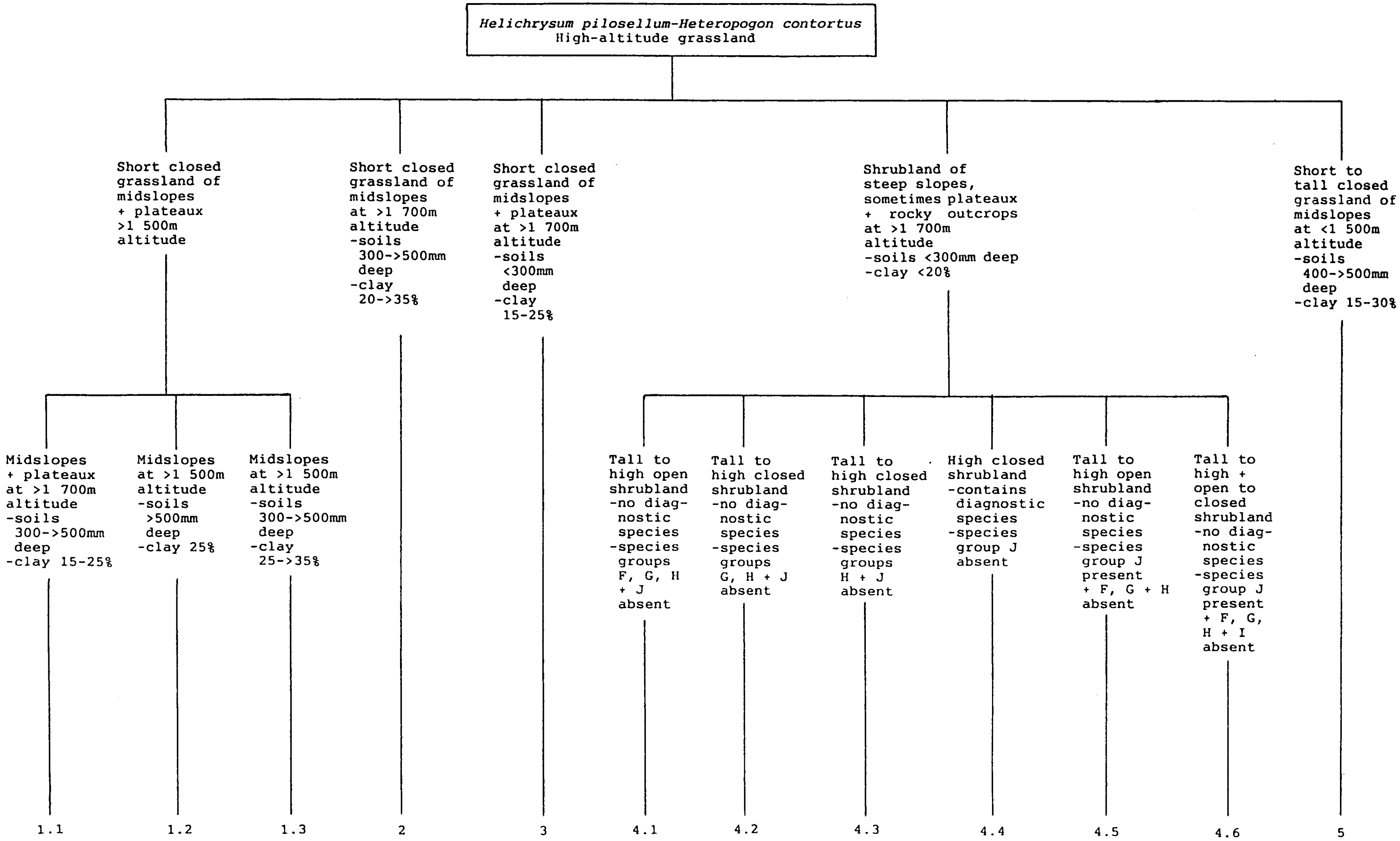


Figure 4 A hierarchical classification of the 12 plant communities (vegetation units) and their associated characteristics.

Table 1 Phytosociological table of the *Helichrysum pilosellum-Heteropogon contortus* High-altitude grassland of northern KwaZulu-Natal

Relevés	248	286	104	111	119	221	293	109	113	118	223	295	166	285	288	160	222	239	187	264	083	093	102	220	228	240	143	224	106	231
Association	1																													
Subassociation	1.1													1.2							1.3									
Community																														
Species group A																														
Monocymbium ceresiiforme	3	1	4		B	3	A		A	A	3	B	A	+	3		+	1	1	1	A	A	A	1	+	1		B	3	1
Helichrysum aureonitens		+	1	1	+	+	1	+	+	+	1	1	1	+	1	1	1		1	1	1	1	1		1		+	1	1	
Helichrysum oreophilum			+		+	+					+		1			1	+						1	+	+	1	1		+	+
Species group B																														
Trachypogon spicatus		3		3	3	3	3	A	A	A	A	A	1	+	1			+								+			+	
Andropogon schirensis		1	3	1	1	1	1	1		1	1	1	1																	
Alloteropsis semialata		A				1	A					A	B	+		A	1								A		+			
Species group C																														
Commelina africana	1		1	1	+		+									1	1		1		1	+	1	1				1	1	
Sebaea leiostyla		1			+			+		1						+		+					+		+	+			+	
Acalypha caperonioides	1	1	1		1		1	1	1			1		+	1					1										1
Hypoxis rigidula	1						+					+		+						1						+				
Hypoxis multiceps				1	1				1							+					+		1						1	
Species group D																														
Microchloa caffra															1						1	1		1	+					A
Helichrysum dasycephalum							+		+							1	1	1			+			+	+	+	+		+	
Species group E																														
Leucosidea sericea								+	1	1			+			A							1							
Helichrysum melanacme																														
Mohria caffrorum																														
Clutia affinis																														
Species group F																														
Rhus discolor													R																	
Species group G																														
Cheilanthes quadripinnata																														
Crepis hypochoeridea															+							+								
Species group H																														
Helichrysum hypoleucum																														
Helichrysum splendidum																														

Relevés	087	088	232	094	243	082	219	244	081	085	086	084	098
Association													
Subassociation													
Community	2									3			
Species group A													
Monocymbium ceresiiforme					1								
Helichrysum aureonitens					+	1		1	+				
Helichrysum oreophilum													
Species group B													
Trachypogon spicatus						B	1	+		5			
Andropogon schirensis		1				1	+						
Alloteropsis semialata						1							
Species group C													
Commelina africana	+	+	1	+					+	+			+
Sebaea leiostyla	+	1		+	1	+					+		
Acalypha caperonioides	1	1	1		1		1						
Hypoxis rigidula	+	+		1	+	1		+	1				
Hypoxis multiceps			1										
Species group D													
Microchloa caffra	1			1	B	B		1	A	1	A	A	1
Helichrysum dasycephalum		+						+					A
Species group E													
Leucosidea sericea		+											
Helichrysum melanacme													+
Mohria caffrorum													
Clutia affinis													
Species group F													
Rhus discolor											+		
Species group G													
Cheilanthes quadripinnata													
Crepis hypochoeridea													
Species group H													
Helichrysum hypoleucum													
Helichrysum splendidum													

Relevés	097	213	099	124	159	208	210	105	114	117	120	121	212	214	215	127	161	162	217	163
Association	4																			
Subassociation	4.1		4.2			4.3			4.4				4.5			4.6				
Community																				
Species group A																				
Monocymbium ceresiiforme																				
Helichrysum aureonitens					+															
Helichrysum oreophilum											+						1			
Species group B																				
Trachypogon spicatus	A								3			1	1	B	A		+		A	1
Andropogon schirensis	+				1			B				1		1	+		1		1	
Alloteropsis semialata					1		+					1	1				A			
Species group C																				
Commelina africana	1										1				+			1		
Sebaea leiostyla								1	+			+					+		+	
Acalypha caperonioides					1						+	1								
Hypoxis rigidula																				
Hypoxis multiceps																				
Species group D																				
Microchloa caffra			1	1	1						1							1		
Helichrysum dasycephalum	1		+	+					+											
Species group E																				
Leucosidea sericea	+	3	5	3	A	3	B	A	A	5	3	3	3	+	A	A		+	A	5
Helichrysum melanacme	1	1	+	+			1				+	1	1		+	1				1
Mohria caffrorum	1		1			1				+			+						1	1
Clutia affinis		+					1			1				+						+
Species group F																				
Rhus discolor			+	1	1	1		+	+		1									
Species group G																				
Cheilanthes quadripinnata	1					+	1	1	+	1	+	1	+							
Crepis hypochoeridea		1	1			+	1	1		1		+								
Species group H																				
Helichrysum hypoleucum										A	1	+								A
Helichrysum splendidum										4		+								

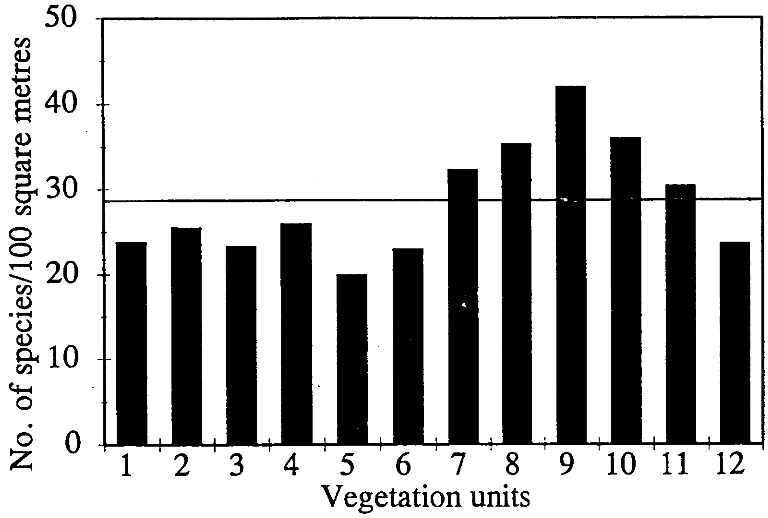
Relevés	459	311	399	251	253	275	279	024	060	589	252	450	006	281	306	282
Association	5															
Subassociation																
Community																
Species group A																
Monocymbium ceresiiforme			1			1										
Helichrysum aureonitens																
Helichrysum oreophilum																
Species group B																
Trachypogon spicatus			B	+		+						1		+		
Andropogon schirensis			+			+										
Alloteropsis semialata	+															
Species group C																
Commelina africana								+					1		+	
Sebaea leiostyla			+									+				
Acalypha caperonioides							+							1		1
Hypoxis rigidula		+		1				+								
Hypoxis multiceps																
Species group D																
Microchloa caffra					1		1				1				1	1
Helichrysum dasycephalum											+					
Species group E																
Leucosidea sericea																
Helichrysum melanacme																
Mohria caffrorum																
Clutia affinis																
Species group F																
Rhus discolor														1		
Species group G																
Cheilanthes quadripinnata																
Crepis hypochoeridea																
Species group H																
Helichrysum hypoleucum																
Helichrysum splendidum																

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12
Species group I												
Sutera polelensis						1 +	+	1 1 1	1 1	+ 1 +	1	
Rabdosiella calycina		+			+	A	+	1 A	B	1 1	+	
Species group J												
Eragrostis caesia	+	1	1							1 B	A A 1 A	
Silene bellidioides	1	+						1		+ 1 1	+ 1 1	
Helichrysum monticola	+									1 1 +	1 1 1	
Helichrysum confertifolium										1 + +	1 1	
Species group K												
Stachys sessilis	+								1 1 +	1 1 1 1	+ 1 1 +	
Andropogon appendiculatus	1 + +	+ 1	+ 1	+					+ + 1 +	+ + 1	A 1 +	+ + .
Species group L												
Helictotrichon turgidulum	+	+ 1	1	+			+	1 1 1	+ +	+ + 1	1 1 +	
Wahlenbergia squamifolia	+							+ + 1	+ +	1 1	+ 1 1	
Sutera sp.	+ + 1	+ .	+ +				+	1 +	1 + +	+	+ + 1	
Harpochloa falx	+ 3		+ 1	+ 1 +				1	+	1 1	1 1	
Gladiolus crassifolius	+			1 +				+	+ +	+	+	
Species group M												
Hypochoeris radicata	1 +	1 + 1 1 + 1	+ + 1 1 1	1 1 1 + +	+ 1	+	1	1 1	1 + +	+	1 1	+ 1 +
Pelargonium luridum	+	1 + 1 +	+ +	+ + 1	+ +		1 1	1	1 1		1 + +	+ + R + +
Conyza podocephala	+	1 + 1	1	1 +	+ 1	1	1 1	1 1	1			+
Species group N												
Tristachya leucothrix	+ A 1 A 3 B 3 3 B A A 3 A	1 + 1	1 A 1 1 1 3 B	1 1 1 B B +	1		+	1 1	A + A	B 3 B	+ B B	+ + +
Helichrysum cephaloideum	+ 1 1 1 1 1 1 1 1 1	1 1 1	+ 1 1 1	1 +	1			1 1	1 1	1	1 1 1	+ R
Vernonia natalensis	+ + + + 1 1	+ 1	1	+ + + 1 +	+ + +		1 1	+ 1 1	1 1 +			+ R +
Helichrysum nudifolium	1 + 1 + 1 1	+ 1	1 + +	1 1 1 1 1 1			+	1		1 1	1 + 1	+ +
Scabiosa columbaria	+ +	+	1 1	1 1 + +		1	+ 1	1 1 1	1	1 + 1	1	+ + + +
Sporobolus centrifugus	1 + 1 + 1 1 1	+	1 B	1					+ +	1 1 1	A 1 1	
Species group O												
Hyparrhenia hirta	1 1	1 B		1 1		A	3	B 1	A B			4 4 B 1 4 3 4 + 3 4 4 4 1 3 B 3
Sporobolus africanus		3 A 1 + 1 B 3		1			+	1 1				1 1 A 1 1 + 1 1 A 1 1 1
Cymbopogon excavatus						+	1			+ + 1	1	A B A A 1 1 1 1 A A A
Pentanisia angustifolia	1 +	+		+								1 + + + + +
Cynodon dactylon			1									1 1 1 1 1
Spermacoce natalensis												1 1 + 1 1
Striga elegans												+ + + +
Species group P												
Eragrostis curvula	1 1 1 1	A 1 3 4 3 3 3	A B B 3 4 3 3 B A B	B 1 3 3 1 1 3 B +	A B 4 3	B 4	1 4 1	3 3 1	+ 1 3 A	3 3 3	3 3 A 4	B B 1 B A B B B A + A 1 1 4 A 3
Eragrostis plana	1 +	3 1 A 3 3 4 B	3 B 4 A 3 3 3 3 + A	A 1 4 1 A 1 1 +	+ 3 B 3	3 A	1 A	1 1	1 A 1		1 1 3 1	1 1 1 1 A 3 A
Helichrysum rugulosum	+ 1 +	1 1 1 1 1 1	1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1	1 1 1 1	1 1	1 1 1	1	1 1 1		1 +	1 + 1 1 1 1 + 1 1 1 1 1 1
Anthospermum rigidum	1 1	1 1 1 1 1	1 + + 1 + 1 1	1 1 1 1 +	1 1 1	1	1 1		1 1		1	+ 1 + + +
Aristida junciformis	+ 1 1	3 1 1 + +	+ + + A	1 + 5	1 + A B	A	1 3	1	1 1	+ 1	1	+ 3 1 1 A 1 3
Berkheya onopordifolia		+ + + 1	+ + 1	+ + + +		+	+	+			+	R 1 + + + + 1 1 1

Species group Q

Heteropogon contortus	3 1 1 A 1 1 1 3 1 1 3 B 3	1 B 3 1 1 1 1	3 A 1 3 1 B A 1 1 3	B B 1 3 3 A B 4 1	1 3 1 A	1	3 1 3	B A 1	B + A 3	1 A 1	B A 3 1	+ + B A A 1 1 + + A 1 B
Eragrostis capensis	+ 1 A A 1 + 1 1 1 A 1 +	1 1 1 1 1 1 1	1 1 A 1 1 1 1 A 1	1 + 1 A 1 1 1 1	1 A 1 1	+	1 1	1	1 + 1	A 1 1	+ A 1 A 1	1 1 1 1 1 1 1 + 1
Eragrostis racemosa	+ 1 1 1 1 1 1 A 1 A A 1	+ 1 1 1 1 1	1 1 1 1 1 1 1 1 1	1 + 1 1 A 1 1 1	1 1 1 1		1 1	1 1	1 1	A A 1	1 A	1 1 1 1 1 1 1 + 1 + A 1 + 1
Themeda triandra	A B + 3 3 B 3 3 3 4 A 1 1	1 A A 1 A	A B A 3 A 1 B 1 A	3 3 1 3 B B 3 B +	A A		1	1 A A	A + 1 1	A 1 B	1 + A B	A 1 A 1 1 B + 1 1 B
Helichrysum pilosellum	1 1 1 1 + 1 1 1 1 1 1	1 1 1 1 1	1 1 1 1 1 1 1	1 1 1 1 +	1 1		1	1 1	1 1 1	1 1 1	1 1	+ + 1 1
Haplocarpha scaposa	1 1 + + 1 1 1 + 1	1 1 1	1 1 1 1	+ + 1	1 1			1	1 1 1	1 1 1	1 1 1	1 + 1 1 + + 1 +
Elionurus muticus	A 1 1 1 1 1 1	1 1 1	1 1 1 1 B	1 B 1 A 1 +				A	1 1 A	1 1 1	A 1	3 A A A 1 + A 1
Berkheya setifera	1 + 1 1 1 1 1	1 1 1	1 1 1 1	1 1 1 1 1	+ +	1	+ 1	1	1	1 1	1 1 1	1 1 1 1 1 +
Vernonia oligocephala	1 + + 1 + 1	1	1 + 1 1 1	1 1 1	+	+	+		+			+ 1 1 + + + + 1 +

AVERAGE SPECIES RICHNESS



TOTAL SPECIES PER VEGETATION UNIT

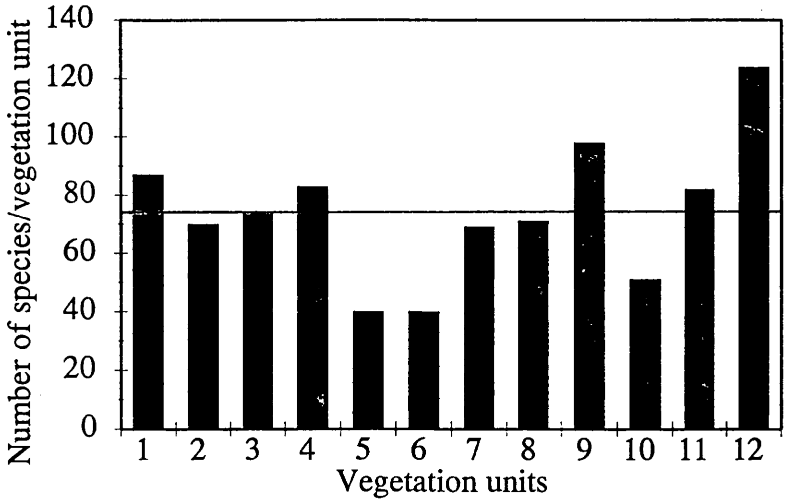


Figure 5 Average species richness and total number of species as calculated for each vegetation unit. Horizontal lines indicate the respective average values for the *Helichrysum pilosellum*-*Heteropogon contortus* Major vegetation type.

1. *Monocymbio ceresiiformis-Themedetum triandrae*
   1.1 *Monocymbio ceresiiformis-Themedetum triandrae trachypogonetosum spicati* (vegetation unit 1)
   1.2 *Monocymbio ceresiiformis-Themedetum triandrae sporoboletosum africani* (vegetation unit 2)
   1.3 *Monocymbio ceresiiformis-Themedetum triandrae eragrostietosum planae* (vegetation unit 3)
2. *Microchloa caffra-Themeda triandra* Grassland (vegetation unit 4)
3. *Microchloa caffra-Aristida junciformis* Grassland (vegetation unit 5)
4. *Leucosideo sericeae-Eragrostietum curvulae*
   4.1 *Leucosideo sericeae-Eragrostietosum curvulo-planae* (vegetation unit 6)
   4.2 *Leucosideo sericeae-Eragrostietum curvulae rhoetosum discolor* (vegetation unit 7)
   4.3 *Leucosideo sericeae-Eragrostietum curvulae cheilanthetosum quadripinnatae* (vegetation unit 8)
   4.4 *Leucosideo sericeae-Eragrostietum curvulae helichrysetosum hypoleucum* (vegetation unit 9)
   4.5 *Leucosideo sericeae-Eragrostietum curvulae tristachyetosum leucothricis* (vegetation unit 10)
   4.6 *Leucosideo sericeae-Eragrostietosum curvulo-caesiae* (vegetation unit 11)
5. *Hyparrhenio hirtae-Eragrostietum curvulae* (vegetation unit 12)

Description of the plant communities

1. *Monocymbio ceresiiformis-Themedetum triandrae* ass. nov.

Nomenclatural type: relevé 293 (holotypus)

This short closed grassland association generally occurs on midslopes and sometimes on plateaux above 1 500 m altitudes, in the area surrounding Groenvlei and directly north of Helpmekaar (Figure 4). Sandstone, mudstone and shale of the Beaufort Group, as well as dolerite, are the predominant rock types comprising the geology of this region. The soils clearly reflect the underlying parent material, the texture being mostly of a sandy nature, although isolated occurrences of dolerite derived soils often occur.

The diagnostic species are listed under species group A (Table 1). Other prominent species are *Heteropogon contortus* and *Themeda triandra, with* Eragrostis racemosa *and* E. capensis being constantly present, although less conspicuous and displaying low cover-abundance values (species group Q, Table 1).

Three sub-associations are recognized under this grassland:

1.1 *Monocymbio ceresiiformis-Themedetum triandrae trachypogonetosum spicati* sub-ass. nov.

Nomenclatural type: relevé 293 (holotypus)

This sub-association of midslopes and plateaux is typical of the association, occurs at altitudes of above 1 700 m and is found on various types of soils, the most common being Avalon, Glenrosa and Pinedene Forms (Figure 4). Soil depths vary from 300 to more than 500 mm. The soils are relatively sandy, mostly having a clay content of only 15-25%. The geology consists mainly of dolerite, and sandstone and shale of the Estcourt Formation. Surface rocks are mostly absent.

Diagnostic species are listed under species group B (Table 1). Another species which is not diagnostic but strongly distinguishes this vegetation unit by constantly high cover-abundance values, is *Tristachya leucothrix* (species group N, Table 1). Other prominent species include *Heteropogon contortus* and *Themeda triandra.*

An average number of 24 species was recorded per sample plot, which is far below the average of the entire *Helichrysum pilosellum-Heteropogon contortus* Grassland, whereas the total number of species (87) for this community is well above the average (Figure 5).

1.2 *Monocymbio ceresiiformis-Themedetum triandrae sporoboletosum africani* sub-ass. nov.

Nomenclatural type: relevé 288 (holotypus)

This grassland is restricted to midslopes at altitudes of > 1 500 m and is mostly found on soils of the Clovelly, Oakleaf and Glenrosa Forms (Figure 4). The soils are sandy, rarely exceeding clay percentages of 25%, and are generally deeper than 500 mm. The geology consists of dolerite, and sandstone and shale of the Vryheid Formation. Surface rocks are absent within this grassland.

The only diagnostic species recognised for this sub-association is the differential grass species *Sporobolus africanus* (species group O, Table 1). The sub-association is also distinguished from the *Monocymbio ceresiiformis-Themedetum triandrae sporoboletosum africani* by the presence of species groups M and P and by the absence of species group B (Table 1). The relatively strong presence of *Sporobolus africanus* (species group O, Table 1) suggests some degree of disturbance possibly caused by the trampling effect of livestock (Moll 1968). This fact is further stressed by the lower cover-abundance values of *Monocymbium ceresiiforme* and *Themeda triandra*, and the simultaneous strong presence of *Eragrostis curvula* and *E. plana*.

Both the species richness (26) and the total number of species (70) for this community are below the respective averages (Figure 5) calculated for the *Helichrysum pilosellum-Heteropogon contortus* major vegetation type.

1.3 *Monocymbio ceresiiformis-Themedetum triandrae eragrostietosum planae* sub-ass. nov.

Nomenclatural type: relevé 93 (holotypus)

This grassland occurs on midslopes at altitudes exceeding 1 500 m, which are mainly underlain by sandstone, shale and mudstone of the Estcourt and Volksrust Formations, and by dolerite (Figure 4). Various soil types are found, being 300 to more than 500 mm deep, with clay percentages varying from 25 to more than 35%. Surface rocks are not present.

This sub-association contains no diagnostic species but is, however, distinguished from the two formerly described sub-associations respectively by the absence of species group B and by the presence of species groups D, M and P (Table 1). Prominent species include *Monocymbium ceresiiforme, Eragrostis curvula, E. plana, Heteropogon contortus* and *Themeda triandra*.
This vegetation unit has the lowest species richness (23) recorded within this major vegetation type, with the total number of species being 74 (Figure 5).

2. *Microchloa caffra-Themeda triandra* Grassland

This short closed grassland community is found on midslopes (>1 700 m above sea-level) which are mainly underlain by sandstone, shale and mudstone of the Volksrust and Estcourt Formations, and to a lesser degree by dolerites (Figure 4). Various soil types are encountered, being 300 to more than 500 mm deep, with clay percentages varying from 20 to more than 35%. Surface rocks are generally absent.
The syntaxonomic position of this grassland is unclear, since no diagnostic species are present. The most common and physiognomically dominant species are *Eragrostis curvula, E. plana, Heteropogon contortus* and *Themeda triandra* (Table 1). Stands of *Microchloa caffra* are usually prominent where patch-selection has occurred.
The average number of species per sample plot is 26 and the total number of species found within this community is 83 (Figure 5).

3. *Microchloa caffra-Aristida junciformis* Grassland

This short closed grassland community occurs on terrain units 1 and 3 at altitudes exceeding 1 700 m (Figure 4). Shallow (<300 mm) soils of the Glenrosa Form are predominant, with clay contents varying from 15-25%. The geology consists of dolerites, and sandstone, shale and mudstone of the Estcourt Formation. Surface rocks are often present, covering less than 2% of the area.
No syntaxonomic rank is allocated as diagnostic species are absent. The most conspicuous and dominant species are *Eragrostis curvula* and *E. plana*, with *Microchloa caffra, Aristida junciformis, Heteropogon contortus* and *Themeda triandra* being less prominent (Table 1).

This community is extremely species poor, with the average number of species per sample plot being 20 and the total number only 40 (Figure 5).

4. *Leucosideo sericeae-Eragrostietum curvulae* ass. nov.

Nomenclatural type: relevé 210 (holotypus)

This association represents shrubland which is generally restricted to the area around Groenvlei north of Utrecht (Figure 1), at altitudes exceeding 1 700 m, and occurs on steep slopes (20°-45°) with a southerly aspect, but is also found on mountain plateaux and rocky outcrops (Figure 4). The predominant soil type is the Glenrosa Form, being less than 300 mm deep and containing less than 20% clay. Sandstone, shale and mudstone of the Estcourt Formation, and dolerite, constitute the geology of this specific area. The diameter of surface rocks exceeds 500 mm, covering more than 20% of the area.

This association can be classified as tall to high closed and tall to high open shrubland, the density of the woody component varying considerably within this vegetation type. Although the variation in species composition and density can be ascribed partly to habitat differences, the main reason could be sought in mismanagement of the original grass layer, *i.e.* overutilization and ecologically unsound burning practices (Edwards 1967). An imbalance is caused between the woody and the herbaceous component, leading to bush encroachment and subsequent replacement of grasslands which can be witnessed by the high density of young *Leucosidea sericea* shrubs. The diagnostic species which characterize this association are included under species group E (Table 1). Other prominent species are *Eragrostis curvula* and *Heteropogon contortus*. Noteworthy is the decline in the cover-abundance and frequency values of *Themeda triandra*, emphasizing gradual degradation in the grass layer.

4.1 *Leucosideo sericeae-Eragrostietosum curvulo-planae* sub-ass. nov.

Nomenclatural type: relevé 213 (holotypus)

This tall to high open shrubland contains no diagnostic species and is distinguished by the absence of species groups F, G, H and J (Table 1) (Figure 4). The most prominent and dominant species are *Leucosidea sericea, Eragrostis curvula* and *E. plana.*

This vegetation unit has the lowest species richness (23) and total number of species (40) of all sub-associations under the *Leucosideo sericeae-Eragrostietum curvulae* ass. nov. (Figure 5).

4.2 *Leucosideo sericeae-Eragrostietum curvulae rhoetosum discolor* sub-ass. nov.

Nomenclatural type: relevé 124 (holotypus)

This tall to high closed shrubland cannot be distinguished from the other sub-associations under the *Leucosideo sericeae-Eragrostietum curvulae* on the basis of diagnostic species (Table 1) (Figure 4). It is, however, distinguished by the absence of species groups G, H and J (Table 1). Prominent species include *Leucosidea sericea* and *Heteropogon contortus.*

The average number of species recorded per sample plot is 32, whereas the total number is 69 (Figure 5).

4.3 *Leucosideo sericeae-Eragrostietum curvulae cheilanthetosum quadripinnatae* sub-ass. nov.

Nomenclatural type: relevé 210 (holotypus)

This tall to high closed shrubland is distinguished by the absence of species groups H and J (Table 1) (Figure 4). No diagnostic species are recognized. The most prominent species are *Leucosidea sericea, Eragrostis curvula, Heteropogon contortus* and *Themeda triandra.* This is the typical sub-association of the *Leucosideo sericeae-Eragrostietum curvulae* ass. nov.

The species richness is 35 and the total number of species recorded is 71 (Figure 5).

4.4 *Leucosideo sericeae-Eragrostietum curvulae helichrysetosum hypoleuci* sub-ass. nov.

Nomenclatural type: relevé 120 (holotypus)

This high closed shrubland is characterized by the diagnostic species group H (Table 1) and is further distinguished by the absence of species group J (Table 1) (Figure 4). The most prominent species are *Leucosidea sericea* and *Heteropogon contortus*.
This sub-association has the highest species richness (42) recorded in this major vegetation type and the second highest total number of species (98) (Figure 5).

4.5 *Leucosideo sericeae-Eragrostietum curvulae tristachyetosum leucothricis* sub-ass. nov.

Nomenclatural type: relevé 215 (holotypus)

This tall to high open shrubland has no diagnostic species and is distinguished by the presence of species group J and the simultaneous absence of species groups F, G and H (Table 1) (Figure 4). The most prominent species are *Leucosidea sericea, Tristachya leucothrix, Eragrostis curvula, E. racemosa* and *Themeda triandra*. This sub-association can be considered as an intermediate stage in the succession from grassland to closed shrubland, with species such as *Tristachya leucothrix* and *Themeda triandra* expected to disappear as *Leucosidea sericea* encroaches.
The average number of species recorded per sample plot is 36, whereas the total number of species found within this community is only 51 (Figure 5).

4.6 *Leucosideo sericeae-Eragrostietosum curvulo-caesiae* sub-ass. nov.

Nomenclatural type: relevé 217 (holotypus)

The structural classification of this sub-association varies from tall to high and from open to closed shrubland. Although no diagnostic species were recorded, this shrubland is distinguished by the presence of species group J and by the absence of species groups F, G and H (Table 1)

(Figure 4). It is further distinguished from the *Leucosideo sericeae-Eragrostietum curvulae tristachyetosum leucothricis* by the absence of species group I (Table 1). Prominent species include *Leucosidea sericea, Eragrostis caesia, E. curvula* and *Heteropogon contortus*. The presence of *Eragrostis caesia* indicates moist conditions which are associated with south-facing slopes.

The average number of species recorded per sample plot is 30 and the total number 82 (Figure 5).

5. *Hyparrhenio hirtae-Eragrostietum curvulae* ass. nov.

Nomenclatural type: relevé 275 (holotypus)

This short to tall closed grassland generally occurs on midslopes at altitudes below 1 500 m (Figure 4). Various soil types are encountered, being 400 to more than 500 mm deep and containing between 15-30% clay. The geology consists of dolerite, and sandstone, shale and mudstone of the Vryheid and Pietermaritzburg Formations. Surface rocks are usually absent within this grassland.

The diagnostic species which characterize this association are listed under species group O (Table 1). Other prominent, and often dominant, species include *Eragrostis curvula, Heteropogon contortus* and *Elionurus muticus*. This association is closely related to the *Helichrysum rugulosum-Hyparrhenia hirta* Grassland, described by Eckhardt *et al.* (1996a), concerning species composition and environmental conditions under which these vegetation units are found. However, the presence of *Heteropogon contortus* and *Elionurus muticus*, as well as other less prominent species, in this association distinguish the two grassland types. Although an extremely high total number of species (124) is found in this grassland, the average number of species per sample plot is only 24 (Figure 5).

