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VEGETATION ECOLOGY OF THE SOUTHERN FREE STATE

by

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Submitted in fulfilment of the requirements
for the degree

PHILOSOPHIAE DOCTOR (BOTANY)

in the Faculty of Science

(Department of Botany & Genetics)

University of the Orange Free State

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I can do all things through Christ which strengthens me

- Philippians 4: 13

I dedicate this dissertation to my parents.

ABSTRACT

VEGETATION ECOLOGY OF THE SOUTHERN FREE STATE

by

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Promotor: Prof. Dr. H.J.T. Venter
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PHILOSOPHIAE DOCTOR (BOTANY)

A detailed phytosociological investigation of the southern Free State was conducted as part of the Grassland Biome Project which aims at a detailed synecological and syntaxonomical synthesis of the Biome. The main purpose of this study was to identify, classify, describe and ecologically interpret the different vegetation types in the southern Free State. Braun-Blanquet procedures and multivariate analysis were used in this study. A phytosociological classification and synecological synthesis of the vegetation of the southern Free State is presented. A DCA (DECORANA) ordination was also applied to the floristic data set in order to determine environmental attributes. This data should be used for future land-use planning, management, research and conservation of the natural recourses of the southern Free State.

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CHAPTER 1

Vegetation ecology of the southern Free State

Introductory Background

CHAPTER 1

INTRODUCTORY BACKGROUND

1.1 INTRODUCTION

Since the large scale classification of vegetation by Acocks (1953, 1988), much progress has been made towards more detailed classifications, but a detailed description of the vegetation of the southern Free State does not exist yet. In view of the fast degradation of the vegetation in the southern Free State and because of widespread ploughing of arable land, together with livestock grazing pressure, it has become necessary that planning, management and conservation strategies should become based on sound ecological principles.

To enable optimal resource utilization and conservation, a vegetation classification programme has been implemented in the Grassland Biome (Mentis & Huntley 1982; Scheepers 1987). Figure 1.1 shows the position of the study area in relation to the Grassland Biome. A detailed phytosociological classification and synecological study of the vegetation of the southern Free State for management and conservation purposes is therefore long overdue. This study thus also forms an integral part of the long-term aim to compile a synecological and syntaxonomical synthesis of the Grassland Biome of southern Africa (Scheepers 1987).

1.2 AIMS

The aims of this study are:

(1) To identify, classify, describe and ecologically interpret the different plant communities of the southern Free State,

(2) to compile a synecological synthesis of the southern Free State, and

(3) to concur with the goals of the Grassland Biome Project namely to identify, describe and determine the location of major vegetation types within the Grassland Biome (Mentis & Huntley 1982).

1.3 METHODS

The methods used during this study were, to a certain extent, dictated by the availability of natural vegetation in this predominantly over-exploited area. Large areas were found to be severely degraded due to inappropriate agricultural land use. Extensive farming is by far the main form of land use in South Africa (Tomlinson 1970, Edwards 1972, Edwards & Werger 1972, Werger 1980). According to Werger (1980) it is generally accepted that mismanagement of veld through overstocking, trampling and incorrect grazing systems are the main reasons for this situation.

The floristic-sociological (Zürich-Montpellier) approach or Braun-Blanquet method (Braun-Blanquet 1932, 1964; Poore 1955 a, b, c; 1956; Becking 1957; Pawlowski 1966; Shimwell 1971; Werger 1974; Mueller-Dombois & Ellenberg 1974; Whittaker 1978; Kent & Coker 1996) was used in this study.

The purpose of the methodology of Braun-Blanquet is to construct a global classification of plant communities (Kent & Coker 1996). Werger (1973) stated that this method satisfies the three basic essential requirements of a vegetation ecological study, namely: (i) it is scientifically sound, (ii) it fulfills the necessity of classification at an appropriate level, and (iii) it is the most efficient and versatile amongst comparable approaches. The approach is, however, not without its problems. Egler (1954) presented one of the most eloquent criticisms, claiming that the method was over-simplified and represented the forcing of a weak methodology onto a much more complex real world. A major reason for Egler's comments was that he was a follower of the Gleasonian individualistic view of the plant community. He himself, however, admitted that much valuable work had been completed by Braun-Blanquet and his colleagues in Europe (Kent & Coker 1996).

Since the introduction of this method to South African phytosociologists it was successfully applied in the Grassland Biome by Coetzee (1974), Bredenkamp (1975), Scheepers (1975), Jarman (1977), Bredenkamp &

Theron (1978, 1980), Du Preez (1979), Potgieter (1982), Rossouw (1983), Bosch *et al.* (1986), Du Preez (1986), Müller (1986), Van Wyk & Bredenkamp (1986), Behr & Bredenkamp (1988), Bezuidenhout (1988), Bredenkamp *et al.* (1989), Turner (1989), Bezuidenhout & Bredenkamp (1990), Bredenkamp & Bezuidenhout (1990), Du Preez & Venter (1990 a & b), Kooij (1990), Kooij *et al.* (1990 a, b, c & d), Bezuidenhout & Bredenkamp (1991 a & b), Breytenbach (1991), Du Preez (1991), Du Preez & Bredenkamp (1991 a & b), Du Preez *et al.* (1991), Kooij *et al.* (1991, 1992), Matthews (1991), Malan (1992), Bezuidenhout (1993), Coetzee (1993), Eckhardt (1993), Fuls (1993), Myburgh (1993) and many others. In the Nama-Karoo Biome Werger (1973), Palmer (1989) and Smitheman & Perry (1990) also applied this method.

Since a mass of field data was collected during this study, and augmented by data from previous studies in the southern Free State, it became necessary to consolidate and incorporate data of relevant plant communities into a comprehensive and suitable data-base. It is difficult and impractical to handle phytosociological tables of this dimension by standard Braun-Blanquet procedures, especially where syntaxa are characterized by different species or specific combinations of species or species groups. The objective demarcation of data into various classes based on numerical classification methods alone is ineffective, mainly due to the heterogeneity of the data and also because of the presence of many species with limited occurrences in the total data set (Du Preez 1991). A proposed procedure for the analysis of large phytosociological data sets in the classification of South African grasslands was recently published by Bredenkamp & Bezuidenhout (1995). This technique was used to compile a synoptic table from 2 370 relevés, representing 394 plant communities.

1.4 DISTRIBUTION, NUMBER AND SIZE OF SAMPLE PLOTS

The sample plots in the study area were as far as possible, randomly distributed in stratification units. The stratification was based firstly on land types and secondly on terrain units. Topographic maps (scale - 1: 250 000) were also used in order to better the stratification. In each sample plot total floristic composition, using the Braun-Blanquet cover-abundance scale (Mueller-Dombois & Ellenberg 1974) was noted. Although land types were used as a first stratification unit, these units were not seen as completely separate vegetation units. Major ecosystems or vegetation types of ecologically homogeneous areas were used as guidelines on a regional and farm-level scale and represent a refinement of Acocks 's (1953, 1988) veld type vegetation (Fuls 1993).

The total data set of this study consists of 2 370 relevés and more than 600 species.

Plot sizes were fixed on 16 m^2 for grassland vegetation and 100 m^2 for woodland (shrubland), which is in accordance with Bredenkamp & Theron (1978), Du Preez (1979), Van Wyk (1983), Malan (1992), Bezuidenhout (1993) and Fuls (1993).

1.5 FLORISTIC ANALYSIS

The floristic survey included a list of all the plant species present in a sample plot. A cover-abundance value was estimated for each of these species according to the Braun-Blanquet scale (Mueller-Dombois & Ellenberg 1974) which is as follows:

r - one or a few individuals (rare) with less than 1% cover of total sample plot area;
+ - infrequent with less than 1% cover of total sample plot area;
1 - frequent with low cover, or infrequent, but with higher cover; 1%-5% cover of total sample plot area;
2 - abundant with > 5%-25 % cover of total sample plot area, irrespective of the number of individuals;
3 - > 25%-50% cover of total sample plot area, irrespective of the number of individuals;
4 - > 50%-75 % cover of total sample plot area, irrespective of the number of individuals;

5 - 75% cover of total sample plot area, irrespective of the number of individuals.

Taxa names conform to those of Arnold & De Wet (1993).

1.6 HABITAT ANALYSIS

Bezuidenhout (1993) stated that the distribution of plant communities is closely related to environmental conditions. Environmental data recorded during this study include land type, geology, terrain unit, soil type and depth, soil texture, aspect, slope, rockiness of the soil surface, erosion and utilization by herbivores (Fuls 1993).

1.7 THESIS EXPOSITION

This dissertation is divided into two parts (Parts 1 & 2). Part 1 contains detailed descriptions of the relevant vegetation groups in each chapter, while Part 2 contains all the relevant figures and tables used in this dissertation. Part 2 should thus be seen as complementary to Part 1.

This study consists of a number of chapters all of which are presented in the form of (as yet) unpublished research papers.

Each chapter or unpublished research paper forms an entity in itself. Although the references relevant to a specific chapter are listed at the end of that chapter, a comprehensive list of references is presented at the back of this dissertation.

This thesis reports on a number of detailed vegetation ecology surveys of the major vegetation units of the southern Free State as identified in Chapter 2. Higrophyllous vegetation of the stream beds and wetlands identified as vegetation unit 4 is split into the wetland vegetation of the southern Free State (Chapter 9) and pan vegetation of the dry south-western Free State (Chapter 10). Chapter 2 also contains a detailed description of the study area. For a detailed description of the relevant area studied in each chapter, please refer to Chapter 2.

This dissertation also contains a comprehensive phytosociological synthesis of the vegetation of the southern Free State which includes data compiled by other researchers within the study area (Scheepers 1975, Du Preez 1991, Kooij 1990, Eckhardt 1993, Fuls 1993).

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CHAPTER 2

Vegetation ecology of the southern Free State

Physical environment and major plant communities of the southern Free State.

* Submitted: *Navorsinge van die Nasionale Museum, Bloemfontein*

CHAPTER 2

Physical environment and major plant communities of the southern Free State.

2.1 INTRODUCTION

Ecosystems are organizations consisting of a unified group of components forming a systematized whole (Kormondy 1996). According to O' Neill *et al.* (1986) an ecosystem consists of two or more components that interact and is surrounded by an environment with which it may or may not interact. According to Acocks (1988) vegetation changes to the way it is treated. This is the essential fact that must be grasped if one is to understand the vegetation of a settled country like South Africa. There is little or no vegetation in South Africa which is in its original condition (Acocks 1988). Mentis & Huntley (1982) predicted that at the present rate of population growth, being higher in South Africa than any other country in the world, South Africans will have less cultivated land per person at the turn of the century than is now available to the average person on earth. This situation will lead to less natural pastures for cattle and game, and the demands on the natural resources will still increase.

Since the large scale classification of vegetation by Acocks (1953, 1988) much advance has been made towards more detailed classifications. Man and animals are dependent on the natural resources and the need to maximize the optimal use for these resources will definitely increase with the growth of the human population. Grazing areas in particular need to be subdivided into ecologically homogeneous grazing units to ensure optimal and sustainable utilization of forage resources (Tainton 1984, Danckwerts & Teague 1989).

To enable optimal resource utilization and conservation, a vegetation classification programme has been implemented in the Grassland Biome (Mentis & Huntley 1982, Scheepers 1987). This Biome supports a major portion of the country's maize, dairy, beef and timber industry and is agriculturally the most productive biome in South Africa (Mentis & Huntley

1982, Rutherford & Westfall 1994). Optimal use of natural resources can not be taken care of without adequate knowledge of the ecosystems involved (Edwards 1983). Therefore, a classification of the vegetation of the southern Free State was undertaken, as little is known about this vegetation.

2.2 STUDY AREA

The present study includes the southern Free State and is situated to the south of the 29° 00' S latitude and to the west of the 27° 00' E longitude, encompassing approximately 27 000 km^2 (Figure 2.1). Important cities and towns situated in this area are Bloemfontein, Petrusburg, Fauresmith, Bethulie and Zastron (Figure 2.1).

Acocks (1953, 1988) divided the vegetation of the study area into 6 different veld types, while Low & Rebelo identified 7 vegetation types within the region (Figure 2.1). Two biomes can be distinguished, namely the Grassland and Nama-Karoo Biomes (Rutherford & Westfall 1994) (Figure 2.2).

2.2.1 BIOMES IN THE SOUTHERN FREE STATE

Many attempts have been made to reduce the great spatial and temporal complexity of man's natural environment into conceptually manageable units. Many conflicting divisions of natural systems have been proposed and mapped and most authors appear unperturbed by the plethora of differently mapped units (Rutherford & Westfall 1994). Du Rietz (1965) counters that, contrary to those biologists, who do not see the forest for all its trees, the phytosociologists of the present day agree that division of the living world into biocoenoses (biomes) is necessary for conceiving, describing and explaining the enormous diversity and variation of the mixed organism populations (Rutherford & Westfall 1994).

According to Odum (1971) a biome is the largest land community unit recognized at a continental or subcontinental level. A biome can therefore not be restricted to a small localized area. A limit on scale for biomes is essential to comply with the requirements of large natural areas in the original definition and eliminates local types, such as fringing ravine forests, cliff faces and various aquatic bodies in southern Africa. Küchler (1949) is one of the very few authors who take map scale into account when applying physiognomic classifications of vegetation. Odum (1971) also suggests that a biome should include an animal component as well. According to Odum (1971) a biome is distinguished from other biomes primarily on the basis of those climatic features that most affect the biota.

A very different view in the use of the term "biome" is that put forward by Walter & Box (1976) and Walter (1979). A hierarchical system of ecological units is presented where the term "biome" is used at various levels together with a prefix. Hence we have, for example zonobiomes (climate zones), orobiomes (mountains), pedobiomes (systems primarily dependent on the soil), lithobiomes, halobiomes and peinobiomes. The lowest levels of the hierarchy are denoted simply as biomes.

In formulating the criteria to determine the biome status of areas in southern Africa, it appears that the animal component as a whole is not necessarily a reliable criterion and that the primary criterion remains dominant plant life form(s) (Rutherford & Westfall 1994).

2.2.1.1 GRASSLAND BIOME

The term "grassland" is well established, is effectively descriptive and is preferred to the vernacular "grassveld", because of the former's local and international acceptance (Rutherford & Westfall 1994). The topography is mainly flat to rolling but can also be mountainous.

The main geological units are the Beaufort and Ecca Groups followed by the Molteno, Elliot and Clarens formations, all of the Karoo Sequence, as well as the Ventersdorp Supergroup (Figure 2.4).

Major rivers draining into the Atlantic Ocean are the perennial Vaal, Caledon and Orange Rivers of which only the Caledon and Orange Rivers flow through the study area.

The most common soil group in the Grassland Biome, accounting for just under 50 % of the area, is the red-yellow-grey latosol plinthic catena. Soil erosion in the Grassland Biome is limited in the higher rainfall areas due to the high vegetation cover. However, where vegetation cover is reduced through veld mismanagement, erosion can be severe, especially on steeper slopes and erodable solonetzic duplex soils such as are found in Natal (Rutherford & Westfall 1994).

The Grassland Biome (Figure 2.2) is limited to the summer and strong summer rainfall areas with mean annual rainfall mostly between 400 and 2 000 mm per annum. The mean annual rainfall in the Grassland Biome within the study area varies between 500 and 700 mm per annum (Figure 2.9).

The part of the Grassland Biome that has been invaded by karroid elements is included in the Nama-Karoo Biome (Veld Type 36 of Acocks, 1988) (Rutherford & Westfall 1994). There is some uncertainty regarding the position of the south-western limits of the original grassland in this Veld Type (Rutherford & Westfall 1994).

2.2.1.1.a VEGETATION

The vegetation of the Grassland Biome is physiognomically monolithic and is characterized by strong dominance of hemicryptophytes of the Poaceae. Canopy cover is moisture dependent and decreases with mean annual rainfall. Grazing has a decisive influence on canopy structure (Rutherford & Westfall 1994).

The vegetation of the Grassland Biome follows a rainfall gradient which generally corresponds to the relative contributions to the plant cover by "sweet" and "sour" grasses. Probably the most noteworthy species with wide distribution in the Grassland Biome is *Themeda triandra* Forssk. The number of rare plants in the Grassland Biome is not particularly large, but increases in the wetter areas and mainly includes non-graminoid plants especially geophytes (Hilton-Taylor 1996).

2.2.1.2 NAMA-KAROO BIOME

The term "Nama-Karoo" is a concatenation of Namaland of southern Namibia and the Karoo of South Africa (Rutherford & Westfall 1994).

The Nama-Karoo Biome is found on the central plateau of the Cape Province, north and the easterly tip of the western Cape folded mountain belt, the southwestern Free State and the southern interior of Namibia. Most of the area consists of extensive to undulating plains, interspersed with mesas, hills or the occasional mountain (Rutherford & Westfall 1994).

The main stratigraphic units are the Beaufort and Ecca groups.

The most common soil group in the Nama-Karoo Biome, accounting for over 80% of the area in South Africa, is lime-rich weakly developed soils. Other soil groups include sands, combinations of red clays and solonetzic soils, and undifferentiated rocks and lithosols (Rutherford & Westfall 1994). The soils are generally alkaline (pH 7.0 to 8.3) (Vorster & Roux 1983). Accumulation of silt or clay is common in depressions and pans. Many of the soil surfaces of the Nama-Karoo area are easily eroded by water and wind. Where vegetation cover has been reduced by persistent overgrazing, erosion of soil has reached an advanced level of degradation in many parts (Rutherford & Westfall 1994). Where the sand veneer of some areas of arid grassland is eroded away, dwarf shrubs invade (Tinley 1977).

This biome is limited to strong summer, summer and evenly spread rainfall areas. Mean annual rainfall for most of the area ranges from about 100 to 500 mm (Rutherford & Westfall 1994). The Nama-Karoo Biome within the study area mainly falls within the 200-400 mm and 400-600 mm per annum rainfall intervals (Figure 2.9).

2.2.1.2.a VEGETATION

The vegetation of the Nama-Karoo Biome is dominated by chamaephytes and hemicryptophytes and can be described as a grassy, dwarf shrubland (Edwards 1983). The hemicryptophytes of the biome are mainly C4 graminoids (Vogel *et al.* 1978). Plant species diversity and the number of rare and endangered species in the biome are relatively low (Hall *et al.* 1980). Retrogression of plant composition is usually taken to start after disturbance by overgrazing. The usual progression, given a significant reduction in grazing pressure and a suitable distribution of rainfall (Vorster & Roux 1983), is a steady increase in hemicryptophyte cover and a more variable decrease in chamaephyte cover.

2.2.2 VEGETATION TYPES

Acocks (1953) compiled a veld type map of southern Africa. Since the release of Acocks' "Veld Types of South Africa" in 1953, there was a quest for a more detailed vegetation map. A vegetation map of South Africa, Lesotho and Swaziland was compiled by Low & Rebelo (1996) and the following vegetation types (from west to east) are present within the southern Free State (Figure 2.1):

Vegetation type 51: Orange River Nama-Karoo
Vegetation type 50: Upper Nama-karoo
Vegetation type 32: Kimberley Thorn Bushveld
Vegetation type 52: Eastern Mixed Nama-karoo
Vegetation type 37: Dry Sandy Highveld Grassland
Vegetation type 39: Moist Cool Highveld Grassland
Vegetation type 40: Moist Cold Highveld Grassland

DESCRIPTION OF THE VEGETATION TYPES

2.2.2.1 VEGETATION TYPE 51: Orange River Nama-karoo

This vegetation type is situated in the extreme western part of the study area (Figure 2.1). Acocks (1988) refers to this area as the Orange Broken Veld and it occurs within the hot, arid drainage basin of the Orange River (Hoffman 1996 b). According to Acocks (1988) it takes the form of invasion of the Vryburg scrub bush veld by *Acacia mellifera* and *Acacia tortilis* with more or less of the Karoo constituent of the Orange River Broken Veld prevailing in the Vaal River Valley.