Ordination

The ordination diagram is a three-dimensional presentation of the distribution of the synrelevés along the first, second and third axes (Figure 6). Relatively distinct groups of synrelevés can be

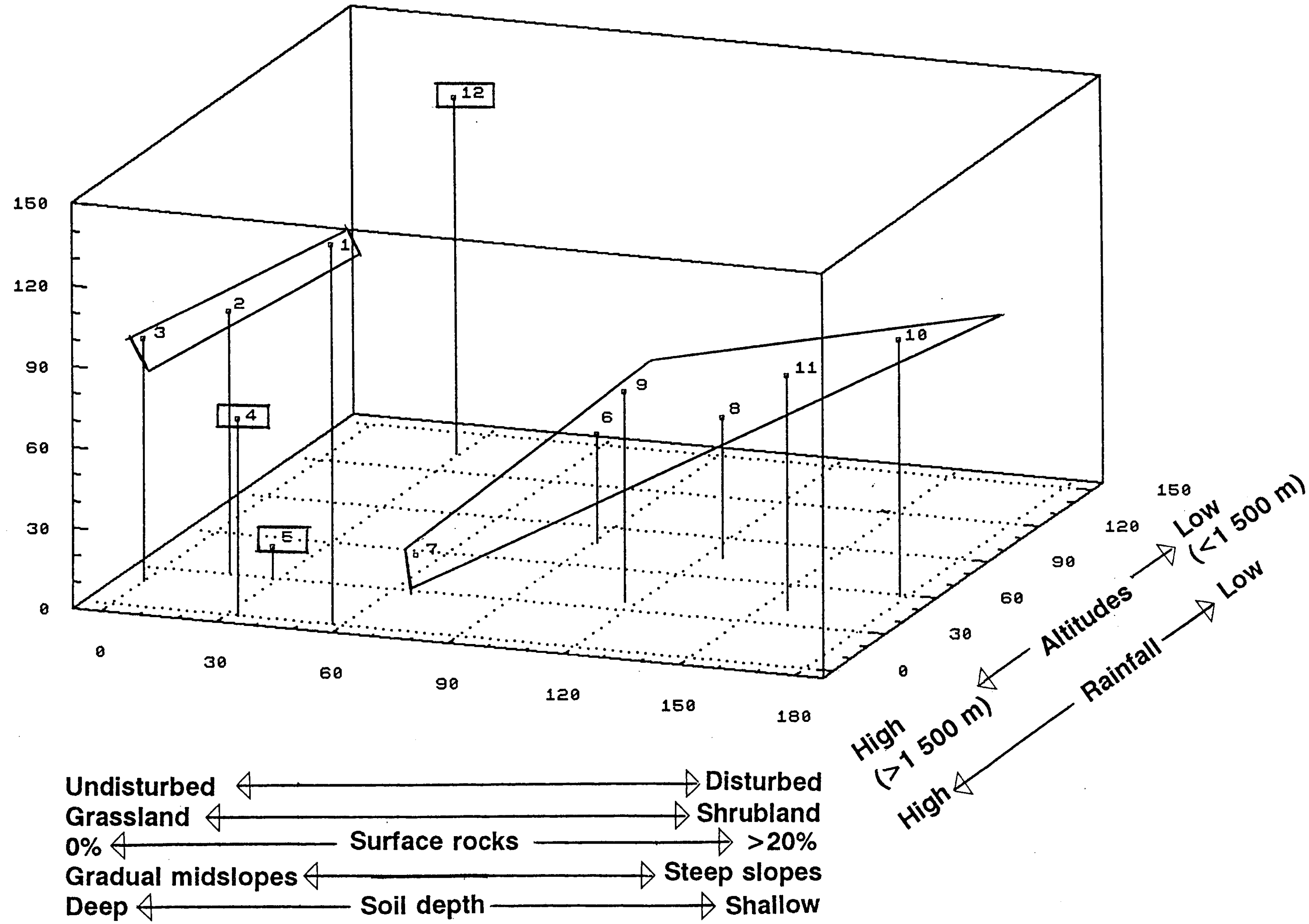


Figure 6 DECORANA ordination diagram illustrating the three-dimensional distribution of the different synrelevés (12 vegetation units) along the first, second and third axes.

observed, suggesting a certain degree of discontinuity. The distribution of the synrelevés corresponds with various environmental gradients along the first and second axis. The distribution of the synrelevés along the third axis, however, cannot be explained by means of environmental factors. The vegetation units occurring to the left front of the diagram are undisturbed, high-altitude (>1 500 m above sea-level) grasslands found on deep soils of gradual midslopes, with surface rocks being absent and rainfall high. The vegetation units occurring to the right front of the diagram represent disturbed shrublands of high rainfall areas, associated with shallow soils of steep slopes, and surface rocks covering more than 20% of the area. The synrelevé at the left back of the diagram represents disturbed, low-altitude (<1 500 m above sea-level) grassland, associated with deep soils of gradual midslopes, low rainfall conditions, and surface rocks being absent.

Concluding remarks

The TWINSPAN classification and subsequent refinement there-of by Braun-Blanquet procedures resulted in the recognition of 12 plant communities. As indicated by the DECORANA scatter diagram, these communities are related to certain environmental factors.
Communities with exceptionally high a diversities as well as a relatively high degree of naturalness are usually considered to have high conservation potentials (Rapoport *et al.* 1986; Götmark 1992). Naturalness was used here as decisive factor in recognizing the conservation value of the *Monocymbio ceresiiformis-Themedetum triandrae trachypogonetosum spicati*. This community was found to be least disturbed, consisting of species which indicate ecological optimal conditions (Edwards 1967; Tainton 1981; Van Oudtshoorn 1991). Another factor which contributes to the increase in conservation value of this community is the possibility of destruction of the latter by the establishment of exotic plantations. The entire *Monocymbio ceresiiformis-Themedetum triandrae* represents an area which is suitable for afforestation purposes and should therefore be granted protection against such activities. The establishment of exotic plantations within this grassland could have detrimental effects on the water supply to major rivers such as the Bivane, Buffalo and Pongolo Rivers, as well as on the vlei areas around Groenvlei. It must also be kept in mind that these vlei areas form ideal habitat for the

endangered wattled crane (Brooke 1984). Draining these wetlands will undoubtedly lead to habitat change with disastrous effects on the wattled crane population.

It seems that the spreading of the shrubland communities described here holds a potential danger for high-lying grasslands. If these grasslands are to become instable due to ecological unsound management, the *Leucosidea sericea* shrublands will most probably expand and replace the grasslands (Edwards 1967; see also Eckhardt *et al.* 1993). Reclamation of the lost grasslands, if possible at all, can be expected to be expensive. Although *Leucosidea sericea* is considered to be a participatory species in the progressive succession, leading to the development of forests (Edwards 1967), the *Leucosideo sericeae-Eragrostietum curvulae* is clearly the result of mismanagement as can be inferred from the relatively poor species composition.

Acknowledgement

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CHAPTER 4.6

Species richness and plant communities of the *Helichrysum rugulosum-Hyparrhenia hirta* Low-altitude grassland of northern KwaZulu-Natal

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Species richness and plant communities of the *Helichrysum rugulosum–Hyparrhenia hirta* Low-altitude grassland of northern KwaZulu-Natal

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The condition of the grasslands of northern KwaZulu-Natal is a source of great concern especially if seen against the background of a lack of knowledge of the ecology of these grasslands. The aim of this study was therefore to produce a classification and description of the plant communities of the *Helichrysum rugulosum–Hyparrhenia hirta* Low-altitude grassland, a major vegetation type of the area. The TWINSPAN classification and subsequent refinement there-of by Braun–Blanquet procedures resulted in the identification of 14 plant communities (vegetation units). The relationship of these communities to environmental factors was then determined by the application of the ordination algorithm DECORANA. Distribution of the synrelevés was explained in terms of soil characteristics and degradation. The phytosociological data were further analyzed to determine the species richness of each community. This parameter, together with species rarity and naturalness of communities, were collectively considered in an attempt to identify potential conservation sites. According to these criteria, one specific community was identified to be of conservational importance.

Keywords: Conservation sites, grassland, naturalness, plant communities, species richness, vegetation units.

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Introduction

Deterioration of the grasslands of South Africa as a result of various factors is clearly realized (Mentis & Huntley 1982). Improvement in the quality of grassland management can only be achieved if based on detailed plant ecological studies (Codd 1949; Foran *et al.* 1986; Bosch *et al.* 1987). Existing vegetation descriptions and maps are often insufficient or have become obsolete. For the identification of conservation sites, it is important to have as much detailed floristic data available as possible.

Since little is known about the phytosociology and diversity of the grasslands of northern KwaZulu-Natal, this study aims at identifying and describing the plant communities of this area. Species richness, species rarity (Hall *et al.* 1980; Rapoport *et al.* 1986) and naturalness (Götmark 1992) were used as criteria on which the attempt to select conservation sites was based. The term 'naturalness' refers to the impact which man has had on the environment.

During a study on the vegetation ecology of the grasslands of northern KwaZulu-Natal (Eckhardt *et al.* 1996a, b, c, d), the *Helichrysum rugulosum–Hyparrhenia hirta* Low-altitude grassland was identified as a major vegetation type. The plant communities, considered here as vegetation units, identified within this major vegetation type are described and floristically analyzed in this article. The floristic and phytosociological analyses of the northern KwaZulu-Natal region form part of a more comprehensive study dealing with the syntaxonomy and synecology of the entire Grassland Biome of South Africa (Bezuidenhout & Bredenkamp 1990; Kooij 1990; Du Preez 1991; Matthews 1991; Smit 1992; Bezuidenhout 1993; Burgoyne 1995; Coetzee 1993; Eckhardt 1993; Fuls 1993; Bredenkamp & Bezuidenhout 1995).

Study area

The entire study area (Figure 1) is situated in central-northern KwaZulu-Natal (Land Type Survey Staff 1986, 1988) and consists of irregular undulating lowlands in the central and southwestern parts, undulating mountains and lowlands in the northwestern and eastern parts, and low mountains in the south-eastern part (Kruger 1983). The area is situated between 27°16′ and 28°31′S latitude and 30°00′ and 31°38′E longitude, comprising

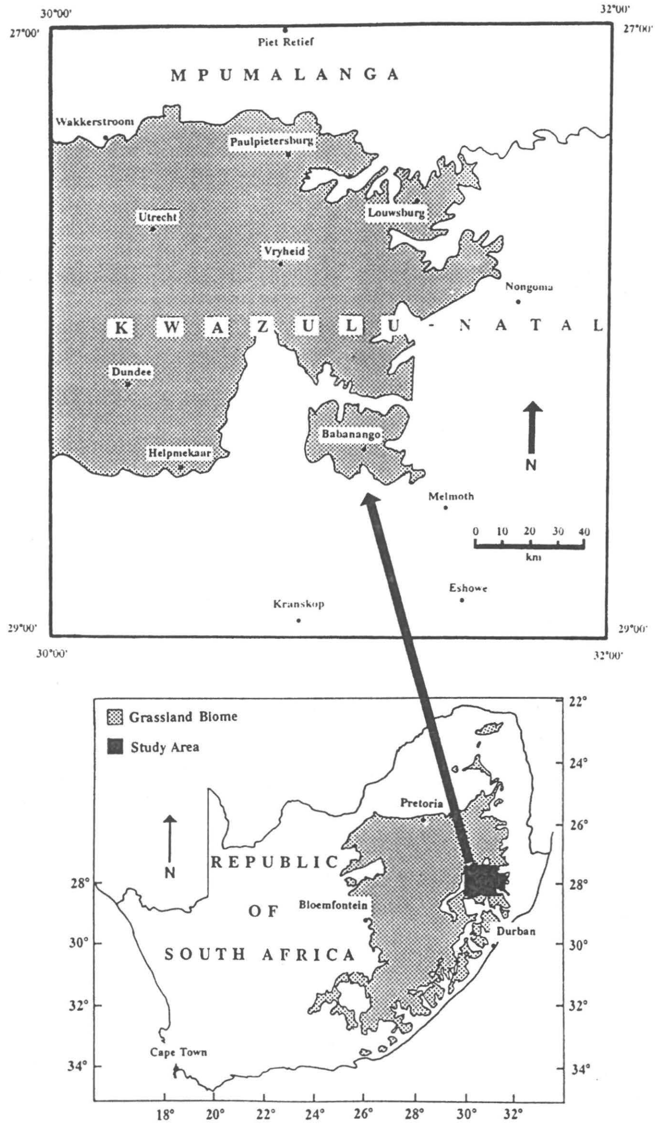

Figure 1 Location of the study area within the Grassland Biome of South Africa.

14 366 km². The high differences in altitudes within the area, varying from 750 to 2 290 m, can be ascribed to the variety of physiographic regions and strongly affects the rainfall, the annual average being 850 mm (Schulze 1982). The specific area covered by the *Helichrysum rugulosum–Hyparrhenia hirta* Low-altitude grassland mainly includes the Hlobane–Manyini–C'eza Block, Bergville–Ladysmith–Elandslaagte Plain, Buffalo Plain, Dundee Plain, Ingagane Plain, Newcastle–Utrecht Plain, Utrecht–Vryheid Plain and the Nondweni–White Umfolozi Basin (Turner 1967) (Figure 2). These lowlands are generally characterized by a relatively low average annual rainfall of 700 to 800 mm and a relatively high mean annual temperature of 17°C (Schulze 1982). This major grassland type highly corresponds with the Southern Tall Grassveld (65) and Natal Sour Sandveld (66) veld types of Acocks (1988) (Figure 3) and occurs primarily at altitudes below 1 400 m although certain communities may occasionally be found at an altitude of up to 1 800 m. Large areas falling within the Natal Sour Sandveld (66) are ploughed mainly for maize production. These areas are primarily restricted to the Buffalo and the Utrecht–Vryheid Plain (Figure 2).

Certain communities of this major vegetation type are also found on the Belelasberg–Skurweberg Plateau and the Helpmekaar Plateau (Turner 1967) (Figure 2).

Methods

Relevés were compiled in 96 sample plots, which were stratified on the basis of terrain units and aspect. Plot sizes were fixed at 100 m² (Scheepers 1975) and species recorded within the sample plots were given a value according to the Braun–Blanquet cover-abundance scale (Mueller-Dombois & Ellenberg 1974). Taxon names conform to those of Arnold & de Wet (1993) and the different plant communities were structurally classified according to the system of Edwards (1983). Environmental data recorded for each relevé include terrain unit, slope, soil depth, soil texture, clay content, rockiness of soil surface and erosion. Although attention was also given to geology, soil types and aspect, the results inferred that these factors did not affect the vegetation and are subsequently not referred to.

Two-way indicator species analysis (TWINSPAN) (Hill 1979b) was applied to derive the first approximation of the floristic data set (see also Eckhardt *et al.* 1996a, b, c, d). The produced classification was further refined by Braun–Blanquet procedures (Westhoff & van der Maarel 1978; Kooij *et al.* 1990; Eckhardt *et al.* 1993; Fuls *et al.* 1993a, b; Bredenkamp & Bezuidenhout 1995) to identify the different plant communities, which were subsequently presented in a phytosociological table.

The relationships between the vegetation and physical environment were identified using the ordination algorithm DECORANA (Hill 1979a). The synoptic data from the table, representing constancy values for species in the different vegetation units, were used for the ordination (see also Eckhardt *et al.* 1996b).

The floristic data within each vegetation unit were further analyzed to calculate α diversity (see also Eckhardt *et al.* 1996a for a more detailed discussion).

The nomenclatural type of each syntaxon represents the typical species composition of the relevant syntaxon, with special emphasis on the diagnostic species. The code of phytosociological nomenclature follows that of Barkman *et al.* (1986).

Results and Discussion

The *Helichrysum rugulosum–Hyparrhenia hirta* Low-altitude grassland is predominantly restricted to midslopes of low-lying (< 1 400 m) undulating plains and occurs sometimes on crests and footslopes (Figure 4). The slopes rarely exceed gradients of 3°, although some may reach 15°. Certain communities may occur at altitudes reaching 1 800 m, but they are localized. Surface rocks are rare but mostly absent in many of the communities

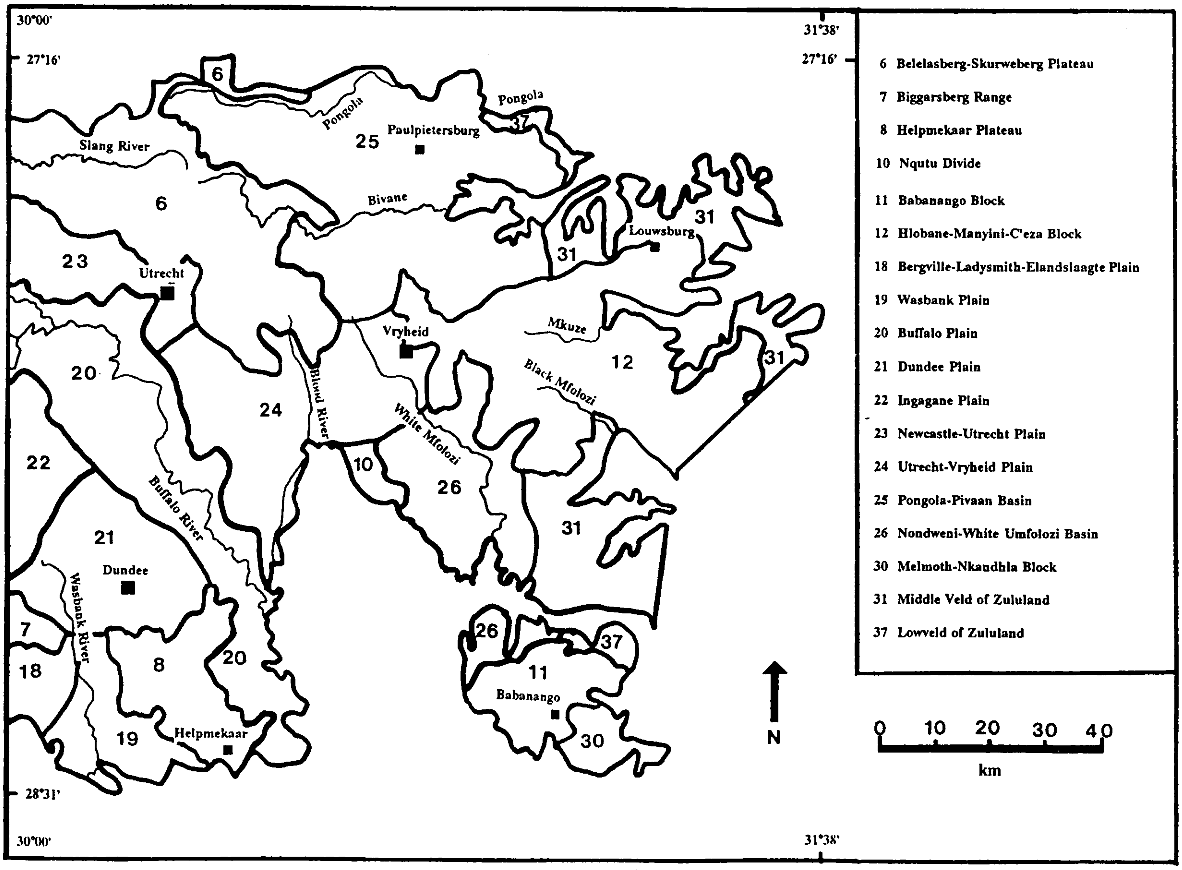

Figure 2 Distribution of the physiographic regions within the study area (Turner 1967).

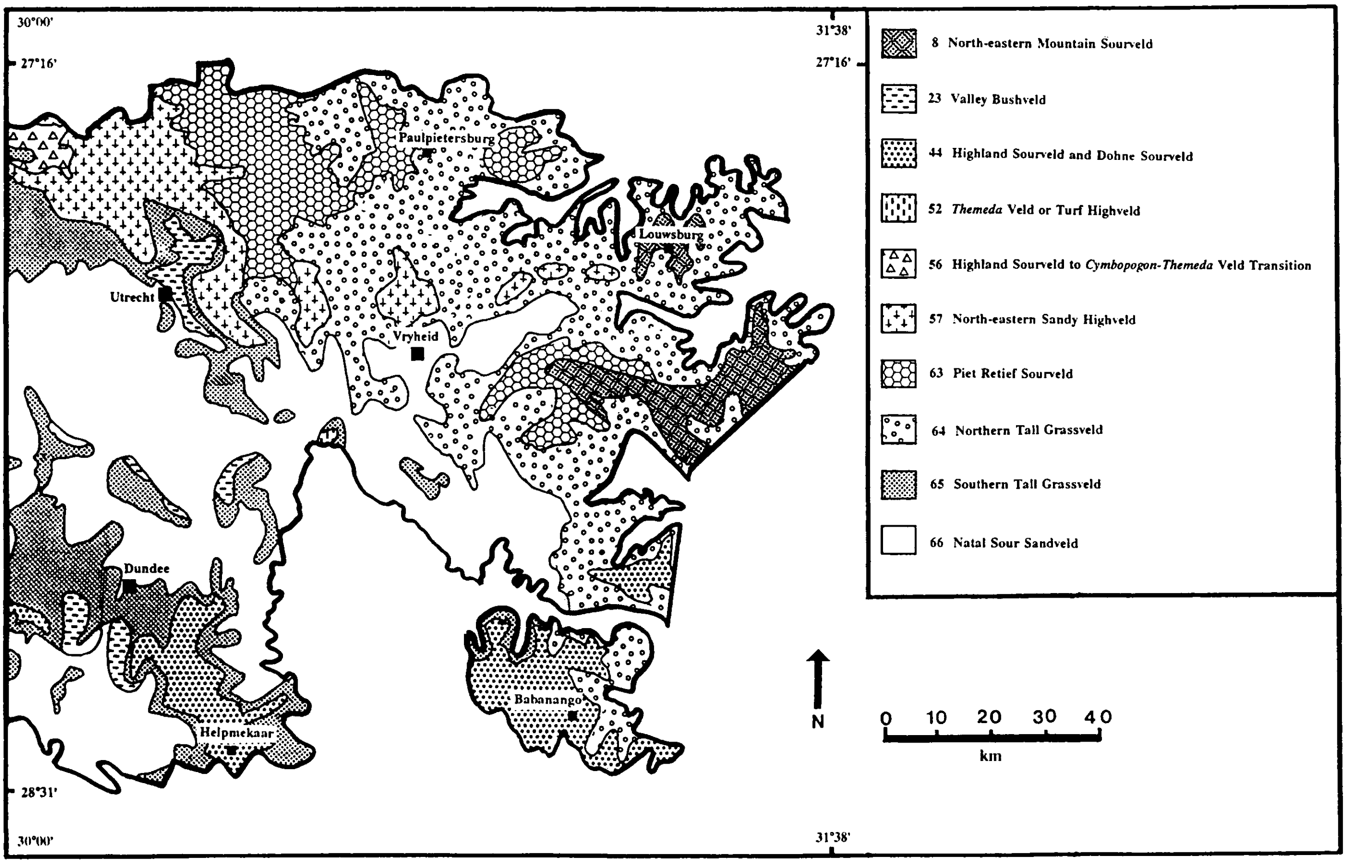

Figure 3 The different veld types (Acocks 1988) found within the study area.

and soils are usually deeper than 500 mm and display clay percentages varying from 10% to more than 35%.

The most common and physiognomically conspicuous species throughout the grasslands of northern KwaZulu-Natal (Eckhardt *et al.* 1996b, c , d) are the graminoids *Eragrostis curvula, E. plana, Hyparrhenia hirta* and *Sporobolus africanus* (species group R, Table 1). This major vegetation type shows clear signs of disturbance, as indicated by species such as *Heteropogon contortus, Cymbopogon excavatus* and *Aristida junciformis,* as well as those listed under group R (Edwards 1967; Tainton 1981; van Oudtshoorn 1991).

The average species richness for this major vegetation type is 22 species per 100 m^2 and the average total number of species recorded per plant community is 66 (Figure 5). Both these values are low if compared to the respective values of the *Alepidea longifolia–Monocymbium ceresiiforme* Grassland (28:118) (Eckhardt *et al.* 1996b), *Panicum natalense–Eragrostis curvula* Grassland (24:68) (Eckhardt *et al.* 1996c) and *Helichrysum pilosellum–Heteropogon contortus* Grassland (29:74) (Eckhardt *et al.* 1996d) identified within the study area. It appears, therefore, that high-lying grasslands have a higher species richness than low-lying grasslands (see also White 1981, 1983; Matthews *et al.* 1993; Eckhardt *et al.* 1996b).

Classification

The analysis of the floristic data resulted in the identification of 14 plant communities (Table 1) which are subsequently hierarchically classified (Barkman *et al.* 1986). To facilitate the reference to the different vegetation units, numbers are attached to each of the units.

1. *Aristido bipartitae–Themedetum triandrae*
   1.1 *Aristido bipartitae–Themedetum triandrae phyllanthetosum burchellii* (vegetation unit 1)
   1.2 *Aristido bipartitae–Themedetum triandrae brachiarietosum serratae* (vegetation unit 2)
   1.3 *Aristido bipartitae–Themedetum triandrae felicietosum muricatae* (vegetation unit 3)
   1.4 *Aristido bipartitae–Themedetum triandrae monsonietosum angustifoliae* (vegetation unit 4)
   1.5 *Aristido bipartitae–Themedetum triandrae elionuretosum muticus* (vegetation unit 5)
2. *Sporoboletum pyramidalo–africani*
   2.1 *Sporoboletum pyramidalo–africani eragrostietosum superbae*
      2.1.1 *Brachiaria brizantha* Variant (vegetation unit 6)
      2.1.2 *Conyza obscura* Variant (vegetation unit 7)
   2.2 *Sporoboletum pyramidalo–africani berkheyetosum setiferae* (vegetation unit 8)
   2.3 *Sporoboletum pyramidalo–africani pogonarthrietosum squarrosae* (vegetation unit 9)
3. *Aristido congestae–Eragrostietum gummifluae* (vegetation unit 10)
4. *Centello asiaticae–Eragrostietum planae*
   4.1 *Centello asiaticae–Eragrostietum planae melinietosum repens* (vegetation unit 11)
   4.2 *Centello asiaticae–Eragrostietum planae themedetosum triandrae* (vegetation unit 12)
5. *Heteropogon contortus–Aristida junciformis* Grassland (vegetation unit 13)
6. *Eragrostis plana–Sporobolus africanus* Grassland (vegetation unit 14)

Description of the plant communities

1. *Aristido bipartitae–Themedetum triandrae* ass. nov.

Nomenclatural type: relevé 77 (holotypus).

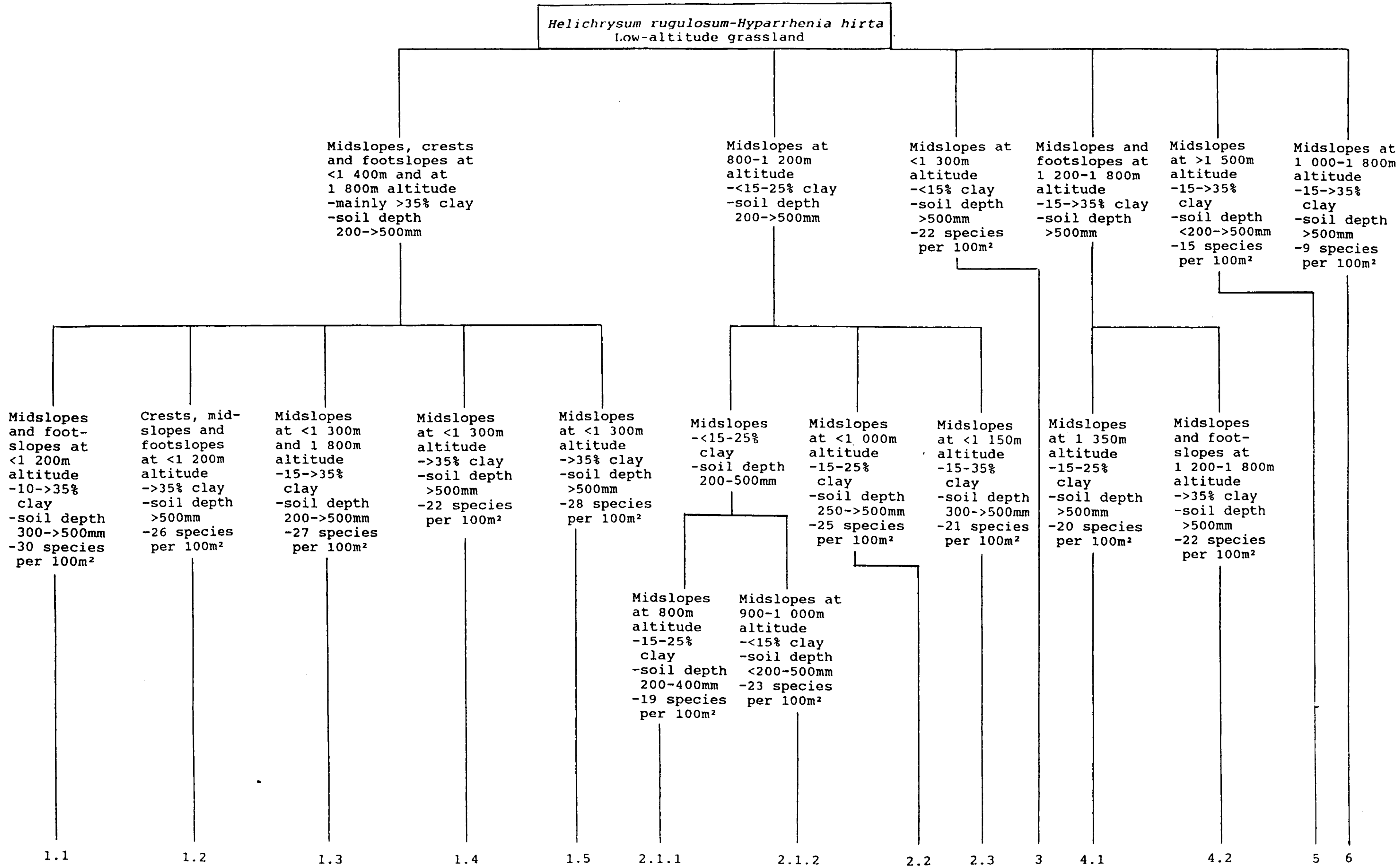

Figure 4 Hierarchical classification and associated environmental characteristics of the 14 plant communities (vegetation units) of the *Helichrysum rugulosum–Hyparrhenia hirta* major vegetation type.

Table 1 Phytosociological table of the *Helichrysum rugulosum–Hyparrhenia hirta* Low-altitude grassland

Association	1					2				3	4			
Subassociation	1.1	1.2	1.3	1.4	1.5	2.1		2.2	2.3		4.1	4.2		
Variant						2.1.1	2.1.2							
Community without rank													5	6
Releve number	0000	000000011	011111	22012	02000	333	453	333333335	33333	00000011222223	102	3002001101 0	0221222430	344120552
	1271	111122358	956679	05447	36548	688	310	000222350	45778	00355599055772	720	23053975759	6809828919	111441579
	2175	789303531	508907	69091	79059	801	724	238126139	92288	34217989367277	151	56808654852	4471377971	213710730
Species group A														
Aristida bipartita	1 A	+1A 1 11	1 1	1111	111 1	1				1 1		11A	1 A	
Elionurus muticus	+ +	++1 1 B	1	1 1A	1 1A1		+				+	+		
Indigofera hedyantha	+	111 +	1	+1	1 ++							+		
Geigeria aspera	1 1		+	+ +	+ 1									
Species group B														
Ledebouria ovatifolia	++ +	11+ +1	+		1							+	+	
Phyllanthus burchellii	111+	+1 +		1				1	1	1 +				
Hibiscus trionum	++1+	11 +		+ 1	+					+	1	+		
Cymbopogon plurinodis	+1	1+1 1												
Anthericum fasciculatum	1R	1+1 +	+ +									+ +		
Oenothera tetraptera	1+	1 1+			1							+ +	1	
Species group C														
Felicia muricata	+		11++11	11					+	+ +	1	1 1 1		
Species group D														
Ipomoea ommaneyi		++ + +1	++++1									+		
Crabbea acaulis		11 + +	1 1 11	1				+				1		
Brachiaria serrata		11111+	A A		1				+			1		
Species group E														
Monsonia angustifolia	+ 1+	1	1 +	1++11					+	++ +1			1	
Striga bilabiata	R	R + 1+	+1 +	+ +										
Brachiaria eruciformis	1	11		B 1										
Species group F														
Setaria sphacelata		1B1 A	+	+ 1	111	+		+1				+ 1 1		+ +
Diheteropogon amplectens		+ +	+	1	+1+			+						
Species group G														
Sporobolus pyramidalis						543	+31	3331 4B	+4+41					1
Species group H														
Eragrostis superba						+11	1+1					1		
Bothriochloa insculpta						R+1	+ 1							
Species group I														
Brachiaria brizantha						R+1		1						
Digitaria ternata						A1				1				
Hyperthelia dissoluta						1A			1					
Species group J														
Spermacoce natalensis								11 +++1+				+	+	
Berkheya setifera	+							+11+ 11	1				+1+1	
Pentanisia angustifolia		+			1			++ 1+ +	+ +					
Dichrostachys cinerea						+		RR						
Species group K														
Chamaechrista stricta							+++	++ + +++	+11 1	+ + +			+	
Conyza obscura							++1	+ R 1+	++R	+ ++ ++			1+ ++	
Indigofera velutina				1			++	+ 1+ R+	1 +	+ + 1		1	+ +	
Species group L														
Aristida congesta ssp. congesta	1				+					+ 11111A1 11 1		1 1		
Kohautia virgata										1111++ 11++		+		
Perotis patens										1 11 A1 +B1				
Stoebe vulgaris										++ R				
Species group M														
Pogonarthria squarrosa									1 + +	+ 1 1A1+1+B1				+
Trichoneura grandiglumis	+		1	1			+ 1	+	+ + 1	111 111+1 1	1	1		+
Species group N														
Centella asiatica	1 +	1 1			1			+1		1	1	++ 1 1 1	1	+
Commelina africana	11	+ 1			1			+ +			+1	+ 1 +1	1	+
Hypochoeris radicata	+	+ 1		+	1			1 +		11		+ 1 1 11	+ +	R1
Species group O														
Melinis repens				1		+11	+++	11 + +	11 1	11AA111AA11+A1	1A			1+ 1
Species group P														
Aristida congesta ssp. barbicollis	+11+	1	11+11	11 B		+	1+1	+	11 1	11 11 11 11	1 1	1 11	1	+
Eragrostis gummiflua	1	1 +	+				+	1+ ++	1 +++	3A1113113 11+ +	+1	111		+
Cynodon dactylon	A A		1	1 1		+A	+	1 AA 1	1 1	111 11A + + 1	1A1	11 11 1	1	A
Zornia capensis			1 1	1+ +	1 1	+ 1	+ 1	1 + +	1	+111 1+ 1 +	+ +	+	1 +	
Hermannia transvaalensis	++	+ 1++	+	+ 1	+		+	++ ++	++	R + + 1	+	+1		
Walafrida densiflora	+ 1	+ + +	++ +	+ + 1				1	1 +	++ 11 1	++	1	+	
Abildgaardia ovata		++ 11	1 1		1 11	1	+	1 1	+ 1	1 1 1	1	+ 1		1
Hermannia depressa		1 1	111111	111 1	+	1	++1		+	+		1111	1	
Polygala hottentotta	++ +	+ + +	++	+	++ +	+	+RR		+	+		R 1+		
Gomphrena celosioides	1 +	+					R +	+++		+1 1+ + +	++	++ +		
Haplocarpha scaposa	1 +	1 1		1+	1 11			+1+ ++		+ +		1 +	+ +	1
Scabiosa columbaria		+ 1	+ 1	1 +1	+ +1			+ + +		+	+	+ +	+	
Chaetacanthus burchellii	+ ++	1 ++	1 1+		+ +			1	+ +	+		1 +	1	
Cucumis zeyheri	+	++ +	+				+	++ +	+	+ + +	1	1		+
Species group Q														
Heteropogon contortus	1+1	+ +A 1B	AAB1B3	1A1 1	1 113	++1	A+1	+1A 1	3 B 1	A 1 AA1A3 11	B A	1 1 B 13 1	B1A1 B 1	1
Helichrysum rugulosum	111	1 11+ 11	11 + 1	1 1 1	1 +1	+	+ 1	++ + 11	11 +	11++11 +1111	11	111+11 1	+1111 1+11	+ +
Themeda triandra	13 +	344+3A33A	3BB AB	+ A3	B+531	+	+ A	1B ++	+ 1			1 1 A113 1	411 1	1
Eragrostis racemosa	+1	+1+11 + 1	+ 1111	1 1	1 +1	+	1 1	+ +1 + +	+	1 111111 1	1 +	1 + 1	1 11 +A	
Eragrostis capensis	11	11+11 111	1111	1 1+1	11+11		+ 1	1+ 11 1	+ +	+ A1 1	1	1+1+ +1111	+1 1 11	
Cymbopogon excavatus	1 +	+ 1	BA111	1A111	1111	1B	11B	AA1 111BA	1A+	1 B 1		1 1 A	+ +1	
Berkheya onopordifolia	++1+	++1++++ +	1+++1+	+++ +	+ +1+			+++	+	++ +++	R	R +1+ +	+ 1 +	+
Anthospermum rigidum	1	+ 11	1 +11	++	1+ 11			1	1	1 +	1	+ 1 1 1	+1+ ++1	+
Microchloa caffra	11	1		1 1	1A		1 1	A1		1 11 1	1	A 1 11 1	1 11 A	
Aristida junciformis		+ A	1 +	1	+				+	+++1 ++	+	+ 131A	+ A+44	RA
Species group R														
Eragrostis curvula	1A3B	1AA3BAABB	ABAA3A	3B1BB	1A 3	+1A	11A	11BBB1B11	1113A	A3AA33B+3A1 3	33A	44A11B3313B	1 ABA B+A3	5B+5414+3
Hyparrhenia hirta	4331	31 3+4AAB	34 433	44533	45AA	A+A	433	34333+445	334 5	A4A4434B334433	334	11433A3 B B	5B544 +541	B+ 1+R3
Eragrostis plana	A1B4	+A11AA41		1 11	11 3A	+	+	1+A11 +	+ A	A1A + 1	1+	31 +3AA315B	111 B+ 3	45A43 5A
Sporobolus africanus		1	+	1 1	1 A	+1	1 1	AA111A1++	1+11	+ A111B	+	1 + +1	11 1 1	A1B ABB

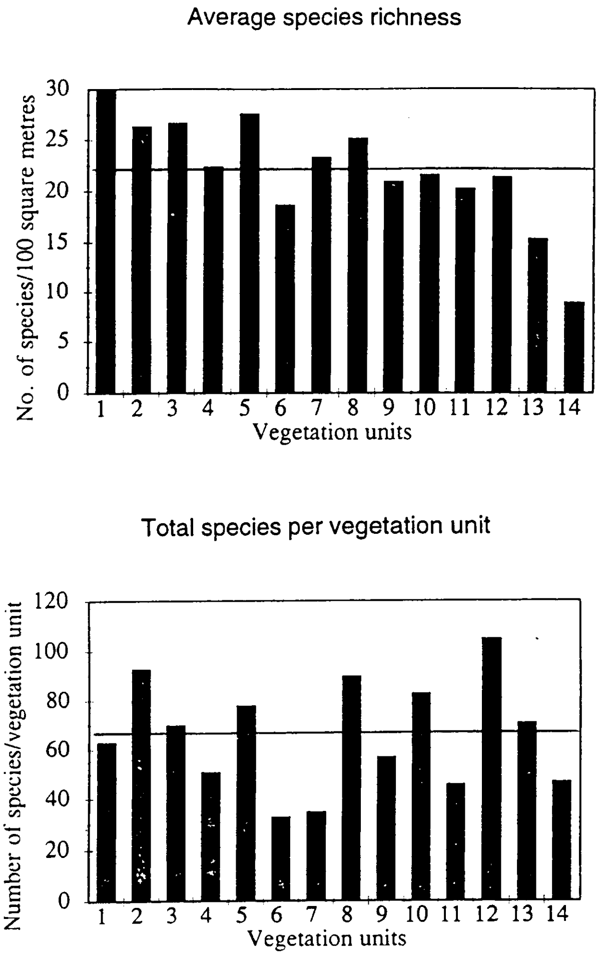

Figure 5 The average species richness and total number of species for each vegetation unit. Horizontal lines indicate the averages for the *Helichrysum rugulosum–Hyparrhenia hirta* major vegetation type.

This short to tall closed grassland is mainly found on midslopes (< 3°) in the undulating plains landscape at altitudes below 1 400 m (Figure 4). This grassland can also, to a lesser degree though, be found on crests and footslopes and sometimes at altitudes of up to 1 800 m. The major physiographical regions to which this grassland is restricted are the Buffalo Plain, Dundee Plain, Ingagane Plain, Newcastle–Utrecht Plain and the Utrecht–Vryheid Plain (Turner 1967) (Figure 2). Soils are relatively rich in clay (> 35%) and deeper than 500 mm. Isolated occurrences of surface rocks may be observed, hardly covering 5% of the surface. The diagnostic species are included in species group A (Table 1). *Aristida bipartita* is associated with clayey, often vertic, soils (van Oudtshoorn 1991). The most dominant species are *Themeda triandra*, *Eragrostis curvula* and *Hyparrhenia hirta* (Table 1).

Five sub-associations are recognized under this association:

1.1 *Aristido bipartitae–Themedetum triandrae phyllanthetosum burchellii* sub-ass. nov.

Nomenclatural type: relevé 77 (holotypus).

This grassland occurs on midslopes and footslopes at altitudes below 1 200m (Figure 4). Clay content of the soils varies from 10% to more than 35% and the depth from 300 to more than 500 mm. No surface rocks were recorded.

This sub-association contains no diagnostic species, but is distinguished by the presence of species groups A, B and E and the absence of species groups C, D and F (Table 1). Most prominent species include the grasses *Hyparrhenia hirta, Eragrostis curvula* and *E. plana* (Table 1). This is the typical sub-association of the *Aristido bipartitae–Themedetum triandrae* association.

This community has the highest average species richness (30) recorded for a community in this major vegetation type, and a total number of 63 species (Figure 5). In contrast to this community, the *Aristida bipartita–Themeda triandra* Grassland occurring apparently under similar environmental conditions and

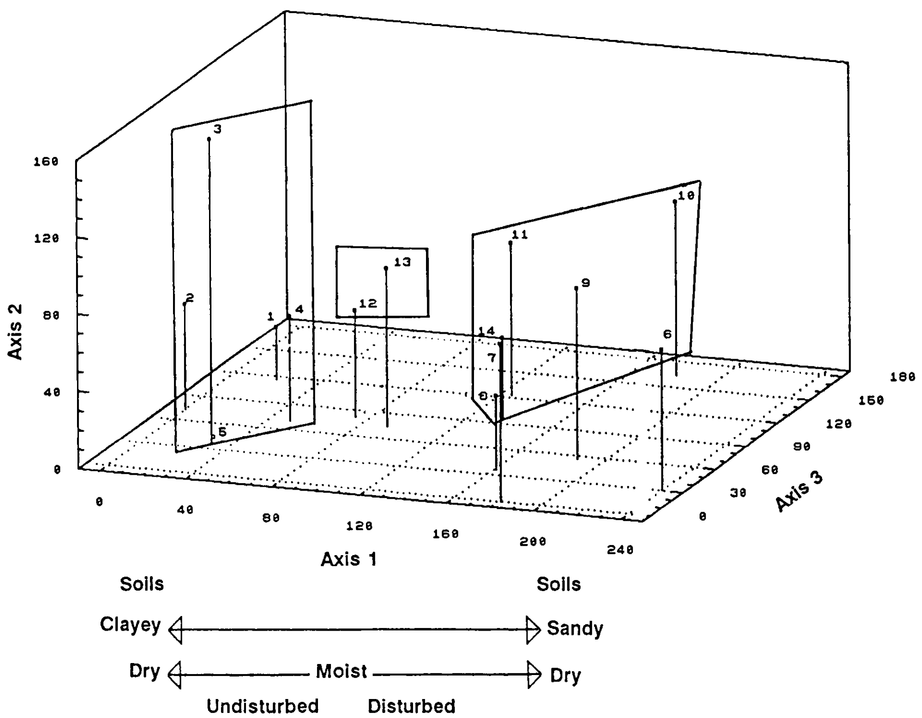

Figure 6 The distribution of the synrelevés (14 plant communities) along the first, second and third axes of a DECORANA ordination (Eigen values: axis 1 = 0.39, axis 2 = 0.167, axis 3 = 0.081).

described by Fuls *et al.* (1993a), has only an average of 23 species per sample plot.

1.2 *Aristido bipartitae–Themedetum triandrae brachiarietosum serratae* sub-ass. nov.

Nomenclatural type: relevé 20 (holotypus).

This grassland occurs on crests, midslopes and footslopes at altitudes below 1 200 m (Figure 4). In general, the soils are clayey (> 35%) and deep (> 500 mm), with surface rocks sometimes present, then covering up to 5% of the area.

Although no diagnostic species were identified, this grassland community is distinguished by the simultaneous presence of species groups A, B, D, E and F (Table 1). Well-preserved areas within this grassland are recognized by the presence of the grass *Brachiaria serrata* (species group D, Table 1). Other prominent species are *Themeda triandra, Hyparrhenia hirta, Eragrostis curvula* and *E. plana* (Table 1). The strong presence of *Themeda triandra* is a clear indication of the relatively good condition of this community (Gibbs Russell *et al.* 1991; van Oudtshoorn 1991).

The average number of species recorded per sample plot is 26, with the total number of species for this community being 93, which is well above the average for the major vegetation type (Figure 5).

1.3 *Aristido bipartitae–Themedetum triandrae felicietosum muricatae* sub-ass. nov.

Nomenclatural type: relevé 170 (holotypus).

This sub-association is mainly associated with midslopes at altitudes below 1 300 m, although isolated patches are also found at an altitude of up to 1 800 m (Figure 4). Clay content of the soils varies from 15% to more than 35% and depth from 200 to more than 500 mm. Surface rocks are present, but usually cover less than 2% of the area.

The only diagnostic species is the small shrub *Felicia muricata* (species group C, Table 1), an indicator of overgrazing (van Wyk *et al.* 1988). Species groups A, D and E (Table 1) are also present. Physiognomically, the most conspicuous and dominant species are *Heteropogon contortus, Themeda triandra, Eragrostis curvula* and *Hyparrhenia hirta*, with the absence of *Eragrostis plana* suggesting relatively dry conditions (Gibbs Russell *et al.* 1991; van Oudtshoorn 1991) (Table 1).

This community has an average species richness of 27 and a total number of 70 species (Figure 5).

1.4 *Aristido bipartitae–Themedetum triandrae monsonietosum angustifoliae* sub-ass. nov.

Nomenclatural type: relevé 206 (holotypus).

This community is found at altitudes below 1 300 m and occurs primarily on midslopes (Figure 4). The soils are clayey (> 35%), the depth of which usually exceeds 500 mm. Surface rocks are generally absent.

No diagnostic species were recorded, although this community can be distinguished from the previously described sub-associations by the absence of species groups B, C and D, and the presence of species groups E and F (Table 1). Prominent species are *Eragrostis curvula* and *Hyparrhenia hirta* (Table 1).

The average number of species recorded per sample plot is 22, with the total number of species being 51 (Figure 5).

1.5 *Aristido bipartitae–Themedetum triandrae elionuretosum muticus* sub-ass. nov.

Nomenclatural type: relevé 50 (holotypus).

This grassland occurs mainly on midslopes at altitudes below 1 300m (Figure 4). The clay content of the soils exceeds 35% and the depth usually exceeds 500 mm. Surface rocks are mostly absent.

Diagnostic species are absent from this sub-association, which is distinguished by the absence of species groups B to E, and the presence of species groups A and F (Table 1). Physiognomically conspicuous and dominant species are *Themeda triandra* and *Hyparrhenia hirta* (Table 1).

This grassland community has the second highest average species richness (28) of all communities within this major vegetation type, with the total number of species being 78 (Figure 5).

2. *Sporoboletum pyramidalo–africani* ass. nov.

Nomenclatural type: relevé 303 (holotypus).

This short to tall grassland of midslopes (< 3°) is primarily restricted to altitudes varying from 800 to 1 200 m (Figure 4). The major physiographical regions with which this grassland is associated are the Hlobane–Manyini–C'eza Block and the Nondweni–White Umfolozi Basin (Turner 1967) (Figure 2). Soils are relatively sandy, varying in clay contents from less than 15% to 25%, and the depths varying from 200 to more than 500 mm. Surface rocks are virtually absent throughout this grassland.

The only diagnostic species is the tough unpalatable grass *Sporobolus pyramidalis* (species group G, Table 1) which is an indicator of overgrazed and trampled veld (Gibbs Russell *et al.* 1991; van Oudtshoorn 1991). Other prominent species include *Cymbopogon excavatus, Eragrostis curvula* and *Hyparrhenia hirta* (Table 1). Noteworthy are the low cover-abundance values and only the occasional occurrence of *Themeda triandra*, emphasizing the relatively poor condition of this grassland association.

2.1 *Sporoboletum pyramidalo–africani eragrostietosum superbae* sub-ass. nov.

Nomenclatural type: relevé 381 (holotypus).

This grassland is found on midslopes, with soils being relatively sandy (< 15–25% clay) and the depth varying from 200 to 500 mm (Figure 4). Isolated occurrences of surface rocks may be encountered, covering less than 2% of the area.

The diagnostic species are the grasses *Eragrostis superba* and *Bothriochloa insculpta* (species group H, Table 1), both species being indicative of disturbed veld (Gibbs Russell *et al.* 1991; van Oudtshoorn 1991). The most dominant species are *Sporobolus pyramidalis* and *Hyparrhenia hirta* (Table 1).

2.1.1 *Brachiaria brizantha* Variant

This variant occurs on midslopes at an altitude of 800 m (Figure 4). Clay content of the soils varies from 15% to 25% and the depth from 200 to 400 mm. Widely scattered surface rocks may occur, usually covering less than 2% of the area. Since the basal grass cover is relatively low, signs of erosion could be clearly detected.

This grassland is characterized by the diagnostic grass species listed under group I (Table 1), however, the dominant species are *Sporobolus pyramidalis* and *Hyparrhenia hirta* (Table 1).

The average number of species recorded per sample plot is 19, with the total number being 33, which is the lowest to be recorded within this major vegetation type (Figure 5).

2.1.2 *Conyza obscura* Variant

This variant is found on midslopes at altitudes ranging from 900 to 1 000 m (Figure 4). Soil depth varies from less than 200 to 500 mm and the clay content is less than 15%. Surface rocks are scarce and widely scattered, covering less than 2% of the area.

Although this grassland is not characterized by diagnostic species, it can be distinguished from the *Brachiaria brizantha* Variant by the absence of species group I and the presence of species group K (Table 1). Physiognomically, the most conspicuous and dominant species are usually *Sporobolus pyramidalis* and *Hyparrhenia hirta* (Table 1).

The species richness (23) is slightly higher than the average species richness for the major vegetation type, however the total number of species is only 35 (Figure 5).

2.2 *Sporoboletum pyramidalo–africani berkheyetosum setiferae* sub-ass. nov.

Nomenclatural type: relevé 303 (holotypus).

This grassland occurs primarily on midslopes at altitudes below 1 000 m (Figure 4). Clay content of the soils varies from 15% to 25% and the depth from 250 to more than 500 mm. Surface rocks are mostly absent from this grassland.

The diagnostic species which characterize this community include the forbs listed under species group J and the sparsely scattered shrub *Dichrostachys cinerea* (Table 1). The most prominent species are *Sporobolus pyramidalis, Eragrostis curvula* and *Hyparrhenia hirta*, with *Cymbopogon excavatus* and *Sporobolus africanus* being less prominent (Table 1). This is the typical sub-association of the association.

A relatively high average species richness of 25 was recorded, with the total number (90) also very high (Figure 5).

2.3 *Sporoboletum pyramidalo–africani pogonarthrietosum squarrosae* sub-ass. nov.

Nomenclatural type: relevé 388 (holotypus).

This grassland is found on midslopes at altitudes below 1 150 m (Figure 4). The clay content of the soils varies largely from 15% to 35% and the depth from 300 to more than 500 mm. Surface rocks are absent throughout this grassland.

No diagnostic species were identified for this community, however, the latter can be distinguished by the absence of species groups H, I and J, and the presence of species group K and the differential species *Pogonarthria squarrosa* and *Trichoneura grandiglumis* (species group M, Table 1). Conspicuous and often dominant species include *Sporobolus pyramidalis, Heteropogon contortus, Eragrostis curvula* and *Hyparrhenia hirta* (Table 1).

The average number of species recorded per sample plot is 21 and the total number 57 (Figure 5).

3. *Aristido congestae–Eragrostietum gummifluae* ass. nov.

Nomenclatural type: relevé 199 (holotypus).

This short to tall grassland is encountered on midslopes at altitudes below 1 300 m (Figure 4). This grassland is primarily associated with the Bergville–Ladysmith–Elandslaagte Plain, Buffalo Plain, Dundee Plain, Newcastle–Utrecht Plain and the Utrecht–Vryheid Plain (Turner 1967) (Figure 2). The soils display a predominantly sandy texture, containing less than 15% clay and are usually deeper than 500 mm. No surface rocks were found throughout this grassland.

The diagnostic species are included in species group L (Table 1). These grasses and the dwarf shrub *Stoebe vulgaris* are typical indicators of disturbed veld (van Wyk *et al.* 1988; Gibbs Russell *et al.* 1991; van Oudtshoorn 1991). *Perotis patens* and the conspicuous *Eragrostis gummiflua* (species group P, Table 1) are also indicative for leached sandy soils. Other prominent species include *Melinis repens, Heteropogon contortus, Eragrostis curvula* and *Hyparrhenia hirta,* with *Themeda triandra* being completely absent (Table 1).

An average species richness of 22 was recorded, whereas the total number of species is 83 (Figure 5).

4. *Centello asiaticae–Eragrostietum planae* ass. nov.

Nomenclatural type: relevé 38 (holotypus).

This short to tall grassland is restricted to moist conditions which occur on midslopes and footslopes at altitudes ranging from 1 200 to 1 800 m (Figure 4). The primary physiographical regions with which this grassland is associated are the Belelasberg–Skurweberg Plateau, Buffalo Plain, Dundee Plain, Newcastle–Utrecht Plain and the Utrecht–Vryheid Plain (Turner 1967) (Figure 2). Soil depth generally exceeds 500 mm, with the clay content varying from 15% to more than 35%. No surface rocks are present.

This association is characterized by the diagnostic but inconspicuous forbs listed under species group N (Table 1). The presence of these species as well as the prominence of *Eragrostis plana* clearly indicate moist soil conditions. The most dominant species are *Eragrostis curvula, E. plana* and *Hyparrhenia hirta* (Table 1).

4.1 *Centello asiaticae–Eragrostietum planae melinietosum repens* sub-ass. nov.

Nomenclatural type: relevé 25 (holotypus).

This grassland occurs on moist midslopes at an altitude of 1 350 m (Figure 4). Soils are deep (> 500 mm) and display a clay content of 15% to 25%. Surface rocks are absent from this community.

The only differential species which distinguishes this grassland is the grass *Melinis repens* (species group O, Table 1), which is indicative of disturbed veld (van Oudtshoorn 1991). The most prominent species include *Heteropogon contortus, Eragrostis curvula* and *Hyparrhenia hirta*, with *Themeda triandra* being absent from this community (Table 1).

The average number of species recorded per sample plot is 20 and the total number is 46 (Figure 5).

4.2 *Centello asiaticae–Eragrostietum planae themedetosum triandrae* sub-ass. nov.

Nomenclatural type: relevé 38 (holotypus).

This grassland is primarily found on moist midslopes and footslopes at altitudes varying from 1 200 to 1 800 m (Figure 4). Although the clay content of the soils varies considerably, in most cases a percentage of more than 35% was recorded. Soil depth usually exceeds 500 mm, with surface rocks being absent from this grassland.

Although no diagnostic species were recorded, this community is nevertheless distinguished from the *Centello asiaticae–Eragrostietum planae melinietosum repens* by the absence of species group O (Table 1). Despite the presence of *Themeda triandra*, this grassland is in a relatively poor condition, with areas subjected to heavy selective grazing and dominated by *Aristida junciformis* (Table 1). The most prominent species are *Eragrostis curvula, E. plana* and *Hyparrhenia hirta* (Table 1). This is the typical sub-association of the association.

Despite a low average species richness of 22, a high total number (105) of species was recorded for this community (Figure 5). This number exceeds the total number of all other communities of this major vegetation type by far.

5. *Heteropogon contortus–Aristida junciformis* Grassland

This short to tall grassland occurs mainly on midslopes at altitudes exceeding 1 500 m (Figure 4). It is generally restricted to the Belelasberg–Skurweberg Plateau and the Helpmekaar Plateau (Turner 1967) (Figure 2). The clay content of the soils varies considerably from 15% to more than 35%, whereas soil depth varies from less than 200 to more than 500 mm. Surface rocks are occasionally found, then covering up to 20% of the area.

No diagnostic species were identified, with the community being distinguished by the presence of species groups Q and R

(Table 1). Most prominent species include *Eragrostis curvula* and *Hyparrhenia hirta*, with *Heteropogon contortus* and *Aristida junciformis* being sometimes dominant where selective overgrazing has been prevalent or where soils are shallow and rocky (Table 1).

This community has an extremely low average species richness of 15, with the total number of species being 71 (Figure 5).

6. *Eragrostis plana–Sporobolus africanus* Grassland

This short to tall grassland is not strictly associated with certain environmental conditions, occurring throughout the study area mainly on midslopes at altitudes ranging from 1 000 to 1 800 m (Figure 4). It is also not restricted to any specific physiographical region (Turner 1967) (Figure 2). Clay percentages vary from 15% to more than 35% and soil depth exceeds 500 mm. No surface rocks were encountered.

This community is not characterized by diagnostic species and consists primarily of the prominent species *Eragrostis curvula, E. plana, Hyparrhenia hirta* and *Sporobolus africanus* (Table 1). It is distinguished from the *Heteropogon contortus–Aristida junciformis* Grassland by the absence of species group Q (Table 1). The high cover-abundance values of the strong competitors *Eragrostis plana* and *Sporobolus africanus* are clear indicators of disturbed and overgrazed veld in high-rainfall regions (Tainton 1981; van Oudtshoorn 1991). Under continuous heavy grazing pressure, these species will gradually replace more palatable species, resulting in the decline of the grazing capacity of this grassland.

The species poorness of this community is clearly reflected by the average species richness (9) and total number (47) of species (Figure 5).

Ordination

A three-dimensional scatter diagram is presented in Figure 6, displaying the distribution of synrelevés along the first, second and third axes of a DECORANA ordination. Although they have no clear distinct discontinuous groups, the three vaguely defined groups could be explained in terms of certain environmental factors along the first axis, rather representing environmental gradients. The distribution of the synrelevés correlates with the two soil characteristics, texture and moisture, but also represents a degradation gradient. Synrelevés occurring to the left of the diagram are associated with clayey, dry soils, representing relatively undisturbed communities, whereas those occurring to the right of the diagram are associated with sandy, dry soils and represent disturbed communities. The intermediate group represents a transition from clayey to sandy moist soils, also showing signs of degradation. The second and third axis could not be used to interpret the distribution pattern of the synrelevés.

Conclusions

The floristic data has been divided into 14 plant communities by the TWINSPAN classification technique and its subsequent refinements. The ordination algorithm DECORANA produced a scatter diagram, presenting three definable groups of synrelevés. It appears from the ordination diagram that vegetation units 1 to 5, represented by the *Aristido bipartitae–Themedetum triandrae*, are less severely degraded than the other vegetation units, with the species composition displaying a relatively high degree of naturalness (see also Götmark 1992; Rapoport *et al.* 1986) and richness. Since these five vegetation units partly represent the Natal Sour Sandveld (Acocks 1988), which is mainly restricted to the study area and of which large areas are under crop production, special attention must be given to this veld type as a whole concerning the conservation of it. Although the size is not known of undisturbed areas of Natal Sour Sandveld occurring outside the study area, this will be estimated once the syntaxonomy of the KwaZulu-Natal grasslands has being completed. The *Aristido bipartitae–Themedetum triandrae phyllanthetosum burchellii* is the community with the highest species richness (30) within this major vegetation type. Although this figure is not particularly high, it exceeds the species richness of many hitherto described grassland communities occurring in other parts of the grassland biome (Kooij *et al.* 1990; Fuls *et al.* 1993a, b; Matthews *et al.* 1994). However, species richness should not be used on its own as a criterion when determining conservation priorities, because it gives no indication of the number of endemic or rare species (Pomeroy 1993). Instead, the prioritization of conservation sites could be improved by taking account of several different factors. No rare species were identified in any of the described communities (Hall *et al.* 1980). Another specific area which also needs to be seriously considered for conservation is the Blood River vlei, situated between the Skurweberge and Bloedrivier station. This vlei belongs to the *Aristido bipartitae–Themedetum triandrae brachiarietosum serratae* and is dominated by dense stands of *Hyparrhenia hirta*. Although this vlei is currently heavily utilized, it should be seriously considered for preservation because of the important ecological role which it fulfils, serving amongst others as a sponge area for the Blood River. The identified and des-cribed communities could assist farmers in the compilation of management plans and in their decision of which areas are to be preserved (see also Wahl 1995).

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CHAPTER 4.7

Plant communities and species richness of the *Agrostis lachnantha-Eragrostis plana* Wetlands of northern KwaZulu-Natal

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Plant communities and species richness of the *Agrostis lachnantha–Eragrostis plana* Wetlands of northern KwaZulu-Natal

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The wetlands described in this article include rivers, streams, vlei areas and pans occurring within the grasslands of northern KwaZulu-Natal. The vegetation of many of the wetlands, in particular high-lying vlei areas, is in danger of being irreversibly changed due to desiccation of the areas caused by the encroachment of exotic plantations into the high-lying grasslands. The objective of this study was to classify and describe the *Agrostis lachnantha-Eragrostis plana* major vegetation type associated with the wetlands. The TWINSPAN classification and subsequent refinement by Braun–Blanquet procedures resulted in the identification of 16 plant communities (also referred to as vegetation units), which were then related to environmental factors using the ordination algorithm DECORANA. Five distinct groups were distinguished, the distribution of which was primarily explained by axis 1. Species richness was calculated for each plant community from the phytosociological data. In addition to this parameter, species rarity and naturalness of communities were also considered in an attempt to estimate the conservation value of specific sites. Although being relatively species poor, the vlei areas and pans are of particular conservation importance due to the restricted occurrence of certain species and the high degree of naturalness. However, no rare species were encountered.

Keywords: Community, conservation, grassland, KwaZulu-Natal, species richness, wetlands.

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Introduction

Wetlands are globally one of the most endangered habitat types (Maltby 1986) with vast areas been modified to alternate land uses (Walmaley 1988). Although wetlands occupied 10–15% of most catchments in Natal, many of these have been virtually eliminated within the last 50 years (Begg 1986), with over half of the wetlands of South Africa been destroyed and lost (Breen & Begg 1989). The disruption in structure and function of wetlands is ascribed to different kinds of practices, among them overgrazing by livestock (Walmsley & Botten 1987). We have presumed therefore that the plant species composition of wetlands has been changed to a great extent since the introduction of cattle and small livestock to this country. The high grazing capacity of wetlands and the availability of palatable grass species during the predominantly drier winter months usually resulted in wetlands being overutilized. In addition to this, the forestry industry has further increased the pressure on wetlands by reducing the water runoff by 200 to 300 mm per annum (Department of Water Affairs and Forestry 1995), mainly by intercepting large amounts of water. Stands of mature pines and eucalypts use about the equivalent of 300 to 600 mm of rainfall per year more than the natural vegetation they replace. This marked reduction in runoff to the wetlands has a profound effect on the water level, negatively affecting the vegetation (Wicht 1971). The effect of afforestation on streamflow is well documented by Nänni (1970a, b), who stated that the decrease in runoff locally may be large. The largest and most important rivers draining the study area are the Bivane, Blood, Buffalo, Pongolo, White and Black Mfolozi, and are all adversely affected to varying degrees by afforestation. This emphasizes the sensitivity of the wetland vegetation and the importance of identifying and describing the plant communities found within these wetlands (see also Walmsley 1988). Areas with conservation value, measured in terms of criteria such as species rarity (Rapoport *et al.* 1986), species richness and naturalness (Götmark 1992), must therefore be identified so they can be granted special attention before being irreparably damaged. In this study, no quantitative assessment is given of the term 'naturalness' and consequently it involves highly intuitive judgements (Ray 1984).

The aim of the study was to identify, classify and describe the plant communities associated with the wetlands of northern KwaZulu-Natal. The results emanating from this study will reveal detailed information on vegetation patterns and species composition. The *Agrostis lachnantha–Eragrostis plana* Wetlands were identified as a major vegetation type during the phytosociological study of the vegetation of northern KwaZulu-Natal (Eckhardt *et al.* 1996a, b, c, d, e). These wetlands represent rivers, streams, vleis and pans throughout the study area, ranging in altitude from 750 to 2 000 m. The floristic data contained within this article, together with the data and phytosociological analysis of the northern KwaZulu-Natal grasslands (Eckhardt *et al.* 1996a, b, c, d, e), will subsequently be incorporated into a comprehensive floristic data set dealing with the syntaxonomy and synecology of the entire Grassland Biome of South Africa (Turner 1989; Kooij 1990; Du Preez 1991; Matthews 1991; Fuls 1993; Myburgh 1993; Bredenkamp & Bezuidenhout 1995). A few other publications dealing with wetlands within the grassland biome are Kooij *et al.* (1991), Fuls *et al.* (1992), Bloem *et al.* (1993) and Eckhardt *et al.* (1993).

Study area

The study area is situated in central-northern KwaZulu-Natal (Land Type Survey Staff 1986, 1988) (Figure 1) and consists of irregular undulating lowlands in the central and south-western parts, undulating mountains and lowlands in the north-western and eastern parts, and low mountains in the south-eastern part (Kruger 1983). It includes the area situated between 27°16′ and 28°31′S latitude and 30°00′ and 31°38′E longitude, comprising a surface area of 14 366 km^2. Several physiographic regions are encountered, giving rise to the high variation in altitude, which ranges from 750 to 2 290 m above sea-level. This strongly affects the rainfall, which varies from 700 mm in the low-lying basins to 1 200 mm in the mountains, the annual average being 850 mm (Schulze 1982). The *Agrostis lachnantha–Eragrostis plana* Wetlands are widespread throughout the area, being restricted to terrain unit 5, which represents rivers, streams, floodplains, vleis and pans (Land Type Survey Staff 1986).

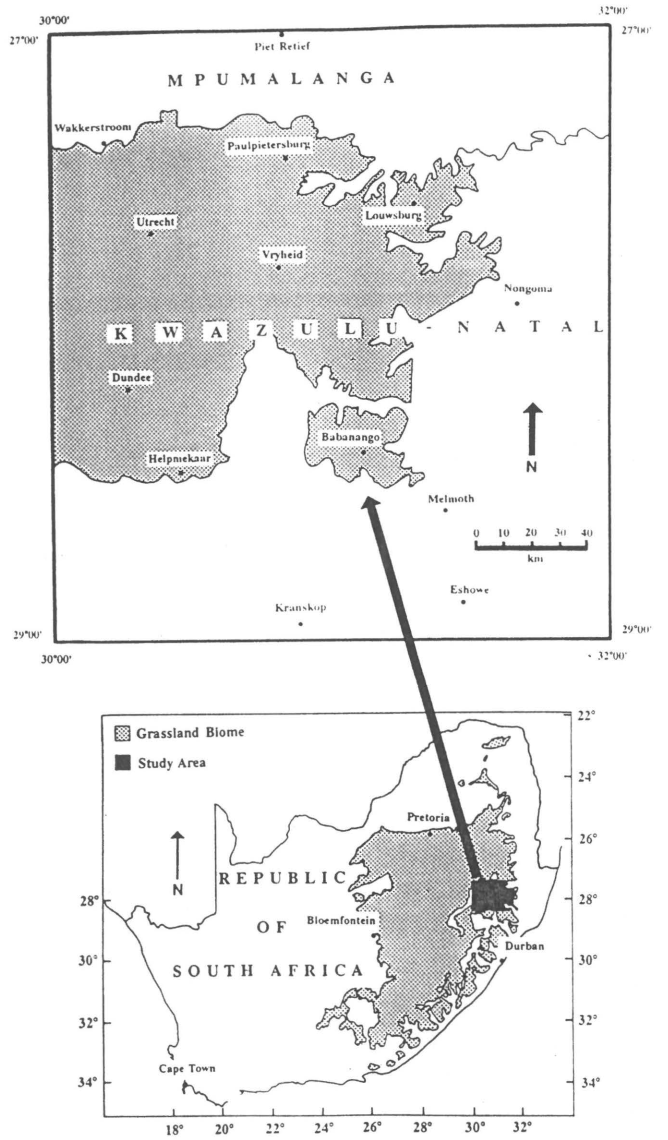


Figure 1 The study area within the Grassland Biome of South Africa.