2.2.2.2 VEGETATION TYPE 50: Upper Nama-karoo

This vegetation type is occupying the western part of the study area between the Orange River Nama-karoo and the Eastern Mixed Nama-karoo (Figure 2.1). This region occupies the central part of the upper plateau at an altitude of between 1 050 and 1 700 m. The topography is generally flat and stony but the area is dotted with hills and mountains (Hoffman 1996 c). The vegetation is fairly grassy Karoo with *Eragrostis lehmanniana* and *Aristida congesta* prominent. Bigger shrubs, such as *Lycium* spp. and *Rhigozum trichotomum* randomly occur.

The flood plains sometimes retain a very dense, grassy, short Karoo vegetation of which two forms occur: (i) dense short grassland and (ii) dense short Karoo (Acocks 1988).

2.2.2.3 VEGETATION TYPE 32: Kimberley Thorn Bushveld

The Kimberley Thorn Bushveld occupies the north-western corner of the study area (Figure 2.1). The summer rainfall varies between 400 and 500 mm per year. Sandy to loamy soils underlain by calcrete are prominent.

This is an open savanna with *Acacia tortilis* and *A. erioloba* prominent. The shrub layer is poorly developed with *Tarchonanthus camphoratus* and *Acacia mellifera* having scattered distributions. Natural grazing is important in this vegetation type. The most important grasses present include *Enneapogon scoparius, Eragrostis lehmanniana, Elionurus muticus* and *Cymbopogon plurinodis* (Leistner 1967 & Bezuidenhout 1994).

2.2.2.4 VEGETATION TYPE 52: Eastern Mixed Nama-karoo

This vegetation type occupies the biggest part of the study area (Figure 2.1) and scarcely differs in appearance from the Upper Nama-karoo. The Eastern Mixed Nama-karoo reflects an extensive ecotone between the Nama-karoo Biome in the west and the Grassland Biome in the east (Hoffman 1996 a). It has more grassiness, especially in the eastern parts.

According to Acocks (1988), the hills are still essentially of grassland type and complete grassland occurs in protected areas.

A complex mix of grass- and shrub-dominated vegetation types, which are subject to dynamic changes in species composition dependent on seasonal rainfall events, occur within this vegetation type (Hoffman 1996).

2.2.2.5 VEGETATION TYPE 37: Dry Sandy Highveld Grassland

This vegetation type lies in the eastern and south-eastern parts of the study area (Figure 2.1). This is a dry grassland with a few Sweet Thorn *Acacia* trees occurring only occasionally along water courses (Bredenkamp & Van Rooyen 1996 a). The soils are mainly deep, red to yellow, apedal, aeolian sand, often covering limestone. The presence of Karoo elements in the west probably represent outliers of Karoo vegetation, but this should not necessarily be considered as encroachment (Bredenkamp & Van Rooyen 1996 a).

2.2.2.6 VEGETATION TYPE 39: Moist Cool Highveld Grassland

This vegetation type occupies wetter country than the preceding type and is located in the eastern parts of the study area (Figure 2.1). Deep, red (Hutton) and yellow (Clovelly) soils, moistly of the Karoo Sequence sediments occur. These soils are excellent for agronomy, and extensive areas are cultivated for maize and other crops (Bredenkamp & Van Rooyen 1996 b). This Turf Highland is being strongly dominated by *Themeda triandra*.

2.2.2.7 VEGETATION TYPE 40: Moist Cold Highveld Grassland

This is the veld of the sandy parts of the wetter, higher elevated portion of the highveld in the Free State. This vegetation type falls within the high rainfall regions of the study area which ranges from 600-800 mm/a (Figure 2.9). The vegetation is a moderately dense grassland and maintains its density well.

Deep, yellow and grey sandy-loam soils derived from sandstones and shales of the Beaufort Group occurs (Bredenkamp *et al.* 1996). The Karoo invasion is well under way in this veld with patches of *Pentzia globosa* and *Felicia muricata* developing on the heavier soil along eroded shale hillsides (Acocks 1988).

2.2.3 GEOLOGY

Scheepers (1975) considers the geology of an area to be the basic environmental factor of prime importance on an extensive scale, because the geology influences the topography and thereby has an influence on the climate, parent materials, soils and the vegetation (Du Preez 1991).

The study area is primarily underlain by the Beaufort, Ecca and Stormberg Groups of the Karoo Sequence (Figure 2.4).

2.2.3.1 THE BEAUFORT GROUP

The Beaufort Group is subdivided into three divisions, i.e. the lower, middle and upper series and consists primarily of red mudstone with cross-bedded sandstone occurring frequently. The beds are rich in reptilian remains and these fossils have been used as a basis for dividing the series into paleontological zones (Du Toit 1954).

This group is subdivided into two subgroups i.e. the Adelaide Subgroup which was deposited during the Upper Permian, and the Tarkastad Subgroup which was deposited during the Lower Triassic (Figure 2.4, Du Toit 1954).

2.2.3.1.a THE ADELAIDE SUBGROUP

This subgroup of the Beaufort Group is indicated on the map (Figure 2.4). In the central part of the Free State, the Adelaide Formation consists of a succession of fine-grained sandstone and coarse arkose, alternating with green and brownish-red mudstone. The positioning of the accompanying Estcourt Formation is problematical, in the sense that, lithologically, it resembles the rocks of the Ecca Group quite closely, but it is a time equivalent of the Adelaide Subgroup and lies directly below the Tarkastad Formation. The Estcourt Formation is composed of an alternation of mainly dark bluish-grey to nearly black, carbonaceous shale and pole-coloured, fine to course-grained sandstone. Fossils occur fairly generally, and remains of reptiles, fishes, insects and plants are known (Visser 1984).

2.2.3.1.b THE TARKASTAD FORMATION

This subgroup, with common lateral variation, forms the boundary between the Palaeozoic and Mesozoic and was probably deposited during the Early Triassic. In the lower part of this succession the percentage of sandstone is higher than in the upper part (Du Toit 1954).

2.2.3.2 THE ECCA GROUP

The Ecca Series mainly consists of shale and sandstone, with red mudstone being absent. It is mainly dark-grey and Carbon-rich. The most important coal deposits in South Africa are found in the Ecca Series, but only in Natal, Free State and the Transvaal (Du Toit 1954). It also contains fossil plants and shells, and tracks of small animals. Ryan (1967) recognized four faces of the Ecca, namely the southern, western, central and northern.

2.2.3.2.a THE TIERBERG SHALE FORMATION

This formation is present in the western and northern marginal area of the Karoo basin and is situated in the western parts of the study area (Figure 2.4). It represents the Central or Blue Ecca and is almost entirely composed of dark bluish-grey, laminated shale, rhythmically bedded shale and siltstone, and a few thin layers of dark-grey sandstone (Du Toit 1954).

2.2.3.3 THE STORMBERG GROUP

The Stormberg Group consists of the Molteno, Elliot and Clarens formations (Du Toit 1926).

2.2.3.3.a THE MOLTENO FORMATION

The Molteno Formation crops out within the Karoo basin and encircles the Lesotho Highlands. This is the first formation of the Stormberg Group and lies on top of the Beaufort Group. It consists of thick layers of glittering sandstones, grits with subordinate grey and black shale, mudstones and coals (Dingle *et al.* 1983).

2.2.3.3.b THE ELLIOT FORMATION

In the Karoo basin the Elliot Formation follows conformably on the Molteno Formation and is composed of brownish-red and greenish-grey mudstone, siltstone and shale, alternating with reddish sandstone (Dingle *et al.* 1983).

2.2.3.3.c THE CLARENCE FORMATION

Wherever the Karoo Sequence is fully developed, this formation is also present. It consists of fine-grained, aeolian sandstone, which bears testimony of the fact that the Late Triassic desiccation reached its climax in this formation. The Clarens Formation lies on top of the Elliot Formation (thus is not indicated in Figure 2.4) and its thickness varies considerably. Fossils are uncommon in the Clarens Formation (Dingle *et al.* 1983).

2.2.3.4 ALLUVIUM, SAND AND CALCRETE

These are quaternary formations and include river-terrace gravel, vlei deposits, deposits around springs, surface limestone, calcified dune sand, alluvium and surface sand (Van Eeden 1972). Small patches are situated in the north-western parts of the study area and in the southern part in the region of Aliwal North. Due to only a limited occurrence it is not indicated in Figure 2.4.

According to Du Toit (1926), the Ecca Series furnishes greyish and brownish soils which are often more loamy than sandy and are better for cultivation purposes. Shales of both the Ecca and Beaufort Series on weathering give rise to clay minerals. When soils of the Beaufort Series weather, sandy soils are derived from sandstone.

2.2.3.5 KAROO DOLERITE

This is a dark-grey to nearly black, dense igneous rock, which invaded the rocks of the Karoo Sequence on a grand scale. Dolerite is mainly found as dykes and sills. The southern folded part of the Karoo Sequence is, however free from dolerite intrusions (Du Toit 1926). The most conspicuous form in which dolerite weathers, is sandstone. This can be seen typically on the dry northern koppie slopes. Principically as a result of mechanical weathering the northern hill and koppie slopes are usually a mass of weathered rounded doleritic boulders and stones without the formation of deep soils. The southern slopes of the large and steep koppies and hills are usually characterised by the presence of deeper soil. The deep nature of the soil on the southern slopes is mainly due to the cooler and more humid conditions which are characteristic of these slopes.

The Upper Orange River virtually flows only over strata of the Karoo System, which are packed upon each other practically horizontally. In the lower parts of the Upper Orange River downstream from the Vanderkloof Dam, red to grey dune sand deposits locally occur (Werger 1973).

2.2.4 PHYSIOGRAPHY

Landscapes are of great importance for understanding the development and distribution of soil and vegetation types (Scheepers 1975).

The study area can be classified into different terrain-morphological classes (Figure 2.5, Eloff 1984).

To the south-west of the study area large pans are prominent characteristics, while outliers of the Maluti Mountains contribute to the mountainous appearance of the south-eastern parts. Dolerite outcrops in the central parts produce chains of hills, which are marked landscape features over long distances.

According to Figure 2.5 the central and western parts of the study area mainly consists of flat plains with a moderate to high relief, while the south-eastern corner mainly consists of plateaux (landscapes where 50-80% of the area have slopes of less than 8% and where the local relief differences are greater then 90 m) with a moderate relief. The ridge veld and valley landscape between Philippolis and Aliwal-North mainly occurs on Beaufort sediments.

Plateaux don't occur regularly, but are prominent east of Zastron. These plateaux mainly consist of different terraces which descend towards the Orange River. Plateaux with a great local relief are found at Fauresmith and Luckhoff. The central and north-western parts of the study area mainly consist of even plains with widely dispersed hills and ridges. Uneven plains with dispersed high ridges are restricted to the Philippolis area and the Tussen-die-Riviere Game Farm near Bethulie (Eloff 1984).

2.2.5 RIDGES, KOPPIES AND MOUNTAINS

This terrain unit covers a very small area mainly in the form of mountain ranges and isolated mountains in the south-eastern Free State. All of the landscapes where 20-50% of the area contains slopes of less than 8%, fall within this category. According to Eloff (1984) a terrain unit only qualifies as a mountain when the relief differences are bigger than 300 m. The Thaba 'Nchu mountain near Thaba 'Nchu and Aasvoëlberg mountain near Zastron are the most important elevations of this landscape in the southern Free State.

2.2.6 SOILS AND LAND TYPES

2.2.6.1 SOILS

Soil is a natural entity which results from a complex of interactions between climate, organisms, topography, parent material and time (Van der Merwe 1973). Jenny (1980) defines soil as a body of nature that has its own internal organization and history of geneses. According to Eloff (1984) the increase in rainfall from west to east plays an important role in the geneses (development) of soil. Soils in the study area are heterogeneous due to the great variation in parent material and topography (Figure 2.6).

Soils of the southern Free State are highly dissected and are drained by the Orange, Riet, Modder and Caledon rivers. Alluvium brought down by these rivers is deposited along the lower reaches and serves as arable soils. The non-arable soils are of the Sterkspruit, Arcadia, Estcourt, Valsrivier and Bonheim forms. Arable soils may be divided into two broad groups (i) soils of alluvial or colluvial origin and (ii) soils of aeolian origin.

Alluvial soils are mainly of the Dundee soil form (Van der Merwe 1973) and are classified as Fluvisols (FAO UNESCO 1987). Colluvial soils represent various soil forms, e.g. Arcadia (Vertisols, FAO UNESCO 1987), Bonheim, Shortlands (Luvisols, FAO UNESCO 1987) etc. (Van der Merwe 1973).

Dundee soils are deposited along river banks and are utilized under irrigation. Arcadia soils under very careful management may be irrigated but extreme care must be taken on account of the high clay content (Van der Merwe 1973). Soils associated with streambeds are usually poorly drained.

Soils of the Estcourt (Planosols), Sterkspruit, Valsrivier (Luvisols), Arcadia, Bonheim and Dundee forms are often cultivated as drylands. The first three mentioned forms are extremely suspectable to erosion and all have horizons of high clay content (Van der Merwe 1973). The A-horizon is easily washed away, exposing the erodable clayey B-horizon. According to Russell (1997), soil can hold water because of the pores between soil particles. The more pores the soil has, the more water can be stored between the particles for use by the plant. The water hold efficiency of sandy soils mainly depends on the amount of clay and humus it contains. The clay and humus particles are the first to be removed by erosion (Russell 1997). Donga erosion follows as a rule, because of the collapse of the highly sodium saturated B-horizon. Valsrivier soils have an orthic A- and red pedocutanic B-horizon. This is mainly a sandy-clayish to clayish soil and is underlain by a layer of sand loam (Eloff 1984). Bonheim and Arcadia soils are more stable and the stability of the Dundee soils depend much upon the nature of the alluvial layers. These soils are easily trampled. When denuded from their natural grass cover, recovery is exceptionally slow and difficult.

Soils of aeolian origin are mainly of the Hutton and Bainsvlei forms (Ferralsols, FAO UNESCO 1987). A notable feature of Hutton soils is the dominance of a fine sand fraction. Fine sand often comprises over 80% of the total sand and is well sorted round 0.1 mm. The clay content of these soils increases with depth. The deeper the soil profile, the easier the drainage of excess rainwater away from the roots (Russell 1997). These soils are, furthermore, usually well-drained (Eloff 1984).

Soils of the Bainsvlei form have the same mother material as Hutton soils, but the soft plinthic horizons of this soil form differentiate it from the Hutton form. Hutton soils are generally well-drained, while Bainsvlei soils are regarded as moderately drained (Eloff 1984).

2.2.6.2 LAND TYPES

The soils in the study area are classified on the basis of land types. Researchers such as Bredenkamp & Theron (1978) and Bezuidenhout (1988) have established that geology, soil and climate are important abiotic factors which correlate well with vegetation communities. Therefore the land type plays an important role in the first stratification of the study area (Bezuidenhout 1993). Bezuidenhout (1993) compiled separate plant sociological tables for each land type.

A land type denotes an area specific uniformity of pattern with respect to terrain form, soil pattern and climate. Consequently one land type is distinguished from another in terms of one or a combination of the following parameters: terrain form, soil pattern or climate (Land Type Survey Staff 1985). Ten different land types are distinguished in the study area, namely the Ae, Ag, Ca, Da, Db, Dc, Ea, Fa, Fb and Ib land types. Because of the size of the study area and the resulted reduction of land type maps (2924 Koffiefontein, 2926 Bloemfontein, 3024 Colesberg and 3026 Aliwal North) to be compiled into a single map, too much detail would have been lost. It was thus decided not to include a detailed land type map. The distribution of land types A, B, C, D, E, F and I in the Free State are shown in Figure 2.7. The B land type, absent in the southern Free State (Figure 2.7), is thus not discussed below.

DESCRIPTION OF THE LAND TYPES

2.2.6.2.1 A LAND TYPE

The A land type is generally found in the northern and north-western parts of the study area (Figure 2.7) with Hutton and Clovelly soils being the most prominent (Land Type Survey Staff, in press). Shallow, stony Glenrosa and Mispah soils are prominent in the rocky areas, while Oakleaf, Sterkspruit and other cutanic soils are associated with the plains and pans. These apedal soils are well-drained and favoured for the production of cash crops like maize. Thunder storms with high rainfall intensity result in a loss of soil water by deep drainage, increasing production risk in the already dry western Free State. The terrain units of the A land types of the southern Free State are mostly plains with a low relief (< 130 mm) and pans. They generally have straight slopes of less than 5% with a low drainage density and low stream frequency (Potgieter *et al.* 1995).

The Ae land type consists of red soils with a high base status. The colour being due to ferric oxide around the particles (Werger 1978). The soils are generally deeper than 300 mm and no dunes occur. The Ag land type also has red soils with a high base status, but is generally less than 300 mm deep (Land Type Survey Staff, in press).

2.2.6.2.2 C LAND TYPE

C land types are found in the central northern parts of the study area, west of Bloemfontein and in the south-eastern corner of the study area in the Zastron-District (Figure 2.7). This unit indicates land that qualifies as a plinthic catena and indicates soil which in its perfect form is represented by (in order from highest to lowest in the upland landscape) Hutton, Bainsvlei, Avalon and Longlands forms. It has, in upland positions, margalitic (soils with melanic and vertic horizons) and/or duplex soils (Swartland and Sterkspruit soil forms) that combined cover more than 10% of the land type (Land Type Survey Staff, in press). The C land type is more sensitive to waterlogging than the A land type making it less suitable for irrigation (Potgieter *et al.* 1995).

Dolerite outcrops of the Ca land type are conspicuous in the general topography of the study area. Gravel and Sterkspruit- and Valsrivier soil forms are prominent on slopes. The Valsrivier, Milkwood and Dundee soil forms are dominant on the low-lying plains (Malan *et al.* 1995).

In the low-lying areas the soils are deep (> 1000 mm) and clayey (Alfisols, Soil Survey Staff 1992). On the slopes the soils are shallow and mainly of the Mispah form (Land Type Survey Staff, in press). These soils are classified as Lithic Quartzipsamments (Soil Survey Staff 1992) and Lithosols (FAO UNESCO 1987) (Malan *et al.* 1995).

2.2.6.2.3 D LAND TYPE

D land types are prominent in the southern Free State (Figure 2.7). Units Da, Db and Dc accommodate land where duplex soils occur and prismacutanic and/or pedocutanic diagnostic horizons are prominent. Upland soils that play duplex character include Estcourt, Sterkspruit, Swartland, Valsrivier and Kroonstad forms. Kroonstad and Estcourt soils are limited to the wetter areas of the Free State (Potgieter *et al.* 1995). These soils have sandy A-horizons with clayey B-horizons. The soils are drier than the plinthic or apedal soils and therefore usually less productive. The "wet" soil forms, Estcourt and Kroonstad, have a positive water balance resulting in subsoil saturation for some time after the rainy season. This attribute can lead to increased productivity of selected crops. Deep ploughing (more than 200 mm) results in the dispersive clays of the B-horizon being brought to the surface. A crust forms and penetration of water is slowed down. Runoff is accelerated, erosion increased and a drier soil results (Potgieter *et al.* 1995).

Da refers to land where duplex soils with red B horizons comprise more than half of the area covered by duplex soils while Db refers to land where duplex soils with non-red B horizons comprise more than half of the area covered by duplex soils. The Dc land type also has duplex soils, but more than 10 % of the land type is made up of soil forms that have one or more of the following diagnostic horizons: vertic, melanic and red structured (Land Type Survey Staff, in press). According to Eloff (1984), limited effective soil depth is the largest single limiting factor of duplex soils.