Methods

The wetland vegetation was surveyed by compiling relevés in 93 sample plots. These plots were stratified on terrain unit 5 to sample the vegetation along water courses, vleis and pans. Plot sizes were fixed at 100 m^2 (Scheepers 1975). Species recorded within the sample plots were given a value according to the Braun–Blanquet cover-abundance scale (Mueller-Dombois & Ellenberg 1974) and taxon names conform to those of Arnold & de Wet (1993). Environmental data recorded for each relevé included terrain unit, slope, soil type and depth, soil texture, rockiness of soil surface and erosion. Where soil types are not mentioned in the description of the communities, the relevant communities are found on several kinds of soils.

To derive a first approximation of the floristic variation within the data set, two-way indicator species analysis (TWINSPAN) (Hill 1979b) was applied. The classification resulting from the TWINSPAN was further refined by Braun–Blanquet procedures (Westhoff & van der Maarel 1978; Behr & Bredenkamp 1988; Bredenkamp & Bezuidenhout 1995) to distinguish between the different plant communities, which were subsequently represented in a phytosociological table.

The relationships between the vegetation and the physical environment are illustrated by using the ordination algorithm DECORANA (Hill 1979a). The synoptic data obtained from the synoptic table, representing the constancy values of species occurring within the different vegetation units, were used for the ordination (see also Eckhardt *et al.* 1996b).

The floristic data within each vegetation unit were further analyzed to calculate α diversity (see also Eckhardt *et al.* 1996a for a more detailed discussion).

The nomenclatural type assigned to each syntaxon name represents the typical species composition of the relevant syntaxon, with special emphasis on the diagnostic species. The code of phytosociological nomenclature follows that of Barkman *et al.* (1986).

Results and Discussion

The *Agrostis lachnantha–Eragrostis plana* Wetlands are generally associated with rivers, streams, floodplains, vleis and pans (Figure 2). The substrate associated with streambeds usually consists of rocks covered with alluvium, whereas river- and stream-banks are primarily made up of alluvial sediments. The soils found in vleis and pans are mostly of a humic, anaerobic, clayey, waterlogged nature, reaching depths exceeding 500 mm. The slopes vary from 0° to 3°.

Physiognomically, the most prominent and common species, which occur virtually throughout these wetlands, are the grasses *Eragrostis plana* (species group P, Table 1), *Paspalum dilatatum* and *Leersia hexandra* (species group V, Table 1), all species representative of wet areas (Gibbs Russell *et al.* 1991; van Oudtshoorn 1991). The species most common throughout the grasslands of northern KwaZulu-Natal, namely *Hyparrhenia hirta, Eragrostis curvula* and *Sporobolus africanus* (species group P, Table 1), are noticeably less abundant in the wetlands compared with the rest of the grasslands (Eckhardt *et al.* 1996b, c, d, e).

It is expected that the *Eragrostis plana–Agrostis lachnantha* major plant community of the north-eastern Free State, identified and described by Eckhardt *et al.* (1993). would show close correspondence with this major vegetation type. A synthesis of the entire grassland biome syntaxonomy will reveal that these vegetation types are quite similar.

The particularly low number of species recorded for the wetlands is clearly reflected by the low average species richness of only 17 species per 100 m^2 and low average total number of only 49 species recorded per community for this major vegetation type (Figure 3) (see also Noble & Hemens 1978). Similar low values are also reported from other wetlands within the grassland biome (Kooij *et al.* 1991; Fuls *et al.* 1992; Eckhardt *et al.* 1993).

Classification

The analysis of the floristic data resulted in the identification of 16 plant communities (vegetation units) (Table 1) which are subsequently hierarchically classified (Barkman *et al.* 1986):

1. *Gunnero perpensae–Eragrostion planae*
   - 1.1 *Limosello grandiflorae–Leucosideetum sericeae* (vegetation unit 1)
   - 1.2 *Arundinello nepalensis–Eragrostietum planae* (vegetation unit 2)
2. *Pycnostachys reticulata–arundinella nepalensis* Wetland (vegetation unit 3)
3. *Mariscus congestus–Setaria pallide-fusca* Wetland (vegetation unit 4)
4. *Hemarthrio altissimae–Miscanthion juncei*
   - 4.1 *Imperato cylindricae–Fimbristylidetum ferrugineae*
     - 4.1.1 *Imperato cylindricae–Fimbristylidetum ferrugineae senecionetosum achilleifolii* (vegetation unit 5)
     - 4.1.2 *Imperato cylindricae–Fimbristylidetum ferrugineae paspaletosum dilatati* (vegetation unit 6)
     - 4.1.3 *Imperato cylindricae–Fimbristylidetum ferrugineae eragrostietosum curvulae* (vegetation unit 7)

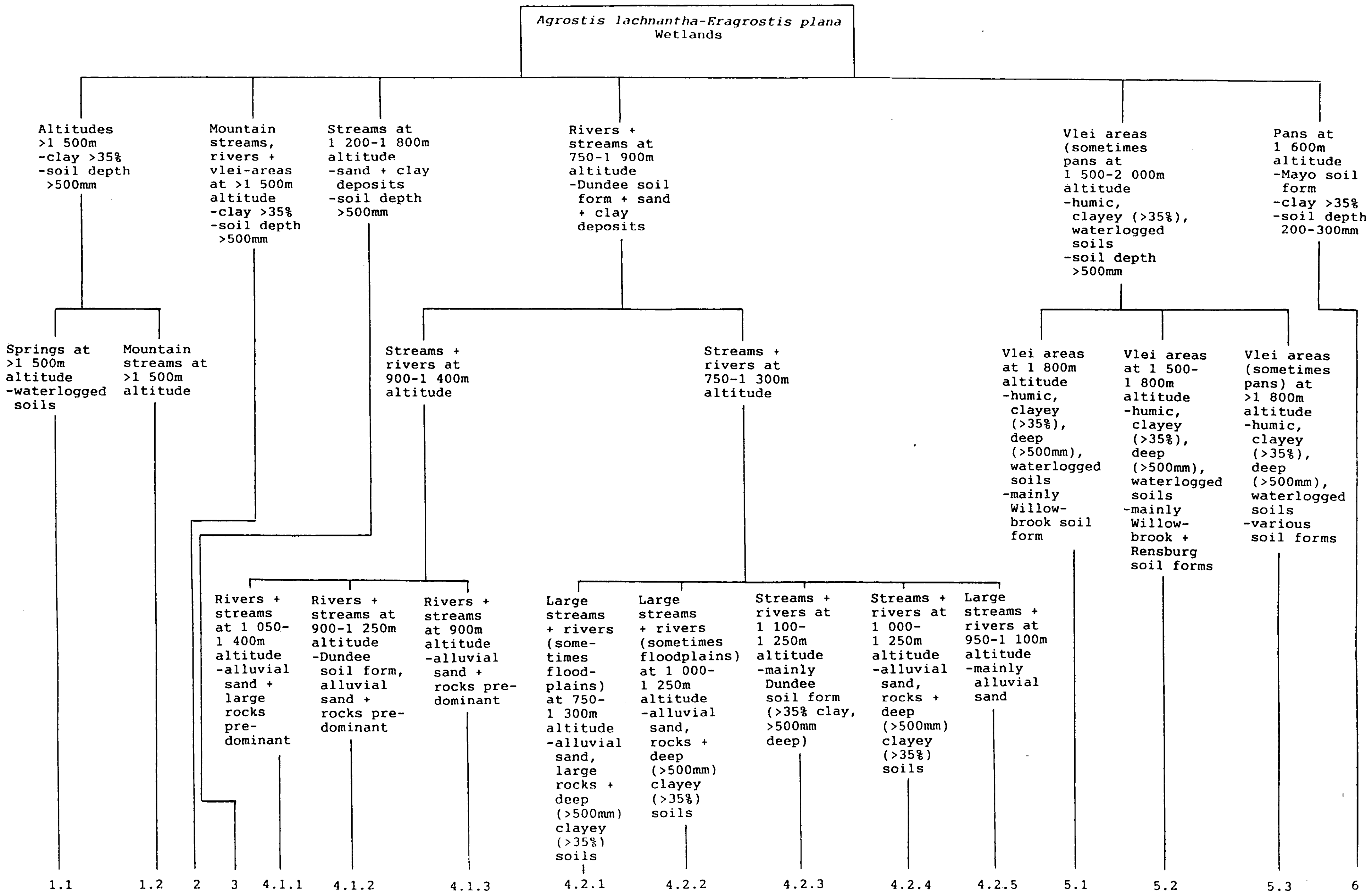


Figure 2 Hierarchical diagram to indicate the prominent habitat characteristics which are associated with the respective plant communities (vegetation units). Numbers at the bottom refer to communities shown in Table 1.

Table 1 Phytosociological table of the *Agrostis lachnantha–Eragrostis plana* Wetlands

Alliance	1				4								5			6
Association	1.1	1.2			4.1			4.2					5.1	5.2	5.3	6
Subassociation					4.1.1	4.1.2	4.1.3	4.2.1	4.2.2	4.2.3	4.2.4	4.2.5				
Community without rank			2	3												
Releve number	111	111111	1122	0000011	001000012222	300012	3334	333333334444550444	35530	44445	44555	33355	12	11211	52222	11
	012	088450	4329	1189233	354123670677	960470	1223	41245667334002014	35343	07890	54255	76615	33	05225	34444	19
	003	189023	2654	1400238	488699144808	669620	0386	86430070240346108	20041	78662	66749	41216	34	76987	72965	23
Species group A																
Limosella grandiflora	1BB															
Juncus dregeanus	AB															
Leucosidea sericea	AA	+		A		+				+						
Prunella vulgaris	1 1															
Agrostis barbuligera	11															
Kyllinga pauciflora	3		3													
Species group B																
Gunnera perpensa	111	A 1+A	11		+											
Helictotrichon turgidulum	1+1	A1 11		+	1	1					+			+ +		
Hypochoeris radicata	11+	11+ 1	1	+ 1				+						+	1	
Wahlenbergia banksiana	+++	+ 1 1						+								
Senecio affinis	1	1+ 1+	1	1											+	
Helichrysum aureonitens	+	1+ 1						1+	1							
Andropogon appendiculatus	AA	A			++1									+		
Helichrysum umbraculigerum	+	1 A														
Juncus tenuis	A	A	1													
Merxmuellera macowanii		3														
Pennisetum thunbergii		B														
Species group C																
Pycnostachys reticulata		+ 1 A	11++								+ +					
Cliffortia linearifolia		B 1	+ +3	+												
Stiburus alopecuroides		11 +	1A										1			+
Nidorella auriculata		+ 1	3										1			
Sium repandum		+	+1					+	R							
Species group D																
Conyza albida		++ 11	111	1 1+	11 1 +11	1 +11								+	1	
Juncus inflexus		A A1		A1 1	AA 1 1 1 11	1 A 1		1								
Juncus punctorius		11	1 1	1 1	1 31			1 +							+	
Digitaria sanguinalis	1	1	A	A	111	A	+							1		
Oenothera rosea		1		1 +1		++								+		
Schizostylis coccinea		1	+	+	1	1										
Species group E																
Imperata cylindrica					BB B3333333A	AA1A3B	34B3	11B33+B111A1+ 1								
Andropogon eucomus			1		1A 1 1A11A1	1 1	+111	+11 1 1 + 1+								
Pulicaria scabra		1			+11 11 1+++	11 +11	1+1	++ + + + +				+				
Juncus effusus				A	AA 1	1		1 A1							1	
Species group F																
Senecio achilleifolius				1	1111 11 1++		1									
Scirpus falsus					1A 11 1			1								
Diheteropogon amplectens					+ + ++											
Species group G																
Mariscus congestus		1 A	1	13A1A	1 1 111	1A11	+111	1 1				+		11	+1	
Species group H																
Paspalum urvillei				B		1		B1 A1B1BABBBAB1A	311A	1A11A	A111	BB1B1				
Persicaria lapathifolia	5	1				+		+ 1 +	+ A	1	++11	+			++	
Mariscus keniensis		1	3	1				B 3	++	1 +	BA					
Sesbania punicea								A A A		A	1	1 +				
Cyperus articularis								1 A11				A3				
Rhus gerrardii								R +		B R	+					
Species group I																
Chamaechrista stricta								1 + + + +	+++ +	1						
Salix babylonica									A							
Kyllinga erecta	1A	1				1		B 1 1 1	1+ 1							
Digitaria ternata				1			+	+	+11	1						
Digitaria eriantha									A							
Sporobolus fimbriatus									A							
Species group J																
Senecio isatideus			1			B		+	1	+A1A1						
Persicaria attenuata			+	1	+			1		1 1+1	++					
Senecio inaequidens			1				1	+ ++		+++1	+	+		+	+	1
Species group K																
Verbena brasiliensis								1+ +		+ +	++1++					
Species group L																
Typha capensis							++	1A B1AB B +	+	+ ++	+	+1 +B			4	
Conyza brasiliensis							+ 1+	+ + + ++ 1	1 +	++	+ +	1				
Species group M																
Hemarthria altissima					+1 A 1 B	A AA	1B	BB13B1 1A A A	A1A1A	1 AAB	3 1B	31111				
Equisetum ramosissimum					+ + 1 1+	1	11	1 +1	1		+	+ 11				
Species group N																
Arundinella nepalensis		BB41+	4AAB	A B4A	A3 3+ 1A3 3	BB1 A	A	B + 11B 11A 1A1 +	3+	+ 1	B1A1B	+1			3	
Fimbristylis ferruginea		1 1		11 11	1A 11BA1A111	1 B1	1A1B	1 1 111 A1 111+1	1113	1	11	+				
Miscanthus junceus		A	3 1	B 3	A A 3 3	AB 3		3A+B34 A BB+3A	+343	43 33	34 3	3+A				
Hyparrhenia dregeana		1 A	A	AA 3	A13 111	1 +3A	+1+	A + +B 1A	11 +	A	3	1+ 1				
Phragmites australis			A	B+	+1 + 1	+ B A	+	3 AB 1 +1 1BB	+ A A	31B	A3	1A AB	A			
Ischaemum fasciculatum		B A1A	1 3B	A	AA 1	+ B1		1AB 1	3	B3 A	A	B				
Species group O																
Schoenoplectus decipiens				A				1					BB			
Species group P																
Eragrostis plana	A11	AA41B1	A1	311BA	111B A+1	B111	A111	1111 1+ 13A1145	1 A1	1 B1	1+ +1	11++	11	5311A		
Hyparrhenia hirta		3	B	1 A+	1BB11 BBA11	1 111	A1A1	1 11 1 1 111111	1 1			1				
Eragrostis curvula		B+13	1	AA	1 +	++1	B1+A	11 B 1 BA	1			1		1		
Sporobolus africanus		1 +1		1	1 1	+ 1	1	1 + 11 1 A 1A1	1	1 1	1 +1	+1++1				
Species group Q																
Eleocharis palustris				A											14334	
Gladiolus papilio													1		+ 1	

Table 1 Continued

Species group R																
Eragrostis planiculmis	1		1	1	1 1A111+	11B		+					53	511A	1+ A	
Species group S																
Agrostis lachnantha	111	A 11	11	1 1	11 1 1 1111	+ 1 11	111	111 1 1				1 +		1	1+ 1	
Schoenoplectus corymbosis	A	1	11	A A	1A1B+A	1 1	A1		+		3 1	+		AA	331	1
Pennisetum sphacelatum	111		1B1	+ 1	1 1	11B		1 A	A+			+	11	++ 11	+ 1	
Pycreus betschuanus	A	A 1	A	1 3	1	1	A	A 1 3 1AA 1B 1	1 A	A	1	B		4	A	
Pseudognaphalium oligandrum	11	+	+	+ + +	+1	+ +		1			R			+++ +	+ + 1	1
Setaria pallide-fusca		11	1	AA1 B		1		1 +	a	1			A	+ AB	1+	
Ranunculus multifidus		1		1	+ +	1		1 + +				1		1 +		
Persicaria serrulata	B+	1	11	1 1	+			+			1	+	A	3	++A1	
Fulrena pubescens		3		1	1 1	11A	1	1							B 1	
Cyperus fasciculatus			1	A				+ 1			3	34	4		1+	
Cyperus marginatus		3	A	A	1			1 A +				A				
Paspalum distichum				1		B 1				A		1 B		3	4	
Species group T																
Isolepis fluitans	A3		1													55
Ornithogalum ornithogaloides																+1
Aponogeton junceus	1		+						1							+1
Cyperus dentatus																A
Juncus oxycarpus							1	11	+							A
Species group U																
Panicum schinzii	1		11	1 1		1								AA	11	B1
Species group V																
Paspalum dilatatum		1A11A	11	B111111	1111 11AA111	1ABBAA	1111	1 1111111A11111	11111	1B1	11 +	B111+	11	1 A11	1 1	1
Leersia hexandra		B+	1AB	1 11	1 1 + 1	11	1	1AB3 313 1+ 11+	3 11	A A1	3AA	AABB1	A	+	11 A	A

4.2 *Paspalo urvillei–Leersietum hexandrae*

4.2.1 *Paspalo urvillei–Leersietum hexandrae pycreetosum betschuani* (vegetation unit 8)

4.2.2 *Paspalo urvillei–Leersietum hexandrae chamaechristetosum strictae* (vegetation unit 9)

4.2.3 *Paspalo urvillei–Leersietum hexandrae senecionetosum isatidei* (vegetation unit 10)

4.2.4 *Paspalo urvillei–Leersietum hexandrae verbenetosum brasiliensis* (vegetation unit 11)

4.2.5 *Paspalo urvillei–Leersietum hexandrae phragmitetosum australis* (vegetation unit 12)

5. *Eragrostio planiculmis–Setarion pallide-fuscae*

5.1 *Schoenoplecto decipientis–Eragrostietum planiculmis* (vegetation unit 13)

5.2 *Eragrostietum plano-planiculmis* (vegetation unit 14)

5.3 *Eleocharito palustris–Schoenoplectetum corymbosi* (vegetation unit 15)

6. *Isolepido fluitantis–Panicetum schinzii* (vegetation unit 16).

Description of the plant communities

1. *Gunnero perpensae–Eragrostion planae* all. nov.

Nomenclatural type: *Arundinello nepalensis–Eragrostietum planae* (holotypus).

This wetland community is found around mountain springs and along streams at altitudes exceeding 1 500 m (Figure 2). The soils usually have a high clay content (> 35%) and are deeper than 500 mm. Steepness of the slopes is less than 3°. Surface rocks are mainly restricted to stream-beds and cover up to 20% of the surface area.

The diagnostic species are listed under group B (Table 1). The most common and prominent species is *Eragrostis plana* (Table 1), a typical species for wet areas (Gibbs Russell *et al.* 1991; van Oudtshoorn 1991).

Two associations are recognized under this alliance:

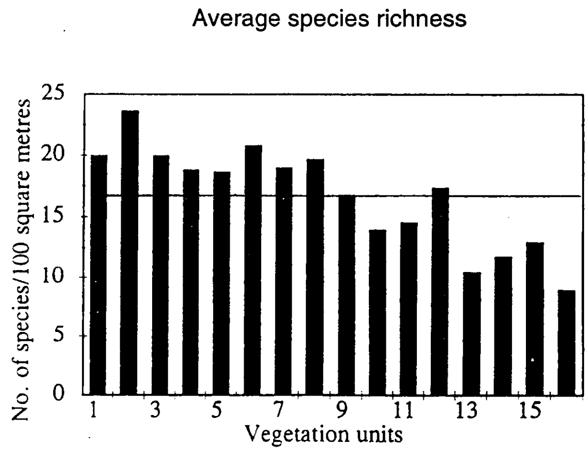
1.1 *Limosello grandiflorae–Leucosideetum sericeae* ass. nov.

Nomenclatural type: relevé 110 (holotypus).

This community is associated only with mountain springs but otherwise similar habitat conditions as the above alliance (Figure 2). Surface rocks are usually absent. The trampling effect of cattle and small livestock is evident and gives rise to erosion.

This community is characterized by hydrophytic forbs, sedges and other species listed under group A (Table 1). The tree *Leucosidea sericea* often forms clusters around wet areas. Other prominent species include *Andropogon appendiculatus* and *Isolepis fluitans* (Table 1).

The average number of species recorded per sample plot is 20, whereas the total number is only 35 (Figure 3), which is well below the average calculated for this major vegetation type.



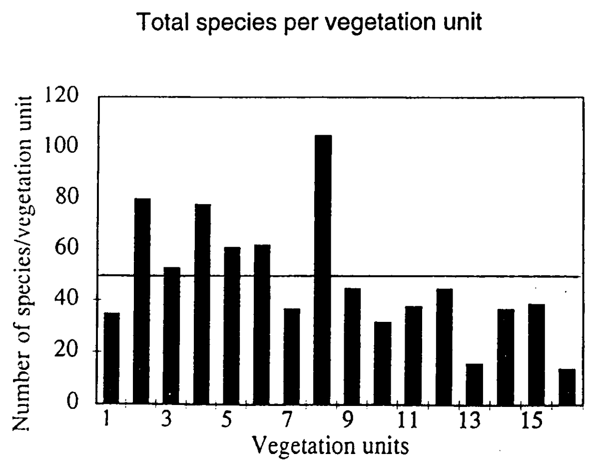


Figure 3 The average species richness and total number of species of each vegetation unit. Horizontal lines represent the respective averages for the *Agrostis lachnantha–Eragrostis plana* major vegetation type.

1.2 *Arundinello nepalensis–Eragrostietum planae* ass. nov.

Nomenclatural type: relevé 140 (holotypus).

This association also occurs at altitudes exceeding 1 500 m and is primarily associated with mountain streams (Figure 2). Although rocks covered by alluvial sand may be present, the substrate consists predominantly of clayey (> 35%) soils, exceeding 500 mm in depth.

Although no diagnostic species were recorded, this community is distinguished from the *Limosello grandiflorae–Leucosideetum sericeae* by the absence of species group A and the presence of species groups C and D (Table 1). The most prominent species include *Arundinella nepalensis, Ischaemum fasciculatum* and *Eragrostis plana* (Table 1). This is the typical association of the alliance.

This community has the highest species richness (24) and second highest total number of species (80) (Figure 3) recorded within this major vegetation type.

2. *Pycnostachys reticulata–Arundinella nepalensis* Wetland

This wetland community, with no syntaxonomic rank, is found along mountain streams, rivers and vlei areas in high-lying (> 1 500 m) areas (Figure 2). The waterlogged soils of the vlei areas are rich in clay (> 35%) and deeper than 500 mm. Surface rocks are mostly associated with river- and stream-beds.

Although no diagnostic species were identified, this community is distinguished by the presence of species groups C and D (Table 1). Physiognomically, the most prominent species include the grasses *Arundinella nepalensis, Ischaemum fasciculatum* and *Leersia hexandra* (Table 1). This wetland community was found relatively undisturbed, with limited signs of trampling.

An average number of 20 species was recorded per sample plot, with the total number of species for this community being 53 (Figure 3).

3. *Mariscus congestus–Setaria pallide-fusca* Wetland

This community, with no syntaxonomic rank, is widely spread and occurs along streams at altitudes of 1 200 to 1 800 m (Figure 2). The substrate consists mainly of alluvial sediments with alternative layers of sand and clay deposits, and is often deeper than 500 mm. Surface rocks are mostly present in stream-beds, covering more than 20% of the area.

Diagnostic species are absent from this community which is distinguished from the *Pycnostachys reticulata–Arundinella nepalensis* Wetland by the absence of species group C and the presence of species group G (Table 1), and consists only of the sedge *Mariscus congestus.* Other prominent species are the grasses *Arundinella nepalensis, Hyparrhenia dregeana, Eragrostis plana* and *Setaria pallide-fusca* (Table 1). Signs of moderate to serious erosion are often visible along stream-banks, caused by the trampling effect of livestock.

The species richness of this community is 19, with the total number of species being 78 (Figure 3).

4. *Hemarthrio altissimae–Miscanthion juncei* all. nov.

Nomenclatural type: *Paspalo urvillei–Leersietum hexandrae* (holotypus).

This alliance is mostly associated with rivers and streams, occurring at altitudes of 750 to 1 900 m (Figure 2). The predominant soil type is the Dundee Form, with alluvial sediments consisting of alternating sand and clay layers. Surface rocks are especially found within river- and stream-beds, covering more than 20% of the surface area. The slopes vary from 0° to 3°.

The diagnostic species which characterize this alliance include the hydrophytes listed under species group M (Table 1). Other prominent species are the grasses *Arundinella nepalensis, Miscanthus junceus* and the reed *Phragmites australis* (Table 1). Two associations are recognized under this alliance:

4.1 *Imperato cylindricae–Fimbristylidetum ferrugineae* ass. nov.

Nomenclatural type: relevé 268 (holotypus).

This association contains no diagnostic species but is easily distinguished by the presence of species groups D, E, F, G and L and the absence of species groups H, I, J and K (Table 1). The most prominent species are the grasses *Imperata cylindrica* and *Arundinella nepalensis*, and the sedge *Fimbristylis ferruginea* (Table 1).

Three sub-associations are distinguished under this association:

4.1.1 *Imperato cylindricae–Fimbristylidetum ferrugineae senecionetosum achilleifolii* sub-ass. nov.

Nomenclatural type: relevé 268 (holotypus).

This community is primarily associated with rivers and streams at altitudes of 1 050 to 1 400 m (Figure 2). Clear signs of erosion are evident and can often be observed where banks are relatively steep. It is not always natural erosion but often also man-induced erosion caused by agricultural malpractices (O'Keeffe 1986; Kotze *et al.* 1995). Alluvial sand, covering large rocks and rock-beds, constitutes the major part of the substrate.

The diagnostic species characterizing this community are listed under species group F (Table 1). Other prominent species include *Imperata cylindrica, Arundinella nepalensis* and also very often *Hyparrhenia hirta* and *Fimbristylis ferruginea* (Table 1). The grass *Eragrostis planiculmis* can also be found in this community. This is the typical sub-association of the *Imperato cylindricae–Fimbristylidetum ferrugineae.*

An average number of 19 species was recorded per sample plot, and the total number was 61 (Figure 3).

4.1.2 *Imperato cylindricae–Fimbristylidetum ferrugineae paspaletosum dilatati* sub-ass. nov.

Nomenclatural type: relevé 200 (holotypus).

This community is primarily found near streams and rivers at altitudes of 900 to 1 250 m (Figure 2). Soils of the Dundee Form as well as alluvial sand covering rocks mainly constitute the substrate. The soils are usually deeper than 500 mm and clay percentages may vary from less than 10% to more than 35%. Steep river- and stream-banks are often characterized by moderate to serious signs of erosion (see also Kooij *et al.* 1991).

Although no diagnostic species were identified, this community is distinguished from the *Imperato cylindricae–Fimbristylidetum ferrugineae senecionetosum achilleifolli* by the absence of species group F (Table 1). Most prominent species include *Imperata cylindrica, Arundinella nepalensis* and *Paspalum dilatatum* (Table 1). The graminoid *Eragrostis planiculmis* is sometimes found within this community.

This community displays the second highest species richness (21) within this major vegetation type, with the total number of species for this community being 62 (Figure 3).

4.1.3 *Imperato cylindricae-Fimbristylidetum ferrugineae eragrostietosum curvulae* sub-ass. nov.

Nomenclatural type: relevé 436 (holotypus).

This sub-association is associated with streams and rivers at low altitudes (900 m) (Figure 2). Alluvial sand and rocks dominate the substrate, which contains less than 10% clay. Where signs of erosion are visible, these are usually of a moderate to serious degree.

No diagnostic species were identified within this community, but it can be distinguished from the two previously described sub-associations by the absence of species groups D, F and R and the presence of species group L (Table 1). Physiognomically, the most dominant and conspicuous species are *Imperata cylindrica, Fimbristylis ferruginea, Hyparrhenia hirta* and *Eragrostis curvula* (Table 1).

This community has an average species richness of 19 and a contrasting low total number of only 37 species (Figure 3).

4.2 *Paspalo urvillei–Leersietum hexandrae* ass. nov.

Nomenclatural type: relevé 360 (holotypus).

This association is characterized by the diagnostic species included in group H (Table 1). The shrub *Sesbania punicea* is a declared noxious weed (Bromilow 1995) and is sometimes found along larger streams and rivers where it forms relatively dense clusters. Other prominent species include *Hemarthria altissima, Miscanthus junceus, Phragmites australis* and *Leersia hexandra* (Table 1). This is the typical association of the alliance.
Five sub-associations are recognized under this association:

4.2.1 *Paspalo urvillei–Leersietum hexandrae pycreetosum betschuani* sub-ass. nov.

Nomenclatural type: relevé 360 (holotypus).

This community is primarily associated with large streams and rivers but may also be encountered on floodplains at altitudes of 750 to 1 300 m (Figure 2). The substrate within the stream- and river-beds consists mainly of alluvial sand and large rocks, whereas soils of the floodplains are relatively deep (> 500 mm) and rich in clay (> 35%). Moderate to serious signs of erosion are often visible on stream- and river-banks, especially where these are deprived of vegetation.

No diagnostic species were identified, with this community being distinguished by the presence of species group E and the absence of species groups I, J and K (Table 1). Physiognomically, the most conspicuous and often dominant species are *Imperata cylindrica, Paspalum urvillei, Typha capensis, Hemarthria altissima, Miscanthus junceus, Phragmites australis, Pycreus betschuanus* and *Leersia hexandra* (Table 1). This is the typical sub-association of the *Paspalo urvillei–Leersietum hexandrae*.

The average number of species recorded per sample plot is 20 and the total number 105, which is the highest number of species to be recorded within this major vegetation type (Figure 3).

4.2.2 *Paspalo urvillei–Leersietum hexandrae chamaechristetosum strictae* sub-ass. nov.

Nomenclatural type: relevé 332 (holotypus).

This sub-association is mainly found along large streams and rivers but sometimes also on floodplains at altitudes of 1 000 to 1 250 m (Figure 2). Rocks and alluvial sand constitute the major part of the substrate within the streams and rivers, whereas deep (> 500 mm), clay-rich (> 35%) soils are associated with the floodplains. Moderate signs of erosion may sometimes be visible.

The diagnostic species which characterize this community are listed under species group I (Table 1). The tree *Salix babylonica* may sometimes be found. Other prominent species are *Hemarthria altissima* and *Miscanthus junceus* (Table 1).

The community has a species richness of 17, whereas the total number of species is 45 (Figure 3).

4.2.3 *Paspalo urvillei–Leersietum hexandrae senecionetosum isatidei* sub-ass. nov.

Nomenclatural type: releve 496 (holotypus).

This sub-association occurs along streams and rivers at altitudes ranging from 1 100 to 1 250 m (Figure 2). Although loose alluvial sand may be found in stream- and river-beds, soils of the Dundee Form are predominant, usually containing more than 35% clay and are deeper than 500 mm. Signs of erosion are sometimes visible.

The diagnostic species are included in species group J (Table 1). Conspicuous and most dominant species include *Hemarthria altissima, Miscanthus junceus* and *Ischaemum fasciculatum* (Table 1) .

A species richness of 14 was recorded, with the total number of species for this community being only 32 (Figure 3).

4.2.4 *Paspalo urvillei-Leersietum hexandrae verbenetosum brasiliensis* sub-ass. nov.

Nomenclatural type: releve 554 (holotypus).

This community is associated with streams and rivers occurring at altitudes of 1 000 to 1 250 m (Figure 2). The substrate consists of alluvial sand and rocks or various soil types, usually containing more than 35% clay and are deeper than 500 mm. A few signs of erosion are sometimes observable.

The only diagnostic species which characterizes this community is the exotic forb *Verbena brasiliensis* (species group K, Table 1). Other prominent species are *Arundinella nepalensis, Miscanthus junceus* and *Leersia hexandra* (Table 1).

An average number of only 15 species was recorded per sample plot, with the total number of species for this community being 38 (Figure 3).

4.2.5 *Paspalo urvillei-Leersietum hexandrae phragmitetosum australis* sub-ass. nov.

Nomenclatural type: relevé 361 (holotypus).

This sub-association occurs primarily along rivers and large streams at altitudes ranging from 950 to 1 100 m (Figure 2). Although the substrate consists mainly of loose alluvial sand, rocks and soils of the Dundee Form are sometimes found. Moderate to serious signs of erosion are sometimes evident.

Although no diagnostic species were identified, this community is, however, distinguished from the previously described sub-associations by the absence of species groups E, I, J and K (Table 1). Physiognomically, the most prominent species are *Paspalum urvillei, Phragmites australis* and *Leersia hexandra* (Table 1). The exotic woody species *Sesbania punicea* and *Acacia dealbata* are sometimes found on the banks of rivers, which is a source of concern.

An average number of 17 species was recorded per sample plot, whereas the total number is 45 (Figure 3).

5. *Eragrostio planiculmis–Setarion pallide-fuscae* all. nov.

Nomenclatural type: *Schoenoplecto decipientis–Eragrostietum planiculmis* (holotypus).

This alliance primarily represents vlei areas and to a lesser extent pans found at altitudes of 1 500 to 2 000 m (Figure 2). The substrate usually consists of humic, clayey (> 35%), waterlogged soils, which are deeper than 500 mm. Surface rocks are virtually absent from these vlei areas which are associated with flat terrain, displaying a gradient of less than 3°.

The only diagnostic species which characterizes this alliance is the graminoid *Eragrostis planiculmis* (species group R, Table 1), which is typical for depressions and vlei margins (Gibbs Russell *et al.* 1991). There are no other prominent species which describe this alliance, as most of the species occur spontaneously.

The species poorness of the vlei areas is clearly depicted by Figure 3.

5.1 *Schoenoplecto decipientis-Eragrostietum planiculmis* ass. nov.

Nomenclatural type: relevé 234 (holotypus).

This community is associated with vlei areas at an altitude of 1 800 m (Figure 2). The soils are usually humic, clayey (> 35%), deep (> 500 mm) and waterlogged, the predominant type being the Willowbrook Form. These vlei areas are mainly filled with water during the rainy season when streams and rivers overflow their banks. Surface rocks are absent. Although these vlei areas are utilized for grazing purposes, the condition appeared to be relatively good.

The diagnostic species for this community is the rush *Schoenoplectus decipiens* (species group O, Table 1), dominating the vegetation to a large extent. Other prominent species are the grass *Eragrostis planiculmis* and sometimes also the rush *Cyperus fastigiatus* (species group S, Table 1). This is the typical association of the alliance.

This community has the second lowest species richness (11) and total number of species (16) (Figure 3) recorded within this major vegetation type.

5.2 *Eragrostietum plano-planiculmis* ass. nov.

Nomenclatural type: relevé 157 (holotypus).

This vlei community occurs at altitudes ranging from 1 500 to 1 800 m (Figure 2). The predominant soil types are the Willowbrook and Rensburg Forms, which are humic, clayey (> 35%), deep (> 500 mm) and seasonally waterlogged. These vlei areas may carry water throughout the year, but mostly dry up during the winter months. No surface rocks were found. The condition of these vlei areas is relatively good, with areas carrying water throughout the year being less easily disturbed and therefore more natural.

Although no diagnostic species were identified, this community is distinguished by the absence of species groups O and Q and the presence of species groups P and U (Table 1). Prominent species include the grasses *Eragrostis plana* and *E. planiculmis* (Table 1).

Both the species richness (12) and the total number of species (37) (Figure 3) recorded for this community are well below the respective averages calculated for this major vegetation type.

5.3 *Eleocharito palustris-Schoenoplectetum corymbosi* ass. nov.

Nomenclatural type: relevé 242 (holotypus).

This association is primarily restricted to vlei areas and to a lesser extent to pans at altitudes exceeding 1 800 m (Figure 2). The substrate associated with these wetlands consists of humic, clayey (> 35%), deep (> 500 mm), waterlogged soils. Surface rocks may be found in pans but are usually absent from vlei areas. Those vlei areas, which are fed by perennial streams or rivers, carry water throughout the year and are normally better preserved than those which dry up during the winter months, because the latter are more heavily utilized by livestock due to their accessibility.

This community is characterized by two diagnostic species, namely the sedge *Eleocharis palustris* and the bulbous forb *Gladiolus papilio* (species group Q, Table 1). Species which are sometimes prominent include *Eragrostis planiculmis, Pycreus betschuanus, Persicaria serrulata, Fuirena pubescens, Paspalum distichum* and *Leersia hexandra* (Table 1).

An average number of only 13 species was recorded per sample plot and a total number of 39 for this community (Figure 3).

6. *Isolepido fluitantis-Panicetum schinzii* ass. nov.

Nomenclatural type: relevé 193 (holotypus).

This pan community is found on flat terrain (< 3°) at an altitude of more than 1 600 m (Figure 2). The predominant soil type is the Mayo Form, which is rich in clay (> 35%) and only 200–300 mm deep. Surface rocks are generally absent. These pans are usually filled with water throughout the year and the vegetation within the pans is consequently less severely utilized. The effects of trampling caused by livestock are often evident along the perimeter of the pans. Most of the pans are classified as grass pans, although some may bear strong resemblance to sedge pans (Noble & Hemens 1978).

The diagnostic species are listed under group T (Table 1).

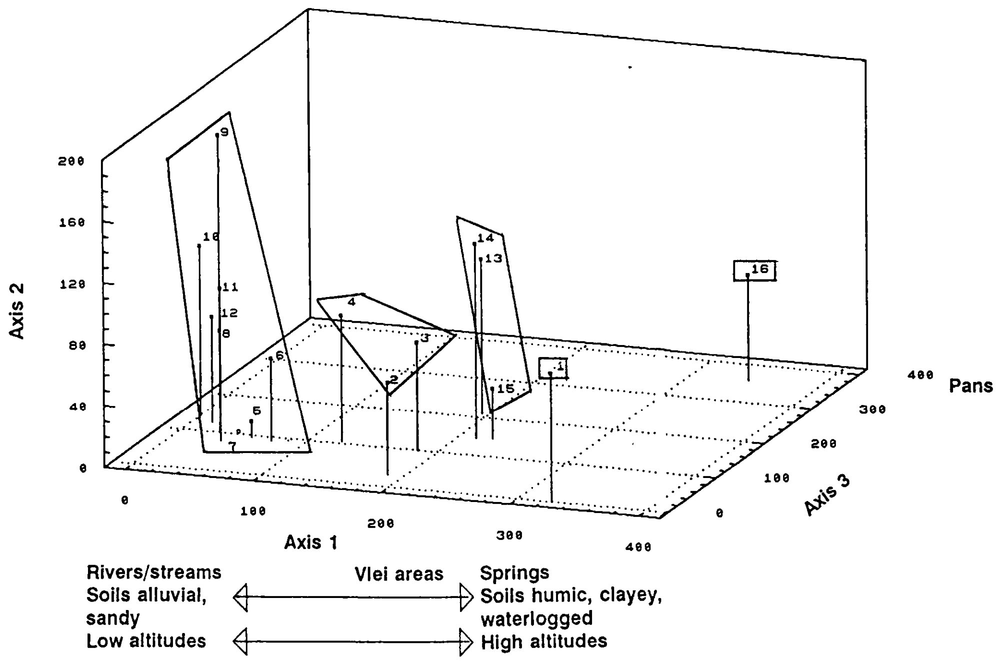


Figure 4 A scatter diagram of the DECORANA ordination of the vegetation units (synrelevés) along the first, second and third axes (Eigen values: axis 1 = 0.596, axis 2 = 0.353, axis 3 = 0.137).

Other species which are typical for pans and sometimes prominent include *Panicum schinzii* and *Leersia hexandra* (Table 1) (Gibbs Russell *et al.* 1991).

The extreme species poorness of the pans is clearly emphasized by the low species richness (9) and total number of species (14) (Figure 3) recorded for this community, both values being the lowest within this major vegetation type (see also Kooij *et al.* 1991; Eckhardt *et al.* 1993).

Ordination

Figure 4 represents a three-dimensional scatter diagram, indicating the distribution of synrelevés, which represent the different communities/vegetation units along the first, second and third axes of a DECORANA ordination. The distribution of the synrelevés reveals a formation of five relatively distinct discontinuous groups, which can be interpreted in terms of various environmental factors. The distinct groups clearly suggest that the wetland plant communities differ greatly from each other with regard to their species compositions. The distribution pattern could be related to environmental gradients associated with the first and third axis. No gradients could be observed on the second axis. Synrelevés 5 to 12 represent rivers and streams, occurring mainly at low altitudes and are principally associated with alluvial sandy soils. Synrelevés 2 to 4 are mainly associated with mountain streams and rivers at high altitudes, the substrate consisting of alluvial sediments or clayey soils, whereas the vlei areas (synrelevés 13–15) are also associated with high altitudes but the substrate consists of humic, clayey, mostly waterlogged soils. Synrelevé 1 represents springs and synrelevé 16 pans, both being associated with high altitudes and humic, clayey, waterlogged soils.

Conclusions

The processing of the floristic data by means of the application of the TWINSPAN classification technique revealed 16 plant communities, which were subsequently refined by Braun–Blanquet procedures. The communities were then identified and described. The relationship between the plant communities and environmental factors was determined using DECORANA.

Although conservation sites were partly selected on the basis of high species richness and total number of species, it appears in fact that the most species-poor plant communities, represented by vlei areas and pans (Figure 3), ought rather to be granted conservation status. Although most wetland plant communities have low species richnesses (Kooij *et al.* 1991; Eckhardt *et al.* 1993) compared with grassland communities, their species composition is unique and habitat specific (Walmsley 1988; Cowan 1995). Although no rare species were encountered during the field surveys, many wetlands contain endangered plant species (Walmsley 1988). Representatives of all wetland types should therefore be conserved to preserve the species diversity (Noble & Hemens 1978). The vlei areas and pans play an important ecological role in the water purification process and in attenuating floods, especially after heavy rains have fallen (Walmsley 1988; Cowan 1995). Vlei areas also serve as important feeding and breeding grounds for the endangered wattled crane and many other birds and animals (Brooke 1984; Cowan 1995). Furthermore, these wetland areas are still in a relatively undisturbed condition and are extremely sensitive to the adverse effects of afforestation. Currently high-lying grasslands are being replaced at an alarming rate by exotic species, mainly eucalypt plantations (Department of Water Affairs and Forestry 1995). The vlei areas and pans will most certainly desiccate, which will lead to the natural wetland vegetation being destroyed (Noble & Hemens 1978).

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CHAPTER 5

Bush encroachment in the Black Mfolozi area of northern KwaZulu-Natal: conversion of grassland to thorny woodland

Unpublished paper

Bush encroachment in the Black Mfolozi area of northern KwaZulu-Natal: conversion of grassland to thorny woodland

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Introduction

Approximately 13 million hectares in South Africa are subjected to bush encroachment, the highly affected areas being the former northern and north-eastern Transvaal, northern and eastern Cape Province and KwaZulu-Natal (Trollope *et al.* 1989). According to Walker (1980), some 53 million hectares of previously open savanna rangelands in the semi-arid and mesic ranching areas of the country were then covered by dense bush. This figure will most probably by now, 17 years later, have grown considerably. Bush encroachment is a phenomenon which is not only restricted to this country, but is also considered to be a serious problem in many other parts of the world, such as other parts of Africa (Kelly & Walker 1976; Schlettwein 1994), Australia (Harrington *et al.* 1984) and North and South America (Archer *et al.* 1988).

Various reasons are given for bush encroachment, some being human-related and others due to natural processes, such as succession. Disturbances in the equilibrium between the herbaceous layer and woody stratum are caused by mismanagement of the veld, usually leading to a seriously reduced grass production and a simultaneous encroachment by woody plants (Walker 1980; San José & Farinas 1983; Bosch 1989; Trollope *et al.* 1989). The ratio of woody plants to grasses at a given location in a savanna is not static, but changes with time, even in the total absence of man (Scholes 1986). A complex interaction between climate, soil, fire and herbivory exists, which will, with human interference, change the ratio.The exact processes and dynamics involved in the conversion of grassland to shrubland or woodland are presently not fully understood. Since the ecological explanations are complex (Walker 1980), results derived from one study area are not necessarily applicable to other areas, especially where soil types and rainfall differ strongly. Various studies were devoted to bush encroachment, trying to explain and describe the successional dynamics involved (Connell & Slatyer 1977; Friedel 1987; Smith & Goodman 1987; Archer *et al.* 1988; Belsky 1994; Milton 1994). Many different types of succession are known, including primary versus secondary, autogenic versus allogenic, progressive versus retrogressive, cyclic versus directional, and chronosequence versus toposequence (Barbour, Burk & Pitts 1980). Each one of these may also embrace one or more of the other succession types. With the limited data currently available on the vegetation dynamics of the relevant study area, one cannot strictly classify the type of succession which has taken place here, as solely being one of the above-mentioned types.

Fire-climax grasslands are particularly prone to bush encroachment and more specifically to invasion by woody plants which are present in the grasslands, albeit at very low densities. Increases in numbers and densities of these woody species are normally suppressed by high frequencies of fire (Tainton 1981), therefore the descriptive term 'fire-climax grasslands'. Even more susceptible to bush encroachment are those grasslands adjoining woodlands, where climatic conditions are similar to those of savanna regions (Scholes 1986). Disturbances in the soil, overgrazing of the grasslands, inappropriate burning practices and droughts usually benefit the woody component, resulting in bush encroachment.

The grasslands of the lower altitudes (< 1 000 m) of northern KwaZulu-Natal are characterized by higher temperatures than the high-altitude temperate grasslands, making conditions more favourable for subtropical woody species such as *Dichrostachys cinerea, Acacia nilotica* and *A. tortilis* (Eckhardt *et al.* 1996). Consequently, it can be assumed that these grasslands are in delicate balance with prevailing environmental conditions. Any disturbances to the system probably trigger a mechanism which will try to compensate for changing conditions, with bush encroachment being one of the possible resultant outcomes. Inspection of historical aerial photographs indeed revealed that what was grassland 20-30 years ago has now become woodland or savanna with a well established grass layer.

The study was not intended to unravel the reasons for former grasslands having become converted to woodland, although some speculations may be made on this phenomenon. The aim was rather to identify and understand the linked processes taking place by means of quantifying rates of changes and developments in vegetation patterns. It is suspected that certain woody pioneer species, in this case study *Dichrostachys cinerea, Acacia nilotica* and *A. tortilis*, act as nuclei within the grassland around which other woody species could become established following a successional process (San José & Farinas 1983; Smith & Goodman 1987). The intermediate stage in the conversion of grassland to woodland appears to be one where woody clusters occur in a grassland matrix. Subsequent developments embrace coalescence of clusters, forming larger closed woodlands. These woodlands seem to resemble those older more mature woodlands which are associated with drainage lines and characterized by higher species richnesses (Archer *et al.* 1988). It appears, therefore, that closed woodlands represent the final stages along the successional line, becoming more stable as additional species get established.

The grasslands affected by bush encroachment in this study apparently belong to the *Sporoboletum pyramidali-africani eragrostietosum superbae* (Eckhardt *et al.* 1996), dominated primarily by *Sporobolus pyramidalis* and *Hyparrhenia hirta*. It is considered as secondary grassland (Moll 1976, 1978) which is probably maintained as such by frequent burning. The withdrawal of fire for long periods might be one of the reasons for the conversion of secondary grasslands into bushveld.

Study area

The study was conducted on two separate farms in the Black Mfolozi area of northern KwaZulu-Natal, approximately 50 km south-east of Vryheid. The one farm comprises an area of 250 ha (situated at 27° 59' S, 31° 07' E) and the other 370 ha (situated at 27° 57' S, 31° 10' E). Both study areas receive an annual rainfall of approximately 700-800 mm, with winters being mild and summer months warm to hot, the mean annual temperature being 17°C (Schulze 1982). The areas are gently undulating and are dissected by seasonal drainage lines. Although the two farms are a few kilometres apart, prevailing environmental conditions are approximately the same.

Both areas fall into the Northern Tall Grassveld (veld type 64), bordering onto the Lowveld (veld type 10) (Acocks 1988). However, according to Low & Rebelo (1996), these areas fall under the Natal Central Bushveld (vegetation type 25), which is part of the savanna biome and not the grassland biome. The grasslands surrounding these areas are classified and described under the *Sporoboletum pyramidali-africani* (Eckhardt *et al.* 1996). It is assumed that the vegetation of both study areas used to represent this association before they became encroached by woody plants. The vegetation on the two farms has not been classified and described during the overall ecological study of the grasslands of northern KwaZulu-Natal due to it being heavily invaded by woody plants (Eckhardt *et al.* 1996). The vegetation consists of a well-developed grass layer with different sizes of woody clusters occurring as isolated islands. The vegetation along drainage lines is characterized by closed woodlands, consisting mainly of larger trees and a prominent shrub stratum. The tree and shrub strata comprise mainly the thorny species *Dichrostachys cinerea, Acacia nilotica* and *A. tortilis*, all species considered to be potential encroachers or woody pioneers (Briers 1984; Pooley 1994).

Methods

Belt transects

A total of 30 belt transects of 2 m width were established in clearings between woody clusters. These transects were selected by overlaying a grid with randomly placed points over the aerial photographs. All woody species present were recorded and their stem diameter at ground level, height and crown diameter measured. Frequency and density numbers were then calculated for each species. The purpose of this survey was to determine which species actually enter the grassland patches between the woody clusters.

Line intercepts

Four line intercepts, each 200 m long and placed into a predetermined direction, were also surveyed so as to measure the distances between clusters and the diameter of the clusters. Clusters were throughout considered to be circular so that diameter measurements were only taken along one of the axes. Within each cluster the largest individual of each woody species was recorded and subsequent measures taken of stem and crown diameter and height.

Woody clusters

A further 61 woody clusters were selected in a way so as to include the whole range of cluster sizes. Where only the largest individual of every woody species was measured during the line intercept survey, each individual of every species present in the 61 clusters was measured as already stated earlier on. This exercise was done to determine the relationship between cluster size, species richness/species composition, and the presence and absence and respective sizes of the three species *Dichrostachys cinerea, Acacia nilotica* and *A. tortilis*. The relationships were tested by the log-linear model in Generalized Linear Modelling (GLIM), using the Poisson distribution (Crawley 1993).

Point-centered quarter technique

Field surveys were also conducted in denser woodlands away from drainage lines as well as closed woodlands along drainage lines, having made use of the point-centered quarter technique. A total number of 10 transects of different lengths and numbers of points were established, with the sample points being randomly spaced. In each quadrant of the 286 points, the nearest woody individual within each of the three different height classes (< 1m, 1-2 m, >2 m) was recorded and only their stem diameter measured. These woodlands were subsequently compared to the different clusters to determine any possible similarities.

Aerial photography interpretation

An aerial photograph interpretation was done by comparing a series of black and white photographs from three different years, *viz.* 1961, 1973 and 1990. The photographs were obtained from the Land Surveyor General in Pretoria. These photographs were used to investigate the extent and rate of bush encroachment which has taken place over the 30 year period. To make comparisons easier, it was necessary to use approximately the same scale, *i.e.* 1:10 000. The photographs were subsequently scanned and down-loaded into the raster-based Geographic Information System (GIS) programme IDRISI, to enable on-screen classification, analysis and interpretation. Image processing was possible only once the digital photographs had been rectified. This was done by resampling the images, relating them to six ground control points (GCP). The exact latitude and longitude for each GCP were physically obtained in the field by means of a Global Positioning System (GPS). Three quadrats were subsequently selected, one (19 ha) within the 250 ha and two (20 ha and 23 ha respectively) within the 370 ha area. A supervised classification was performed, whereby woody plants were clearly distinguished from the herbaceous vegetation. The woody cover was then calculated and expressed as a percentage of the total area of each respective quadrat.

Within each of the three quadrats, 10 'point clusters' were selected, consisting either of a single woody plant or a cluster. Only point clusters were selected which could be traced on all the photographs for the three different dates. The area of each of the 30 point clusters was subsequently determined. The following two formulae were used to calculate the relative and absolute growth rates (Hunt 1978) of the woody clusters:

$$RGR = (\ln S2 - \ln S1)/(t2 - t1)$$

and

$$GR = (S2 - S1)/(t2 - t1)$$

where S1 was the size (m^2) of the point cluster at time t1, and S2 the size at time t2. A two-sample analysis was conducted to determine significant differences between the obtained data.

The following calculation was made to determine the actual increase in the total woody plant cover at the expense of the grass cover (matrix) of 1961:

$$\text{total woody plant cover (\%)} = (\text{total grass cover 1961} - \text{current total grass cover} + \text{current woody cover}) \div (\text{total grass cover 1961}).$$

The percentage woody plant cover for 1961 is consequently only the total area occupied by woody plants divided by the grass cover of 1961.

Results

Belt transects

A total of seven woody species was found in the grassland patches (Table 1). The three pioneer species *Dichrostachys cinerea, Acacia nilotica* and *A. tortilis* occurred respectively in 83%, 97% and 40% of all transects. However, *Acacia tortilis* was not present in any of the transects of one of the study areas, resulting in a considerably lower percentage frequency compared to the other two species. Measurements of the height as well as stem and crown diameter clearly give an indication of the size of woody plants encountered in the grassland patches. Both species, *Dichrostachys cinerea* and *Acacia nilotica,* were found to occur at high densities, with even higher standard deviations. These species were also strongly represented in terms of total number of individuals.

Line intercepts

During the line-intercept survey, eight woody species were identified, with 42% of all clusters containing only one species, 33% containing two species and 25% containing more than three but less than six species. *Dichrostachys cinerea* occurred within 83% of the clusters, whereas *Acacia nilotica* and *A. tortilis* only in 50% and 38% respectively. Although the average distance between clusters was 6.4 m, 63% of all clusters were within 5 m of one another, 14% between 5-10 m and 23% more than 10 m apart. The average cluster diameter was 6.8 m, as measured along the line-intercept, whereas 45% of all clusters had a diameter of less than 5 m, 37% were 5-10 m and 18% more than 10 m in diameter (Figure 1).

Woody clusters

Within the 61 clusters sampled, 19 woody species were encountered. *Dichrostachys cinerea* was found in 84% of these clusters, whereas *Acacia nilotica* was present in 80% and *A. tortilis* in 71% of the clusters. However, all three these species displayed relatively similar frequencies for all three respective size classes (Figure 2), showing no specific preferences for

Table 1 Number of individuals, frequency and density of species found in grassland patches as well as mean values and variances of stem diameter, height and crown diameter.

Species	No. of plants	Freq. (%)	Density (plants/ha) Mean	(SE)	Basal diameter (cm) Mean	(SE)	Height (cm) Mean	(SE)	Crown diameter (cm) Mean	(SE)
Dichrostachys cinerea	151	83.3	515	608	1.2	1.0	34.8	32.3	59.4	37.8
Acacia nilotica	148	96.7	508	485	1.2	1.5	39.7	40.1	55.8	51.2
Acacia tortilis	23	40.0	222	190	2.1	2.3	61.9	50.1	87.2	47.9
Maytenus heterophylla	4	6.7	10	36	1.3	0.4	51.3	14.4	45.5	38.5
Diospyros lycioides	6	3.3	17	83	0.4	0.1	47.0	4.0	23.3	10.8
Ziziphus mucronata	1	3.3	13	12	1.0	....	40.0	......	30.0	......
Rhus pyroides	1	3.3	13	12	1.1	....	57.0	......	50.0	......

Table 2 The 14 most frequent species recorded from the woodlands with their respective frequencies for three height strata. A total of 29 species was recorded. Results were obtained from 10 transects with a total of 286 points.

Species	Plant height classes (m)			
	Total frequency (%)	<1 Frequency (%)	1 - 2 Frequency (%)	>2 Frequency (%)
Dichrostachys cinerea	86.4	60.5	45.1	54.6
Acacia tortilis	74.5	21.0	43.7	55.9
Acacia nilotica	88.8	37.1	48.3	79.0
Rhus pyroides	41.3	27.3	26.9	8.7
Maytenus heterophylla	54.9	40.9	31.8	11.5
Acacia sieberiana	7.0	0.0	3.2	4.6
Commiphora harveyi	5.3	2.1	1.8	1.8
Flueggea virosa	2.1	0.7	0.7	1.1
Ziziphus mucronata	24.5	10.8	7.7	8.7
Diospyros lycioides	25.9	12.6	16.1	3.9
Berchemia zeyheri	11.2	2.5	5.6	4.6
Maytenus undata	3.9	1.4	1.4	1.4
Coddia rudis	14.0	11.2	6.6	0.4
Zanthoxylum capense	14.3	3.9	8.7	3.9

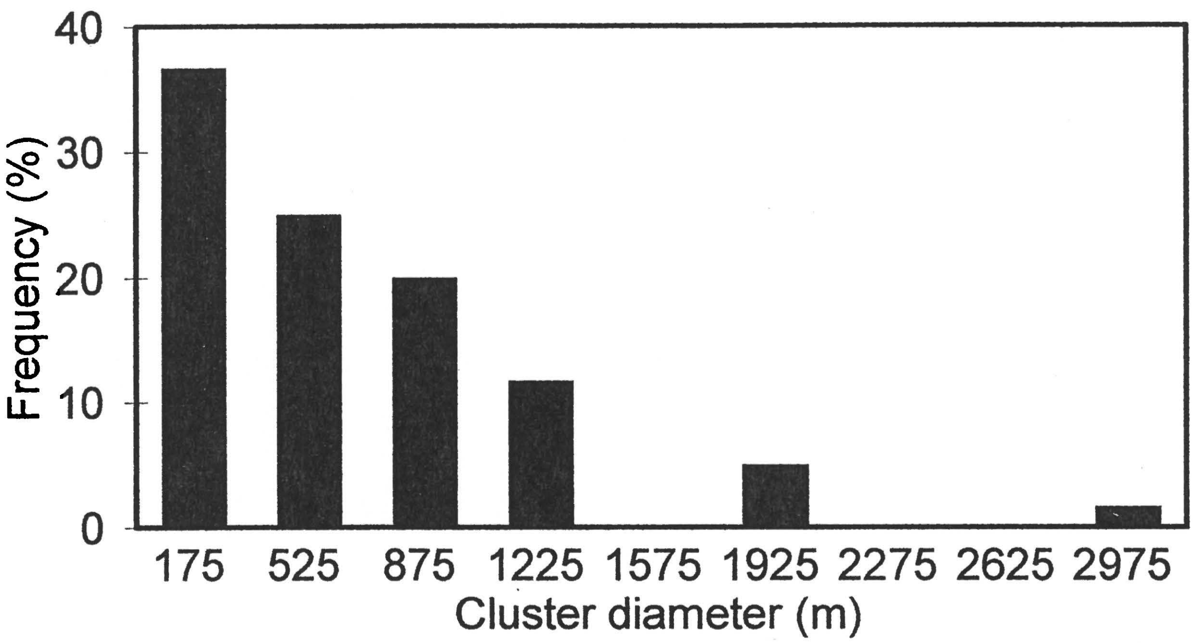

Figure 1 Distribution of cluster diameter as measured along line-intercepts. Diameter values represent the median for nine size classes. Values were derived from four line-intercepts representing 60 clusters.

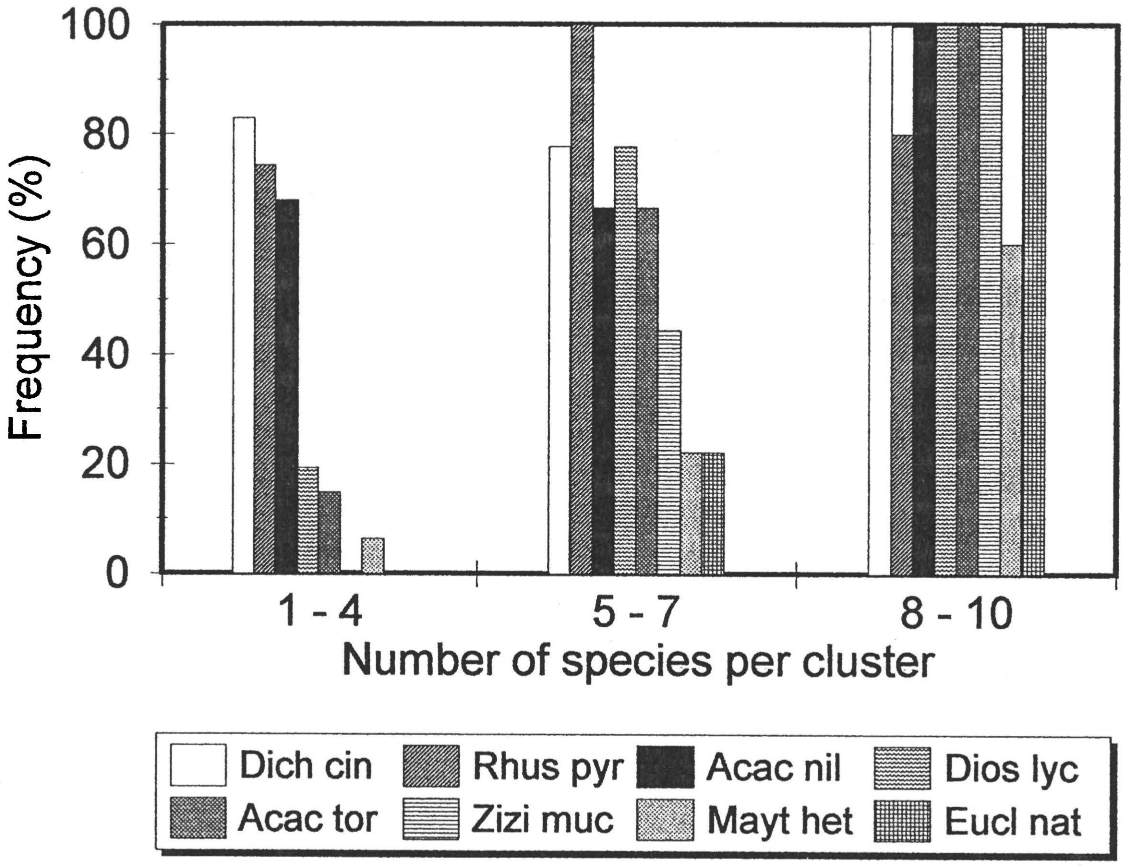

Figure 2 Frequency distribution of the eight most prominent species found in 61 clusters, clearly indicating the association of certain species with clusters consisting of higher numbers of species.

size of cluster and number of species. This is contrary to other species, which were mostly associated with larger and more diverse clusters.

In the following models, species richness was used as response variable and stem and crown diameter and tree height of the three relevant species as explanatory variables. The log-linear analysis indicated that where the three parameters were modelled per species, in the case of *Dichrostachys cinerea* stem (χ^2=8.09, α=0.05) and crown diameter (χ^2=3.86, α=0.05) had a significant influence on species richness. Only stem diameter (χ^2=5.87) proofed to be significant in the case of *Acacia tortilis,* whereas none of the parameters of *Acacia nilotica* had any influence whatsoever on species richness (change in scaled deviances at various degrees of freedom and at α=0.05 had to be larger than respective χ^2 values). However, in those cases where the three parameters were tested for all three species together, *Dichrostachys cinerea* proofed to be insignificant throughout in having any influence on species richness. *Acacia tortilis* displayed highly significant values in all three parameters, with *Acacia nilotica* also displaying significant values although with lower χ^2 values. Where the three parameters were combined into one factor for each species and built into a model, *Dichrostachys cinerea* again proofed to be insignificant, with *Acacia tortilis* (χ^2=25.18) being highly significant and *A. nilotica* (χ^2=8.28) being of lesser significance. A further model was put together consisting of factors which are a product of two species so that all three different combinations are tested. Only the two combinations *i.e. Dichrostachys cinerea/Acacia tortilis* (χ^2=6.33) and *Acacia nilotica/Acacia tortilis* (χ^2=4.13) were significant. In a model where cluster diameter was added as a factor to the other three parameters, the former caused a very small insignificant change in the scaled deviance. This implies that the diameter of clusters has no effect on species richness. The models were subsequently changed with the cluster diameter being the response variable. Due to overdispersion, causing abnormal high scaled deviances, various calculations had to be done to lower the deviances to an acceptable level close to the number of degrees of freedom. Modelling the effect of each species on cluster diameter separately, with the factors representing a combination of the three parameters of each species, it was clear that *Acacia tortilis* (χ^2=9.55), followed by *A. nilotica* (χ^2=8.79) and then *Dichrostachys cinerea* (χ^2=5.97) had the most significant effect on cluster diameter. In the model where all three factors are simultaneously represented and the effect of each species tested, all three species again proofed to have a significant effect on cluster diameter.

Point-centered quarter technique

A total number of 29 woody species was recorded within the woodlands, surveyed by the point-centered quarter technique (Table 2). From this Table, it appears clearly that the three most prominent species are *Dichrostachys cinerea, Acacia tortilis* and *A. nilotica*. However, various other species were also recorded, with some displaying relatively high percentage frequencies. Within the 286 points (a total of 1 144 quarters) sampled, *Dichrostachys cinerea* without doubt dominated the <1 m height category, whereas in the 1-2 m category all three species displayed more or less the same percentage frequencies. The >2 m height category was particularly dominated by *Acacia nilotica,* although the other two species also featured strongly compared to the other height classes. If the percentage frequencies of species in Table 1 and 2 are compared to each other, it becomes quite clear that where species occurred at relatively high frequencies in the woodlands the opposite was true in the case of the woody clusters. Only the three woody pioneer species occurred at high frequencies in both woodlands and clusters. Various species found in the woodlands (total of 29 species) were absent from the clusters (total of 19 species), whereas only three species found in the clusters were absent from the woodlands.

Aerial photography interpretation

An illustration of the extent of bush encroachment in the two study areas is given in Figure 3 & 4. These photographs display more or less the same areas of the respective farms for the three different dates. All three quadrats, *i.e.* sites 1, 2 and 3, displayed clear signs of bush encroachment (Figure 5). The average percentage woody cover for all three sites for the period 1961 was 4.2%, which increased by 176% to an average of 11.6% by 1973. By 1990 the average percentage woody cover was 16.6%, which is an increase of 43% of the 1973 value. If the total woody plant cover is expressed in terms of the grass cover of 1961, then the average percentage woody cover for the 30 year period was 22% for site 1, 13% for site 2 and

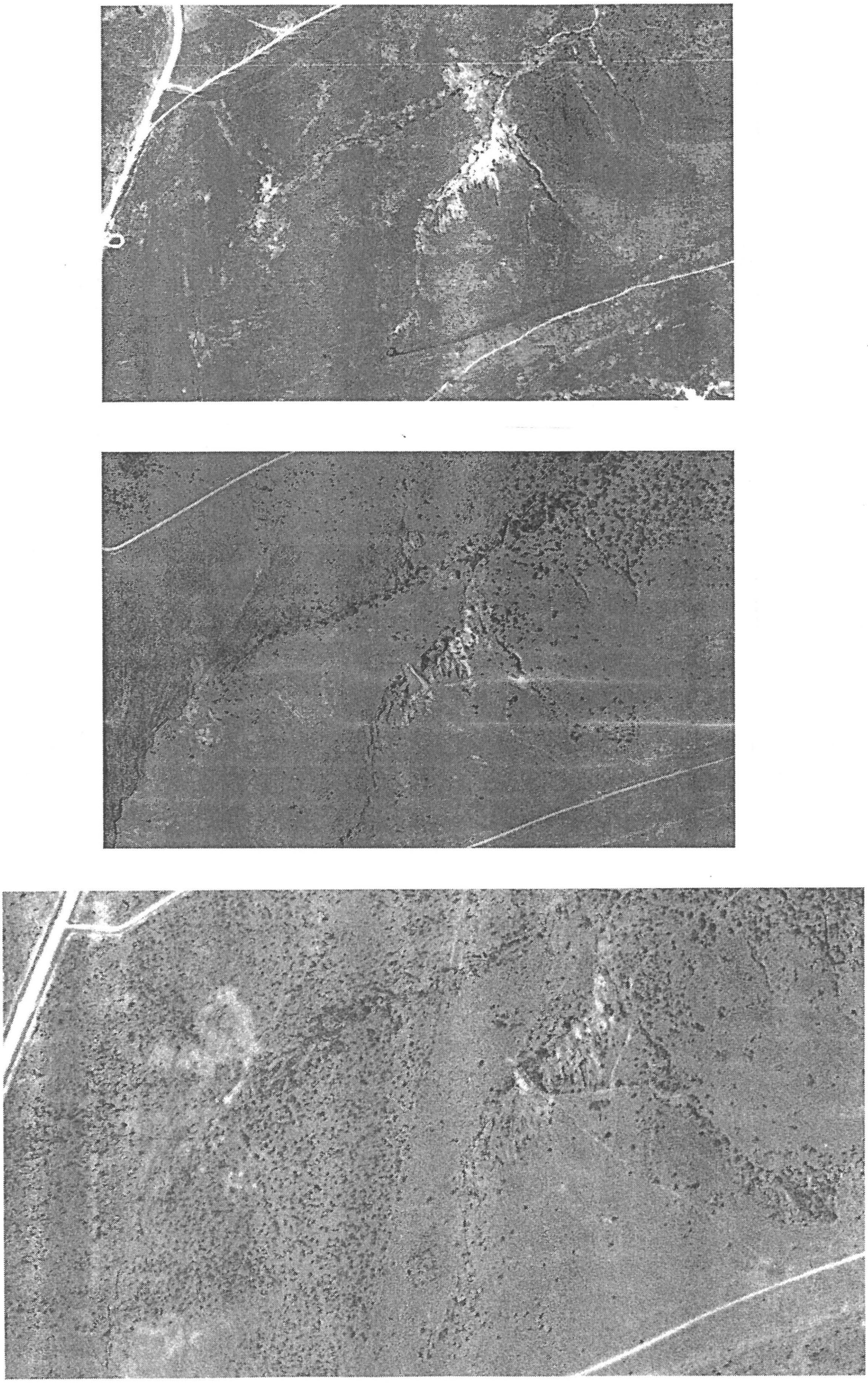

Figure 3 The three photographs from top to bottom show the same area, at different scales, for the periods 1961, 1973 and 1990 respectively. Clear signs of bush encroachment are visible, with the left-hand half being most affected.