2.2.6.2.4 E LAND TYPE

E land types indicate land with a high base status and accommodate the expansive soils. These soils are generally described with the term "vertic". The most abundant soil forms are the Arcadia and Rensburg forms. They have a strong structure and form cracks in the dry state which close in the rainy season. Generally, the clay content of these vertic soils is high. Usually they are 800-1000 mm deep, but are often shallow and stony where associated with outcrops of basic rocks like dolerite. These soils dry out quickly and therefore have a low crop potential compared to sandy soils. They are effectively utilized with crops like sunflower which are much better adopted to these conditions. Vertic soils are difficult to manage and although they are relatively fertile, they are considered marginal soils in the drier parts of the Free State. Vertic soils in the dry Free State take up water quickly as the water infiltrates through the cracks. Once expanded the infiltration rate is low and the risk of erosion by runoff water higher. The soils generally are resistant to dispersion, crust formation and degradation (Potgieter *et al.* 1995).

2.2.6.2.5 F LAND TYPE

The F land type is intended to accommodate pedologically young landscapes that are not predominantly rock and not predominantly alluvial or aeolian and in which the dominant soil forming processes have been rock weathering, the formation of orthic topsoil horizons and commonly, clay illuviation, giving rise to typically lithocutanic horizons. The soil forms which epitomize these processes are Glenrosa and Mispah. The potential for crop production is very low and cultivation should be avoided. Degradation risks are water and wind erosion when the veld is degraded (Potgieter *et al.* 1995).

Fa refers to land in which lime in the soil is not encountered regularly in any part of the landscape while Fb indicates land where lime occurs regularly in one or more valley bottom soils (Land Type Survey Staff, in press).

2.2.6.2.6 I LAND TYPE

The I land types are miscellaneous soil groups varying from mountain slopes to alluvial river banks. The attributes, potential and risk for degradation vary with soil type (Potgieter *et al.* 1995).

The Ib land type indicates land with exposed rock covering 60-80% of the area. These rocky portions may be underlain by soil which would have qualified the unit for inclusion in another broad soil pattern was it not for the surface rockiness (Land Type Survey Staff, in press). The Dundee and Oakleaf soil forms are the most common soils associated with this land type (Potgieter *et al.* 1995).

2.2.7 CLIMATE

Climate plays an important role in the land- and soil forming processes (Strahler 1975). The entire study area is subjected to a summer rainfall climate, although there are significant differences along the east-west gradient. According to Acocks (1988) climate has a major influence on the distribution of vegetation.

Precipitation and temperature are the most significant climatic factors in vegetation development (Schultze & McGee 1978, Woodward & Williams 1987) and are therefore discussed below.

2.2.7.1 PRECIPITATION

Rainfall statistics are available from four weather stations in the study area. Data are given in Figure 2.8.

The mean monthly rainfall for the weather stations Bloemfontein (1 351 m), Gariep Dam (1 291 m), Fauresmith (1 363 m) and Wepener (1 438 m) is presented in Figure 2.8. This is mainly a summer rainfall area with most of the annual rain falling during the summer months of November to April. Precipitation is lowest during the winter months with June and July the periods of minimum rainfall (Figure 2.8).

Strong precipitation gradients extend across the study area (Figure 2.9). The average annual precipitation increases from west to east (Figure 2.9). This is caused by the increasing relief and decrease of average daily temperatures from west to east (Van der Wall 1976, Schulze & McGee 1978).

According to Figure 2.9, the driest part of the study area is situated within the 200-400 mm/a rainfall interval with the wettest part within the 600-800 mm/a interval. Figure 2.9 also shows the iso-evaporation lines in the Free State. Evaporation decreases from west to east. In the south-western corner (where the lowest rainfall also prevails) evaporation is as high as 2 794 mm per annum, while it decreases systematically towards the east (1 778 mm per annum). The lower rainfall accompanied with higher evaporation rates explain the higher aridity of the western parts.

2.2.7.2 TEMPERATURE

Topography has a definite influence on the temperature of the study area, especially along the rivers (Barker 1985). The hottest months of the year are from December to February with June and July the coldest months (Figure 2.10).

Although there is no big temperature difference between the western and eastern parts of the study area, the western parts tend to be warmer (Figure 2.10).

In the study area the Gariep Dam has the highest mean annual temperature of 16.7 °C, with Wepener the coldest at 15.5 °C. Figure 2.10 shows that the months of December and January are the months with the highest extreme daily maximum temperatures and June and July the months with the coldest extreme temperatures. Fauresmith is the town in the study area with the biggest difference between the two extreme temperatures, 37 °C in June and 38 °C during July. This is probably due to the topography in which the town is situated.

2.2.7.3 CLIMATE DIAGRAMS

The climate diagrams of the four weather stations used in this study, are presented in Figure 2.11.

Figure 2.11 also indicates that the humid period (where rainfall exceeds temperature in the diagram) in Bloemfontein stretches from middle September to the end of April.

Wepener has the shortest period of drought (where temperature exceeds rainfall in the diagram) and also has the highest annual rainfall of the weather stations (Figure 2.11).

2.3 METHODS

Relevés were compiled in 924 sample plots. Stratification was based on land type, topographical position (crest, plateau or slope), aspect and geology. Plot sizes were fixed on 16 m^2 for grassland vegetation and 100 m^2 for woodland (shrubland) which is in accordance with Scheepers (1975), Bredenkamp & Theron (1978), Du Preez (1979), Rossouw (1983), Van Wyk (1983), Turner (1989), Malan (1992), Bezuidenhout (1993), Eckhardt (1993), Fuls (1993) and Malan *et al.* (1995). In each sample plot, all species present were recorded and their respective canopy cover values and/or abundance recorded, according to the Braun-Blanquet cover-abundance scale (Mueller-Dombois & Ellenberg 1974). Other environmental variables such as soil type, land type, rockiness of the soil surface, erosion and degree of utilization by herbivores were also recorded.

Two-way indicator species analysis (TWINSPAN) (Hill 1979 b) was applied to the floristic data set in order to derive a first approximation of the vegetation units of the area. Refinement was done by the application of Braun-Blanquet procedures (Braun-Blanquet 1932 & 1964) and resulted in a phytosociological table. From the final phytosociological table, seven major plant communities were identified. A synoptic table was compiled for the communities (also see Fuls 1993). A procedure of successive approximation, including the recently proposed method for large data sets (Bredenkamp & Bezuidenhout 1995), was applied to the data set.

An ordination algorithm, DECORANA (Hill 1979 a), was also applied to the floristic data to illustrate the floristic relationships between plant communities. Taxa names conform to those of Arnold & De Wet (1993).

2.4 RESULTS AND DISCUSSION

A schematic presentation of the hierarchical classification and associated environmental interpretation of the seven major vegetation units of the study area is presented in Figure 2.12. Unit numbers refer to the numbers in Table 2.1.

A simplified terrain form sketch, compiled from Land Type Survey Staff (In press), is presented in Figure 2.13. Terrain unit 1 represents plateaux, terrain unit 2 the crests, terrain unit 3 and 4 rocky slopes of hills and terrain unit 5 the lower-lying plains as well as drainage channels.

By far the most dominant species in the study area is the grass, *Themeda triandra* (species group 80, Table 2.1). Other species with high constancies are *Protasparagus suaveolens, P. laricinus, Eragrostis lehmanniana, E. curvula, Melolobium candicans, Chenopodium album, Sporobolus fimbriatus, Chrysocoma ciliata* and *Lycium cinereum* (species group 80, Table 2.1).

Conspicuous trees and shrubs occasionally encountered include *Acacia tortilis, Tarchonanthus camphoratus* (species group 13), *A. mellifera* (species group 14), *Rhus erosa, Grewia occidentalis, Osyris lanceolata, Rhus pyroides* subsp. *pyroides, Rhamnus prinoides* (species group 25), *Felicia filifolia, Rhigozum obovatum, Euclea crispa* subsp. *ovata* (species group 49), *Diospyros austro-africana* (species group 50), *Rhus burchellii, R. lancea, R. ciliata, Ehretia rigida* (species group 51), *A. karroo* (species group 71), *D. lycioides* (species group 79), *Protasparagus suaveolens, Lycium cinereum* and *P. laricinus* (species group 80, Table 2.1).

The following major vegetation units were distinguished (Figure 2.12):

(1) shrubland of the rocky outcrops;
(2) shrubland of the drainage lines;
(3) grassland of the undulating plains and crests of rocky outcrops; and
(4) hygrophylic vegetation of the stream beds and wetlands.

1 SHRUBLAND OF THE ROCKY OUTCROPS

This vegetation unit includes the tree and shrub communities associated with the rocky outcrops within the study area. The vegetation type occurs on isolated dolerite or sandstone rocky outcrops (Terrain units 1, 2, 3 and 4,

Figure 2.13). Dolerite hills and ridges occur throughout the study area, but sandstone ridges are nearly restricted to the south-eastern corner of the study area in the Zastron district. In some cases the exposed rocks may consist of a combination of dolerite and sandstone with mudstone and/or shale sometimes present.

Species of species group 19 are diagnostic within this vegetation group and include the fern *Pellaea calomelanos* and the forbs *Hermannia modesta, Polygala hottentottica* and *Argyrolobium pauciflorum* (species group 19, Table 2.1).

This vegetation unit can be divided into three distinct sub units (Table 2.1).

1.1 LEUCOSIDEA SERICEA - STOEBE PLUMOSA SHRUBLAND OF THE MOIST EASTERN PARTS

This vegetation unit is restricted to the south-eastern parts of the study area near Zastron. The Molteno Formation is the most important geological unit and the Avalon soil form is the most prominent.

The vegetation often is very dense, especially in the ravines where *Leucosidea sericea* (species group 11), *Myrsine africana, Euclea crispa* subsp. *crispa*, the exotic *Rosa eglanteria* (species group 1) and *Rhus dentata* (species group 3) dominate (Table 2.1).

Diagnostic species are listed in species group 1 (Table 2.1) and include the trees and shrubs *Euclea crispa* subsp. *crispa, Rhus dregeana, Buddleja salviifolia* and *Rhus pyroides* subsp. *gracilis. Passerina montana, Myrsine africana, Cliffortia nitidula, Rosa eglanteria* and the fynbos shrub *Cliffortia paucistaminea* (species group 1) are the most abundant shrubs. Diagnostic grasses are scarce with only *Tristachya leucothrix* (species group 1) present (Table 2.1).

Other prominent trees and shrubs include *Rhus erosa, Grewia occidentalis, Osyris lanceolata, Rhamnus prinoides, Olea europaea* (species group 12), *Felicia filifolia* (species group 46), *Diospyros austro-africana* (species group 47), *Rhus burchellii* (species group 48) and *Diospyros lycioides* (species group 80). *Pellaea calomelanos* (species group 6) and *Cheilanthes eckloniana* (species group 46) are the most important ferns present. Important grasses encountered include *Digitaria eriantha* (species group 35), *Heteropogon contortus* (species group 46), *Cymbopogon plurinodis* (species group 77), *Themeda triandra* and *Eragrostis curvula* (species group 81).

A detailed description of this vegetation type is presented in Chapter 3 of this dissertation.

1.2 BUDDLEJA SALIGNA - OLEA EUROPAEA SHRUBLAND OF THE DRY CENTRAL PARTS

This shrubland is restricted to the steep slope (generally > 30°) (Terrain units 1 & 4) with a high percentage of surface rock. Geologically this area is underlain by the Beaufort and Ecca Groups in the drier parts (rainfall < 500 mm/a) of the study area (Figure 2.9).

The diagnostic species within this vegetation unit are listed in species group 2 (Table 2.1) and are virtually restricted to graminoids. The only woody species present are *Boscia albitrunca, Protasparagus cooperi, P. denudatus* and *Maytenus heterophylla* (species group 2, Table 2.1).

Other dominant species within this vegetation unit include: the woody species, *Buddleja saligna* (species group 3), *Rhus erosa, Osyris lanceolata, Olea europaea* subsp. *africana, Euclea crispa* subsp. *ovata, Protasparagus striatus, Felicia filifolia* (species group 46), *Diospyros austro-africana, Ehretia rigida* (species group 47), *Rhus burchellii, R. ciliata, R. lancea* (species group 48) and *Diospyros lycioides* (species group 80). *Solanum coccineum* (species group 12), *Protasparagus suaveolens* and *P. laricinus* (species group 81) are the most important semi-woody species.

Among the graminoids *Eustachys paspaloides* (species group 45), *Elionurus muticus* (species group 38), *Aristida congesta, Heteropogon contortus* (species group 46), *Aristida diffusa* (species group 48), *Fingerhuthia africana* (species group 68), *Cymbopogon plurinodis* (species group 77), *Enneapogon scoparius* (species group 79), *Themeda triandra, Eragrostis lehmanniana, Sporobolus fimbriatus* and *Eragrostis curvula* (species group 81) are the most abundant (Table 2.1).

The ferns *Pellaea calomelanos* (species group 19) and *Cheilanthes eckloniana* (species group 49) are sometimes very abundant, especially in high-lying rocky habitat.

This vegetation type is discussed in more detail in Chapter 4 of this dissertation.

1.3 ACACIA MELLIFERA - ACACIA TORTILIS SHRUBLAND OF THE DRY WESTERN PARTS OF THE STUDY AREA

This vegetation unit occurs on the upper slopes and plateaux of rocky hills and ridges as well as on the rocky crests of high undulating terrain (terrain units 2 & 3, Figure 2.13).

The diagnostic species of this vegetation unit are listed in species group 4 (Table 2.1) of which the shrub, *Grewia flava*, is the most important. Prominent woody species include *Acacia erioloba* and *A. hebeclada* (species group 4, Table 2.1). The rest of the species listed in species group 4 all have low constancies (Table 2.1).

Ziziphus mucronata (species group 36), *Rhigozum obovatum* (species group 46) and *Ehretia rigida* (species group 48) are the most important woody species with the shrub *Protasparagus laricinus* (species group 81), the most abundant semi-woody species.

The herbaceous layer is presented by *Eriocephalus ericoides* (species group 35), *E. spinescens* (species group 58), *Barleria rigida,* (species group 67), *Pentzia globosa* (species group 69), *Talinum caffrum* (species group 78), *Protasparagus suaveolens, Chrysocoma ciliata* and *Chenopodium album* (species group 81). Important grasses *Cymbopogon excavatus* (species group 13), *Digitaria eriantha* (species group 35), *Aristida congesta, Heteropogon contortus* (species group 46), *Aristida diffusa* (species group 48), *Fingerhuthia africana* (species group 68), *Enneapogon scoparius* (species group 79), *Themeda triandra, Eragrostis lehmanniana, E. curvula* and *Sporobolus fimbriatus* (species group 81).

A more detailed discussion on this vegetation type is presented in Chapter 5 of this dissertation.

2 SHRUBLAND OF THE DRAINAGE CHANNELS

This shrubland occurs throughout the study area on terrain unit 4 (Figure 2.13) which constitutes gradually sloping terrain.

This vegetation unit occurs on all soil types within the study area and is characterized by the species listed in species group 7 (Table 2.1), with the exotic *Salix babylonica* the most important.

The drainage channels are dominated by the trees *Acacia karroo* (species group 69), *Diospyros lycioides* (species group 80) and the shrub, *Protasparagus laricinus* (species group 81).

Prominent trees encountered, include *Rhus pyroides* subsp. *pyroides, Celtis africana, Olea europaea* subsp. *africana* (species group 12), *Ziziphus mucronata* (species group 36), *Diospyros austro-africana* (species group 47) and *Rhus lancea* (species group 48).

Dominant shrubs are scarce with only *Rhus burchellii, R. ciliata* (species group 48), *Lycium cinereum* (species group 81) and *L. hirsutum* (species group 65) present (Table 2.1).

Species typically associated with wetlands and periodically waterlogged areas, are *Cyperus longus, Salix mucronata* and *Phragmites australis* (species group 54), further characterize this vegetation unit.

Numerous forbs are also present and include *Zinnia peruviana* (species group 12), *Hermannia coccocarpa, Verbena bonariensis* (species group 32), *Artemisia afra* (species group 43), *Rumex lanceolatus* (species group 55), *Xanthium strumarium* (species group 61), *Tribulus terrestris* (species group 69), *Berkheya pinnatifida, Tagetes minuta, Walafrida saxatilis* (species group 76), *Protasparagus suaveolens, Melolobium candicans, Chenopodium album* and the Karoo encroacher species *Chrysocoma ciliata* (species group 81).

Important graminoids include *Eragrostis obtusa, Panicum maximum* (species group 69), *Themeda triandra, Eragrostis lehmanniana, E. curvula* and *Sporobolus fimbriatus* (species group 81).

More detail of this vegetation type is presented in Chapter 6 of this dissertation.

3 GRASSLAND VEGETATION OF THE UNDULATING PLAINS AND CRESTS OF ROCKY OUTCROPS

The grassland vegetation of the study area covers approximately 80% of the study area and is restricted to terrain units 1, 2, 3 and 4 (Figure 2.13). This vegetation unit occurs on all soil types. Species of species group 26 are diagnostic of this vegetation unit and include the forbs *Becium angustifolium, Flaveria bidentis, Hermannia linearifolia, Senna italica* and *Kyllinga alba* (species group 38, Table 2.1).

Numerous graminoids with a wide ecological amplitude characterize this grassland. The most important are *Aristida congesta* (species group 46), *A. diffusa* (species group 48), *Eragrostis obtusa* (species group 69), *E. lehmanniana* and *E. curvula* (species group 81). Important dwarf shrubs include *Nidorella resedifolia* (species group 64), *Pentzia globosa* (species group 69), *Walafrida saxatilis* (species group 76) and *Chrysocoma ciliata* (species group 81, Table 2.1). All of the above mentioned species have a constancy of 20% and higher (Table 2.1). These species, singly or collectively, often comprise more than 80% of the total vegetation cover. This vegetation unit does not have a strongly developed woody component and can be further divided into two distinct plant communities (Table 2.1).

3.1 ARISTIDA CONGESTA - ARISTIDA DIFFUSA GRASSLAND OF THE DISTURBED AND RETROGRESSED AREAS

This vegetation unit is restricted to terrain units 1, 3 and 4 (Figure 2.13) and are restricted to poorly drained soil in disturbed and retrogressed areas. The diagnostic species are listed in species group 14 which includes only one tree species, the exotic *Prosopis velutina* and two grass species, *Eragrostis bergiana* and *E. truncata* (Table 2.1).

This vegetation type is rather characterized by the scarcity of woody species. The only shrubs present are *Eberlanzia spinosa, Euphorbia mauritanica* (species group 17), *Euryops multifidus* (species group 24), *Tarchonanthus camphoratus* (species group 35), *Rhigozum obovatum, Euclea crispa* subsp. *ovata* (species group 46), *Rhus ciliata* and *R. burchellii* (species group 48), all of which have a low constancy (Table 2.1). Tree species encountered include the exotic *Schinus molle* (species group 18), *Acacia tortilis* (species group 35), and *Rhus lancea* (species group 48).

Nearly all the graminoids encountered have a low constancy and include *Tetrachne dregei* (species group 27), *Enneapogon cenchroides* (species group 29), *Tragus koelerioides, Urochloa panicoides* (species group 31), *Cenchrus ciliaris, Digitaria eriantha* (species group 35), *Setaria sphacelata, Eragrostis nindensis, Melinis repens, Triraphis andropogonoides* (species group 42), *Aristida congesta, Heteropogon contortus, Eragrostis superba* (species group 46), *Fingerhuthia africana* (species group 68) and *Setaria incrassata* (species group 73).

Numerous forb species occur, all of which have low constancies and include *Becium angustifolia, Flaveria bidentis, Hermannia lineare, Senna italica, Kyllinga alba* (species group 26), *Mestoklema tuberosum* (species group 29), *Hermannia coccocarpa, Verbena bonariensis, Nenax microphylla* (species group 32), *Eriocephalus ericoides* (species group 35), *Salvia disermas* (species group 41), *Melianthus comosus* (species group 42), *Oxalis depressa, Selago albida* (species group 44), *Sesamum capense* and *Solanum incanum* (species group 46).

Forbs normally associated with overgrazed vegetation with constancy values of 40% and higher include *Schkuhria pinnata* (species group 66), *Pentzia globosa* (species group 69), *Berkheya onopordifolia* (species group 75), *B. pinnatifida, Tagetes minuta* and *Salvia verbenaca* (species group 76). The grasses *Chloris virgata* (species group 68) and *Eragrostis obtusa* (species group 69) are also indicative of overgrazed conditions.

This vegetation type is discussed in more detail in Chapter 7 of this dissertation.

3.2 THEMEDA TRIANDRA - DIGITARIA ERIANTHA GRASSLAND ON WELL-DRAINED SOIL

This vegetation unit is primarily associated with moist and well-drained soils. The habitat is mostly relatively undisturbed south-facing slopes (terrain units 1, 3 & 4).

In contrast with the *Aristida congesta - Aristida diffusa* grassland, this grassland is dominated by *Themeda triandra* (species group 81) and *Digitaria eriantha* (species group 35, Table 2.1). Other important graminoids encountered, include *Setaria sphacelata* (species group 42), *Aristida congesta, Heteropogon contortus* (species group 46), *A. diffusa* (species group 48), *Eragrostis obtusa* (species group 69), *Cymbopogon plurinodis* (species group 77), *Panicum coloratum* (species group 79), *Eragrostis lehmanniana, Sporobolus fimbriatus* and *E. curvula* (species group 81).

The diagnostic species are listed in species group 25 (Table 2.1). Trees and shrubs are scarce and inconspicuous. The herbaceous layer further characterizes this vegetation unit with *Nidorella resedifolia* (species group 64), *Schkuhria pinnata* (species group 66), *Pentzia globosa* (species group 69), *Berkheya onopordifolia* (species group 75), *Walafrida saxatilis, Berkheya pinnatifida, Tagetes minuta* and *Salvia verbenaca* (species group 76) and *Chrysocoma ciliata* (species group 81) the most important (Table 2.1).

This vegetation type is discussed in more detail in Chapter 8 of this dissertation.

4 HYGROPHILIC VEGETATION OF THE STREAM-BEDS AND WETLANDS

This vegetation unit is typical of streambeds and wetlands and is restricted to the low-lying areas of the study area (terrain unit 5, Figure 2.13). Most species associated with this vegetation unit occur on seasonally or permanently waterlogged soils.

The diagnostic species are listed in species group 49 with *Juncus kraussii, Portulaca oleracea* and *Persicaria serrulata* the only species attaining a constancy of 40%.

Broadly, this wetland can be classified as the *Asclepias fruticosa - Juncus kraussii* wetland with *Asclepias fruticosa* (species group 76) having a constancy of 60% (Table 2.1). Forb species contribute most to the species richness of the wetlands. The species composition varies greatly between the different wetland habitats, especially when the vegetation of the stream-beds is compared with that of the drier habitats such as pans of the flat to undulating areas.

Species of species groups 49-81 are all associated with this vegetation type (Table 2.1). The most important are *Cyperus rupestris* (species group 50), *Sporobolus ioclados* (species group 52), *Lobelia thermalis* (species group 53), *Cyperus longus* (species group 54), *Lactuca dregeana* (species group 55), *Cirsium vulgare* (species group 63), *Nidorella resedifolia, Mariscus congestus* (species group 64), *Cyperus marginatus, Cynodon incompletus* (species group 65) and *Senecio consanguineus* (species group 79, Table 2.1).

Woody species are virtually absent from this vegetation unit. The most important are the shrub, *Rhigozum trichotomum* (species group 68), and the trees, *Acacia karroo* (species group 69) and *Diospyros lycioides* (species group 80).

The hygrophilic vegetation of the stream-beds and wetlands of the southern Free State is discussed in more detail in Chapter 9 and the pan vegetation in Chapter 10 of this dissertation.

ORDINATION

In the scatter diagram the distribution of the syntaxa along the first and second axes of the DECORANA ordination is given (Figure 2.14). Along the first axis the woodland syntaxa (1.1, 1.2, 1.3 & 2) are to the left and middle of the diagram, the grassland syntaxa (3.1 & 3.2) to the middle and right and the syntaxa associated with wetlands and pans (4) to the right of the diagram. Also illustrated on the first axis is a gradient which is related to altitude and rockiness of the soil surface. Axis 2 illustrates a moisture gradient. Syntaxa to the top of the diagram are associated with relatively wetter habitat conditions than those to the bottom of the diagram (Figure 2.14).

2.5 CONCLUDING REMARKS

The seven vegetation sub-units (four major vegetation units, Figure 2.12) are easily distinguishable in the southern Free State. All these plant communities have their own sets of environmental and ecological variables and conditions, but overlapping exists (Figure 2.14). Consequently, each of these plant communities should be regarded as an unique managerial and ecological unit.

A detailed classification and ecological interpretation of each of these plant communities will be presented and will form an integral part of the long-term goal to compile a comprehensive synecological and syntaxonomical synthesis of the Grassland Biome of southern Africa (Scheepers 1987).

Table 2.1: Synoptic table of the major vegetation units of the southern Free State.

Vegetation unit number	1.1	1.2	1.3	2	3.1	3.2	4
SPECIES GROUP 1							
Passerina montana	3						
Stoebe plumosa	3						
Cliffortia nitidula	2						
Cliffortia paucistaminea	2						
Euclea crispa subsp. crispa	2						
Myrsine africana	2						
Rosa eglanteria	2						
Senecio isatideus	2						
Aloe ferox	1						
Buddleja salviifolia	1						
Crassula capitella	1						
Dicoma anomala	1						
Gnidia microcephala	1						
Helichrysum appendiculatum	1						
Helichrysum nudifolium	1						
Helichrysum pilosellum	1						
Indigofera nigromontana	1						
Linum thunbergii	1						
Pelargonium alchemilloides	1						
Peucedanum capense	1						
Rhus dregeana	1						
Rhus pyroides subsp. gracilis	1						
Tristachya leucothrix	1						
Vernonia capensis	1						
SPECIES GROUP 2							
Achyranthes aspera		1					
Aloe broomii		1					
Boophane disticha		1					
Boscia albitrunca		1					
Bromus catharicus		1					
Cheilanthes hirta		1					
Cineraria lobata		1					
Commelina benghalensis		1					
Cotyledon orbiculata		1					
Crassula nudicaulis		1					
Crassula setulosa		1					
Dimorphotheca cuneata		1					
Ehrharta erecta		1					
Eriochloa parvispiculata		1					
Garuleum pinnatifidum		1					
Gerbera piloselloides		1					
Homeria pallida		1					
Kleinia longifolia		1					
Lepidium africanum		1					

Plant community number	1.1	1.2	1.3	2	3.1	3.2	4
Lithospermum cinereum		1					
Maytenus heterophylla		1					
Mohria caffrorum		1					
Opuntia vulgaris		1					
Peliostomum leucorrhizum		1					
Pennisetum sphacelatum		1					
Pentarrhinum insipidum		1					
Protasparagus capensis		1					
Protasparagus cooperi		1					
Protasparagus denudatus		1					
Rhynchosia totta		1					
Salvia repens		1					
Schoenoxiphium sparteum		1					
Silene undulata		1					
Sisymbrium capense		1					
Stapelia grandiflora		1					
Trachyandra aspera		1					
Urtica dioica		1					
Vicia sativa		1					
Withania somnifera		1					
SPECIES GROUP 3							
Buddleja saligna	1	3					
Clutia pulchella	2	1					
Cussonia paniculata	2	1					
Rhus dentata	2	1					
Sutera filicaulis	2	1					
Cotoneaster sp.	1	1					
Delosperma pottsii	1	1					
Eragrostis racemosus	1	1					
Haemanthus humilis	1	1					
Kalanchoe paniculata	1	1					
Prunus persica	1	1					
Rhynchosia nervosa	1	1					
Turbina oblongata	1	1					
SPECIES GROUP 4							
Grewia flava			2				
Abutilon pycnodon			1				
Acacia erioloba			1				
Acacia hebeclada			1				
Alternanthera pungens			1				
Commicarpus pentandrus			1				
Dimorphotheca zeyheri			1				
Heliophila carnosa			1				
Justicia protracta			1				
Melhania rehmannii			1				

Plant community number	1.1	1.2	1.3	2	3	4.1	4.2
SPECIES GROUP 5							
Corbichonia decumbens		1	1				
Kedrostis africana		1	1				
Pachypodium succulentum		1	1				
Pupalia lappacea		1	1				
Scilla nervosa		1	1				
SPECIES GROUP 6							
Pellaea calomelanos	3	2	1				
Argyrolobium pauciflorum	1	1	1				
Hermannia modesta	1	1	1				
Polygala hottentotta	1	1	1				
SPECIES GROUP 7							
Salix babylonica				3			
Conium chaerophylloides				1			
Datura ferox				1			
Equisetum ramosissimum				1			
Gomphostigma virgatum				1			
Hemarthria altissima				1			
Leucas martinicensis				1			
Mentha longifolia				1			
Polygonum kitaibelianum				1			
Scirpus inanis				1			
SPECIES GROUP 8							
Polygala uncinata			1	1			
SPECIES GROUP 9							
Crassula lanceolata		1		2			
Achyranthes aquatica		1		1			
Cineraria lyrata		1		1			
Heteromorpha trifoliata		1		1			
Phyla nodiflora		1		1			
Pollichia campestris		1		1			
Setaria verticillata		1		1			
SPECIES GROUP 10							
Sonchus oleraceus		1	1	1			
SPECIES GROUP 11							
Leucosidea sericea	3			1			
SPECIES GROUP 12							
Rhus erosa	5	3		1			
Grewia occidentalis	3	1		1			
Osyris lanceolata	3	2		1			
Rhus pyroides subsp. pyroides	1	1		3			

Plant community number	1.1	1.2	1.3	2	3.1	3.2	4
Rhamnus prinoides	3	1		1			
Melica decumbens	1	1		1			
Clematis brachiata	1	1		3			
Celtis africana	2	1		3			
Zinnia peruviana	1	1		2			
Olea europaea subsp. africana	3	3		3			
Solanum coccineum	1	2		1			
SPECIES GROUP 13							
Cymbopogon excavatus	2	1	1	1			
Pavonia burchellii	2	1	1	1			
Lantana rugosa	1	1	1	1			
SPECIES GROUP 14							
Amaranthus thunbergii					1		
Aptosimum marlothii					1		
Aptosimum spinescens					1		
Convolvulus boedeckerianus					1		
Deverra denudata					1		
Drosanthemum species					1		
Eragrostis bergiana					1		
Eragrostis truncata					1		
Galenia africana					1		
Geigeria ornativa					1		
Hertia ciliata					1		
Mariscus capensis					1		
Phyllanthus maderaspatensis					1		
Plinthus karooicus					1		
Prosopis velutina					1		
Psilocaulon junceum					1		
Pteronia incana					1		
Pterothrix spinescens					1		
Rosenia humilis					1		
Ruschia rigida					1		
Salsola calluna					1		
Sarcocaulon salmoniflorum					1		
Stachys hyssopoides					1		
Suaeda fruticosa					1		
Zygophyllum macrocarpon					1		
Zygophyllum microphyllum					1		
SPECIES GROUP 15							
Blepharis diversispina			1		1		
Eriocephalus aspalathoides			1		1		
Justicia cuneata			1		1		
Saltera sarcocolla			1		1		
Schmidtia kalahariensis			1		1		
Schmidtia pappophoroides			1		1		

Plant community number	1	1	1	2	3	3	4
	.1	.2	.3		.1	.2	
Thesium strictum			1		1		
SPECIES GROUP 16							
Aptosimum indivisum		1			1		
Lightfootia nodosa		1			1		
Panicum stapfianum		1			1		
Senecio longifolia		1			1		
SPECIES GROUP 17							
Eberlanzia spinosa		1	1		1		
Euphorbia mauritanica		1	1		1		
Pteronia glauca		1	1		1		
Stipagrostis namaquensis		1	1		1		
SPECIES GROUP 18							
Schinus molle		1		1	1		
SPECIES GROUP 19							
Sutera pinnatifida	1				1		
SPECIES GROUP 20							
Sutera atropurpurea	1			1	1		
SPECIES GROUP 21							
Viscum rotundifolium	1	2			1		
Lightfootia albens	1	1			1		
SPECIES GROUP 22							
Teucrium trifidum	1	1		1	1		
SPECIES GROUP 23							
Indigofera sessilifolia	1	1	1		1		
SPECIES GROUP 24							
Euryops multifidus	1	1	1	1	1		
SPECIES GROUP 25							
Ammocharis coranica						1	
Chasmatophyllum musculinum						1	
Cullen obtusifolia						1	
Dipcadi glaucum						1	
Helichrysum species						1	
Hermannia cuneifolia						1	
Hypoxis filiformis						1	
Lotononis listii						1	
Microchloa caffra						1	
Oenothera indecora						1	
Papaver aculeatum						1	

Plant community number	1.1	1.2	1.3	2	3.1	3.2	4
Senecio erubescens						1	
Tragopogon dubius						1	
Veronica anagilis-aquatica						1	
Wahlenbergia undulata						1	
SPECIES GROUP 26							
Becium angustifolium					1	1	
Flaveria bidentis					1	1	
Hermannia linearifolia					1	1	
Kyllinga alba					1	1	
Senna italica					1	1	
SPECIES GROUP 27							
Tetrachne dregei				1	1	1	
SPECIES GROUP 28							
Kyphocarpa angustifolia			1			1	
Pogonarthria squarrosa			1			1	
SPECIES GROUP 29							
Enneapogon cenchroides			1		1	1	
Mestoklema tuberosum			1		1	1	
Prosopis chilensis			1		1	1	
SPECIES GROUP 30							
Argemone ochroleuca		1				1	
Arctotis venusta		1				1	
Bidens bipinnata		1				1	
Brunsvigia radulosa		1				1	
Crotalaria eremicola		1				1	
Elephantorrhiza elephantina		1				1	
Enneapogon scaber		1				1	
Eragrostis chloromelas		1				1	
Eragrostis gummiflua		1				1	
Euphorbia rectirama		1				1	
Helichrysum dregeanum		1				1	
Helichrysum zeyheri		1				1	
Indigofera alternans		1				1	
Monsonia angustifolia		1				1	
Moraea spathulata		1				1	
Opuntia sp.		1				1	
Pelargonium abrotanifolium		1				1	
Pseudognaphalium luteo-album		1				1	
Solanum supinum		1				1	
Sphaeralcea bonariensis		1				1	
Sporobolus discoporus		1				1	
Turbina oenotheroides		1				1	

Plant community number	1.1	1.2	1.3	2	3.1	3.2	4
SPECIES GROUP 31							
Tragus koelerioides		1			1	1	
Urochloa panicoides		1			1	1	
SPECIES GROUP 32							
Hermannia coccocarpa		1		2	1	1	
Verbena bonariensis		1		2	1	1	
Nenax microphylla		1		1	1	1	
SPECIES GROUP 33							
Acacia mellifera		1	4			1	
Commelina africana		1	1			1	
Hermannia comosa		1	1			1	
Plexipus pinnatifidus		1	1			1	
Senecio hastatus		1	1			1	
SPECIES GROUP 34							
Convolvulus arvensis		1		1		1	
Sida dregei		1		1		1	
SPECIES GROUP 35							
Digitaria eriantha		3	2		1	4	
Eriocephalus ericoides		1	2		2	1	
Acacia tortilis		1	4		1	1	
Tarchonanthus camphoratus		2	4		1	1	
Hermannia vestita		1	2		1	1	
Stachys rugosa		2	1		1	1	
Cenchrus ciliaris		1	3		1	1	
Commelina eckloniana		1	1		1	1	
SPECIES GROUP 36							
Ziziphus mucronata		2	2	3	1	1	
Osteospermum muricatum		1	1	1	1	1	
SPECIES GROUP 37							
Helichrysum rugulosum	2					1	
Delosperma cooperi	1					1	
Eragrostis capensis	1					1	
SPECIES GROUP 38							
Elionurus muticus	1	2				1	
Hibiscus pusillus	1	1				1	
Populus canescens	1	1				1	
Salvia namaensis	1	1				1	
Salvia stenophylla	1	1				1	
Senecio burchellii	1	1				1	
Tragus racemosus	1	1				1	

Plant community number	1.1	1.2	1.3	2	3.1	3.2	4
SPECIES GROUP 39							
Melolobium microphyllum	1		1			1	
SPECIES GROUP 40							
Scabiosa columbaria	1			1		1	
SPECIES GROUP 41							
Salvia disermas	1				1	1	
SPECIES GROUP 42							
Setaria sphacelata	1	1			1	2	
Eragrostis nindensis	1	1			1	1	
Melianthus comosus	1	1			1	1	
Melinis repens	1	1			1	1	
Triraphis andropogonoides	1	1			1	1	
SPECIES GROUP 43							
Artemisia afra	1	1		3		1	
Oxalis corniculata	2	1		1		1	
Pentzia sphaerocephala	2	1		1		1	
Thesium sp.	1	1		1		1	
SPECIES GROUP 44							
Oxalis depressa	2	1		1	1	1	
Selago albida	1	1		1	1	1	
SPECIES GROUP 45							
Eustachys paspaloides	1	2	1			1	
Geigeria filifolia	1	1	1			1	
Phyllanthus parvulus	1	1	1			1	
Melinis nerviglume	1	1	1			1	
Solanum panduriforme	1	1	1			1	
SPECIES GROUP 46							
Felicia filifolia	5	3	1		1	1	
Rhigozum obovatum	2	1	3		1	1	
Aristida congesta	2	3	2		2	3	
Cheilanthes eckloniana	3	3	1		1	1	
Euclea crispa subsp. ovata	1	4	1		1	1	
Heteropogon contortus	3	4	4		1	2	
Protasparagus striatus	1	2	1		1	1	
Eragrostis superba	2	1	1		1	1	
Helichrysum callicomum	1	1	1		1	1	
Opuntia ficus-indica	1	1	1		1	1	
Sesamum capense	1	1	1		1	1	
Solanum incanum	1	1	1		1	1	

SPECIES GROUP 47

Plant community number	1.1	1.2	1.3	2	3	4.1	4.2
Diospyros austro-africana	5	2	1	2		1	
SPECIES GROUP 48							
Rhus burchellii	3	4	1	2	1	1	
Aristida diffusa	2	3	3	1	2	2	
Ehretia rigida	1	2	3	1	1	1	
Rhus lancea	1	2	1	4	1	1	
Hermannia bryoniifolia	1	1	2	1	1	1	
Rhus ciliata	1	4	1	2	1	1	
SPECIES GROUP 49							
Juncus kraussii							2
Persicaria serrulata							2
Portulaca oleracea							2
Alternanthera nodiflora							1
Barleria macrostegia							1
Cichorium intybus							1
Convolvulus sagittatus							1
Cyperus eragrostis							1
Cyperus laevigatus							1
Cyperus sp.							1
Diplachne fusca							1
Eragrostis bicolor							1
Medicago polymorpha							1
Phragmites mauritianus							1
Pulicaria scabra							1
Schoenoplectus paludicola							1
Scirpus dioecus							1
Sporobolus tenellus							1
Walafrida densiflora							1
SPECIES GROUP 50							
Cyperus rupestris						1	2
Agrostis lachnantha						1	1
Eragrostis plana						1	1
Fuirena hirsuta						1	1
Juncus rigidus						1	1
Scirpus nodosus						1	1
Sporobolus virginicus						1	1
SPECIES GROUP 51							
Cynodon dactylon	1					1	1
SPECIES GROUP 52							
Sporobolus ioclados					1		2
Aristida canescens					1		1
Atriplex nummularia					1		1
Osteospermum spinescens					1		1