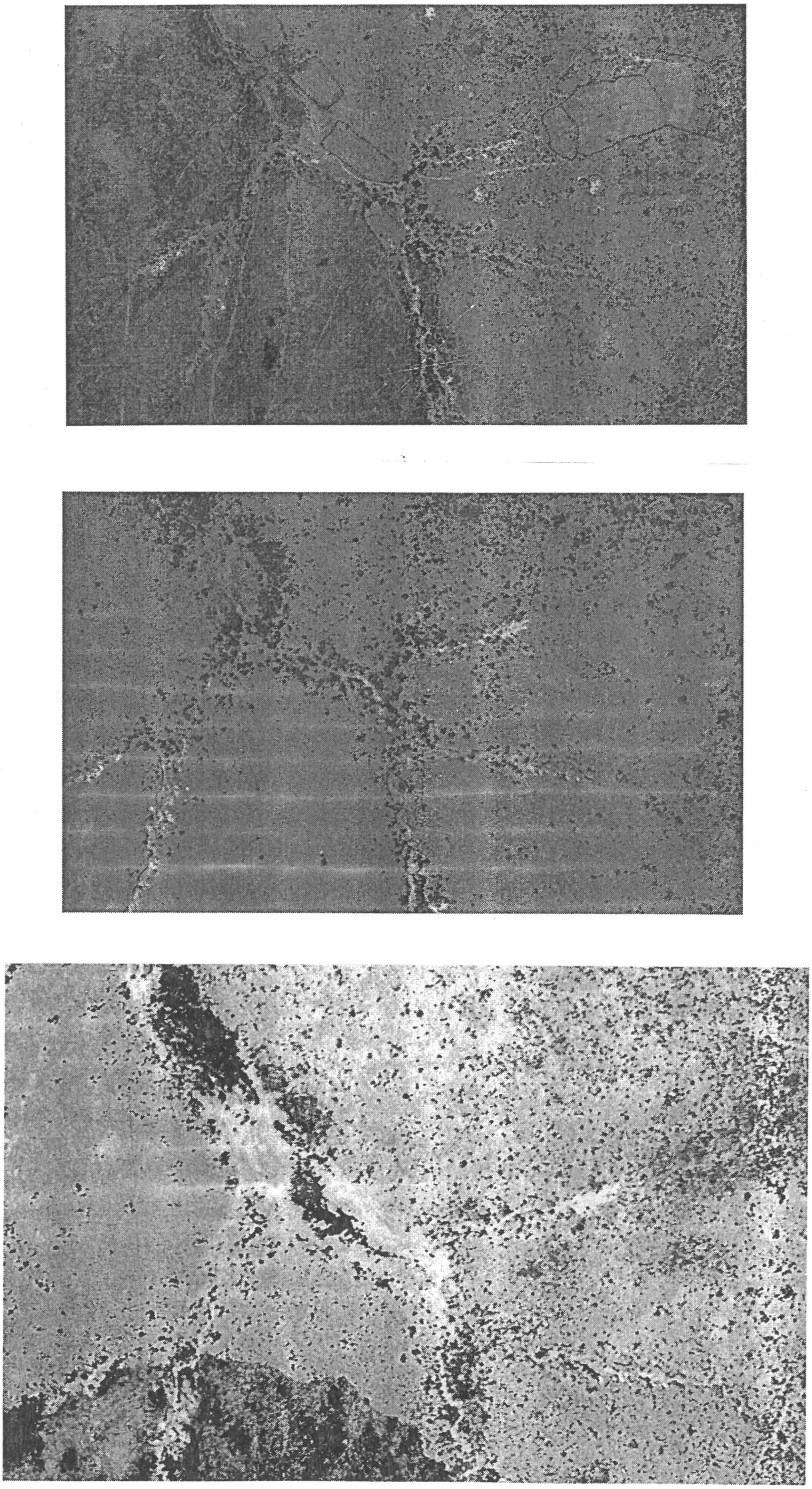

Figure 4 The three photographs from top to bottom show the same area, at different scales, for the periods 1961, 1973 and 1990 respectively. Note the degree of bush encroachment on the right-hand side of the photograph.

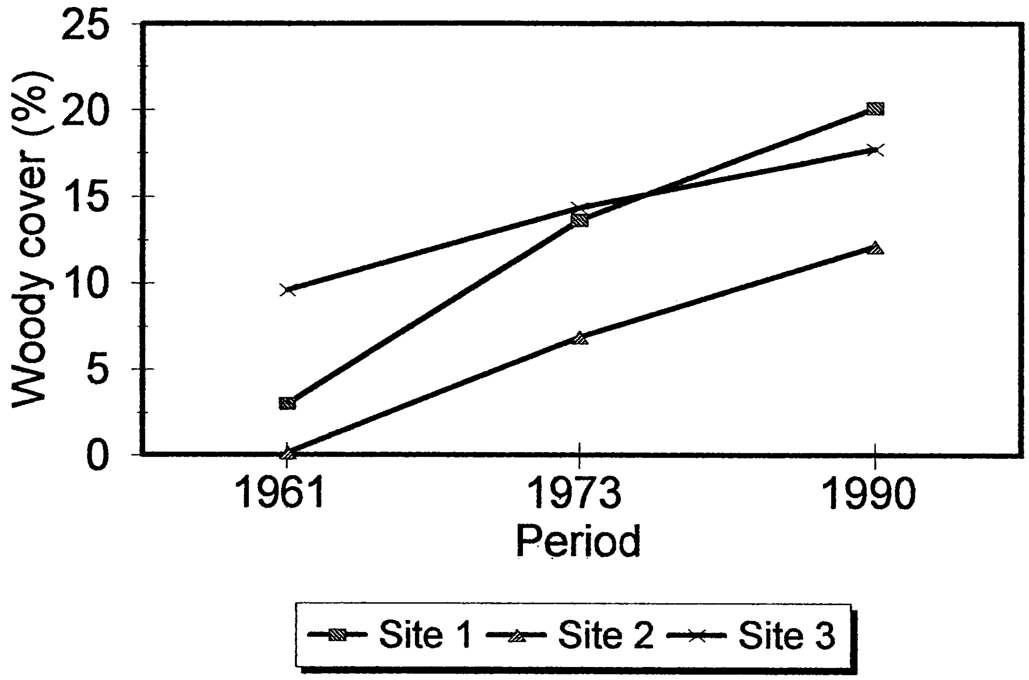

Figure 5 Changes in percentage of area covered by woody species for the three respective sites selected on the aerial photographs as determined for the three different periods 1961, 1973 and 1990.

20% for site 3. The same values averaged over the three sites for each date were respectively 4.7%, 20% and 30%.

After the areas of all 30 point clusters had been determined, they were subsequently allocated to one of four different size classes (Table 3). The data indicate the average area and standard error for the three specific dates. All classes, with the exception of one, display increasing cluster areas for the entire 30 year period. The class showing a decline in cluster area between the period 1961-1973 only consisted of one point cluster, explaining the zero standard error. This drop also gets clearly reflected by the negative absolute and relative growth rates for the 1961-1973 period (Table 4). An inspection of the areas of all 30 point clusters revealed a general increase in size, although quite a large number of clusters indicated declines especially for the 1961/1973 period. Declines were usually associated with disintegration of clusters, whereas increases were attributable to the coalescence of woody plants or clusters. The two-sample analysis conducted on the data of Table 4 showed that only the absolute and relative growth rates of size class 1 differed significantly (α=0.05) when the 1961/1973 figures were compared to those of 1973/1990.

Table 3 Mean cluster size and standard error of 30 point clusters allocated to four different size classes as calculated for the three periods. Zero variances indicate that only one cluster was recorded for that specific class.

Size classes (m^2)	Mean cluster size (m^2)		
	1961	1973	1990
1 < 50	29 ± 13	87 ± 38	90 ± 75
2 50 - 100	68 ± 7	112 ± 85	134 ± 74
3 100 - 150	122 ± 18	139 ± 22	142 ± 7
4 150 - 200	171 ± 0	151 ± 0	154 ± 0

Table 4 Absolute and relative growth rates of point clusters as calculated by two formula (Hunt 1978). Negative values indicate decreases in size.

Size classes (m^2)	Growth rate (m^2/yr)		Relative growth rate (m^2/m^2/yr)	
	1961 - 1973	1973 - 1990	1961 - 1973	1973 - 1990
1 < 50	3.48 ± 3.41	1.11 ± 2.61	0.21 ± 0.44	0.01 ± 0.03
2 50 - 100	3.68 ± 7.04	1.27 ± 2.00	0.02 ± 0.07	0.02 ± 0.03
3 100 - 150	1.49 ± 0.38	0.16 ± 0.91	0.01 ± 0.00	0.01 ± 0.01
4 150 - 200	-1.62 ± 0.00	0.16 ± 0.00	-0.01 ± 0.00	0.00 ± 0.00

Discussion

Without doubt the most prominent species dominating the vegetation were *Dichrostachys cinerea, Acacia nilotica* and *A. tortilis.* These three woody species and in particular the first two are well known for their abilities of encroaching into grassland (Smith & Goodman 1987; Schlettwein 1994). The overwhelming majority of individuals which occurred in the open grassland patches between the woody clusters were of the above-mentioned species, emphasizing their pioneering characteristics. The fact that these individuals were small shrubs clearly suggests that the current grassland patches have only very recently been encroached. Although single shrubs were usually encountered, small clusters consisting of 2 - 4 individuals were not the exception. The recent encroachment by woody plants is further stressed by the presence of mainly smaller clusters and short distances between them.

It would appear that during the initial stages of cluster development, individuals of *Dichrostachys cinerea, Acacia nilotica* and *A. tortilis* invade open grassland patches. Such observations were also made by Smith & Goodman (1987) in Mkuze Game Reserve, who found that *Acacia nilotica* seedlings were restricted to open areas. The development of dune grassland into Secondary Dune Forest in the area between Richards Bay and the Mfolozi River, with mature *Acacia karroo* Woodland as intermediate stage in the succession, is also well documented by Weisser & Marques (1979). As above-mentioned shrubs increase in size, more individuals, either of the same or other usually bird-dispersed species, establish themselves around the nucleus plant. The first clusters are relatively small in diameter and are characterized by similarly smaller individuals and low numbers of species. It can be clearly inferred from the results that increasing height and stem and crown diameter of above-mentioned species affect cluster size and species richness. This implies that cluster diameter and species richness are a function of the sizes of *Dichrostachys cinerea* and the two *Acacia* species. However, according to the results, species richness is not affected by cluster diameter, which means that these two factors are not directly related to each other. Similar findings were reported by Archer *et al.* (1988) in the eastern Rio Grande Plains of Texas, where the honey mesquite (*Prosopis glandulosa*) was found to be invading the grassland. As the clusters increase in size, probably due to the absence of fire, coalescence with other clusters takes place, resulting in even larger clusters. The endproduct is one of large areas being occupied by open to closed woodlands with a well-developed grass layer found underneath the trees. It must be stressed here that no grass surveys were conducted, which means that no statements can be made on probable changes which might have taken place in the species composition of the grass layer. It can only be assumed that shade-tolerant species, particularly forbs, are replacing shade-intolerant grasses. This assumption is supported by San José & Farinas (1983) who found that in the *Trachypogon* savanna of Venezuela, the grass layer surrounding the formerly isolated trees was replaced by a herbaceous layer. They also found that so-called nurse trees seem to favour seedling establishment and that the harmful effect of shade on the grasses benefits the herbaceous layer typical of the groves (Archer *et al.* 1988). While clusters coalesce to form larger groves, with the pioneer species still dominant, other less prominent woody plants emerge. These plants only rarely develop into trees, filling the newly created niches beneath the trees. Conditions within the woody patches are more suitable for shade-tolerant species such as *Rhus pyroides, Maytenus heterophylla, Commiphora harveyi, Ziziphus mucronata* and *Diospyros lycioides* just to name a few. The fruits of these species are mainly dispersed by birds, which explains the sudden emergence thereof within the woody patches.

When considering the species composition and height distribution of the woody component of the woodlands, it becomes clear that higher numbers of species were found, most of them falling into the lower height classes (<1 and 1-2 m). However, all three height classes were still dominated by *Dichrostachys cinerea, Acacia nilotica* and *A. tortilis*. This was especially the case in woodlands away from drainage lines, where soil moisture and nutrient status were assumed to be less optimal. Although the woodlands along drainage lines, where soil conditions are more suitable, were also essentially dominated by the above species, larger trees were more frequently encountered, some of them being *Acacia sieberiana*. Unfortunately, no distinction has been made between these two woodland types, although it is assumed that the moister woodlands represent more mature phases within the successional process (Archer *et al.* 1988).

The approximate scale of 1:10 000 was found to be suitable for the aerial photographic interpretation. Individual trees and shrubs were clearly distinguishable, enabling the estimation of surface area. Although the scale differences between the various photographic dates caused some minor problems initially, these were overcome by making use of various points on the images for which the co-ordinates were determined and thereby enabling the calculation of the pixel-area for each image. When the raster images, which were created for each of the three selected sample areas, had been georeferenced, they displayed some degree of distortion. However, since woody cover was expressed as percentage in terms of the entire area of the specific sample quadrat, the distortion effect was cancelled out. Problems with scale differences between aerial photographs were also experienced by Norton-Griffiths (1984), who studied the vegetation dynamics of the Serengeti. It seems that whatever problems may be encountered with historical aerial photographs, they will always remain a good reference to what conditions were like in earlier days. The changes in woody cover observed on the photographs were so extreme, that any type of analysis would clearly have pointed out what has actually happened. Here, site 2 is a good example, with only 0.13% of the plot covered by woody plants during 1961 and ending up with 12.11% in 1990. It can be inferred from the results, that major changes in woody cover have occurred during the 1961-1973 period, but less so for the 1973-1990 period. These changes must be seen against the background of the differences in length of the two periods (12 and 17 years respectively) as well as the fact that the sixties were characterized by a dry cycle. If the growth rates and in particular the absolute growth rates of the woody clusters are compared to each other, then a similar picture emerges. Although the various growth rates for the 1961-1973 period do not differ significantly (α=0.05) from those for the 1973-1990 period, except for those of class 1 which do differ significantly, visual differences can nevertheless be detected. Once again this emphasizes the rapid increase in woody cover which has taken place over the first 12 years since 1961. In some cases where extreme increases in cluster areas were observed, these could be ascribed to the coalescence of two or more clusters. Where decreases were recorded, these could be ascribed to splitting, caused by die-offs of individual plants within the clusters. Various reasons can be put forward to explain bush encroachment into what has been previously known as grassland. Whether this process can be ascribed to mismanagement or droughts is something to be investigated. The intricate processes involved in vegetation dynamics are not always well understood, with many studies (Kelly & Walker 1976; Connell & Slatyer 1977; Walker 1980; Norton-Griffiths 1984; Belsky 1985; Smith & Goodman 1987; Archer *et al.* 1988; Belsky 1994, 1995; Dublin 1995) having dealt with this issue in an attempt to gain more insight into the complexities. However, most of these studies indicated that no one system is in a stable state but rather fluctuates between grassland dominated vegetation on the one hand and woodlands on the other. The primary determinants of landscape patterns in African savannas seem to be soil moisture, geomorphology, edaphic properties (Cole 1986; Belsky 1990) and climate (Scholes 1986). Yet, the overriding effect of fire and herbivory are often witnessed by the way certain game reserves and national parks, situated in savannas, have been shaped (Buechner & Dawkins 1961; Agnew 1968; Laws 1970; Leuthold 1977; Pellew 1983; Dublin, Sinclair & McGlade 1990).

It has also been realized in this study that, although no investigations were conducted to assess the influence of herbivory, rainfall, temperature, soil moisture, nutrient contents, texture and structure on the vegetation dynamics, these are the primary regulative factors. This has been substantiated by the various studies which have dealt with these issues (McNaughton 1983; San José & Farinas 1983; Smith & Goodman 1983; Friedel 1987; Belsky 1994; Brönn 1994; O'Connor 1994; Zacharias 1994). Therefore, it can only be suspected that a very low fire frequency concomitant with overgrazing by cattle, gave rise to the bush encroachment described in this paper. According to Archer (1990), increased grazing pressure and reduced fire frequency and intensity lead to succession from a grassland to a shrubland domain. Overgrazing results in lesser combustible material being available and reduced competitive capabilities of grasses, enabling woody seedling establishment. Archer (1990) suggests that, in order to prevent continued initiation and expansion of woody clusters, seed dispersal of woody plants, particularly by livestock, must be reduced, the competitive capacity of grasses be enhanced, and periodic use of fire be enabled. The extent to which drought conditions have contributed to the bush encroachment problem in the two affected areas is as yet unclear. It is also not clear whether any definite changes in species diversity have occurred since 1961 apart from the increase in woody species richness witnessed in the woodlands. However, landscape diversity can be maximised to support a greater diversity of plant and animal species (Fulbright 1996). This can be achieved by changing the vegetation configuration in the form of woody plant control and requires managerial inputs which are aimed at maintaining the selected landscape architecture.

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CHAPTER 6

A brief overview of the origin, management and conservation of, and research on the grasslands of South Africa

A brief overview of the origin, management and conservation of, and research on the grasslands of South Africa

Introduction

The often ignorant attitude towards grasslands, particularly in South Africa, has paid it's price in terms of losses of large grassland areas and veld degradation, the latter being clearly manifested in changes in plant species composition and decreases in vegetative cover and productivity (Tainton 1981). One such an example is the large-scale intrusion of once pure grassveld of the eastern Cape and southern Free State by secondary Karoo dwarf shrubland, which is mainly ascribed to poor land management practices (Acocks 1953, 1988; White 1983). Major developments have taken place within the grassland biome since the beginning of this century, including large-scale urbanization and industrialization (Mentis & Huntley 1982). This has led to the establishment of large metropolitan and other urban areas as well as mining and agricultural activities, the latter in particular having reshaped and altered the grasslands of southern Africa.

It is argued that recent changes in the vegetation are widely ascribed to poor grazing practices (Werger & Coetzee 1978), incorrect use of fire and clearing of woody plants (Acocks 1988; Werger 1983a). Retrogression in grasslands can primarily be attributed to over-utilization due to overstocking. According to Menke & Bradford (1992), range ecologists generally agree that the demise of perennial bunchgrasses in both the intermountain and California rangeland systems can be attributed to the combination of high stocking rates of domestic livestock, plant introductions and periodic droughts. The above-mentioned developments have taken place amidst a lack of detailed knowledge on the phytosociology, let alone the dynamics, of grasslands. Some of the few studies having dealt with the origin and evolution of grasslands are those of Werger (1978), Clayton (1981, 1983), Meadows (1985), Scott (1989), Ellery & Mentis (1992) and Meadows & Linder (1993), whereas others discuss certain vegetation types only or the general vegetation of southern Africa (Van Zinderen Bakker & Werger 1974; White 1981, 1983; Van Zinderen Bakker 1983; Werger 1983b; Meadows & Meadows 1988).

Of the earliest accounts dealing with the vegetation of South Africa are those of Bews (1916, 1918), Pole-Evans (1936), Adamson (1938), Irvine (1941) and Pentz (1949). These were the first studies to shed some light on the classification and distribution of vegetation types. After these followed the first detailed and complete vegetation classification for South Africa including a vegetation map, which was conducted by Acocks (1953). This description of the various veld types of South Africa, turned out to be a very useful and frequently quoted reference for ecologists and agriculturalists.

Despite the pioneer work conducted by these scientists, little was known about grasslands until very recently (Meadows 1985), when the Grassland Biome Project was initiated in the 1980's. Since then, huge data sets have been accumulated, dealing primarily with the classification and description of grassland communities. A large number of publications resulted from these studies, many of them forming part of dissertations and theses (e.g. Bredenkamp 1975; Scheepers 1975; Bezuidenhout 1988, 1993; Bloem 1988; Turner 1989; Kooij 1990; Breytenbach 1991; Du Preez 1991; Matthews 1991; Smit 1992; Coetzee 1993; Eckhardt 1993; Fuls 1993; Myburgh 1993). These studies also partially contributed to the new vegetation map of South Africa compiled by Low & Rebelo (1996). Most of these publications dealt with the vegetation of certain areas, each one representing a smaller part or building stone of a larger picture, *i.e.* the entire grassland biome. Eventually, the end-product will take the format of a comprehensive syntaxonomical synthesis, depicting the distribution of the different vegetation types within the grassland biome. This ultimate synthesis will not necessarily replace Acocks's veld types but will instead use the latter as a basis amongst others to enable further refinements.

Acocks (1988) recognised 31 grassland types of which 13 were 'pure', considered to be climatic climax grasslands, and eight were 'false' grassland types, interpreted as fire-climax grasslands. These grassland types are currently in a process of being subdivided into further units, resulting in a much higher number of distinct recognized 'communities'. These communities were subsequently lumped together to form the vegetation types described by Low & Rebelo (1996).

This chapter aims to present a brief discussion on the grasslands of South Africa by dealing with the subjects origin and evolution, management, research and conservation. Due to the close relationship between grassland and savanna, these two will often be treated together, especially in the discussion on the origin and evolution. These issues will be discussed within a broader international context. The current status of grasslands will also be looked at as well as some speculations made for the future.

Origin and evolution of grasslands

Although much uncertainty exists on the origin of grasses as such, general agreement suggests that they are related to the Commelinales and the Flagellariaceae in particular (Clayton 1981). The most likely relatives seem to be found in tropical forests. However, the future of the grasses lay not in these forests but in the zone between forest and desert, the so-called savanna.

The development of the grassland ecosystem is characterized by three main phases. During the first phase, which was associated with the Paleocene, grasses were of little significance within the closed rainforests but became more prominent and important as they established themselves under the canopies of marginal woodlands (Clayton 1981). From here on, the grasses moved into progressively drier and more open habitats, occupying the niches underneath the canopies of the tropical woodland and bushland. Fire played an important role during this phase, participating in the formation of the savanna physiognomy. The various fire-resistant features displayed by savanna trees, suggest that fire has for a long time been part of the savanna system.

The second phase of development was characterized by the introduction of herbivores and the development of a symbiotic relationship between the latter and grassland. By this time, grassland had emerged as a vegetation type and was undergoing further modifications.

The association of the grasslands with man constituted the third phase, during which the former were changed and adapted to meet man's needs.

Fossil records indicate that grasses were already abundantly present during the early Tertiary, the time at which the continents were starting to drift away (Clayton 1981). It is suspected that there were certain routes along which seed dispersal could take place between Africa, Eurasia, North America and South America in the first half of the Tertiary. A direct temperate climate connection existed between South America, Antarctica and Australia until the Eocene, whereas South Africa and Antarctica were only parting by late Cretaceous. The major taxa were primarily associated with different worldwide climatic belts, with most of them being more or less sympatric in the tropics. The Pooideae, however, differs quite strongly from the other taxa by having a predominantly north temperate distribution, whereas the Arundinoideae displays a southern subtropical pattern.

According to Meadows (1985), the grasslands and savannas of the world represent a biogeographical enigma, which is expressed in the following two statements: "Perhaps of all vegetation the savanna is the most difficult to define, the least understood and the one whose distribution is the most subject to controversy" (Cole 1960) and "Knowledge of the origin of grasslands generally is fragmentary, uneven and often controversial" (Singh *et al.* 1983). Even more problematic is the issue of defining savannas and grasslands, since both these biomes consist of a strongly developed herbaceous layer which is dominated by grasses. Even when describing vegetation it is often difficult to distinguish between different savanna and grassland types. One can argue, for example, whether the pure grasslands of the highveld of South Africa should be regarded as tropical savannas (Misra 1979), since they are not strictly tropical but rather of a temperate variety (Simmons 1982). Some of the temperate grasslands covering considerable areas of the northern hemisphere are the Great Plains of North America and the Eurasian Steppelands. Although insufficient precipitation is the limiting factor in these areas inhibiting forest development, many observers claim that human activity over the last few thousand years has actually resulted in the temperate northern hemisphere grasslands we know today. The savannas are a complex of various vegetation types, including grasslands to closed woodlands, in which the ratio of woody to herbaceous components can vary widely. A broad definition would describe savannas as a tropical formation with a continuous ground-layer dominated by grasses (Meadows 1985). This includes the deciduous woodlands of North, East, Central and Southern Africa, as well as equivalent formations in South America and South-East Asia. A similar definition for savannas is given by Huntley & Walker (1982), although they add that fire-tolerant woody plants may occur at varying densities from widely scattered individuals to closed woodlands.

Various theories exist about the origin and development of grasslands and woodlands of southern Africa, being based on climatic, edaphic, geomorphological, anthropogenic and grazing factors. However, the major vegetation changes which occurred during the Quaternary in southern Africa were primarily caused by changes in temperature, and the amount of precipitation and seasonality of the rainfall (Van Zinderen Bakker 1978). Dramatic temperature decreases, influx of polar air and winter rainfall caused the replacement of the temperate grassland of the high altitude inland plateau by alpine grassland, whereas the Cape coastal plain was devoid of forest and covered by grassland. During warm interglacial times Karoo and desert sand dunes moved into the present grassland plateau, while certain elements of Karoo vegetation even invaded the Cape coastal plain. It is generally accepted that the grasslands and savannas, which cover the largest part of South Africa, are much younger than the Cape and Karoo floras (Levyns 1962). Although climate is considered to act as an 'umbrella' factor which is largely responsible for present day distributions of vegetation types, the effect which Quaternary climate had, must always be kept in mind (Meadows 1985). While climatic factors were and still are of paramount importance in the shaping of grasslands and savannas (see also Ellery *et al.* 1991), edaphic, geomorphological and anthropogenic factors also played vital roles, making the whole evolutionary and developmental processes appear even more complicated. The true grassland of the Highveld plateau of South Africa may indeed be the natural climax vegetation due to certain climatic conditions, but the treelessness of the landscape may also partially be the result of the combined effects of grazing and burning (Cole 1966). The origin of the prairie of North America can be similarly explained. Whereas the notion of the fire origin of the grassland may be dismissed, the restriction of tree growth in transitional country has actually been caused by fire (Malin 1953). Bredenkamp & Van Vuuren (1987) suggest that the grassveld of the Pietersburg plateau is largely the result of relatively cool climatic conditions (see also Coetzee, Bredenkamp & Van Rooyen 1994). This statement is based on observations of open savanna vegetation and bush clumps in sheltered localities which are as much exposed to fire as the grassveld areas. Moll (1967) distinguishes between primary and secondary grasslands, the former being the result of climatical conditions and the latter being the product of veld management practices, including the use of fire. The tall *Hyparrhenia hirta* Grasslands, which are so characteristic of large parts of KwaZulu-Natal, are typical secondary grasslands and the consequence of selective grazing, veld disturbance and old cultivation (Moll 1967). According to O'Connor & Bredenkamp (1997), the distribution of the grassland biome is the result of the combined effect of climate, topography, fire and grazing. Climate is the overriding factor determining the extent of grassland, with fire and grazing being secondary determinants. However, the role of fire in maintaining grassland is greater in the wetter parts of the country than in semi-arid areas.

Management, research and conservation

Management

That human activities have worldwide dramatic influences on ecosystems are a fact which cannot be denied. The current distribution and arrangement of ecosystems are a direct and indirect result of man's activities, the latter in most cases being more detrimental than preservative over the long term. Changes in vegetation over periods of a century or less, like the eastward spread of the desert, the decline and retreat of tropical and montane forest and the replacement of tropical grassveld by bushveld in South Africa, cannot be ascribed to natural causes (Meadows 1985; Acocks 1988). The massive and large-scale felling of rainforests worldwide and the die-offs of large patches of temperate forests in Europe due to acid rain are just a few examples from other parts of the world where man's destructive activities can be witnessed. The problem is two-fold in that it causes the depletion of natural resources in the first place, which are so essential for human's survival, and secondly, it weakens the ecological processes which sustain life on earth (Meadows 1985). The symptoms of environmental degradation are mostly the same throughout the world. Increasing global population leads to increased pressure on natural resources which results in overgrazing and overcropping. The first signs of environmental deterioration to appear are those of reduced biomass and productivity, soil erosion, changes in species composition and structure, loss of indigenous plant species and invasion by potential encroachers and alien plant species.

It is accepted that those activities which are associated with agriculture have the most widespread and diffuse effect on the environment. One of the most important reasons for veld deterioration is continuous selective grazing, whereby palatable species are over-utilized to such an extent that they die off and either become replaced by unpalatable ones, as is usually the case in wetter parts, or leave bare patches behind which can be witnessed mostly in drier parts of the country (Acocks 1988; Bosch 1989). The disappearance of grass from the Karoo is ascribed to selective grazing and so is the development of the Ngongoni Veld of KwaZulu-Natal. According to Acocks (1988), the eastward spread of the Karoo has reached distances of up to 250 km in certain parts. Elements of Karoo vegetation have already reached the north-eastern Free State, with isolated individuals having even crossed the Drakensberg into the sourveld of KwaZulu-Natal. However, this theory, which states that the eastern Karoo has changed from a perennial grassland to a dwarf shrubland invading the grasslands of the southern Free State, is not accepted nor supported anymore. Various historical and photographic evidence and survey data refute this theory (Hoffman & Cowling 1990; Fuls 1993; Hoffman, Bond & Stock 1995). It is claimed that rainfall is the principal factor which strongly affects the balance between the grass and shrub components (Hoffman, Barr & Cowling 1990), with increased summer rain benefitting the grasses which increase at the expense of the shrub layer (Low & Rebelo 1996). Vegetation dynamic changes are very complex, even more so if interpreted in terms of rainfall and grazing regimes, and cannot be clearly understood unless long-term monitoring studies are conducted (Kellner 1994). The concerns about the dwindling grasslands were so far related to agricultural mispractices and mismanagement, but one should not forget the various developments which are taking place within this biome. Large pieces of grassland are transformed into residential areas, especially since the inception of the newly formulated housing policy. Although the industrial sector also has an impact on the grasslands, it is usually concentrated on smaller isolated areas. However, one of the biggest concerns is related to the timber industry. More and more grassland areas become afforested, especially the high rainfall grassveld types of the eastern escarpment. This concern has also been expressed by Matthews, Van Wyk & Bredenkamp (1993), who indicated that the grasslands of the north-eastern Transvaal Escarpment are under heavy pressure from the timber industry while supporting an extremely endemic-rich vegetation. Once these grasslands are sacrificed for afforestation purposes, they are lost forever. It is not only the diminishing grasslands which causes a lot of concern, but the change in vegetation also adversely affects available water resources (Nänni 1970a, b; Wicht 1971; Johnson 1988; Conley 1995) and the habitats of certain wild animals such as oribi (Rowe-Rowe 1988) and bushbuck (Rowe-Rowe 1989).

Research

While the grasslands were heavily impacted upon by the various activities mentioned above, little was done to understand the ecological processes involved in grasslands. Research in the grassland biome actually commenced with the publication of the Drought Investigation Commission report in 1923 (Tainton 1984). During the time when the report was compiled, the Commission realized that there was a general lack of information on the management of the different veld types. Since then, various organizations and institutions became involved in grassland research, such as universities, Department of Agriculture, Department of Forestry and the National and Provincial Nature Conservation Agencies. Unfortunately, however, much of the research was restricted to certain areas only, leaving large parts of the grassland biome untouched. Due to a lack of cooperation between research organizations, no specific goals were formulated to address the need for a better understanding of the structure and function of communities (Mentis & Huntley 1982; Tainton 1984).