Plant community number	1.1	1.2	1.3	2	3.1	3.2	4
Zygophyllum incrustatum					1		1
SPECIES GROUP 53							
Lobelia thermalis					1	1	2
Medicago sativa					1	1	1
Panicum schinzii					1	1	1
SPECIES GROUP 54							
Cyperus longus				5			2
Phragmites australis				3			1
Salix mucronata				3			1
Juncus exsertus				1			1
Miscanthus capensis				1			1
Nicotiana glauca				1			1
Ranunculus multifidus				1			1
Typha capensis				1			1
SPECIES GROUP 55							
Rumex lanceolatatus				2		1	1
Lactuca dregeana				1		1	2
SPECIES GROUP 56							
Lycium pilifolium				1	1		1
SPECIES GROUP 57							
Rumex crispus				1	1	1	1
SPECIES GROUP 58							
Eriocephalus spinescens			2		2		1
SPECIES GROUP 59							
Helichrysum lineare			1		1	1	1
SPECIES GROUP 60							
Solanum retroflexum		1				1	1
Sutera aurantiaca		1				1	1
SPECIES GROUP 61							
Oenothera rosea		1		1			1
Xanthium strumarium		1		3			1
SPECIES GROUP 62							
Bulbine narcissifolia		1			1		1
Limeum aethiopicum		1			1		1
Stipagrostis ciliata		1			1		1
SPECIES GROUP 63							
Cirsium vulgare		1		1		1	2

Plant community number	1.1	1.2	1.3	2	3.1	3.2	4
SPECIES GROUP 64							
Hertia pallens		1			2	1	1
Nidorella resedifolia		1			1	2	2
Mariscus congestus		1			1	1	2
Atriplex semibaccata		1			1	1	1
Conyza bonariensis		1			1	1	1
SPECIES GROUP 65							
Cynodon incompletus		1		1	1	1	2
Cyperus marginatus		1		1	1	1	2
Lycium hirsutum		1		3	1	1	1
SPECIES GROUP 66							
Schkuhria pinnata		1	1			2	1
Xanthium spinosum		1	1			1	1
SPECIES GROUP 67							
Barleria rigida		1	2		1		1
Thesium hystrix		1	1		2		1
Lycium horridum		1	2		2		1
Eragrostis echinochloidea		1	1		1		1
Protasparagus mucronatus		1	1		1		1
SPECIES GROUP 68							
Salsola glabrescens		1	1		3	1	1
Pentzia incana		1	1		2	1	1
Chloris virgata		1	1		1	2	1
Fingerhuthia africana		1	3		2	1	1
Helichrysum pentzioides		1	1		1	1	1
Rhigozum trichotomum		1	1		1	1	1
Salsola kali		1	1		1	1	1
Stipagrostis obtusa		1	1		1	1	1
Stipagrostis obtusa		1	1		1	1	1
SPECIES GROUP 69							
Acacia karroo		1	1	5	1	1	1
Eragrostis obtusa		1	1	2	3	3	1
Pentzia globosa		2	3	1	4	3	1
Tribulus terrestris		1	2	3	1	1	1
Panicum maximum		1	1	3	1	1	1
SPECIES GROUP 70							
Helictotrichon turgudulum	2						1
SPECIES GROUP 71							
Hyparrhenia hirta	2	1					1
Sutherlandia microphylla	1	1					1

Plant community number	1	1	1	2	3	3	4
	.1	.2	.3		.1	.2	
SPECIES GROUP 72							
Wahlenbergia androsacea	1	1		1			1
SPECIES GROUP 73							
Hibiscus trionum	2	1				1	1
Pseudognaphalium undulatum	1	1				1	1
Setaria incrassata	2	1				1	1
Salvia runcinata	1	1				1	1
Vahlia capensis	1	1				1	1
SPECIES GROUP 74							
Hyparrhenia dregeana	1	1		1		1	1
SPECIES GROUP 75							
Ruschia hamata	2	1			1	1	1
Berkheya onopordifolia	1	1			1	2	1
Gazania krebsiana	1	1			1	1	1
SPECIES GROUP 76							
Walafrida saxatilis	2	2		3	2	2	1
Berkheya pinnatifida	1	1		2	1	2	1
Asclepias fruticosa	1	1		1	1	1	3
Tagetes minuta	1	1		5	1	2	1
Salvia verbenaca	1	1		1	1	2	1
Euryops empetrifolius	1	1		1	1	1	1
Paspalum dilatatum	1	1		1	1	1	1
SPECIES GROUP 77							
Cymbopogon plurinodis	3	2	1			3	1
Sutera albiflora	1	1	1			1	1
SPECIES GROUP 78							
Talinum caffrum	1	1	2		1		1
SPECIES GROUP 79							
Enneapogon scoparius	1	2	3		1	1	1
Maytenus polyacantha	2	1	1		1	1	1
Senecio consanguineus	1	1	1		1	1	2
Panicum coloratum	1	1	1		1	2	1
Tragus berteronianus	1	1	1		1	1	1
SPECIES GROUP 80							
Diospyros lycioides	4	3	1	5		1	1
SPECIES GROUP 81							
Themeda triandra	5	5	3	4	1	5	1
Eragrostis lehmanniana	2	3	2	1	3	4	1
Chrysocoma ciliata	1	3	2	2	3	3	1

Plant community number	1112334 ... .. 123 12
Eragrostis curvula	3223231
Protasparagus suaveolens	1343211
Melolobium candicans	1112211
Chenopodium album	1132111
Sporobolus fimbriatus	1232121
Lycium cinereum	1113311
Protasparagus laricinus	1225111

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CHAPTER 3

Vegetation ecology of the southern Free State

Vegetation ecology of the southern Free State: Plant communities of the Zastron area

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Vegetation ecology of the southern Free State: Plant communities of the Zastron area

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ABSTRACT

An analysis of the plant communities of the Zastron area (South Africa) is presented. The Braun-Blanquet-technique, supplemented by TWINSPAN, was used for the phytosociological classification of the vegetation. Twenty distinct plant communities were recognized and described. An hierarchical classification is presented and each vegetation unit is related to specific environmental characteristics. A DECORANA ordination is also presented, showing environmental gradients.

3.1 INTRODUCTION

Each plant community may be regarded as an unique entity with its own species composition associated with a specific set of environmental factors. According to Westhoff (1971) the description of plant communities is essential to provide a scientific inventory for conservation and in general for the preservation of biotic diversity. The fact that Acocks' (1988) broad analysis and description of South African vegetation types is one of the most cited botanical publications, indicates the importance and need for such vegetation classifications. The necessity to identify and describe the Grassland and Nama Karoo Biomes was stated by Mentis & Huntley (1982), Scheepers (1986) and Hilton-Taylor (1987).

From a phytosociological viewpoint, relatively little is known about the vegetation of the southern Free State and this data set and resulting classifications provide the basis for a phytosociological synthesis of the vegetation of the southern Free State which is currently under study by the authors. This paper specifically reports on the detailed Braun-Blanquet classification and plant-ecological interpretation of the plant communities of the Zastron area.

3.2 STUDY AREA

The study area covers approximately 1 270 km^2 and is situated between 27° 00' and 27° 30' E longitude and 30° 00' and 30° 40' S latitude in the south-eastern part of the southern Free State (Figure 1). The study area lies within the *Cymbopogon-Themeda* Veld (Veld type 48, Acocks 1953) and within the 600-800 mm rainfall interval (Figure 1).

According to Acocks (1988), Karoo invasion is well under way in the Southern Variation of the *Cymbopogon-Themeda* Veld with patches of *Pentzia globosa*, *Walafrida saxatilis* and *Felicia filifolia*, developing on the heavier soil forms along valleys and eroded shaly hillsides. This phenomenon is well illustrated in Table 3.1 (species groups V, W and Z).

Geologically the area is characterized by Molteno and Elliot Formations. The uppermost formation, namely the Clarens Formation, forms a prominent cliff on the northern side of Aasvoëlberg. The endangered Cape Vulture (*Gyps coprotheres*) used to breed here. The Molteno Formation, the first of the Stormberg Group, lies on top of the Beaufort Group. The Elliot Formation follows conformably on the Molteno Formation (Dingle *et al.* 1983). The topography of the area consists mainly of continuous hills and mountains with moderate and high relief, allowing only stock farming and small-scale crop production.

The Ca and Ib land types are the most prominent in the study area (Land Type Survey Staff, In Press).

The Ca land type qualifies as a plinthic catena (which is represented by Hutton-, Bainsvlei-, Avalon- and Longlands soil forms) (Land Type Survey Staff, in press). Dolerite outcrops are conspicuous in the general topography of the study area. Loose scree, as well as Mispah, Sterkspruit and Valsrivier soil forms are prominent on slopes while Valsrivier, Milkwood and Dundee soil forms are prominent on the low-lying plains (Malan *et al.* 1995).

The Ib land type accommodates land where exposed rocks cover 60-80% of the soil surface. These rocky portions may be underlain by soil which would have qualified the unit for inclusion in another broad soil pattern would it not have been for the surface rockiness. Dundee and Oakleaf soil forms are the most common soils within this land type (Land Type Survey Staff, in press).

Generally the soils in the Zastron area are referred to as "Podsolic" (pH < 7) soils. This soils are generally deeper than "solonetic" [pH > 7 and contains a high salt (especially sodium compounds) content] soils and also comprises well-developed horizons. Donga and surface erosion are a common phenomenon of these soils (Potgieter *et al.* 1995).

Altitude ranges from 1 350-2 000 m above sea level.

3.3 METHODS

Relevés were compiled in 76 sample plots. Stratification was based on topographical position (crest, plateau or slope), aspect and geology. Plot sizes were fixed on 100 m^2 (10 m x 10 m) (Scheepers 1975). In each sample plot the floristic composition was recorded and a cover-abundance value according to the Braun-Blanquet scale (Braun-Blanquet 1964) was allocated to each species. Other environmental variables such as soil form, land type, percentage rockiness of the soil surface and habitat disturbance were also recorded.

Two-way indicator species analysis (TWINSPAN) (Hill 1979 b) was applied to the floristic data set and refined by the application of Braun-Blanquet procedures that resulted in a phytosociological table (Table 3.1).

An ordination algorithm, DECORANA (Hill 1979 a) was also applied to the floristic data to analyse the floristic relationships between plant communities. Taxa names conform to those of Arnold & De Wet (1993). No attempt was made to formally distinguish between different sub species, except for *Euclea crispa* subsp. *crispa* and *E. crispa* subsp. *ovata* and *Rhus pyroides* subsp. *gracilis* and *R. pyroides* subsp. *pyroides*, because these sub species occur in different habitats (Venter & Joubert 1985). According to Coates Palgrave (1984), *Euclea crispa* subsp. *crispa* has a very widespread distribution, while *E. crispa* subsp. *ovata* has a restricted distribution in the southern Free State and extends down to Cradock and Middelburg in the Eastern Cape and westwards to Kimberley and Kuruman in the Northern Cape. According to Venter & Joubert (1985), *Rhus pyroides* subsp. *pyroides* is common in open veld, ravine or stream bank scrub throughout the whole of the Free State, except the north-eastern corner. *Rhus pyroides* subsp. *gracilis*, however, is restricted to forest margins and along river banks in the north-eastern corner of the Free State (Venter & Joubert 1985).

3.4 RESULTS AND DISCUSSION

In this study the classification of the vegetation was achieved by way of the floristic-sociological approach with the essential viewpoint that plant communities are units of classification based primarily on species composition (Mueller-Dombois & Ellenberg 1974, Whittaker 1978). The general vegetation of this area can be considered as the *Themeda triandra-Olea europaea* vegetation unit (species AB & group AC, Table 3.1). According to Fuls (1993) variations in moisture and microclimate are related to differences in irradiation due to different aspects and gradients.

Three major plant communities, of which one (major community 1) is not further divided into distinct communities and sub-communities, have been recognized and are illustrated in the phytosociological table (Table 3.1). The hierarchical classification of these communities is summarized as follows:

1 *Cliffortia nitidula-Rhus erosa* Major community

2 *Stoebe plumosa-Leucosidea sericea* Major community
2.1 *Leucosidea sericea-Themeda triandra* Community
2.2 *Stoebe plumosa-Elionurus muticus* Community
2.3 *Stoebe plumosa-Peucedanum capense* Community
2.4 *Cliffortia paucistaminea-Passerina montana* Community
2.5 *Leucosidea sericea-Pelargonium alchemilloides* Community
2.6 *Hyparrhenia hirta-Osyris lanceolata* Community
2.6.1 *Helichrysum rugulosum-Leucosidea sericea* Sub-community
2.6.2 *Rhus dregeana-Leucosidea sericea* Sub-community

3 *Olea europaea-Rhus burchellii* Major community
3.1 *Euclea crispa* subsp. *crispa-Rhus dentata* Community
3.2 *Clutia pulchella-Diospyros lycioides* Community
3.2.1 *Jamesbrittenia atropurpurea-Rhus erosa* Sub-community
3.2.2 *Rhus lancea-Celtis africana* Sub-community
3.3 *Protasparagus suaveolens-Eragrostis lehmanniana* Community
3.3.1 *Cymbopogon excavatus-Protasparagus suaveolens* Sub-community
3.3.2 *Eragrostis curvula-Sutera albiflora* Sub-community
3.3.3 *Cheilanthes eckloniana-Tragus koelerioides* Sub-community
3.3.4 *Olea europaea-Melianthus comosus* Sub-community
3.3.5 *Olea europaea-Walafrida saxatilis* Sub-community
3.4 *Aloe ferox-Rhigozum obovatum* Community
3.4.1 *Aloe ferox-Setaria incrassata* Sub-community
3.4.2 *Aloe ferox-Olea europaea* Sub-community
3.5 *Rhus ciliata-Olea europaea* Community
3.6 *Euclea crispa* subsp. *ovata-Olea europaea* Community

DESCRIPTION OF THE COMMUNITIES

1 *Cliffortia nitidula-Rhus erosa* Major Community

A plant community which was found to be restricted to the moderately steep east-facing footslopes of the Aasvoëlberg Mountain, where Avalon soils are the most prominent. The Elliot and Molteno Formations are the most important geological formations with the Ca land type covering nearly 80% of the area. These areas are often disturbed by hikers and have a low species diversity (Table 3.1).

Species of species group A (Table 3.1) characterize this plant community with *Cliffortia nitidula* (species group A) the most conspicuous, having high cover-abundance values. According to Coates Palgrave (1984), *C. nitidula* can reach six metres in height. However, the average height of *C. nitidula* in this major community did not exceed three metres. The only other conspicuous species present include the woody shrub, *Rhus erosa* (species group Z, Table 3.1). *R. erosa* is commonly found in the rocky areas in the southern Free State (See Chapter 4).

2 *Stoebe plumosa-Leucosidea sericea* Major community

This vegetation unit is encountered on the wet or slightly moist, steep southerly facing slopes (30°- 60°), where also a higher species diversity is found to be present (Table 3.1).

The diagnostic species are those listed in species group J (Table 3.1). *Leucosidea sericea* is the only diagnostic tree species being abundant in some areas. The height of this tree varies from two to six metres and is widely dispersed in the mountainous areas, especially in kloof forests and on mountain slopes in the Free State (Venter & Joubert 1985). The exotic rose, *Rosa eglanteria* (species group J) has long pendulous branches which are spinose. This species often forms dense impenetrable stands. *Passerina* *montana* and *Stoebe plumosa* (species group J) are the only two other diagnostic species present (Table 3.1).

Seven distinct vegetation units were identified within this plant community (Table 3.1).

2.1 *Leucosidea sericea-Themeda triandra* Community

The *Leucosidea sericea-Themeda triandra* Community is encountered on the virtually undisturbed moist, steep (30°-60°) slopes, facing south-south-east to south-south-west. Large dolerite and sandstone boulders occur and cover 40-60% of the soil surface.

In the absence of diagnostic species, *Themeda triandra* (species group AC, Table 3.1) has a high constancy and canopy cover. Other species present include *Stoebe plumosa, Passerina montana, Leucosidea sericea, Rosa eglanteria* (species group J), *Rhus erosa* and *Rhamnus prinoides* (species group Z). According to Coates Palgrave (1984), *L. sericea* can reach up to seven metres in height and usually occurs at high altitudes along streams and in ravines, as was also the case in this instance. In KwaZulu-Natal, *Leucosidea* is troublesome as it invades overgrazed and disturbed areas, forming impenetrable thickets which are best eradicated by chopping plants down to ground. In mountainous areas the presence of these trees is taken as an indication that the streams are suitable for trout-stocking (Coates Palgrave 1984).

2.2 *Stoebe plumosa-Elionurus muticus* Community

This plant community is associated with open shrubland at the feet of southerly facing hills. This vegetation unit thrives in full sun. Large uneven and rough rock plates occur and cover 50% of the soil surface.

The grass species, *Elionurus muticus* (species group B), is the only differentiating species present (Table 3.1). According to Van Oudtshoorn

(1991) this species is well adapted to rocky habitat. Patches are severely utilized and disturbed, especially by the rock dassie (*Procavia capensis*). Fuls (1993) also reports patch-like over-utilization by rock dassies, especially on southerly facing slopes of the low thicket communities of rocky outcrops in the northern Free State. The forb *Stoebe plumosa* (species group J) is indicative of disturbed areas. *Themeda triandra* (species group AC) is the only dominant grass species (Table 3.1).

2.3 *Stoebe plumosa-Peucedanum capense* Community

This plant community is restricted to the feet of cool south-facing slopes. Although dolerite may be present, these slopes consist predominantly of sandstone ledges. Fine gravel may be present, but the soil is primarily clayish, especially in the lower-lying localities.

Like the *Stoebe plumosa-Elionurus muticus* Community of the *Stoebe plumosa-Leucosidea sericea* Major Community, no diagnostic woody species occur. *Peucedanum capense* (species group C) differentiates this community (Table 3.1). Noteworthy is the locally high cover-abundance of *Leucosidea sericea* and the absence of the thorny, exotic rose, *Rosa eglanteria* (species group J). Other important woody species are *Diospyros lycioides*, *D. austro-africana*, *Rhus erosa* and *Rhamnus prinoides* (species group Z). According to Coates Palgrave (1984), a decoction of the decorticated root of *R. prinoides* is taken as a blood purifier and to treat pneumonia. Parts of this plant are widely favoured as a protective charm which is used against lightning, to protect homes and to safeguard the courts of Basuthu chiefs (Coates Palgrave 1984).

2.4 *Cliffortia paucistaminea-Passerina montana* Community

This plant community is encountered at the feet of south to south-west-facing slopes. Rocks and pieces of fine gravel are visible on the soil surface. Large sandstone boulders occur at these footslopes.

Apart from *Cliffortia paucistaminea* (species group D) and *Passerina montana* (species group J), this plant community does not have a dominant or conspicuous woody component. The small forb species, *Oxalis corniculata* (species group D), together with *C. paucistaminea,* are the only two diagnostic species with the latter having a notably high cover-abundance (Table 3.1). *Leucosidea sericea* (species group J) has a relatively low cover-abundance and is, together with *Rhus erosa* (species group Z), the only woody species present (Table 3.1).

2.5 *Leucosidea sericea-Pelargonium alchemilloides* Community

This plant community is restricted to the lower altitudes of moist plateaux of dolerite hills. Flat rock slabs are prominent and cover 60-70% of the soil surface.

Diagnostic tree species are absent with only the species of species group E characterizing this vegetation unit (Table 3.1). *Leucosidea sericea, Passerina montana* (species group J), *Myrsine africana, Rhus dentata, Euclea crispa* subsp *crispa* (species group L), *Osyris lanceolata* (species group S), *Felicia filifolia, Diospyros austro-africana, Rhus erosa* and *Rhamnus prinoides* (species group Z) are the only shrubs present, all with a maximum height not exceeding two metres - probably due to the rockiness of the substratum.

2.6 *Hyparrhenia hirta-Osyris lanceolata* Community

This plant community is mainly associated with moist and cool south-facing slopes of the Aasvoëlberg Mountain near Zastron. The slopes are often cliff-like.

The presence of the grass, *Hyparrhenia hirta* (species group M), the most widespread of all the hyparrhenias (Gibbs Russell *et al.* 1990), together with the species from species group J) differentiate this vegetation unit (Table 3.1). *H. hirta,* commonly known as "dektamboekiegras" is a perennial, rhizomatous grass which grows well in stony soils (Gibbs Russell *et al.* 1990). The vegetation often is dense with *Leucosidea sericea* (species group J) often exceeding four metres in height. The tree, *Osyris lanceolata* (species group S), the exotic rose, *Rosa eglanteria* (species group J), and the shrub, *Rhus erosa* (species group Z), are the only other widely distributed woody species.

Two distinct sub-communities were identified (Table 3.1).

2.6.1 *Helichrysum rugulosum-Leucosidea sericea* Sub-community

This very limited plant community was encountered on footslopes of southerly facing hills. The area is rocky and large sandstone boulders (> 2 m in diameter) cover 60-70% of the soil surface. This is an important thoroughfare for hikers and thus resulted in the degradation of the vegetation due to trampling.

The diagnostic species are listed in species group F (Table 3.1). *Helichrysum rugulosum* and the grasses *Helictotrichon turgudulum, Setaria sphacelata* and *Eragrostis nindensis* are the most widely distributed among these species. *Leucosidea sericea, Rosa eglanteria* (species group J), *Osyris lanceolata* (species group S) and *Rhus erosa* (species group Z) are the most abundant woody species with *Hyparrhenia hirta* (species group M) and *Themeda triandra* (species group AC) the grasses with the highest cover-abundance (Table 3.1). *Themeda triandra* has a higher cover-abundance in this vegetation unit than in the *Rhus dregeana-Leucosidea sericea* Sub-community (Table 3.1).

2.6.2 *Rhus dregeana-Leucosidea sericea* Sub-community

This sub-community is associated with the moist and cool south-facing slopes. These slopes predominantly consist of sandstone ledges, often being cliff-like. The slopes are moist and cool due to the shading by the cliffs. The vegetation is dense and the rocky slabs covering 60-70% of the soil surface give the area a rocky appearance.

This moist shrubland is typical of the mountainous areas of the eastern Free State, Lesotho, Natal and eastern Cape and has been described by several botanists (Bews 1917, West 1951, Story 1952, Killick 1959, 1963, Roberts 1966, Edwards 1967 & Du Preez 1991). According to Roberts (1966), the *Leucosidea sericea-Myrsine africana* forest of Thaba 'Nchu Mountain is more closely related to the mesophytic bush and moist forest communities of the eastern Cape, as described by Story (1952), than to the shrublands of the Natal Midlands, as reported by Killick (1959, 1963). Du Preez (1991) stated that the *Leucosidea sericea-Buddleja saligna* moist shrubland of Korannaberg occurs on sites where conditions are too harsh for the development of ravine forest or in places where destruction of forest took place.

Species of species group H (Table 3.1) characterize this vegetation unit with *Rhus dregeana* the only diagnostic woody species present. The only other diagnostic species present, is *Aristea cognata*. The grass *Tristachya leucothrix* and the small fern, *Pellaea calomelanos* (species group I) are evident, especially between the rock slabs. Only a few other woody species occur with *Leucosidea sericea* (species group J), *Rhus dentata*, *Euclea crispa* subsp. *crispa*, *Myrsine africana* (species group L), *Buddleja salviifolia* (species group O), *Osyris lanceolata* (species group S), *Diospyros lycioides* and *Rhamnus prinoides* (species group Z) being the most important (Table 3.1). Species of species groups L and O are prominent within this vegetation unit, but are absent within the *Helichrysum rugulosum-Leucosidea sericea* Sub-community. The latter also lacks *Rhamnus prinoides* (species group Z) which is prominent within this vegetation unit (Table 3.1).

3 *Olea europaea-Rhus burchellii* Major Community

This open woodland major community is associated with the ravines as well as moist south- and south-east facing slopes of hills. The habitat conditions here are drier than in the previous two major communities (major communities 1 and 2). The soil surface is rocky and of doleritic origin.

Species of species group AB (Table 3.1) are diagnostic. *Olea europaea* subsp. *africana* and *Rhus burchellii* (species group AB) are the differentiating species with *Euclea crispa* subsp. *ovata* also abundant (Table 3.1). Other widely distributed woody species include the tree *Diospyros lycioides* and the shrubs *D. austro-africana, Felicia filifolia* and *Rhus erosa* (species group Z, Table 3.1).

Six distinct plant communities further characterize this major vegetation unit (Table 3.1).

3.1 *Euclea crispa* subsp. *crispa-Rhus dentata* Community

This shrubland is restricted to the rocky ravines at the foot of south-facing slopes. Stones and fine gravel from upslope occur on the soil surface.

This is a inconspicuous vegetation unit with only a few diagnostic species. *Thesium* sp., *Delosperma cooperi* and *Cussonia paniculata* (species group K) are the diagnostics of this community, all having low cover-abundance values (Table 3.1). *Myrsine africana, Rhus dentata, Euclea crispa* subsp. *crispa* (species group L), *Buddleja salviifolia* (species group O), *Osyris lanceolata* (species group S), *Rhigozum obovatum, Grewia occidentalis* (species group Y), *Diospyros lycioides, D. austro-africana, Rhus erosa* (species group Z), *R. burchellii* and *Olea europaea* subsp. *africana* (species group AB) are the most abundant woody species present. Among the graminoids *Hyparrhenia hirta* (species group M) and *Themeda triandra* (species group AC) are the most abundant (Table 3.1).

3.2 *Clutia pulchella-Diospyros lycioides* Community

A shrubland community situated at low altitude on south-facing hills. The soil is poorly drained and dolerite rock sheets cover large areas (50-70%) of the soil surface. Pieces of fine sandstone gravel eroding from upslope are common.

Clutia pulchella (species group P) differentiates this plant community. According to Coates Palgrave (1984), *C. pulchella* occurs over a wide range of altitudes and in a variety of habitats, from karroid scrub to evergreen forests. Venter & Joubert (1985), however, emphasized that this species commonly occurs in shady ravines and below large trees. This was mainly the case here, as *Clutia pulchella* grows well in the shade of especially *Diospyros lycioides* (species group Z) and *Rhus lancea* (species group Q). Species of species groups B, C, G, H, I, R and X are absent from this community (Table 3.1). Species of species groups S, Z, AB and AC (Table 3.1) occur widespread with *Osyris lanceolata* (species group S), *Diospyros austro-africana, D. lycioides, Rhus erosa* (species group Z), *Rhus burchellii, Olea europaea* subsp. *africana* (species group AB) the most important woody species and *Aristida diffusa* (species group AB) the only conspicuous grass. The small fern, *Cheilanthes eckloniana* (species group S), grows especially well in the cracks between rock sheets, but is inconspicuous here.

This vegetation unit is further subdivided into two distinct sub-communities (Table 3.1).

3.2.1 *Jamesbrittenia atropurpurea-Rhus erosa* Sub-community

This sub-community occurs in low altitude areas on south-facing hills and along streambeds where a sandy deposit often overlies the rock sheets. No loose scree is visible and the soil is of a clayish nature.

This sub-community is characterised by the species listed in group N (Table 3.1). Besides these diagnostic species, all of which have low cover-abundance values, *Diospyros lycioides* and especially *Rhus erosa* have high cover-abundance values (species group Z, Table 3.1). It further differs from the *Euclea crispa* subsp. *crispa-Rhus dentata* Community in the presence of *Cliffortia nitidula* and *Rhus pyroides* subsp. *gracilis* (species group A), as well as the higher cover-abundance of, *Diospyros austro-africana, D. lycioides, Rhus erosa* (species group Z) and *Rhus burchellii* (species group AB), and the absence of the grass, *Hyparrhenia hirta* (species group M). Besides *Themeda triandra* (species group AC) with a low constancy, *Aristida diffusa* (species group AB) is the only other graminoid with a high constancy and cover-abundance values (Table 3.1).

3.2.2 *Rhus lancea-Celtis africana* Sub-community

This vegetation unit is situated at low altitudes and is restricted to drainage channels at the footslopes of south-facing hills. Gravel and sandstone stones occur on the soil surface.

Species of species group Q differentiate this community with *Rhus lancea* and *Celtis africana* the only two diagnostic woody species. *Buddleja salviifolia* (species group O) and *Rhus erosa* (species group Z) are absent within this vegetation unit (Table 3.1). *Diospyros lycioides* (species group Z), *Rhus burchellii* and *Olea europaea* subsp. *africana* (species group AB) are among the other conspicuous woody species. *Diospyros lycioides,* especially, is very abundant and *Rhamnus prinoides* (species group Z) and *Euclea crispa* subsp. *ovata* (species group AB), though inconspicuous, are also present (Table 3.1).

3.3 *Protasparagus suaveolens-Eragrostis lehmanniana* Community

This plant community is associated with moist habitat conditions at the midslopes of south-facing slopes. Habitat disturbance is a more common phenomenon than in the *Clutia pulchella-Diospyros lycioides* Community. 50%-60% of the soil surface is covered with dolerite and sandstones stones.

Walafrida saxatilis, Protasparagus suaveolens and *Eragrostis lehmanniana* (species group W) are the diagnostic species of this vegetation unit (Table 3.1). Also conspicuous are *Diospyros lycioides, Rhus erosa* (species group Z), *R. burchellii* and *Olea europaea* subsp. *africana* (species group AB), none of which are higher than two metres.

This community can be subdivided into five sub-communities (Table 3.1).

3.3.1 *Cymbopogon excavatus-Protasparagus suaveolens* Sub-community

This plant community occurs on low altitudes of the midslopes, especially along the disturbed, moist rocky areas of low south-facing hills. Due to the rockiness of the soil surface, especially in the lower-lying areas, standing water is visible for weeks after good rains.

Species listed in species group R characterize this vegetation unit (Table 3.1) of which the grass, *Cymbopogon excavatus*, and the shrub, *Tarchonanthus camphoratus*, have the highest cover-abundance values (Table 3.1). *C. excavatus*, commonly known as Broad-leaved Turpentine Grass is highly unpalatable to livestock due to the terpentine smell of its leaves (Van Oudtshoorn 1991). The semi-parasite *Viscum rotundifolium* (species group R) is virtually restricted to *Tarchonanthus camphoratus*. According to Coates Palgrave (1984), splinters of *T. camphoratus* are poisonous, causing septic sores which are difficult to heal. It provides good fuel, burning even when green. Zulu women use the leaves to perfume their hair (Coates Palgrave 1984).

3.3.2 *Eragrostis curvula-Sutera albiflora* Sub-community

This plant community has a restricted distribution and is present on the midslopes of the south-facing slopes of low hills. The soil surface is rocky and the vegetation is often disturbed, mostly by local farming practices (cattle and sheep).

The characteristic species are listed in species group T (Table 3.1) with *Eragrostis curvula* the only species with a noteworthy occurrence. The tree, *Diospyros lycioides* (species group Z), is conspicuous and completely dominates the vegetation (Table 3.1).

3.3.3 *Cheilanthes eckloniana-Tragus koelerioides* Sub-community

A community restricted to the midslopes of south-facing hills with an abundance of dolerite and sandstone rocks (> 2 m in diameter). The habitat is more disturbed than the habitat associated with *Eragrostis curvula-Sutera albiflora* Sub-community.

Tragus koelerioides, a common grass species in disturb and overgrazed areas and the forb *Oxalis depressa* (species group U) are restricted to the shady patches between big dolerite and sandstone boulders. The woody component is inconspicuous and only the trees, *Diospyros lycioides* (species group Z), and *Olea europaea* subsp. *africana* (species group AB), as well as the shrubs, *Rhus erosa* and *Diospyros austro-africana* (species group Z) and *R. burchellii* (species group AB) occur. Besides *Tragus koelerioides*, *Themeda triandra* (species group AC) and *Heteropogon contortus* (species group AB) are the only noteworthy graminoids present (Table 3.1).

3.3.4 *Olea europaea-Melianthus comosus* Sub-community

This is a very local and limited plant community occurring on moist clayish soil of the midslopes. Big rocks are common, but no gravel or stones occur on the soil surface.

Melianthus comosus is the most conspicuous among the five differentiating species (species group V, Table 3.1). *Diospyros lycioides* (species group Z) is the most abundant tree species. This vegetation unit differs markedly from the *Cheilanthes eckloniana-Tragus koelerioides* Sub-community in the presence of *Eragrostis lehmanniana* (species group W), the stronger presence of *Diospyros lycioides* (species group Z) and the low cover-abundance values of *Olea europaea* subsp. *africana* (species group AB) and *Themeda triandra* (species group AC, Table 3.1).

3.3.5 *Olea europaea-Walafrida saxatilis* Sub-community

This vegetation unit is very limited, occurring only locally at very disturbed patches of the midslopes of south-facing hills, south-west of Wepener. This sub-community is not characterized by any diagnostic species group (Table 3.1). *Rhus burchellii* and *Olea europaea* subsp. *africana* (species group AB) are the only two conspicuous woody species present. Grasses are scarce and are restricted to *Eragrostis lehmanniana* (species group W), *Aristida diffusa* (species group AB) and *Themeda triandra* (species group AC, Table 3.1).

3.4 *Aloe ferox-Rhigozum obovatum* Community

The *Aloe ferox-Rhigozum obovatum* Community is found on the moist upland crests of steep (30°-60°) south- and south-east-facing slopes in the south-eastern parts of the study area near the former Transkei border. The vegetation of these dolerite hills is virtually undisturbed. However, patches of overgrazing, particularly by rock dassies (*Procavia capensis*) occur.

Aloe ferox (species group Y) is the only exclusively diagnostic species present with the shrubs, *Rhigozum obovatum* and *Grewia occidentalis*, also evident (species group Y, Table 3.1). According to Bornman & Hardy (1971) *A. ferox* is distributed over a range of 1 000 kilometres from Swellendam in the Western Cape to the southern parts of Lesotho and varies considerably in its different localities. These aloe plants grow singly or in dense groups and have tall stems up to 3 metres high (Bornman & Hardy 1971). The present authors endorse their observations. Other wide distributed woody species, besides *R. obovatum* and *G. occidentalis*, include the shrubs *Felicia filifolia* and *Diospyros austro-africana* (species group Z). The trees, *Diospyros lycioides* (species group Z), *Olea europaea* subsp. *africana* (species group AB) and the shrubs, *Rhus erosa* (species group Z) and *R. burchellii* (species group AB) are inconspicuous. *Hyparrhenia hirta* (species group M) and *Themeda triandra* (species group AC) are the abundant grasses (Table 3.1). This vegetation unit shows affinities with the *Hyparrhenia hirta-Osyris lanceolata* Community and *Euclea crispa* subsp. *crispa-Rhus dentata* Community by the presence of *Hyparrhenia hirta* (species group M, Table 3.1).

Two distinct units further divide this community (Table 3.1).

3.4.1 *Aloe ferox-Setaria incrassata* Sub-community

The *Aloe ferox-Setaria incrassata* Sub-community occur in well-drained areas with big sanstone rocks covering 40-60% of the surface. The aspect is mainly south-east. Overgrazing of the vegetation, especially by the rock dassie is common.

The differential species are listed in species group X of which *Setaria incrassata* and *Ruschia hamata* are the most abundant. *Rhus erosa* (species group Z) is the most conspicuous woody species with *Themeda triandra* (species group AC), *Heteropogon contortus* (species group AB) and especially *Hyparrhenia hirta* (species group M) the most prominent grasses (Table 3.1).

3.4.2 *Aloe ferox-Olea europaea* Sub-community

This vegetation unit occurs on the well-drained areas on south-facing slopes of hills. The habitat is drier than that of the *Aloe ferox-Setaria incrassata* Sub-community.

This sub-community further differs from the *Aloe ferox-Setaria incrassata* Sub-community in the absence of diagnostic species, the absence of *Diospyros lycioides* (species group Z) and *Euclea crispa* subsp. *ovata* (species group AB), the higher cover-abundance of *Hyparrhenia hirta* (species group M) and *Aloe ferox* (species group Y), as well as the lower cover-abundances of the shrub *Rhus erosa* (species group Z) and the grasses, *Heteropogon contortus* (species group AB) and *Themeda triandra* (species group AC, Table 3.1).

3.5 *Rhus ciliata-Olea europaea* Community

The *Rhus ciliata-Olea europaea* Community is strongly associated with the drier hills and ridges of the study area between Wepener and Zastron. The aspects are mostly south to south-east on isolated dolerite hills and ridges. The Ca land type is the most important and indicates land that qualifies as a plinthic catena with Hutton-, Bainsvlei-, Avalon- and Longlands soils the most prominent (Land Type Survey Staff, in press).

The *Rhus ciliata-Olea europaea* Community is limited in distribution and size and have only two differentiating species, *Rhus ciliata* and *Euphorbia mauritanica*, of which only *R. ciliata* is abundant (species group AA). *Olea europaea* (species group AB) is the only conspicuous tree species with *Aristida congesta*, *A. diffusa* (species group AB) and *Themeda triandra* (species group AC) the most prominent grasses (Table 3.1).

3.6 *Euclea crispa* subsp. *ovata-Olea europaea* Community

Like the *Rhus ciliata-Olea europaea* Community, this vegetation unit is also restricted to the drier hills and ridges of the study area. The aspect is south to south-east. The Fb land type is most prominent and indicates land where lime regularly occurs in the soil. Glenrosa, Mispah and Oakleaf soils are the most abundant (Land Type Survey Staff, in press).

This is also a very limited vegetation unit with only a few species present. Diagnostic species are absent. *Euclea crispa* subsp. *ovata* is the only shrub present in abundance (species group AB, Table 3.1). This plant community also lacks species of species group AA (Table 3.1) which characterize the *Rhus ciliata-Olea europaea* Community. The shrubs *Rhus* *burchellii* and *Euclea crispa* subsp. *ovata* (species group AB) are the only other abundant woody representatives (Table 3.1).

ORDINATION

In the scatter diagram (Figure 2) the distribution of the relevés along the first and second axes of the DECORANA ordination is given. The distribution of the different plant communities and sub-communities on the diagram were not clear. It was thus decided to only include differences between the different plant major communities. Major communities associated with ravines in relatively wet conditions on Elliot Formations are situated to the right of the diagram and relatively dry open woodland vegetation on Molteno Sandstone to the left (axis 1). Along the second axis, the plant communities with relatively low species diversity are situated at the bottom of the diagram, while the plant communities with higher species diversity are situated towards the top (Figure 2).

DISCUSSION

The aim of this study was to identify, characterize and ecologically interpret the plant communities of the Zastron area in the southern Free State.

Although the *Olea europaea-Rhus burchellii* Major Community (major community 3) are generally regarded as dry shrubland (Malan 1992, Malan *et al.* 1995), these vegetation units also occur within the 600-800 mm rainfall interval and are thus included in this manuscript.

The study area offers a wide variety of habitats and microclimates in a limited area. All vegetation units in this study can be related to specific environmental conditions and can therefore be ecologically distinguished and interpreted.

The strong presence of woody species on many rocky outcrops in the climatic climax Grassland Biome is ascribed to the shelter and favourable moisture regimes associated with high percentages of surface and sub-surface rock. Rainfall accumulation between rocks, concomitant with the volume of the soil profile occupied by sub-surface rocks, results in deeper rainfall infiltration, favouring species with a taproot system. Equally important may be the protection of seedlings and young plants by the rocks, from frost and fire (Fuls 1993).