Over the last two decades, many published and unpublished papers have seen the light, some of them forming part of theses and dissertations. Many of these papers dealt with the phytosociology of grasslands *i.e.* research which could be considered as part of the inventory phase. Although much work still needs to be done to complete the inventory phase, more advanced specialized studies, some of which are based on the results of inventory studies, have produced excellent results so far. Most of the earliest studies were undertaken in the grassland biome of KwaZulu-Natal (Bews 1912, 1931; Pentz 1949; Bayer 1952; Killick 1958,1963; Wells 1963; Ross 1972, 1973; Scheepers 1975). Although few other localized studies were also conducted in other parts of the grassland biome outside KwaZulu-Natal, it was only with the onset of the Grassland Biome Project, that all the other grasslands also started receiving attention. One of the interdependent components of this research programme is, "the analysis, description and interpretation of the characteristics and distribution of grassland ecosystems across gradients of climate, geomorphology and soils within South Africa" (Mentis & Huntley 1982). Many of the studies are consequently of a phytosociological nature, having used the approach and methodology of the Zürich-Montpellier School of Phytosociology. The results derived from the studies are currently incorporated into a comprehensive syntaxonomical synthesis of the entire grassland biome of South Africa. This thesis is one of several contributing to the synthesis. The various phytosociological studies made primarily use of land types and terrain units (Land Type Survey Staff 1986) for the stratification of study areas. The derived plant communities are thus indicative of different combinations of soil types, climatic conditions and topographical positions.

There are many scientists who have their doubts about the value of descriptive studies, often asking what contributions these studies actually make towards science. The negative attitude towards these studies is very apparent from the various comments of scientists having refereed papers which were submitted to scientific journals. Although the actual reason for this attitude is not very clear, it is suspected that the relevant referees either do not have the necessary knowledge or understanding of the approach and methodology being followed or they have a misconception of what vegetation ecology and veld management is all about. For the management of a farm based on ecological principles, it is important to know what kind of vegetation units or plant communities are found in the area and how they are distributed. The delineation of vegetation units forms an important and integral part of management plans, since each unit needs to be managed separately. Special care can consequently be given to those areas which are extremely sensitive or have any other conservation value. Consolidation of different vegetation units into one management unit could be detrimental to such units, in particular to those which have a high percentage of palatable species and therefore tend to experience higher degrees of utilization by livestock.

Conservation

According to Low & Rebelo (1996), only about 2.23% of the grassland biome is conserved. This means that the proportion of grasslands conserved contributes only 0.58% to southern Africa's total of 5.22% currently conserved. Most of these areas are included in national parks, provincial reserves and state forests. Of the 31 grassland veld types occurring in South Africa, 18 are not represented in any conservation areas (Mentis & Huntley 1982). Low & Rebelo (1996) recognized 15 grassland vegetation types of which three are neither partially nor entirely included in conservation areas. Meanwhile, increasing pressure is being exerted on the natural resources and the chances of acquiring additional conservation areas are getting slimmer. The success of conserving remaining relatively undisturbed 'islands' between oceans of developed areas is bound to be of short duration due to the 'island biogeographical effect', in which case the long-term isolation adversely affects the gene pool of organisms occurring within the conserved areas (Mentis & Huntley 1982). Without any buffer zones around the protected 'islands', impacts from surrounding developed areas will hamper conservation efforts. The South African Natural Heritage Programme of the Department of Environmental Affairs and Tourism is an attempt whereby ecological sensitive areas of privately-owned land are set aside to allow for ecological sound management (Wahl 1995). However, as mentioned above, the chances of survival of such areas in the far future are highly dependent on the condition of the surrounding environment. What South Africa desperately needs now, is a change in the approach and attitude towards conservation, namely "from its present focus on the 'islands' to the extensive 'oceans' in between" as quoted from Mentis & Huntley (1982). Private landowners, in particular farmers, should be encouraged to apply management strategies which are aimed at promoting and maintaining species diversity and system resilience. In order to apply such strategies, it is essential to have proper veld knowledge, including issues such as the resilience of systems, so that landowners will be aware of the type and degree of changes which can be tolerated by the systems before undesirable conditions are caused. The conservation of biodiversity is justified by the fact that the latter promotes stability (Tilman & Downing 1994). These two authors have found that diverse plant communities have a higher resilience and are consequently more resistant to major droughts. Not only do we need to apply ecologically sound management strategies to the 'inbetween oceans', but veld rehabilitation should definitely form part of the whole conservation attempt. Many rehabilitation successes have been achieved by means of applying certain remedial strategies. In the case of grasslands, the manipulation of the movements and stocking rates of livestock and of livestock ratios, the correct placing of fences and the judicious use of fire have been successfully applied to achieve an improvement in range quality and quantity (Mentis & Huntley 1982). A reassessment of the potential use of the grasslands of South Africa needs to be done, where different types and degrees of utilization and development are to be allowed in specific areas (Tainton 1984). During the evaluation, various factors have to be considered, including climatic conditions such as rainfall and temperature, soil characteristics, topography, erodibility, and existing infrastructure and urban development. The aim of such a reassessment is to avoid developments in areas which are unsuitable for that specific purpose. Areas which are found unsuitable for agricultural or any other development purposes, would automatically fall into the conservation category. The whole reassessment process will enable private landowners to compile management plans which give the necessary attention to different vegetation types. It is therefore emphasized again that qualitative and quantitative assessments need to be done, by way of vegetation studies which also reflect habitat factors, to determine the conservation value of an area.

Conclusions

The discussion of the origin and evolution of grasslands clearly reveals that the distribution of the grasslands over the last hundreds of thousands of years was never stable. Large-scale changes occurred throughout the country, which can primarily be ascribed to continuously changing long-term climatic conditions. Although the southern African grasslands, as we know them today, were mainly shaped by the climate which prevailed over the southern tip of the African continent, other factors also played an important role. Such factors were fire, topography, geology, soils and anthropogenic activities. However, the impact which anthropogenic activities have had in the recent past, is of such a scale and nature that it can be considered as the single most important contributor towards major changes in species composition and vegetation cover. These activities are sometimes aggravated by droughts, the combined effect of which is often disastrous. Many of the droughts experienced in the country, are also largely amplified by human activities. Tainton (1984) refers to various authors who attribute vegetation change to bad land-use practices. One may start wondering what will happen to our precious grasslands if current practices continue to be applied. Although Acocks's (1988) hypothesis concerning the advancement of the Karoo into the grassland biome may be disproved (Hoffman & Cowling 1990; Fuls 1993), it nevertheless contains some truth about the deteriorating state of certain grassland veld types. Grasslands may be resilient enough to recover from severe drought conditions especially after having experienced periods of high rainfall. However, persistent overgrazing by livestock will ultimately weaken the vitality of grasses and adversely affect ecological processes, leading subsequently to a sharp decrease in the sustainable biomass production of the grass layer. This could have dramatic consequences for the beef industry.

The increasing pressure on the agricultural sector to produce even more food in order to be able to feed an increasing number of people will be to the detriment of the environment. Preserving and maintaining biodiversity and other aesthetic values will be considered more and more as luxury commodities which are not essential for the survival of human populations. In California, for example, most federal lands must now be managed according to multiple-use objectives, with some being even contradictory (Menke & Bradford 1992). Such uses are commodity production, maintenance of biodiversity and aesthetic values. In South Africa, some changes to existing land-use practices should even include the possibility of using the veld for game production (Walker 1976; Mentis 1979). To combine cattle and game farming into one system would, indeed, increase the yield of many farms here in this country. According to Menke & Bradford (1992), it is essential to build rangeland management on the following three main goals, *i.e.* livestock production, management of game animals for recreational use, and conservation of biological diversity. If biological diversity goals are met, the rest of the system uses will automatically succeed in achieving their goals as well. Although the diversification of land use systems would mean more effective use of all available natural resources, the various uses will have to be measured in terms of the achievement of biodiversity goals.

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CHAPTER 7

CONCLUDING REMARKS

The ecological studies conducted in the grasslands of northern KwaZulu-Natal produced various results, complying with the objectives set in the introduction. The major objective, however, was the identification, classification and description of plant communities, forming the bulk of this thesis. This included determining the conservation status of certain plant communities or areas, using specific criteria. Subsequent to these followed a study investigating the processes involved in bush encroachment in an area which appeared to be grassveld 30 years ago. One of the chapters presents a brief overview of the grasslands of South Africa in general, dealing with issues such as origin, evolution, research, management and conservation. A complete list of all species recorded within the study area is attached as an appendix, the species being arranged according to the family sequences of Arnold & De Wet (1993).

The analysis of the phytosociological data resulted in the identification of a large number of plant communities, which were then classified, described and related to environmental factors. It was decided that the vegetation classification should follow the code of phytosociological nomenclature (Barkman *et al.* 1986) since this was the first phytosociological study, following the Braun-Blanquet approach, to be conducted on the grasslands of northern KwaZulu-Natal. This formal classification serves as a basis into which subsequent classifications of grasslands from other parts of KwaZulu-Natal will be incorporated. However, the results of this study will further be used as part of a comprehensive formal syntaxonomical classification of the whole of the Grassland Biome of South Africa.

The results of the synthesis of the phytosociological data showed a strong correlation with the topography of the study area, with altitude (and associated climatic conditions) being a principal factor in determining the distribution of plant communities. Four major vegetation types were clearly distinguished, differing from one another on the basis of physiognomical and floristical characteristics. However, the classification down to community level proofed to be more complicated as differentiating factors became more vaguely defined and communities more closely related. The different plant communities found within these major vegetation types were nevertheless recognizable and correlated with various combinations of environmental factors.

It has also become clear from the study that certain grassland communities, in particular those of the lower-lying altitudes, display strong elements typical of savanna vegetation. Although these are recognised as grasslands (Acocks 1988), they have the potential of changing to savanna vegetation. This explains the often abundant presence of woody components within certain grassland communities. Depending on the kind of management applied, these can be changed to thickets and woodlands or relatively pure grasslands.

Although the phytosociological part of this study served mainly the identification, classification and description of plant communities, a more updated species list could also be compiled for the grasslands of northern KwaZulu-Natal. The results obtained by the phytosociological study are not only of importance to the academic world, but also to farmers, conservation agencies and other managers, including those from the timber industry. The new vegetation map of South Africa, Lesotho and Swaziland (Low & Rebelo 1996) is partially based on these results, making especially use of the numerous other phytosociological studies conducted within the Grassland Biome to verify the borders of grasslands as delineated by Acocks (1988).

Although plant communities form part of vegetation gradients, they reflect different environmental conditions in terms of soil types and depths and topography and consequently should be managed as entities. The delineation of extremely large management units, often comprising several such entities, usually leads to excessive patch selection and weakens the grass layer (Fuls 1992). The end product will be one of bare soil patches developing within the grass layer and deteriorating to such an extent that recolonization by pioneer species is prevented.

The study on bush encroachment revealed some interesting facts, which were also known from other parts of the world where relatively similar environmental conditions prevail.

Although aerial photographs suggest that the areas encroached by woody plants were originally grassland, it is not known whether this is a long-term dynamic process where grasslands are changing into woodlands and *vice versa*. Such findings have been made by various researchers in eastern Africa (Leuthold 1977; Belsky 1985, 1990, 1995; Dublin 1995), stating that grassland and woodland ecosystems are continuously changing from one extreme to the other over several decades. Since the area affected by bush encroachment is situated on the periphery of Natal Central Bushveld (25) and Natal Lowveld Bushveld (26) (Low & Rebelo 1996), it can be expected that similar ecosystem changes, as found in eastern Africa, occurred here. However, the impact which humans had on the vegetation and to what extent this has lead to bush encroachment is not known. Also, whether the woodlands will return to grasslands again within the next few decades is debatable.

The chapter, consisting of a brief overview of the grasslands, was intended to put the Grassland Biome of South Africa into a new perspective, particularly with regard to the conservation issue. It appears that scientists are relatively certain about the origin of the grasslands of southern Africa. In short this means that they agree that the grasslands were always unstable for the last thousands of years, being primarily shaped by climatic factors and secondarily by topography, geology, fire and anthropogenic activities. However, more recent changes like those observed in the eastern Karoo and within the grasslands of the southern Free State drew much attention with divergent opinions on the actual causes thereof. The theory of vegetation changes in the eastern Karoo and southern Free State has now been refuted by Hoffman & Cowling (1990), who also stated that the potentially dynamic seasonal responses of grasses and shrubs must necessarily be acknowledged. This means that seasonal changes may occur, with shifts from grass dominated vegetation to Karoo shrubs and *vice versa*, depending mainly on the rainfall. Such changes in the vegetation may persist for decades, correlating with rainfall and other climatic cycles. Although the dynamic nature of vegetation must be fully acknowledged and natural processes be allowed to occur with regard to changes, it is important to distinguish between natural and unnatural changes. Rainfall variation may well strongly influence perennial grasses and shrubs, but grazing treatments may further influence the rate and extent of change (O'Connor & Roux 1995). The effect of grazing treatments on longer-lived plants only really becomes important over a longer time period. Vast stretches of grassland have already been degraded to such an extent that they cannot even be reclaimed by proper management strategies. In addition to this, only 2.23% of the Grassland Biome is currently under conservation (Low & Rebelo 1996). As the Grassland Biome is considered to be one of the most important biomes from an agricultural point of view, necessary steps will have to be taken to prevent any further degradation or losses of relatively undisturbed grasslands.

SUMMARY

Vegetation ecology of the northern KwaZulu-Natal grasslands

by

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This study was conducted in the grasslands of northern KwaZulu-Natal, an area comprising approximately 14 366 km². The area is relatively heterogeneous in terms of environmental attributes and vegetation, which is reflected in the number of physiographic regions and land types. The primary factor causing this heterogeneity is the topography of the area, with altitudes ranging from as low as 750 m to a considerable height of 2 290 m. Rainfall figures and other climatic factors are closely related to the variations in topography, resulting in a large number of plant communities encountered.

The primary objective of this study was to present a complete identification, classification and description of the plant communities of northern KwaZulu-Natal grasslands. The second objective was to compile a syntaxonomical and synecological synthesis from the results obtained by the phytosociological study. The conservation status of plant communities and other areas was also determined, making use of criteria such as species richness, rarity of species and naturalness, the latter referring to the healthiness of the environment. The fourth objective was to investigate the processes involved in bush encroachment in an area known to

be grassveld 30 years ago. The fifth and last objective was to present a brief overview of the grasslands of South Africa, concentrating on issues such as the origin and evolution, management, research and conservation.

The Braun-Blanquet method (Zürich-Montpellier approach) was applied to survey a total number of 601 sample plots, recording plant species and environmental factors. The study area was stratified according to land types and terrain units. The phytosociological classification resulted in the identification of 95 plant communities, comprising a total of 800 plant species. Multivariate analysis techniques were used to investigate the relationships between plant communities and environmental variables.

The data on the 95 plant communities were subsequently lumped together into a synoptic table and a synthesis conducted on the entire data set. This resulted in 20 vegetation types being recognized, which were then described and their distribution interpreted with regard to environmental attributes. Four major vegetation types were also distinguished, namely the woody vegetation (forests, woodlands and thickets), high-lying grasslands, low-lying grasslands and wetlands.

The conservation status of plant communities or specific areas was determined using the three criteria species richness, presence of rare species and naturalness. Naturalness was not expressed in terms of quantitative values but was rather based on subjective assessments.

The problem of bush encroachment was also investigated in an area previously known to be grassveld. Historical aerial photographs were analysed in the raster-based GIS programme IDRISI in an attempt to determine the extent and rate of bush encroachment which has taken place over the last 30 years. Field surveys were also conducted to substantiate the changes which were clearly displayed by the aerial photographs. These surveys were restricted to belt and line transects as well as quadrats. The results clearly indicated that bush encroachment had taken place and that the process is one of succession starting with woody pioneer plant species invading open grasslands. Subsequent developments roughly embraced the establishment of woody clusters, increasing in size and numbers until coalescence occurred to finally form closed woodlands and thickets.

A brief overview and discussion is presented of the origin and evolution, management, research and conservation of the grasslands of South Africa. This was done to once again put the grasslands into new perspective, partly with regard to other biomes, but also to draw the attention of scientists, farmers and other landowners, to the current status of the Grassland Biome. This includes our lack of knowledge of the functioning of grasslands sketched against the background of large stretches of grassland lost annually to urbanization and development but also due to mismanagement.

OPSOMMING

Plantekologie van die noordelike KwaZulu-Natal grasvelde

deur

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Hierdie studie is in die grasvelde van noordelike KwaZulu-Natal uitgevoer, 'n area wat ongeveer 14 366 km² beslaan. Die gebied is relatief heterogeen in terme van omgewingseienskappe en plantegroei en word weerspieël in die aantal fisiografiese streke en landtipes. Die topografie is die hooffaktor wat aanleiding gee tot die heterogeniteit van die gebied, met hoogtes wat varieer vanaf 750 m tot 2 290 m bo seespieël. Reënvalsyfers en ander klimaatsfaktore is nou verwant aan die variasies in topografie wat 'n hoë aantal plantgemeenskappe tot gevolg het.

Die hoofdoelwit van hierdie studie was om 'n volledige identifikasie, klassifikasie en beskrywing van die plantgemeenskappe van noordelike KwaZulu-Natal te doen. Die tweede doelwit was om 'n sintaksonomiese en sinekologiese sintese saam te stel uit die resultate verkry deur die fitososiologiese studie. Die bewaringsstatus van plantgemeenskappe en ander gebiede is ook bepaal deur gebruik te maak van sekere kriteria soos spesiesrykheid, skaarsheid van spesies en 'natuurlikheid', waar laasgenoemde na die ongeskondenheid van die omgewing verwys. Die vierde doelwit het 'n bestudering van die prosesse wat by

bosindringing betrokke is, behels. Die spesifieke gebied was 30 jaar gelede nog grasveld en het intussen verbos. Die vyfde en laaste doelwit was om 'n beknopte oorsig van die grasvelde van Suid-Afrika aan te bied, met die klem op aspekte soos die oorsprong en ewolusie, bestuur, navorsing en bewaring.

Die Braun-Blanquet metode (Zürich-Montpellier benadering) is aangewend om 'n totaal van 601 relevés saam te stel. Plantspesies en omgewingsfaktore is binne hierdie persele aangeteken. Die studiegebied is volgens landtipes en terreineenhede gestratifiseer. Die fitososiologiese klassifikasie het 95 plantgemeenskappe opgelewer wat in totaal uit 800 plantspesies bestaan. Meervoudige analises is gebruik om die verwantskappe van plantgemeenskappe met omgewingseienskappe te ondersoek.

Die data van die 95 plantgemeenskappe is daarna in 'n sinoptiese tabel saamgegroepeer en 'n sintese daarop uitgevoer. Dit het tot die onderskeiding van 20 plantegroeitipes gelei. Hierdie plantegroeitipes is dan beskryf en hul verspreiding met betrekking tot omgewingseienskappe geïnterpreteer. Vier hoofplantegroeitipes is ook onderskei, naamlik die houtagtige plantegroei (woude, boomveld en bosruigtes), hoogliggende grasvelde, laagliggende grasvelde en vleilande.

Die bewaringsstatus van plantgemeenskappe en spesifieke gebiede is bepaal deur gebruik te maak van die drie kriteria spesiesrykheid, aanwesigheid van skaars spesies en natuurlikheid. Natuurlikheid of ongeskondenheid is nie in terme van kwantitatiewe waardes uitgedruk nie maar eerder op subjektiewe bepalings gebaseer.

Die probleem van bosindringing is ook ondersoek in 'n gebied wat vroeër as grasveld bekend gestaan het. Historiese lugfoto's is in die raster-gebaseerde GIS-program IDRISI geanaliseer in 'n poging om die omvang en tempo van bosindringing oor die afgelope 30 jaar te bepaal. Veldopnames is ook uitgevoer om die veranderings wat deur die lugfoto's duidelik uitgebeeld word, te bevestig. Hierdie opnames is tot strook- en lyntransekte beperk asook kwadrate. Die resultate dui duidelik daarop dat bosindringing plaasgevind het en dat die proses een van suksessie was wat begin het met die indringing van grasvelde deur houtagtige pionierplante. Verdere ontwikkelinge het die vestiging van bosgroepe behels wat mettertyd in grootte en getalle toegeneem het. Die samesmelting van bosgroepe het uiteindelik tot die vorming van geslote boomveld en bosruigtes gelei.

'n Beknopte oorsig en bespreking van die oorsprong en ewolusie, bestuur, navorsing en bewaring van die grasvelde van Suid-Afrika is ook aangebied. Die doel hiervan was om die grasvelde weer eens in nuwe perspektief te plaas, deels met betrekking tot ander biome, maar ook om die aandag van wetenskaplikes, boere en ander grondeienaars, op die huidige status van die Grasveldbioom te vestig. Dit sluit ons gebrek aan kennis van die funksionering van grasvelde in, terwyl groot grasveldareas jaarliks afgestaan word aan verstedeliking en ontwikkeling maar ook verlore raak as gevolg van wanbestuur.

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CURRICULUM VITAE

Holger Christian Eckhardt was born in Beiruth, the capital of Lebanon, on the 12th February 1965. He matriculated at the Deutsche Schule Pretoria in 1983, after which he enrolled at the University of Pretoria. In 1986 he obtained his B.Sc. degree with Zoology and Botany as major subjects. A year later he received his B.Sc. (Hons.) degree in Wildlife Management.

During the two years 1988 and 1989 he did his military service, undergoing a training course at the South African Intelligence School at Kimberley. In 1989 he was appointed as an officer in the Ecological Services of the South African Defence Force, spending most of his time conducting vegetation surveys and revising the management plan of Riemvasmaak, by then a military training area north of Augrabies National Park.

From 1991 to mid 1996 he was appointed as Research Assistant in the Department of Botany of the University of Pretoria, been involved in the Grassland Biome Classification Project. In 1993 he received his M.Sc. Wildlife Management degree (cum laude), dealing with the classification of the vegetation of the north-eastern Free State.

Since 1996 Holger Eckhardt has been employed by the South African National Parks as a Research Officer in the Scientific Services Section at Skukuza.

APPENDIX 1. Species list of the grasslands of northern KwaZulu-Natal. An asterisk (*) in front of a species name indicates that the species is exotic to South Africa. The preceding numbers indicate the sequence of each genus as listed in Arnold & De Wet (1993).

PTERIDOPHYTA

SELAGINELLACEAE

30 Selaginella Beauv.
S. caffrorum (Milde) Hieron.

EQUISETACEAE

50 Equisetum L.
E. ramosissimum Desf.

SCHIZAEACEAE

120 Mohria Swartz
M. caffrorum (L.) Desv. var. caffrorum

CYATHEACEAE

180 Cyathea J.E. Sm.
C. dregei Kunze

DENNSTAEDTIACEAE

260 Pteridium Gled ex Scop.
P. aquilinum (L.) Kuhn

ADIANTACEAE

300 Adiantum L.
A. aethiopicum L.

340 Cheilanthes Swartz
C. eckloniana (Kuntze) Mett.
C. quadripinnata (Forssk.) Kuhn
C. viridis (Forssk.) Swartz
C. sp.

360 Pellaea Link
P. calomelanos (Swartz) Link var. calomelanos

ASPLENIACEAE

520 Asplenium L.
A. aethiopicum (Burm. f.) Becherer

THELYPTERIDACEAE

532 Thelypteris Schmidel
T. interrupta (Willd.) K. Iwats.

ASPIDIACEAE

620 Dryopteris Adans.
D. inaequalis (Schlechtd.) Kuntze

BLECHNACEAE

690 Blechnum L.
B. australe L. var. australe

Gymnospermae

PODOCARPACEAE

130 Podocarpus L'Hérit. ex Pers.
P. latifolius (Thunb.) R. Br. ex Mirb.

Angiospermae

Monocotyledonae

TYPHACEAE

49 Typha L.
T. capensis (Rohrb.) N.E. Br.

APONOGETONACEAE

65 Aponogeton L.f.
A. junceus Lehm. ex Schlechtd.

POACEAE

10 Ischaemum L.
I. fasciculatum Brongn.

17 Urelytrum Hack.
U. agropyroides (Hack.) Hack.

21 Hemarthria R. Br.
H. altissima (Poir.) Stapf & C.E. Hubb.

28 Elionurus Kunth ex Willd.
E. muticus (Spreng.) Kunth

37 Imperata Cirillo
I. cylindrica (L.) Raeuschel

38 Miscanthus Anderss.
M. junceus (Stapf) Pilg.

53 Eulalia Kunth
E. villosa (Thunb.) Nees

63 Bothriochloa Kuntze
B. bladhii (Retz.) S.T. Blake
B. insculpta (A. Rich.) A. Camus

68 Schizachyrium Nees
S. sanguineum (Retz.) Alst.

71 Andropogon L.
A. appendiculatus Nees
A. eucomus Nees
A. schirensis A. Rich.

72 Cymbopogon Spreng.
C. excavatus (Hochst.) Stapf ex Burtt Davy
C. plurinodis (Stapf) Stapf ex Burtt Davy
C. validus (Stapf) Stapf ex Burtt Davy

73 Hyparrhenia Anderss. ex Fourn.
H. cymbaria (L.) Stapf
H. dichroa (Steud.) Stapf
H. dregeana (Nees) Stapf
H. filipendula (Hochst.) Stapf var. filipendula
H. filipendula (Hochst.) Stapf var. pilosa (Hochst.) Stapf
H. hirta (L.) Stapf
H. poecilotricha (Hack.) Stapf

73a Hyperthelia Clayton
H. dissoluta (Nees ex Steud.) Clayton

75 Monocymbium Stapf
M. ceresiiforme (Nees) Stapf

78 Trachypogon Nees
T. spicatus (L.f.) Kuntze

80 Heteropogon Pers.
H. contortus (L.) Roem. & Schult.

81 Diheteropogon Stapf
D. amplectens (Nees) Clayton
D. filifolius (Nees) Clayton

83 Themeda Forssk.
T. triandra Forssk.

89 Digitaria Haller
D. diagonalis (Nees) Stapf. var. diagonalis
D. eriantha Steud.
D. longiflora (Retz.) Pers.
D. monodactyla (Nees) Stapf.
D. sanguinalis (L.) Scop.
D. ternata (A. Rich.) Stapf.
D. thouaresiana (Fluegge) A. Camus
D. tricholaenoides Stapf

94 Alloteropsis J.S. Presl
A. semialata (R. Br.) Hitch. ssp. semialata

104 Brachiaria (Trin.) Griseb.
B. brizantha (A. Rich.) Stapf
B. deflexa (Schumach.) C.E. Hubb. ex Robyns
B. eruciformis (J.E. Sm.) Griseb.
B. serrata (Thunb.) Stapf
B. sp.

107 Paspalum L.
* P. dilatatum Poir.
P. distichum
* P. notatum Fluegge
P. scrobiculatum L
* P. urvillei Steud.

110 Urochloa Beauv.
U. panicoides Beauv.

112 Echinochloa Beauv.

E. colona (L.) Link
E. jubata Stapf

115 Oplismenus Beauv.
O. hirtellus (L.) Beauv.

116 Panicum L.
P. coloratum L. var. coloratum
P. maximum Jacq.
P. natalense Hochst.
P. schinzii Hack.
P. subalbidum Kunth

128 Setaria Beauv.
S. megaphylla (Steud.) Dur. & Schinz
S. nigrirostris (Nees) Dur. & Schinz
S. pallide-fusca (Schumach.) Stapf. & C.E. Hubb.
S. sphacelata (Schumach.) Moss var. sphacelata
S. verticillata (L.) Beauv.

134 Melinis Beauv.
M. nerviglumis (Franch.) Zizka
M. repens (Willd.) Zizka ssp. repens

139 Pennisetum Rich.
P. clandestinum Chiov.
P. sphacelatum (Nees) Dur. & Schinz.
P. thunbergii Kunth
P. unisetum (Nees) Benth.

159 Leersia Swartz.
L. hexandra Swartz

163 Phalaris L.
P. arundinacea L.

173 Arundinella Raddi
A. nepalensis Trin.

174 Tristachya Nees
T. leucothrix Nees

175a Loudetia Steud.
L. simplex (Nees) C.E. Hubb.

197 Helictotrichon Bess. ex Schult.
H. turgidulum (Stapf) Schweick.

204c Merxmuellera Conert
M. macowanii (Stapf) Conert

205 Pentaschistis Stapf
P. natalensis Stapf

214 Phragmites Trin.
P. australis (Cav.) Steud.

243 Agrostis L.
A. barbuligera Stapf var. barbuligera
A. lachnantha Nees var. lachnantha
* A. montevidensis Spreng. ex Nees

262 Aristida L.
A. bipartita (Nees) Trin. & Rupr.
A. congesta Roem. & Schult. ssp. barbicollis (Trin. & Rupr.) De Winter
A. congesta Roem. & Schult. ssp. congesta
A. diffusa Trin. ssp. diffusa
A. junciformis Trin. & Rupr. ssp. junciformis

263 Stipa L.
S. dregeana Steud.

274 Tragus Haller
T. berteronianus Schult.

280 Perotis Aiton
P. patens Gand.

283 Sporobolus R. Br.
S. africanus (Poir.) Robyns & Tournay
S. centrifugus (Trin.) Nees
S. fimbriatus (Trin.) Nees
S. pectinatus Hack.
S. pyramidalis Beauv.
S. stapfianus Gand.

286 Eragrostis Beauv.
E. caesia Stapf
E. capensis (Thunb.) Trin.
E. curvula (Schrad.) Nees
E. gummiflua Nees
E. heteromera Stapf
E. lappula Nees
E. micrantha Hack.

E. plana Nees
E. planiculmis Nees
E. pseudosclerantha Chiov.
E. racemosa (Thunb.) Steud.
E. sclerantha Nees ssp. sclerantha
E. superba Peyr.
E. sp.

294 Microchloa R. Br.
M. caffra Nees

294a Rendlia Chiov.
R. altera (Rendle) Chiov.

296 Cynodon Rich. ex Pers.
C. dactylon (L.) Pers.
C. hirsutus Stent

298 Harpochloa Kunth
H. falx (L.f.) Kuntze

299 Ctenium Panzer
C. concinnum Nees

300 Enteropogon Nees
E. monostachyus (A. Rich.) Benth.

334 Pogonarthria Stapf
P. squarrosa (Roem. & Schult.) Pilg.

344b Bewsia Goossens
B. biflora (Hack.) Goossens

353 Trichoneura N.J. Anderss.
T. grandiglumis (Nees) Ekman var. grandiglumis

371 Fingerhuthia Nees
F. sesleriiformis Nees

374 Koeleria Pers.
K. capensis (Steud.) Nees

400 Stiburus Stapf
S. alopecuroides (Hack.) Stapf

407 Poa L.
* P. annua L.

417 Festuca L.
F. scabra Vahl
F. sp.

428 Bromus L.
B. catharticus Vahl

433 Lolium L.
* L. perenne L.

CYPERACEAE

459 Cyperus L.
C. albostriatus Schrad.
C. articulatus L.
C. denudatus L.f.
C. esculentus L.
C. fastigiatus Rottb.
C. marginatus Thunb.
C. obtusiflorus Vahl var. obtusiflorus
C. rigidifolius Steud.
C. rupestris Kunth var. rupestris
C. sexangularis Nees
C. sphaerospermus Schrad.

459a Pycreus Beauv.
P. betschuanus (Boeck.) C.B. Cl.
P. mundii Nees
P. polystachyos (Rottb.) Beauv.
P. unioloides (R. Br.) Urb.

459c Mariscus Gaertn.
M. congestus (Vahl) C.B. Cl.
M. dregeanus Kunth
M. keniensis (Kuekenth.) Hooper
* M. sumatrensis (Retz.) J. Raynal

462 Kyllinga Rottb.
K. erecta Schumach.
K. pauciflora Ridley

467 Fuirena Rottb.
F. pachyrrhiza Ridley var. pachyrrhiza
F. pubescens (Poir.) Kunth
F. stricta Steud.

468 Scirpus L.
S. falsus C.B. Cl.
S. ficinioides Kunth

468a Schoenoplectus Palla
S. corymbosus (Roth. ex Roem. & Schult.) J. Raynal
S. decipiens (Nees) J. Raynal
S. muricinux (C.B. Cl.) J. Raynal
S. paludicola (Kunth) Palla ex J. Raynal

468b Isolepis R. Br.
I. fluitans (L.) R. Br.

469a Eleocharis R. Br.
E. palustris R. Br.

471 Fimbristylis Vahl
F. complanata (Retz.) Link
F. ferruginea (L.) Vahl
F. sp.

471a Bulbostylis Kunth
B. humilis (Kunth) C.B. Cl.
B. oritrephes (Ridley) C.B. Cl. ssp. australis B.L. Burtt
B. sp.

471b Abildgaardia Vahl
A. ovata (Burm. f.) Kral

492 Rhynchospora Vahl
R. brownii Roem. & Schult.

521 Schoenoxiphium Nees
S. rufum Nees

525 Carex L.
C. glomerabilis Krecz.
C. spicato-paniculata C.B. Cl.

ARACEAE

748 Zantedeschia Spreng.
Z. aethiopica (L.) Spreng.
Z. albomaculata (Hook.) Baill. ssp. albomaculata

COMMELINACEAE

896 Commelina L.
C. africana L. var. africana
C. benghalensis L.

904 Cyanotis D. Don
C. robusta Oberm.
C. speciosa (L.f.) Hassk.

JUNCACEAE

936 Juncus L.
J. dregeanus Kunth
J. effusus L.
J. inflexus L.
J. oxycarpus E. Mey. ex Kunth
J. punctorius L.f.
J. tenuis Willd.

COLCHICACEAE

964 Littonia Hook.
L. modesta Hook.

ASPHODELACEAE

985 Bulbine Willd.
B. coetzeei Oberm.

985b Trachyandra Kunth
T. asperata Kunth var. nataglencoensis (Kuntze) Oberm.
T. asperata
T. reflexipilosa (Kuntze) Oberm.

989 Anthericum L.
A. angulicaule Bak.
A. fasciculatum Bak.

ERIOSPERMACEAE

1012 Eriospermum Jacq. ex Willd.
E. sp.

ASPHODELACEAE

1024 Kniphofia Moench
K. linearifolia Bak.
K. triangularis Kunth ssp. obtusiloba (Berger) Codd

K. sp.

1026 Aloe L.
A. arborescens Mill.
A. ecklonis Salm-Dyck
A. greatheadii Schonl. var. davyana (Schonl.) Glen & Hardy
A. maculata All.
A. marlothii Berger
A. zebrina Bak.
A. sp.