The most important woody species encountered include *Buddleja salviifolia, Diospyros austro-africana, D. lycioides, Euclea crispa* subsp. *ovata, Felicia filifolia, Grewia occidentalis, Leucosidea sericea, Olea europaea* subsp. *africana, Osyris lanceolata, Rhamnus prinoides, Rhus burchellii, R. erosa* and the exotic rose *Rosa eglanteria*. *Cheilanthes eckloniana* is the most important fern and grows especially well in crevices between rocks as well as on the plateaux. Abundant grasses are restricted to *Aristida diffusa, A. congesta, Heteropogon contortus, Hyparrhenia hirta* and *Themeda triandra*.

Leucosidea sericea and *Buddleja saligna* are also abundant in the moist shrubland and forest communities of Korannaberg described by Du Preez (1991).

According to Du Preez (1991), a geological feature that plays an important role in the survival of the Afro-montane forest communities, is the narrow ravines where dolerite dykes cut through the Clarens Formation at the edge of the cliffs. During the intrusion phase (Jurassic Period), hot igneous material penetrated the sandstone and baked it to hard solid rock, which is resistant to weathering. The ravines developed by the subsequent more rapid weathering of the dolerite dykes (Du Preez 1991). Yellow, apedal, well-drained, oligotrophic soils are restricted to the plateaux. Lithosols are found mainly on the talus slopes (Du Preez 1991).

Roberts (1966) mentions Afro-montane fynbos communities from Thaba 'Nchu mountain, but his classification is derived from an association analysis, which is not comparable to a Braun-Blanquet classification.

The presented delineation of the plant communities and associated habitats should be used as the basis for future management and conservation of these areas.

Although the distribution of these plant communities is restricted to the south-eastern corner of the southern Free State, there are distinct similarities and differences between these species and communities and those plant communities encountered in the drier part of the southern Free State (Malan *et al.* 1995).

Due to the vulnerability of the vegetation in this area, special care should be taken to protect it from destruction by fire, habitat disturbance by hikers, especially on the Aasvoëlberg Mountain, and the collection of firewood. This shrubland vegetation is of great importance for the conservation of wildlife. Besides the providing of shelter for numerous mammals and bird species, it also hosts important nesting sites for the endangered Cape Vulture (*Gyps coprotheres*).

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CHAPTER 4

Vegetation ecology of the southern Free State

Vegetation ecology of the southern Free State: Dry shrubland communities of the rocky outcrops

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Vegetation ecology of the southern Free State: Dry shrubland communities of the rocky outcrops.

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ABSTRACT

A phytosociological analysis of the vegetation of the rocky outcrops of the southern Free State is presented. Relevés were compiled in 185 stratified random sample plots. A TWINSPAN classification, refined by Braun-Blanquet procedures, resulted in 35 plant communities. All these communities have ecological similarities and differences as pointed out by the DCA ordination. The described communities serve as a basis for their spatial distribution in this area as well as for determining their conservation status in the face of increasing development and agriculture.

4.1 INTRODUCTION

The Grassland Biome in South Africa is under heavy pressure from several different forms of man induced activities (Du Preez 1991). To enable optimal resource utilization and conservation, a vegetation classification program has been implemented in the Grassland Biome (Mentis & Huntley 1982; Scheepers 1987). This survey was planned to provide data for the synecological synthesis of the Grassland Biome Project (Scheepers 1987).

Attempts to conserve biotic diversity are pointless and impossible if the entities contributing to diversity are not known. Plant communities are conceived as individual, recognizable entities (Coetzee *et al.* 1993) and are characterised by their floristic composition (Whittaker 1978). Because the natural vegetation of the rocky outcrops in the southern Free State are clearly adversely affected by past and existing farming practices as well as continuous urban development (Fuls 1993), a detailed study of these areas is long overdue.

The main object of this study was, therefore, to classify, describe and ecologically interpret the shrubland communities of the rocky outcrops in the southern Free State. These data should be of importance for ecologically sound resource management, planning as well as for the identification of possible conservation areas, especially in the urban areas.

4.2 STUDY AREA

The area studied is situated in the southern Free State west of the 600-800 mm rainfall interval and is bounded by 24° 20' and 27° 00' E longitude and 29° 00' and 30° 50' S latitude. Plant communities east of the 600-800 mm rainfall interval are discussed elsewhere (Malan *et al.* in press.). Towns situated in the study area are (from north to south) Bloemfontein, Petrusburg, Fauresmith, Wepener, Zastron and Bethulie (Figure 4.1). In this area, wetlands are mostly represented by streams, rivers and vleis and are mainly found in bottomland situations. The area covers approximately 26 000 km^2. Permanently waterlogged soils are scarce and seasonally standing water is mostly restricted to slow-draining watercourses and drainage channels. Slow-draining streams are common owing to the flatness of the terrain over most of the study area.

The rainfall is erratic, especially in the western part of the study area and increases in an easterly direction from a 300-400 mm per annum rainfall interval to a 600-800 mm per annum rainfall interval.

A detailed description of the study area and environmental attributes is given elsewhere (Chapter 2).

4.3 METHODS

Relevés were compiled in 185 stratified random sample plots. Surveys were done during the summer and late summer of 1993 and 1994. Stratification was based on rainfall, topographical position (slope, crest and plateau), soil form and geology. No care was taken to place sample plots in severely degraded areas. Plot sizes were fixed at 100 m^2 (Scheepers 1975). In each sample plot a list of all species present were compiled and the cover-abundance of each species noted using the Braun-Blanquet scale (Mueller-Dombois & Ellenberg 1974). Taxa names conform to those of Arnold & De Wet (1993). No distinctions were made between different subspecies except for *Euclea crispa* subsp. *crispa* and *Euclea crispa* subsp. *ovata.* According to Venter & Joubert (1985) the latter is mainly distributed through the drier ridge veld of the southern Free State, while *Euclea crispa* subsp. *crispa* is common to abundant in the kloof forests and rocky habitat in the moist areas in the southern Free State. This is confirmed by Malan *et al.* (Submitted). *Euclea crispa* subsp. *ovata* is referred to as *Euclea crispa* while *Olea europaea* subsp. *africana* is referred to as *Olea europaea* in the text. All the reference specimens are housed at the Geo Potts Herbarium at the University of the Orange Free State. Other relevant information such as habitat disturbance, degradation of the vegetation, rockiness of the soil surface and human impact on the habitat were also noted. Soil depth was determined by driving a marked steel pin as deep as possible into the soil.

Two-way indicator species analysis (TWINSPAN) (Hill 1979 a) was applied to the floristic data set in order to derive a first approximation of the vegetation types of the area. Refinement was done by means of Braun-Blanquet procedures (Bredenkamp *et al.* 1989). The floristic data set was further subjected to an ordination algorithm (Hill 1979 b), to determine habitat gradients and the relationship with environmental variables.

4.4 RESULTS AND DISCUSSION

The vegetation of the rocky outcrops of the study area generally has a low species diversity (See Table 4.1), but contains a variety of trees, shrubs, herbs and forbs. The general vegetation of the rocky outcrops can be classified as the *Themeda triandra-Euclea crispa* Shrubland. This vegetation can be divided into two major communities, namely shrubland vegetation of hills and ridges (Major community 1) and dwarf shrubland associated with flat areas on the plateaux of hills (Major community 2).

The shrubland of the hills and ridges can further be divided into four distinct vegetation types:

1.1 shrubland of ravines and south- and east-facing slopes;
1.2 shrubland of the drier north and west-facing slopes;
1.3 shrubland of the dry, overutilized and disturbed crests and plateaux; and
1.4 shrubland of low hills on north and west-facing slopes.

The most abundant woody species associated with the hills include *Olea europaea*, *Grewia occidentalis* (species group K, Table 4.1), *Buddleja saligna* (species group Q), *Tarchonanthus camphoratus* (species group Z), *Euclea crispa*, *Rhus erosa*, *Felicia filifolia*, *Diospyros austro-africana*, *Ehretia rigida* (species group AF), *Rhus burchellii*, and *R. ciliata* (species group AJ, Table 4.1).

The grasses, *Digitaria eriantha* (species group U) and *Eustachys paspaloides* (species group T) frequently occur in open shrubland, but are limited to the low shrubland vegetation. Graminoids such as *Themeda* *triandra* and *Heteropogon contortus* (species group AJ) are conspicuous throughout the entire study area (Table 4.1).

Dwarf shrubland associated with flat areas on the plateaux of hills occurs primarily under dry conditions, is virtually unprotected from wind erosion, and is restricted to only a few shrubs and dwarf shrubs such as *Rhus erosa, R. ciliata, Eberlanzia spinosa* and *Felicia muricata* as well as the small fern, *Mohria caffrorum* (Table 4.1).

The vegetation is classified into 35 distinct plant units (Table 4.1). The hierarchical classification of the two major plant communities of the shrublands of the rocky outcrops of the southern Free State is as follows:

1 *Euclea crispa-Aristida diffusa* Major Community.

1.1 *Olea europaea-Buddleja saligna* Community.
1.1.1 *Crassula lanceolata-Buddleja saligna* Sub-community.
1.1.2 *Cussonia paniculata-Maytenus heterophylla* Sub-community.
1.1.3 *Diospyros lycioides-Buddleja saligna* Sub-community.
1.1.3.1 *Turbina oenotheroides-Diospyros lycioides* Variant.
1.1.3.2 *Cussonia paniculata-Diospyros lycioides* Variant.
1.1.3.3 *Solanum coccineum-Rhus burchellii* Variant.
1.1.3.4 *Olea europaea-Diospyros lycioides* Variant.
1.1.3.5 *Rhus lancea-Diospyros lycioides* Variant.
1.1.4 *Rhus lancea-Buddleja saligna* Sub-community.
1.1.4.1 *Acacia karroo-Schinus molle* Variant.
1.1.4.2 *Rhus lancea-Olea europaea* Variant.
1.1.4.3 *Osyris lanceolata-Rhus lancea* Variant.
1.1.5 *Osyris lanceolata-Olea europaea* Sub-community.
1.1.6 *Ziziphus mucronata-Olea europaea* Sub-community.
1.1.7 *Olea europaea-Buddleja saligna* Sub-community.

1.2 *Buddleja saligna-Euclea crispa* Community
1.2.1 *Opuntia ficus-indica-Buddleja saligna* Sub-community.
1.2.2 *Hermannia bryoniifolia-Pavonia burchellii* Sub-community.
1.2.3 *Maytenus polyacantha-Buddleja saligna* Sub-community.

1.2.4 *Pupalia lappacea-Lantana rugosa* Sub-community.
1.2.5 *Aloe broomii-Themeda triandra* Sub-community.
1.2.6 *Triraphis andropogonoides-Buddleja saligna* Sub-community.
1.2.7 *Buddleja saligna-Themeda triandra* Sub-community.

1.3 *Tarchonanthus camphoratus-Themeda triandra* Community.
1.3.1 *Digitaria eriantha-Tarchonanthus camphoratus* Sub-community.
1.3.1.1 *Hermannia vestita-Protasparagus capensis* Variant.
1.3.1.2 *Selago albida-Oxalis corniculata* Variant.
1.3.1.3 *Lightfootia albens-Eustachys paspaloides* Variant.
1.3.2 *Helichrysum zeyheri-Themeda triandra* Sub-community.
1.3.3 *Euryops multifidus-Tarchonanthus camphoratus* Sub-community.
1.3.4 *Rhigozum obovatum-Tarchonanthus camphoratus* Sub-community.
1.3.4.1 *Stipagrostis namaquensis-Rhigozum obovatum* Variant.
1.3.4.2 *Rhigozum obovatum-Heteropogon contortus* Variant.

1.4 *Euclea crispa-Themeda triandra* Community.
1.4.1 *Euclea crispa-Tragus berteronianus* Sub-community.
1.4.2 *Setaria sphacelata-Rhus ciliata* Sub-community.
1.4.3 *Phyllanthus parvulus-Sesamum capense* Sub-community.
1.4.4 *Kleinia longifolia-Themeda triandra* Sub-community.
1.4.5 *Cymbopogon excavatus-Euclea crispa* Sub-community.
1.4.6 *Euclea crispa-Aristida diffusa* Sub-community.

2 *Mohria caffrorum-Themeda triandra* Major-community.
2.1 *Eberlanzia spinosa-Mohria caffrorum* Community.
2.2 *Felicia muricata-Mohria caffrorum* Community.

DESCRIPTION OF THE COMMUNITIES

1 *Euclea crispa-Aristida diffusa* Major Community

This shrubland occurs mostly on the southerly and easterly facing slopes of hills and ridges and also within ravines and drainage lines or depressions on northerly facing slopes. These slopes are relatively undisturbed to mildly disturbed and/or overgrazed.

The most common, often dominant, woody species encountered is *Euclea crispa* (species group AF, Table 4.1). This species is widely distributed on the rocky outcrops of the southern Free State (Venter & Joubert 1985). According to the Tree Society of southern Africa (1969), *E. crispa* is one of the most common trees throughout South Africa. The shrubs, *Rhus erosa* and *Diospyros austro-africana* (species group AF) are also frequently encountered. *Rhus burchellii* (species group AJ) is the most common shrub in rocky ravines and on outcrops. Graminoids include *Aristida diffusa, Sporobolus fimbriatus, Cymbopogon plurinodis, Eragrostis curvula, Elionurus muticus* (species group AF), *Themeda triandra*, and *Heteropogon contortus* (species group AJ, Table 4.1).

This shrubland is further divided into four distinct plant communities (Table 4.1).

1.1 *Olea europaea-Buddleja saligna* Community

This shrubland commonly occurs as scrub on rocky places and ravine areas. The aspects are mostly southerly and easterly. The habitat is generally cool due to the shading of overhanging cliffs, moist and undisturbed. Areas of fine gravel, due to continuous erosion, give the soil a stony appearance. This shrubland also occurs on the gradual footslopes of hills and ridges. The soil here is generally deep (> 100 mm deep) and of the Avalon form with a clay content of often higher than 35% (Macvicar *et al.* 1977).

Trees and shrubs are totally dominant within this plant community. The differentiating species are listed in species group K (Table 4.1). *Buddleja saligna* (species group Q) and *Olea europaea* (species group K) are the most common tree species present. The most locally conspicuous shrub is *Grewia occidentalis* (species group K) which has an average height of < 3 m. This species generally does not have a high cover-abundance, but is widely distributed, especially in the dense ravine areas. *Euclea crispa* (species group AF) frequently occurs and is sometimes very abundant in rocky habitats. The shrub, *Rhus burchellii* (species group AJ), is also very abundant (Table 4.1).

Amongst the graminoids, *Themeda triandra* (species group AJ), is by far the most conspicuous. Other grasses which also commonly occur include *Heteropogon contortus* in rocky habitats, *Aristida congesta* and *Eragrostis lehmanniana* (species group AJ, Table 4.1) which are commonly associated with overgrazed and disturbed habitats (Van Oudtshoorn 1991).

The semi-parasite, *Viscum rotundifolium* (species group K) is a stemparasite which occurs most frequently on *Acacia karroo*, *Buddleja saligna* and *Ziziphus mucronata*.

This vegetation unit comprises seven distinct sub-communities (Table 4.1).

1.1.1 *Crassula lanceolata-Buddleja saligna* Sub-community

This is a very limited plant community which is restricted to shady areas of ravines at the footslopes of south-facing slopes. The soil is rocky and large boulders (> 3 metres in diameter) occur randomly. Rock slabs virtually cover the soil surface. The habitat is moist and cool with overhanging cliffs causing minimum exposure to direct sunlight.

The small forb, *Crassula lanceolata* (species group A), characterizes this sub-community (Table 4.1). *Buddleja saligna* (species group Q) and *Olea europaea* (species group K) are the only conspicuous tree species. The small fern, *Mohria caffrorum* (species group AI), which often grows luxuriously in this rocky habitat, is also abundant. Shrubs are scarce and restricted to *Grewia occidentalis* (species group K), *Rhus burchellii* and *Protasparagus laricinus* (species group AJ, Table 4.1). *Triraphis andropogonoides* (species group P) and *Eragrostis lehmanniana* (species group AJ) are the most common graminoids present (Table 4.1).

An average of 12 species/relevé was recorded for this sub-community (Table 4.1).

1.1.2 *Cussonia paniculata-Maytenus heterophylla* Sub-community

This plant community is restricted to the upper half of south-facing slopes where large dolerite boulders are common and the habitat is moist and cool. The diagnostic species (species group B, Table 4.1) and *Talinum caffrum* especially grow randomly in clayish soil in the shade of large boulders (generally > 2 metres in diameter).

This is a poorly developed plant community with all the differentiating species having a low cover-abundance (species group B, Table 4.1). The most abundant woody species are *Cussonia paniculata* (species group D), *Buddleja saligna* (species group Q), *Olea europaea* (species group K) and *Euclea crispa* (species group AF). According to the Tree Society of southern Africa (1969), *C. paniculata* commonly grows in the open, preferring dry situations. This was not the case here as the habitat is cool and moist. *Themeda triandra* and *Heteropogon contortus* (species group AJ) are the most common grass species (Table 4.1).

An average of 18 species/relevé was recorded for this sub-community (Table 4.1).

1.1.3 *Diospyros lycioides-Buddleja saligna* Sub-community

This plant community is found on the middle and lower half of south-facing slopes and within drainage lines or depressions of east-facing slopes. It is also common in ravines and along water courses. The soil is generally rocky, except along the water courses where clayish soil is abundant.

Diospyros lycioides (species group F) differentiates this vegetation unit. According to Coates Palgrave (1984), *D. lycioides* occurs in almost all types of habitat and can reaches heights of up to 7 metres. The tree, *Olea* *europaea* (species group K) has a low cover-abundance value and often reaches heights in excess of 5 metres. *Buddleja saligna* (species group Q) is very abundant, especially in the *Cussonia paniculata-Diospyros lycioides* Variant (Table 4.1). *Euclea crispa* (species group AF) and *Rhus burchellii* (species group AJ) are the most abundant shrubs present (Table 4.1). Grasses are absent from this community with the exception of *Themeda triandra* and *Heteropogon contortus* which have wide distributions (Table 4.1).

Five distinct vegetation units further characterize this sub-community (Table 4.1).

1.1.3.1 *Turbina oenotheroides-Diospyros lycioides* Variant

This variant is restricted to lower south-facing slopes. The habitat is marginally less rocky than that of the *Cussonia paniculata-Diospyros lycioides* Variant and the soil is clayish. Runoff water from upslope causes accumulation of water, especially in the low-lying areas so tat standing water is visible for virtually weeks after good rains.

This variant is differentiated by the scanty occurrence of *Turbina oenotheroides* (species group C). Conspicuous species are limited and restricted to the woody species *Cussonia paniculata* (species group D), *Diospyros lycioides* (species group F), *Buddleja saligna* (species group Q), *Euclea crispa*, *Rhus erosa* (species group AF) and *R. burchellii* (species group AJ).

An average of 11 species/relevé was recorded for this variant (Table 4.1).

1.1.3.2 *Cussonia paniculata-Diospyros lycioides* Variant

This variant is restricted to the midslopes of south-facing slopes of hills and ridges. The gradient is sometimes very steep (> 70°), but generally varies between 20°-50° with a rock cover of 30-60 %.

The *Cussonia paniculata-Diospyros lycioides* Variant lacks exclusive diagnostic species with the absence of species from species groups A, B and C also evident (Table 4.1). *Cussonia paniculata* (species group D), generally not exceeding two metres in height, is widely distributed, but has a low cover-abundance throughout the entire variant (Table 4.1). The high cover-abundance of *Buddleja saligna* (species group Q) and *Olea europaea* (species group K) is characteristic. The stemparasite *Viscum rotundifolium* (species group K) is semi-parasitic and is associated with *Olea europaea* (species group K) and *Buddleja saligna* (species group Q, Table 4.1). Other less common woody species include *Diospyros lycioides* (species group F), *Grewia occidentalis* (species group K) and *Rhus burchellii* (species group AJ). Graminoids are scarce and are virtually restricted to *Themeda triandra* (species group AJ, Table 4.1).

This variant recorded an average of 13 species/relevé (Table 4.1).