ALLIACEAE

1046 Agapanthus L' Herit.
A. campanulatus Leighton ssp. campanulatus

HYACINTHACEAE

1084 Dipcadi Medik.
D. viride (L.) Moench

1088 Eucomis L' Herit.
E. autumnalis (Mill.) Chitt.

1089 Ornithogalum L.
O. ornithogaloides (Kunth) Oberm.

1090a Ledebouria Roth.
L. cooperi (Hook. f.) Jessop
L. ovatifolia (Bak.) Jessop
L. revoluta (L. f.) Jessop
L. sp.

ASPARAGACEAE

1113a Protasparagus Oberm.1
P. laricinus (Burch.) Oberm.
P. setaceus (Kunth) Oberm.
P. virgatus (Bak.) Oberm.

1113b Myrsiphyllum Willd.
M. asparagoides (L.) Willd.

AMARYLLIDACEAE

1 According to Arnold & De Wet (1997), the genus *Protasparagus* has changed to *Asparagus*

1167 Haemanthus L.
H. humilis Jacq.
H. sp.

1167a Scadoxus Raf.
S. puniceus (L.) Friis & Nordal

1168 Boophane Herb.
B. disticha (L. f.) Herb.

1175 Nerine Herb.
N. angustifolia (Bak.) Bak.

1177 Brunsvigia Heist.
B. orientalis (L.) Ait. ex Eckl.

HYPOXIDACEAE

1230 Hypoxis L.
H. acuminata Bak.
H. filiformis Bak.
H. galpinii Bak.
H. hemerocallidea Fisch. & C.A. Mey.
H. iridifolia Bak.
H. multiceps Buchinger ex Bak.
H. rigidula Bak. var. rigidula

VELLOZIACEAE

1247a Xerophyta Juss.
X. retinervis Bak.

DIOSCOREACEAE

1252 Dioscorea L.
D. retusa Mast.
D. sylvatica (Kunth) Eckl.

IRIDACEAE

1265 Moraea Mill.
M. brevistyla (Goldbl.) Goldbl.
M. moggii N.E. Br. ssp. albescens Goldbl.
M. natalensis Bak.

1295 Aristea Ait.
A. abyssinica Pax

A. woodii N.E. Br.

1299 Schizostylis Backh. & Harv.
S. coccinea Backh. & Harv.

1301 Hesperantha Ker-Gawl.
H. baurii Bak. ssp. baurii

1303 Dierama K. Koch
D. medium N.E. Br.
D. sp.

1311 Gladiolus L.
G. crassifolius Bak.
G. dalenii Van Geel
G. elliotii Bak.
G. papilio Hook. f.
G. sericeo-villosus Hook. f. forma sericeo-villosus
G. sp.

1315 Watsonia Mill.
W. latifolia N.E. Br. ex Oberm.

1316a Anomatheca Ker-Gawl.
A. laxa (Thunb.) Goldbl.

ORCHIDACEAE

1408 Holothrix L.C. Rich. ex Hook.
H. orthoceras (Harv.) Reichb. f.

1422 Habenaria Willd.
H. chlorotica Reichb. f.
H. pseudociliosa Schelpe ex J.C. Manning

1428 Brachycorythis Lindl.
B. tenuior Reichb. f.

1430 Satyrium Swartz
S. longicauda Lindl.

1434 Disa Berg.
D. versicolor Reichb. f.

1437 Disperis Swartz
D. fanniniae Harv.
D. tysonii H. Bol.

Dicotyledonae

SALICACEAE

1873 Salix L.
* S. babylonica L.
S. mucronata Thunb.

MYRICACEAE

1874 Myrica L.
M. pilulifera Rendle

ULMACEAE

1898 Celtis L.
C. africana Burm. f.

MORACEAE

1961 Ficus L.
F. abutilifolia (Miq.) Miq.
F. craterostoma Warb. ex Mildbr. & Burret
F. ingens (Miq.) Miq. var. ingens
F. natalensis Hochst. ssp. natalensis
F. sur Forssk.
F. thonningii Blume

PROTEACEAE

2034 Faurea Harv.
F. saligna Harv.
2035 Protea L.
P. caffra Meisn. ssp. caffra

LORANTHACEAE

2074a Tapinanthus (Blume) Reichb.
T. natalitius (Meisn.) Danser

SANTALACEAE

2118 Thesium L.
T. sp.

POLYGONACEAE

2195 Rumex L.
R. lanceolatus Thunb.

2201c Persicaria Mill.
P. attenuata (R. Br.) Sojak
P. lapathifolia (L.) S.F. Gray
P. serrulata (Lag.) Webb & Moq.

2204 Oxygonum Burch. ex Campd.
O. dregeanum Meisn. ssp. lanceolatum Germishuizen

CHENOPODIACEAE

2223 Chenopodium L.
* C. schraderianum Roem. & Schult.

AMARANTHACEAE

2299 Amaranthus L.
* A. hybridus L.

2312 Cyathula Blume
C. cylindrica Moq.
C. uncinulata (Schrad.) Schinz
C. sp.

2328 Achyranthes L.
* A. aspera L. var. aspera

2338 Gomphrena L.
* G. celosioides Mart.

AIZOACEAE

2376 Limeum L.
L. pauciflorum Moq.

2379 Psammotropha Eckl. & Zeyh.
P. mucronata (Thunb.) Fenzl.

PHYTOLACCACEAE

2380 Phytolacca L.

P. heptandra Retz.

MESEMBRYANTHEMACEAE

2405.033 Delosperma N.E. Br.
D. carolinense N.E. Br.
D. herbeum (N.E. Br.) N.E. Br.

ILLECEBRACEAE

2467 Pollichia Ait.
P. campestris Ait.

CARYOPHYLLACEAE

2490 Silene L.
S. bellidioides Sond.
S. undulata Ait.

2502 Dianthus L.
D. mooiensis F.N. Williams ssp. mooiensis

RANUNCULACEAE

2542 Clematis L.
C. brachiata Thunb.
C. oweniae Harv.

2546 Ranunculus L.
R. meyeri Harv.
R. multifidus Forssk.

2548 Thalictrum L.
T. rhynchocarpum Dill. & Rich.

TRIMENIACEAE

2759a Xymalos Baill.
X. monospora (Harv.) Baill.

LAURACEAE

2813 Cryptocarya R. Br.
C. woodii Engl.

BRASSICACEAE

2883 Lepidium L.
L. africanum (Burm. f.) DC.

CAPPARACEAE

3082 Cleome L.
C. monophylla L.

CRASSULACEAE

3166 Kalanchoe Adans.
K. paniculata Harv.
K. rotundifolia (Haw.) Haw.

3168 Crassula L.
C. alba Forssk.
C. dependens H. Bol.
C. lanceolata (Eckl. & Zeyh.) Endl. ex Walp.
C. vaginata Eckl. & Zeyh.

VAHLIACEAE

3201 Vahlia Thunb.
V. sp.

PITTOSPORACEAE

3252 Pittosporum Banks ex Gaertn.
P. viridiflorum Sims

ROSACEAE

3333 Cotoneaster Medik.
* C. franchetii Boiss.

3333a Pyracantha M.J. Roemer
* P. angustifolia (Franch.) Schneid.

3353 Rubus L.
R. ludwigii Eckl. & Zeyh. ssp. spatiosus C.H. Stirton
R. rigidus J.E. Sm.

3379 Leucosidea Eckl. & Zeyh.
L. sericea Eckl. & Zeyh.

3388 Cliffortia L.
C. linearifolia Eckl. & Zeyh.

C. nitidula (Engl.) R.E. & Th. Fries Jr. ssp. pilosa Weim.

CHRYSOBALANACEAE

3405 Parinari Aubl.
P. capensis ssp. capensis

FABACEAE

3446 Acacia Mill.
A. caffra (Thunb.) Willd.
* A. dealbata Link
A. karroo Hayne
A. sieberiana DC.

3452 Dichrostachys (A. DC.) Wight & Arn.
D. cinerea (L.) Wight & Arn. ssp. africana

3506 Schotia Jacq.
S. sp.

3536a Chamaecrista Moench
C. mimosoides (L.) Greene
C. stricta E. Mey.

3607 Calpurnia E. Mey.
cf. C. aurea (Ait.) Benth. ssp. sylvatica (Burch.) Brummitt
C. villosa Harv.

3657 Lotononis (DC.) Eckl. & Zeyh.
L. amajubica (Burtt Davy) B-E. van Wyk
L. calycina (E. Mey.) Benth.
L. eriantha Benth.
L. mucronata Conrath

3657a Pearsonia Dümmer
P. sessilifolia (Harv.) Dümmer ssp. sessilifolia

3662 Aspalathus L.
cf. A. gerrardii H. Bol.

3669 Crotalaria L.
C. capensis Jacq.
C. globifera E. Mey.

3673 Argyrolobium Eckl. & Zeyh.
A. adscendens Walp.

A. pauciflorum Eckl. & Zeyh.
A. tuberosum Eckl. & Zeyh.
A. sp.

3689 Melilotus Mill.
* M. alba Desr.

3690 Trifolium L.
T. africanum Ser. var. africanum
* T. repens L. var. repens

3702 Indigofera L.
cf. I. crebra N.E. Br.
I. dregeana E. Mey.
I. frondosa N.E. Br.
I. hedyantha Eckl. & Zeyh.
I. hilaris Eckl. & Zeyh.
I. velutina E. Mey.

3703d Otholobium C.H. Stirton
O. wilmsii (Harms) C.H. Stirton

3718 Tephrosia Pers.
T. capensis (Jacq.) Pers. var. capensis
T. elongata E. Mey. var. elongata
T. multijuga R.G.N. Young
T. natalensis H.M. Forbes ssp. natalensis
T. polystachya E. Mey.
T. shiluwanensis Schinz

3747 Sesbania Scop.
* S. punicea (Cav.) Benth.

3796 Smithia Ait.
S. erubescens (E. Mey.) Bak. f.

3804 Zornia J.F. Gmel.
Z. capensis Pers.

3808 Pseudarthria Wight & Arn.
P. hookeri Wight & Arn. var. hookeri

3810 Alysicarpus Desv.
A. rugosus (Willd.) DC.

3821 Dalbergia L.f.
D. obovata E. Mey.

3870 Erythrina L.
E. latissima E. Mey.
E. lysistemon Hutch.
E. zeyheri Harv.

3897 Rhynchosia Lour.
R. adenodes Eckl. & Zeyh.
R. minima (L.) DC.
R. monophylla Schltr.
R. reptabunda N.E. Br.
R. totta (Thunb.) DC. var. totta
R. woodii Schinz

3898 Eriosema (DC.) G. Don
E. cordatum E. Mey.
E. kraussianum Meisn.
E. salignum E. Mey.
E. sp.

3905 Vigna Savi
V. vexillata (L.) A. Rich.
V. sp.

GERANIACEAE

3924 Geranium L.
G. natalense Hilliard & Burtt

3925 Monsonia L.
M. angustifolia E. Mey. ex A. Rich.
M. attenuata Harv.

3928 Pelargonium L'Hérit.
P. bowkeri Harv.
P. luridum (Andr.) Sweet

OXALIDACEAE

3936 Oxalis L.
* O. corniculata L.
O. sp.

ERYTHROXYLACEAE

3956 Erythroxylum P. Br.
E. delagoense Schinz

RUTACEAE

3991 Zanthoxylum L.
Z. capense (Thunb.) Harv.
Z. sp.

4035 Calodendrum Thunb.
C. capense (L.f.) Thunb.

4076 Vepris Comm. ex A. Juss.
V. lanceolata (Lam.) G. Don

4091 Clausena Burm. f.
C. anisata (Willd.) Hook. f. ex Benth.

MELIACEAE

4175 Melia L.
* M. azedarach L.

4193 Ekebergia Sparrm.
E. capensis Sparrm.

POLYGALACEAE

4273 Polygala L.
P. hottentotta Presl
P. ohlendorfiana Eckl. & Zeyh.
P. virgata Thunb. var. decora (Sond.) Harv.

EUPHORBIACEAE

4299 Phyllanthus L.
P. burchellii Müll. & Arg.
P. glaucophyllus

4407 Acalypha L.
A. angustata Sond. var. glabra Sond.
A. caperonioides Baill.
A. punctata Meisn.

4422 Dalechampia L.
D. capensis Spreng. f.

4448 Clutia L.
C. affinis Sond.
C. hirsuta E. Mey. ex Sond. var. hirsuta
C. pulchella L. var. pulchella

4464 Suregada Roxb. ex Rottl.
S. procera (Prain) Croizat

4498 Euphorbia L.
E. clavaroides Boiss. var. clavaroides

ANACARDIACEAE

4594 Rhus L.
R. chirindensis Bak. f.
R. dentata Thunb.
R. discolor E. Mey. ex Sond.
R. gerrardii (Harv. ex Engl.) Schonl.
R. leptodictya Diels
R. lucida L.
R. pallens Eckl. & Zeyh.
R. pentheri Zahlbr.
R. pyroides Burch. var. gracilis (Engl.) Burtt Davy
R. tomentosa L.
R. tumulicola S. Moore

CELASTRACEAE

4626 Maytenus Molina
M. acuminata (L.f.) Loes. var. acuminata
M. heterophylla (Eckl. & Zeyh.) N.K.B. Robson
M. mossambicensis (Klotzsch) Blakelock var. mossambicensis
M. peduncularis (Sond.) Loes.
M. undata (Thunb.) Blakelock

4630 Pterocelastrus Meisn.
P. echinatus N.E. Br.

ICACINACEAE

4671 Cassinopsis Sond.
C. ilicifolia (Hochst.) Kuntze

4686 Apodytes E. Mey. ex Arn.
A. dimidiata E. Mey. ex Arn. ssp. dimidiata

SAPINDACEAE

4734 Allophylus L.
A. africanus Beauv. var. africanus
A. melanocarpus (Sond.) Radlk.

4753 Pancovia Willd.
P. golungensis (Hiern) Exell & Mendonca

4836 Hippobromus Eckl. & Zeyh.
H. pauciflorus (L.f.) Radlk.

MELIANTHACEAE

4854 Melianthus L.
M. dregeanus Sond.

GREYIACEAE

4855 Greyia Hook. & Harv.
G. sutherlandii Hook. & Harv.

RHAMNACEAE

4861 Ziziphus Mill.
Z. mucronata Willd. ssp. mucronata
Z. zeyheriana Sond.

4874 Scutia (Comm. ex DC.) Brongn.
S. myrtina (Burm. f.) Kurz

4875 Rhamnus L.
R. prinoides L'Hérit.

4886 Phylica L.
P. natalensis Pillans

VITACEAE

4917 Rhoicissus Planch.
R. tridentata Wild & Drum.

4918a Cyphostemma (Planch.) Alston
C. sulcatum (C.A. Sm.) J.J.M. V.D. Merwe
C. sp.

TILIACEAE

4953 Corchorus L.
C. confusus Wild

4957 Sparrmannia L.f.
S. ricinocarpa (Eckl. & Zeyh.) Kuntze

4966 Grewia L.
G. occidentalis L.

MALVACEAE

5007 Pavonia Cav.
P. burchellii (DC.) R.A. Dyer

5013 Hibiscus L.
H. aethiopicus L.
H. microcarpus Garcke
H. trionum L.

STERCULIACEAE

5047 Melhania Forssk.
M. didyma Eckl. & Zeyh.

5053 Dombeya Cav.
D. burgessiae Gerr. ex Harv.
D. cymosa Harv.
D. rotundifolia (Hochst.) Planch. var. rotundifolia

5056 Hermannia L.
H. depressa N.E. Br.
H. geniculata Eckl. & Zeyh.
H. grandistipula (Buchinger ex Hochst.) K. Schum.
H. oblongifolia (Harv.) Hochr.
H. transvaalensis Schinz
H. woodii Schinz

OCHNACEAE

5112 Ochna L.
O. sp.

CLUSIACEAE

5168 Hypericum L.
H. aethiopicum Thunb.
H. lalandii Choisy

FLACOURTIACEAE

5296 Kiggelaria L.
K. africana L.

5304 Scolopia Schreb.
S. mundii (Eckl. & Zeyh.) Warb.
S. oreophila (Sleum.) Killick
S. zeyheri (Nees) Harv.

5315 Trimeria Harv.
T. grandifolia (Hochst.) Warb.

5328 Dovyalis E. Mey. ex Arn.
cf. D. rhamnoides (Burch. ex DC.) Harv.

CACTACEAE

5417 Opuntia Mill.
* O. ficus-indica (L.) Mill.

OLINIACEAE

5428 Olinia Thunb.
O. emarginata Burtt Davy

THYMELAEACEAE

5435 Gnidia L.
G. burchellii (Meisn.) Gilg
G. caffra (Meisn.) Gilg
G. capitata L.f.
G. gymnostachya (C.A. Mey.) Gilg
G. kraussiana Meisn. var. kraussiana
G. microcephala Meisn.
G. nodiflora Meisn.
G. polyantha Gilg

5461 Passerina L.
P. rubra C.H. Wr.
P. sp.

5465 Dais L.
D. cotinifolia L.

LYTHRACEAE

5473 Rotala L.
R. dinteri Koehne

5486 Nesaea Comm. ex Juss.
N. sagittifolia (Sond.) Koehne

COMBRETACEAE

5538 Combretum Loefl.
C. erythrophyllum (Burch.) Sond.
C. kraussii Hochst.
C. molle R. Br. ex G. Don

MYRTACEAE

5583 Syzygium Gaertn.
S. cordatum Hochst.

5588a Heteropyxis Harv.
H. natalensis Harv.

MELASTOMATACEAE

5659 Dissotis Benth.
D. canescens (E. Mey. ex R.A. Grah.) Hook. f.

ONAGRACEAE

5795 Epilobium L.
E. salignum Hausskn.

5804 Oenothera L.
* O. indecora Cambess. ssp. indecora
* O. rosea L'Hérit. ex Ait.
* O. tetraptera Cav.

HALORAGACEAE

5836 Gunnera L.
G. perpensa L.

ARALIACEAE

5872 Cussonia Thunb.
C. paniculata Eckl. & Zeyh.
C. spicata Thunb.

APIACEAE

5894 Centella L.
C. asiatica (L.) Urb.

5922 Alepidea De La Roche
A. longifolia E. Mey. var. longifolia

5992 Heteromorpha Cham. & Schlechtd.
H. trifoliata (Wendl.) Eckl. & Zeyh.

5994 Bupleurum L.
B. mundii Cham. & Schlechtd.

6033 Pimpinella L.
P. caffra (Eckl. & Zeyh.) D. Dietr.
P. transvaalensis H. Wolff

6038 Sium L.
S. repandum Welw. ex Hiern

CORNACEAE

6156 Curtisia Ait.
C. dentata (Burm. f.) C.A. Sm.

ERICACEAE

6237 Erica L.
E. holtii Schweick.
E. oatesii Rolfe var. oatesii

MYRSINACEAE

6283 Maesa Forssk.
M. lanceolata Forssk.

6313 Myrsine L.
M. africana L.

6314 Rapanea Aubl.
R. melanophloeos (L.) Mez

SAPOTACEAE

6386 Mimusops L.
M. caffra E. Mey. ex A. DC.
M. sp.

EBENACEAE

6404 Euclea Murray
E. crispa (Thunb.) Guerke ssp. crispa

6406 Diospyros L.
D. austro-africana De Winter
D. lycioides Desf. ssp. lycioides
D. whyteana (Hiern) F. White

OLEACEAE

6422 Schrebera Roxb.
S. alata (Hochst.) Welw.

6434 Olea L.
O. europaea L. ssp. africana (Mill.) P.S. Green

LOGANIACEAE

6469 Nuxia Comm. ex Lam.
N. congesta R. Br. ex Fresen.

6470 Gomphostigma Turcz.
G. virgatum (L.f.) Baill.

6473 Buddleja L.
B. auriculata Benth.
B. salviifolia (L.) Lam.

GENTIANACEAE

6481 Sebaea Soland. ex R. Br.
S. filiformis Schinz
S. grandis (E. Mey.) Steud.
S. leiostyla Gilg

APOCYNACEAE

6559 Carissa L.
C. bispinosa (L.) Desf. ex Brenan

ASCLEPIADACEAE

6778 Schizoglossum E. Mey.
S. bidens E. Mey. ssp. pachyglossum (Schltr.) Kupicha

6778a Aspidoglossum E. Mey.
A. lamellatum (Schltr.) Kupicha

6783 Cordylogyne E. Mey.
C. globosa E. Mey.

6791 Asclepias L.
A. fruticosa L.

6860 Secamone R. Br.
cf. S. gerrardii Harv. ex Benth.

CONVOLVULACEAE

7003 Ipomoea L.
I. crassipes Hook.
I. ommaneyi Rendle

7008a Turbina Rafin.
T. oblongata (E. Mey. ex Choisy) A. Meeuse

BORAGINACEAE

7043 Ehretia P. Br.
E. rigida (Thunb.) Druce

7064 Cynoglossum L.
C. hispidum Thunb.
C. lanceolatum Forssk.

VERBENACEAE

7138 Verbena L.
* V. bonariensis L.
* V. brasiliensis Vell.
* V. venosa Gill. & Hook.

7144 Lantana L.

* L. camara L.

7145 Lippia L.
L. javanica (Burm. f.) Spreng.
L. rehmannii H. Pearson

7148 Plexipus Rafin.
P. latifolius (Harv.) R. Fernandes var. transvaalensis (Moldenke) R. Fernandes

7191 Clerodendrum L.
C. glabrum E. Mey. var. glabrum
C. sp.

LAMIACEAE

7211 Ajuga L.
A. ophrydis Burch. ex Benth.

7212 Teucrium L.
T. kraussii Codd
T. trifidum Retz.

7254 Prunella L.
* P. vulgaris L.

7264 Leonotis (Pers.) R. Br.
L. ocymifolia (Burm. f.) Iwarsson var. raineriana

7281 Stachys L.
S. kuntzei Guerke
S. natalensis Hochst. var. natalensis
S. sessilis Guerke

7328 Mentha L.
M. aquatica L.

7347 Pycnostachys Hook.
P. reticulata (E. Mey.) Benth.

7350 Plectranthus L'Hérit
P. fruticosus L'Hérit.
P. grallatus Briq.
P. madagascariensis (Pers.) Benth. var. ramosior Benth.
P. spicatus E. Mey. ex Benth.

7350c Rabdosiella Codd
R. calycina (Benth.) Codd

7359 Syncolostemon E. Mey. ex Benth.
S. concinnus N.E. Br.
S. sp.

7365 Hemizygia (Benth.) Briq.
H. pretoriae (Guerke) Ashby
H. subvelutina (Guerke) Ashby

7366 Becium Lindl.
B. grandiflorum (Lam.) Pichi-Serm.

SOLANACEAE

7407 Solanum L.
S. aculeatissimum Jacq.
* S. elaeagnifolium Cav.
S. incanum L.
* S. mauritianum Scop.
S. panduriforme E. Mey.
S. retroflexum Dun.
S. supinum Dun.

SCROPHULARIACEAE

7476 Nemesia Vent.
N. caerulea Hiern

7493 Halleria L.
H. lucida L.

7519 Sutera Roth
S. aurantiaca (Burch.) Hiern
S. neglecta (Wood & Evans) Hiern
S. polelensis Hiern ssp. polelensis
S. sp.

7523 Zaluzianskya F.W. Schmidt
Z. microsiphon (Kuntze) K. Schum.
Z. schmitziae Hilliard & Burtt

7558 Limosella L.
L. grandiflora Benth.
L. longiflora Kuntze

SELAGINACEAE

7566 Hebenstretia L.
H. angolensis Rolfe

7568 Selago L.
S. elongata Hilliard
S. galpinii Schltr.
S. sp.

7568a Walafrida E. Mey.
W. densiflora (Rolfe) Rolfe

7568d Tetraselago Junell
T. natalensis (Rolfe) Junell

SCROPHULARIACEAE

7579 Veronica L.
V. anagallis-aquatica L.

7597a Alectra Thunb.
A. sessiliflora (Vahl) Kuntze var. sessiliflora

7614 Graderia Benth.
G. scabra (L.f.) Benth.

7625 Striga Lour.
S. asiatica (L.) Kuntze
S. bilabiata (Thunb.) Kuntze
S. elegans Benth.
S. gesnerioides (Willd.) Vatke ex Engl.

GESNERIACEAE

7823 Streptocarpus Lindl.
S. vandeleurii Bak. f. & S. Moore

ACANTHACEAE

7914 Thunbergia Retz.
T. atriplicifolia E. Mey. ex Nees

7941 Chaetacanthus Nees
C. burchellii Nees
C. setiger (Pers.) Lindl.

7972 Crabbea Harv.
C. acaulis N.E. Br.

C. angustifolia Nees
C. hirsuta Harv.
C. nana Nees
C. ovalifolia Fical. & Hiern

7973 Barleria L.
B. obtusa Nees

7980 Blepharis Juss.
B. integrifolia (L.f.) E. Mey. ex Schinz var. setosa (Nees) Oberm.

8031 Dicliptera Juss.
D. zeylanica Nees

8032 Hypoestes Soland. ex R. Br.
H. aristata (Vahl) Soland. ex Roem. & Schult. var. aristata
H. forskaolii (Vahl) R. Br.

8063 Ruttya Harv.
R. ovata Harv.

8079 Isoglossa Oerst.
I. eckloniana (Nees) Lindau

8094 Justicia L.
J. anagalloides (Nees) T. Anders.
J. protracta (Nees) T. Anders. ssp. protracta

PLANTAGINACEAE

8116 Plantago L.
* P. lanceolata L.
P. longissima Decne.
* P. virginica L.

RUBIACEAE

8136f Kohautia Cham. & Schlechtd.
K. amatymbica Eckl. & Zeyh.
K. virgata (Willd.) Brem.

8136g Conostomium Cuf.
C. natalense (Hochst.) Brem. var. natalense

8281 Burchellia R. Br.
B. bubalina (L.f.) Sims

8308 Tricalysia A. Rich.
T. lanceolata (Sond.) Burtt Davy

8348 Pentanisia Harv.
P. angustifolia (Hochst.) Hochst.

8351 Vangueria Juss.
V. infausta Burch. ssp. infausta

8351b Pygmaeothamnus Robyns
P. chamaedendrum (Kuntze) Robyns

8351c Tapiphyllum Robyns
T. parvifolium (Sond.) Robyns

8352 Canthium Lam.
C. ciliatum (Klotzsch) Kuntze
C. inerme (L.f.) Kuntze
C. mundianum Cham. & Schlechtd.
C. pauciflorum (Klotzsch) Kuntze
C. sp.

8359 Pachystigma Hochst.
P. pygmaeum (Schltr.) Robyns
P. sp.

8383 Pavetta L.
P. edentula Sond.
P. sp.

8399 Psychotria L.
P. capensis (Eckl.) Vatke ssp. capensis var. capensis

8438 Anthospermum L.
A. rigidum Eckl. & Zeyh. ssp. pumilum (Sond.) Puff
A. sp.

8464 Richardia L.
* R. brasiliensis Gomes

8475 Spermacoce Gaertn.
S. natalensis Hochst.

8489 Rubia L.
R. horrida (Thunb.) Puff

DIPSACACEAE

8541 Cephalaria Roem. & Schult.
C. natalensis Kuntze
C. oblongifolia (Kuntze) Szabo
C. zeyheriana Szabo

8546 Scabiosa L.
S. columbaria L.

CUCURBITACEAE

8599 Cucumis L.
C. hirsutus Sond.
C. zeyheri Sond.

8628 Coccinia Wight & Arn.
C. adoensis (A. Rich.) Cogn.
C. hirtella Cogn.

CAMPANULACEAE

8668 Wahlenbergia Schrad. ex Roth
W. banksiana A. DC.
W. huttonii (Sond.) Thulin
W. krebsii Cham. ssp. krebsii
W. squamifolia V. Brehm.
W. undulata (L.f.) A. DC.

LOBELIACEAE

8681 Cyphia Berg.
C. elata Harv. var. glabra Harv.

8694 Lobelia L.
L. angolensis Engl. & Diels
L. flaccida (Presl.) A. DC. ssp. flaccida

8695 Monopsis Salisb.
M. decipiens (Sond.) Thulin

ASTERACEAE

8751 Vernonia Schreb.
V. capensis (Houtt.) Druce
V. hirsuta (DC.) Sch. Bip.
V. natalensis Sch. Bip. ex Walp.
V. neocorymbosa Hilliard

V. oligocephala (DC.) Sch. Bip. ex Walp.
V. steetziana Oliv. & Hiern

8900 Aster L.
* A. squamatus (Spreng.) Hieron.

8919 Felicia Cass.
F. filifolia (Vent.) Burtt Davy
F. mossamedensis (Hiern) Mendonca
F. muricata (Thunb.) Nees ssp. muricata

8925 Nidorella Cass.
N. anomala Steetz
N. auriculata DC.

8926 Conyza Less.
* C. albida Spreng.
* C. bonariensis (L.) Cronq.
C. obscura DC.
C. podocephala DC.

8930 Chrysocoma L.
C. ciliata L.

8936 Brachylaena R. Br.
B. discolor DC.
B. elliptica (Thunb.) DC.
B. sp.

8937 Tarchonanthus L.
T. camphoratus L.

8992e Pseudognaphalium Kirp.
P. oligandrum (DC.) Hilliard & Burtt

9006 Helichrysum Mill.
H. adenocarpum DC. ssp. adenocarpum
H. albo-brunneum S. Moore
H. albilanatum Hilliard
H. appendiculatum (L.f.) Less.
H. aureonitens Sch. Bip.
H. cephaloideum DC.
H. cerastioides DC.
H. chionosphaerum DC.
H. chrysargyrum Moeser
H. confertifolium Klatt
H. coriaceum Harv.

H. dasycephalum O. Hoffm.
H. herbaceum (Andr.) Sweet
H. hypoleucum Harv.
H. interjacens Hilliard
H. melanacme DC.
H. monticola Hilliard
H. mundtii Harv.
H. nudifolium (L.) Less.
H. obductum H. Bol.
H. oreophilum Klatt
H. pallidum DC.
H. pilosellum (L.f.) Less.
H. polycladum Klatt
H. rugulosum Less.
H. setosum Harv.
H. spiralepis Hilliard & Burtt
H. splendidum (Thunb.) Less.
H. umbraculigerum Less.
H. sp.

9037 Stoebe L.
S. vulgaris Levyns

9050 Relhania L'Hérit. emend Bremer
R. acerosa (DC.) Bremer

9055 Athrixia Ker-Gawl.
A. gerrardii Harv.
A. phylicoides DC.

9059 Printzia Cass.
P. pyrifolia Less.

9078 Pulicaria Gaertn.
P. scabra (Thunb.) Druce

9090 Geigeria Griesselich
G. aspera Harv. var. aspera
G. filifolia Mattf.

9130 Acanthospermum Schrank
* A. australe (Loefl.) Kuntze

9148 Xanthium L.
* X. strumarium L.

9155 Zinnia L.

* Z. peruviana (L.) L.

9237 Bidens L.
* B. bipinnata L.
* B. pilosa L.

9246 Galinsoga Ruiz & Pav.
* G. parviflora Cav.

9291 Schkuhria Roth
* S. pinnata (Lam.) Cabr.

9311 Tagetes L.
* T. minuta L.

9326a Inulanthera Kallersjo
I. calva (Hutch.) Kallersjo

9332 Achillea L.
* A. millefolium L. *sens. lat.*

9336 Phymaspermum Less. emend. Kallersjo
P. acerosum (DC.) Kallersjo

9341 Adenanthellum B. Nord.
A. osmitoides (Harv.) B. Nord.

9356 Schistostephium Less.
S. crataegifolium (DC.) Fenzl ex Harv.
S. griseum (Harv.) Hutch.
S. heptalobum (DC.) Oliv. & Hiern

9401 Lopholaena DC.
L. segmentata (Oliv.) S. Moore

9411 Senecio L.
S. achilleifolius DC.
S. affinis DC.
S. anomalochrous Hilliard
S. coronatus (Thunb.) Harv.
S. erubescens Ait.
S. glaberrimus DC.
S. harveianus MacOwan
S. hieracioides DC.
S. inaequidens DC.
S. inornatus DC.
S. isatidioides Phill. & C.A. Sm.

S. madagascariensis Poir.
S. othonniflorus DC.
S. oxyriifolius DC.
S. polyodon DC.
S. subrubriflorus O. Hoffm.
S. tamoides DC.
S. venosus Harv.
S. sp.

9417 Euryops Cass.
E. laxus (Harv.) Burtt Davy

9426 Garuleum Cass.
G. latifolium Harv.
G. woodii Schinz

9432c Haplocarpha Less.
H. lyrata Harv.
H. scaposa Harv.

9434 Gazania Gaertn.
G. krebsiana Less. ssp. serrulata (DC.) Roessl.

9438 Berkheya Ehrh.
B. echinacea (Harv.) O. Hoffm. ex Burtt Davy ssp. echinacea
B. maritima Wood & Evans
B. onopordifolia (DC.) O. Hoffm. ex Burtt Davy var. glabra Bohnen ex Rössl.
B. pinnatifida (Thunb.) Thell. ssp. stobaeoides (Harv.) Rössl.
B. radula (Harv.) De Wild.
B. setifera DC.
B. zeyheri (Sond. & Harv.) Oliv. & Hiern
B. sp.

9462 Cirsium Mill. emend. Scop.
* C. vulgare (Savi) Ten.

9501 Dicoma Cass.
D. anomala Sond.
D. zeyheri Sond.

9528 Gerbera L.
G. piloselloides (L.) Cass.

9572 Hypochoeris L.
* H. radicata L.

9592 Taraxacum Wiggers

* T. officinale Weber *sens. lat.*

9595 Sonchus L.
S. dregeanus DC.
cf. S. integrifolius Harv.
S. wilmsii R.E. Fr.

9596 Lactuca L.
L. capensis Thunb.

9605 Crepis L.
C. hypochoeridea (DC.) Thell.

Usnea trichoides Mot.[2]

2 This species has been identified by the National Herbarium but is not listed in Arnold & De Wet (1993).

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