1.1.3.3 *Solanum coccineum-Rhus burchellii* Variant

This vegetation unit is common on the midslopes of south-facing hills. The soil surface is rocky with large boulders (> 2 metres in diameter) occurring. Fine sandstone, due to continuous erosion of dolerite, is common and often causes a slippery soil surface. Virtually the whole vegetation unit occurs in the shade of *Buddleja saligna* and *Olea europaea*.

Exclusive diagnostic species are absent, but the vegetation unit is differentiated by the constant presence of *Solanum coccineum* (species group E, Table 4.1). Also conspicuous is the absence of species of species groups A-D (Table 4.1). Abundant species are scarce with only the trees, *Olea europaea* (species group K), *Buddleja saligna* (species group Q), the shrub, *Rhus burchellii* (species group AJ) and Karoo encroacher, *Chrysocoma ciliata* (species group AJ), worth mentioning (Table 4.1). *C. ciliata*, especially, is a sure sign of pasture degradation (See Chapter 7).

This variant recorded an average of 9 species/relevé (Table 4.1).

1.1.3.4 *Olea europaea-Diospyros lycioides* Variant

This variant occurs on the lower half of slightly south-west-facing rocky slopes. Large dolerite rocks (> 4 metres in diameter) occur on the soil surface and the habitat is drier than the *Solanum coccineum-Rhus burchellii* Variant.

This vegetation unit also lacks an exclusive diagnostic species group (Table 4.1), but it is rather characterised by the absence of *Solanum coccineum* (species group E) as well as a slightly higher cover-abundance of *Diospyros lycioides* (species group F). Prominent trees include *Olea europaea* (species group K) and *Diospyros lycioides* (species group F). Among the shrubs, only *Buddleja saligna* (species group Q), *Euclea crispa, Rhus erosa, Felicia filifolia, Diospyros austro-africana* (species group AF), *Rhus burchellii* and *Protasparagus suaveolens* (species group AJ) are conspicuous. *Themeda triandra* (species group AJ) is the only abundant grass species (Table 4.1).

This variant recorded an average of 13 species/relevé (Table 4.1).

1.1.3.5 *Rhus lancea-Diospyros lycioides* Variant

The *Rhus lancea-Diospyros lycioides* Variant occurs mainly on the lower half of the south-facing slopes slightly above drainage channels. The soil is very shallow (< 50 mm deep) and rocky with gravel and stones from upslope covering the soil surface. No large dolerite boulders are visible on the soil surface.

Diagnostic species are absent (Table 4.1). The constant presence of *Rhus lancea* (species group H) is the most conspicuous difference between this variant and the other sub-divisions of the *Diospyros lycioides-Buddleja saligna* Sub-community (Table 4.1). *Buddleja saligna* (species group Q), *Olea europaea* (species group K), *Diospyros lycioides* (species group F) and *Rhus lancea* (species group H) have high constancies with, *D. lycioides* and *R. lancea* less abundant (Table 4.1). Shrubs are scarce with *Rhus erosa* (species group AF) and *R. burchellii* (species group AJ) being the most common species present (Table 4.1).

This variant recorded an average of 12 species/relevé (Table 4.1).

1.1.4 *Rhus lancea-Buddleja saligna* Sub-community

This sub-community is encountered on gentle (5°-20°) south-facing slopes and in drainage channels with shallow soils (< 150 mm deep). The soil is less rocky than in the *Diospyros lycioides-Buddleja saligna* Sub-community. Fine gravel cover the soil surface.

Diagnostic species are absent, but the absence of *Diospyros lycioides* (species group F) in particular and the higher cover-abundance of *Rhus lancea* (species group H) are noteworthy (Table 4.1).

The *Rhus lancea-Buddleja saligna* Sub-community comprises three distinct variants (Table 4.1).

1.1.4.1 *Acacia karroo-Schinus molle* Variant

The *Acacia karroo-Schinus molle* Variant is associated with the footslopes of south-facing slopes in drainage channels. The soil is generally clayey and covered by a thick layer (100-150 mm thick) of gravel and stones.

Acacia karroo, together with the exotic *Schinus molle* (species group G), differentiate this variant (Table 4.1). According to Carr (1976), *A. karroo* is more widely distributed than any of our other acacias (See Chapter 5). *A. karroo* in the Free State is usually a single- or several-stemmed tree, branching well clear of the ground to give a rounded outline and having a height varying between 5 to 10 metres. A variant from the North-West is generally similar when seen from a distance but tends to be somewhat smaller (Carr 1976). *Schinus molle* is a hardy foreign tree from South America that has become completely blended into the landscape of the more arid areas (Venter & Joubert 1985).

Rhus lancea (species group H), *Olea europaea* (species group K) and *Buddleja saligna* (species group Q) dominate the vegetation. The only abundant shrubs are *Rhus burchellii* and *R. ciliata* (species group AJ) with *Themeda triandra* and *Eragrostis lehmanniana* (species group AJ) being the most abundant graminoids (Table 4.1).

This variant recorded an average of 11 species/relevé (Table 4.1).

1.1.4.2 *Rhus lancea-Olea europaea* Variant

This vegetation unit is restricted to the gentle (5°-10°) west-facing slopes. The soil is shallow (< 100 mm deep) and more rocky than in the *Acacia karroo-Schinus molle* Variant. Fine gravel covers 60-80% of the soil surface.

This variant lacks exclusive diagnostic species. *Acacia karroo* and *Schinus molle*, which differentiate the *Acacia karroo-Schinus molle* Variant, are absent in this variant (Table 4.1). *Rhus lancea* (species group H) has a wide distribution and generally exceeds 2 metres in height. *Olea europaea* (species group K) and *Rhus lancea* (species group H) are the most common tree species present. The shrubs, *Buddleja saligna* (species group Q), *Rhus erosa* (species group AF) and *R. burchellii* (species group AJ) are not widely dispersed but have high cover-abundances in certain areas (Table 4.1). *Themeda triandra* (species group AJ) is the most important grass encountered.

An average of 9 species/relevé was recorded for the *Rhus lancea-Olea europaea* Variant (Table 4.1).

1.1.4.3 *Osyris lanceolata-Rhus lancea* Variant

The *Osyris lanceolata-Rhus lancea* Variant is restricted to ravines of south-facing footslopes. The habitat is more moist than that of the previous two variants of the *Rhus lancea-Buddleja saligna* Sub-community. Large dolerite boulders are common and provide perfect hiding places for the rock hyrax (*Procavia capensis*). The soil surface is trampled due to continuous overgrazing by livestock.

This variant lacks exclusive diagnostic species, but the presence of *Osyris lanceolata* differentiates it from the previous two variants of the *Rhus lancea-Buddleja saligna* Sub-community (Table 4.1). According to the Tree Society of southern Africa (1969), *O. lanceolata* is found growing on rocky ridges, outcrops and hillsides amongst other species and is never found in abundance in the Witwatersrand. This was also the case here. *Rhus lancea* (species group H) and *Olea europaea* (species group K) are the only other regularly occurring tree species present. *Buddleja saligna* (species group Q) and *Rhus erosa* (species group AF) are the most prominent shrubs. Grasses are scarce with *Elionurus muticus* (species group AF), *Themeda triandra* and *Heteropogon contortus* (species group AJ) being most common (Table 4.1).

An average of 14 species per sample plot was recorded for this variant (Table 4.1).

1.1.5 *Osyris lanceolata-Olea europaea* Sub-community

This plant community is encountered on the steeper (25°-50°) south-facing slopes. The soil is generally rocky and shallow (< 100 mm deep). Rock sheets are frequently found and the average rock cover is 30-50%.

This sub-community has no diagnostic species but is characterised by the presence of *Osyris lanceolata* (species group I) in the absence of *Rhus lancea* (species group H). *Olea europaea* (species group K) and *Osyris lanceolata* (species group I) are the most abundant tree species with the shrubs *Buddleja saligna* (species group Q), *Euclea crispa, Rhus erosa* (species group AF), *R. burchellii* and *R. ciliata* (species group AJ) also being conspicuous. *Themeda triandra* and *Heteropogon contortus* (species group AJ) are the most abundant grasses.

An average of 13 species per sample plot was recorded for this sub-community (Table 4.1).

1.1.6 *Ziziphus mucronata-Olea europaea* Sub-community

This sub-community is found on the steep (15°-50°), boulder-rich south-facing slopes of hills. The soil surface is uneven and rocky.

The high constancy of *Ziziphus mucronata* (species group J) and *Olea europaea* (species group K), as well as the concentrated occurrence of the exotic *Cotoneaster* sp. (species group J), differentiate this sub-community from the *Osyris lanceolata-Olea europaea* Sub-community (Table 4.1). According to Coates Palgrave (1984), *Z. mucronata* occurs in a wide variety of habitats, varying from open woodland to alluvial soils along rivers. It is also said to indicate the presence of underground water (Coates Palgrave 1984).

Olea europaea (species group K) and *Buddleja saligna* (species group Q) are conspicuous with *Euclea crispa, Felicia filifolia* (species group AF), *Rhus burchellii, R. ciliata* and *Protasparagus laricinus* (species group AJ) being the most abundant shrubs. Grass species are scarce with *Themeda triandra* (species group AJ) being the most common (Table 4.1).

The *Ziziphus mucronata-Olea europaea* Sub-community recorded an average of 13 species per sample plot (Table 4.1).

1.1.7 *Olea europaea-Buddleja saligna* Sub-community

This shrubland sub-community occurs randomly on hills and ridges in the study area. The aspects are generally south, south-west and east. The soil is rocky and shallow (< 100 mm deep).

Characteristic of this widely distributed sub-community is the absence of diagnostic species and the complete dominance of *Olea europaea* (species group K) and *Buddleja saligna* (species group Q). This vegetation unit also lacks species of species groups A to J (Table 4.1). This is an open shrubland with few other woody species occurring. *Tarchonanthus camphoratus* (species group Z), *Euclea crispa*, as well as the shrubs *Rhus erosa*, *Ehretia rigida*, *Felicia filifolia* (species group AF), *Rhus burchellii* and *R. ciliata* (species group AJ) are also prominent. The grass, *Themeda triandra* (species group AJ), has a restricted dominance (Table 4.1).

The *Olea europaea-Buddleja saligna* Sub-community recorded an average of 10 species per sample plot (Table 4.1).

1.2 *Buddleja saligna-Euclea crispa* Community

This plant community occurs on the drier north- and west-facing footslopes and crests of hills and ridges. Overgrazing is a more common phenomenon than in the *Olea europaea-Buddleja saligna* Community. In contrast to the *Olea europaea-Buddleja saligna* Community, *Olea europaea* (species group K) is virtually absent from this vegetation unit (Table 4.1).

Seven distinct vegetation units were distinguished (Table 4.1).

1.2.1 *Opuntia ficus-indica-Buddleja saligna* Sub-community

This sub-community is restricted to the crests of hills. The soil is generally shallow (< 100 mm deep) with large dolerite boulders and rock sheets commonly occurring. The *Opuntia ficus-indica-Buddleja saligna* Sub-community is virtually completely exposed to direct sunlight and wind, with the trees generally not exceeding 2 m in height.

The exotic *Opuntia ficus-indica* (species group K), introduced from the U.S.A. (Coates Palgrave 1984) have become naturalised and are now widespread and extremely troublesome in certain areas. The high cover-abundance values for *Buddleja saligna* (species group Q) are characteristic. These shrubs are small (< 2 m high), but numerous. *Euclea crispa* (species group AF) is the only other noteworthy tree species present. The grass, *Themeda triandra* (species group AJ), dominates the lower stratum with *Felicia filifolia* (species group AF) and *Rhus ciliata* (species group AJ) being the most prominent representatives of the shrub stratum (Table 4.1).

An average of 7 species per sample plot was recorded for this sub-community (Table 4.1).

1.2.2 *Hermannia bryoniifolia-Pavonia burchellii* Sub-community

This infrequent sub-community occurs in shady spots on the north-facing footslopes of hills. Large, round boulders virtually cover the soil surface. The tree stratum is generally not higher than 2 metres. The vegetation is overgrazed by livestock and the exposed soil surface is trampled.

The differentiating species listed in species group L (Table 4.1) mainly occur in the shade of dolerite boulders, with *Hermannia bryoniifolia* and *Pavonia burchellii* (species group L) being the most abundant (Table 4.1). It further differs from the *Opuntia ficus-indica-Buddleja saligna* Sub-community in the absence of *Opuntia ficus-indica* (species group K). *Senecio consanguineus* and *Melianthus comosus* are exclusive to this sub-community where *Buddleja saligna* (species group Q) is rather inconspicuous (Table 4.1). The locally dominant *Rhus ciliata* (species group AJ) is the only shrub worth mentioning and *Themeda triandra* and *Aristida congesta* (species group AJ) are the only abundant grasses (Table 4.1).

An average of 8 species/relevé was recorded for this sub-community (Table 4.1).

1.2.3 *Maytenus polyacantha-Buddleja saligna* Sub-community

This vegetation represents an open scrub and occurs mainly on and around the crests of rocky hills. Overgrazing is a common phenomenon and damage to the vegetation particularly by the rock hyrax is evident. *Maytenus polyacantha* (species group M) is often heavily utilized.

The most conspicuous woody species is *Buddleja saligna* (species group Q) which has a high cover-abundance (Table 4.1). In the absence of species from species group O, *Maytenus polyacantha* (species group M) is diagnostic of the *Maytenus polyacantha-Buddleja saligna* Sub-community. *Rhus burchellii* (species group AJ) and to a lesser extent *Diospyros lycioides* (species group F) are the only other prominent woody species, with *Themeda triandra* (species group AJ) the only dominant grass (Table 4.1). *Euclea crispa* and *Diospyros austro-africana* (species group AF) occur locally (Table 4.1).

An average of 10 species/relevé was recorded for this sub-community (Table 4.1).

1.2.4 *Pupalia lappacea-Lantana rugosa* Sub-community

This sub-community mainly occurs on west-facing slopes of low hills in the shade of trees. Generally the soil surface is rocky and covered with fine gravel.

The *Pupalia lappacea-Lantana rugosa* Sub-community is characterised by *Grewia occidentalis* (species group K) in the presence of the differentiating *Pupalia lappacea, Lantana rugosa, Solanum retroflexum, Chenopodium ambrosioides, C. album, Schkuhria pinnata, Hibiscus trionum,* the grass *Setaria verticillata* and *Commelina benghalensis* (species group N). These forbs are indicating continuous habitat disturbance. *Buddleja saligna* (species group Q), *Grewia occidentalis* (species group K) and *Rhus burchellii* (species group AJ) are the most common and widely distributed woody species. Among the grasses *Eustachys paspaloides* (species group T) and *Sporobolus fimbriatus* (species group AF) are abundant. *Themeda triandra* (species group AJ) is conspicuously absent. The small fern, *Pellaea calomelanos* (species group AJ) occurs, with a high constancy, in the crevices between rocks.

An average of 18 species/relevé was recorded for this sub-community (Table 4.1).

1.2.5 *Aloe broomii-Themeda triandra* Sub-community

The *Aloe broomii-Themeda triandra* Sub-community occurs on north-easterly-facing slopes and ravines with gradients varying from 8°-25°. Large dolerite boulders and rock sheets are abundant. In the lower-lying areas, weathered sandstone and gravel are common. The soil surface is disturbed by trampling of livestock.

Aloe broomii, commonly known as "Bergaalwyn" or "Slangaalwyn", *Indigofera sessilifolia* and *Nenax microphylla* (species group O) differentiate this sub-community (Table 4.1). According to Jeppe (1974), *A. broomii* got its native name "Slangaalwyn" because of the developing racemes resembling a cobra-like snake. *A. broomii* is found from Prieska in the Northern Cape to Luckhoff in the western Free State where it grows well in soil with a high lime content and flourishes best in low rainfall areas with frost in winter (Bornman & Hardy 1971). Woody species are scarce with only *Maytenus polyacantha* (species group M), *Buddleja saligna* (species group Q), *Euclea crispa* and *Rhus erosa* (species group AF) common. *Themeda triandra* (species group AJ) is the only prominent grass species with *Digitaria eriantha* (species group U), *Sporobolus fimbriatus*, *Cymbopogon plurinodis*, *Eragrostis curvula* (species group AF) and *Heteropogon contortus* (species group AJ) less abundant. The forb, *Stachys* *rugosa* (species group AJ), is commonly found growing in the crevices between the dolerite rocks.

The *Aloe broomii-Themeda triandra* Sub-community recorded an average of 16 species per sample plot (Table 4.1).

1.2.6 *Triraphis andropogonoides-Buddleja saligna* Sub-community

This sub-community is encountered on north-facing slopes of less than 10° and ravines where the soil is well-drained and 60-70% of the surface is covered by rock sheets. No large boulders occur.

The constant occurrence of the grass, *Triraphis andropogonoides* (species group P) differentiates this sub-community (Table 4.1). According to Van Oudtshoorn (1991), *T. andropogonoides* is unpalatable and commonly occurs in open grasslands on rocky hills. *Buddleja saligna* (species group Q), *Euclea crispa* (species group AF) and *Rhus burchellii* (species group AJ) are the most important woody species present with *R. ciliata* (species group AJ) being the most locally abundant shrub, particularly at the footslopes. The only other commonly occurring graminoids are *Themeda triandra*, *Heteropogon contortus* and *Eragrostis lehmanniana* (species group AJ, Table 4.1).

The *Triraphis andropogonoides-Buddleja saligna* Sub-community recorded an average of 8 species per sample plot (Table 4.1).

1.2.7 *Buddleja saligna-Themeda triandra* Sub-community

This widely distributed sub-community occurs mainly on the middle and upper half of the northerly and westerly-facing slopes of the hills and ridges. The gradient varies from 10-20°, with a rock cover of 20%-70%. Large sandstone boulders are a common phenomenon, especially at the edges of the overhanging cliffs.

This sub-community lacks diagnostic species and most of the species in species groups A to P (Table 4.1). The only exceptions are the scanty occurrences of *Solanum coccineum* (species group E), *Pavonia burchellii* (species group L) and *Hibiscus trionum* (species group N, Table 4.1).

A shrub stratum is well developed with the woody species *Buddleja saligna* (species group Q), *Euclea crispa* (species group AF), *Rhus burchellii* (species group AJ) and to a lesser extent *Rhus erosa* (species group AF) being dominant. The small shrub, *Rhus ciliata* (species group AJ), is also abundant, especially in the sheltered and moist environment provided by the boulders. The hardy *Protasparagus striatus* (species group AF) is locally common to abundant. Grasses are scarce with only *Themeda triandra* (species group AJ) and *Sporobolus fimbriatus* (species group AF) being conspicuous (Table 4.1).

An average of 8 species/relevé was recorded for this sub-community (Table 4.1).

1.3 *Tarchonanthus camphoratus-Themeda triandra* Community

This plant community occurs on dry, overutilized crests and plateaux of hills and ridges. Isolated patches of this shrubland occur on dry, disturbed, westerly or northerly-facing slopes. Generally the habitat is less rocky than in the *Olea europaea-Buddleja saligna* - and *Buddleja saligna-Euclea crispa* Community. This shrubland is primarily characterised by the regular occurrence of *Tarchonanthus camphoratus* (species group Z), a species that is dominant over large areas of the scrub veld of the western Free State (Venter & Joubert 1985).

In contrast to the shallow (< 100 mm deep) soils of the *Olea europaea-Buddleja saligna-* and *Buddleja saligna-Euclea crispa* Communities, the soils associated with this community are often deep (> 300 mm deep). Duplex soils with B-horizons are prominent on the slopes (Land Type Survey Staff, in press) while calcareous soils occur in the low-lying areas and plains.

Four distinct sub-communities further characterize this plant community (Table 4.1).

1.3.1 *Digitaria eriantha-Tarchonanthus camphoratus* Sub-community

This plant community is present on the plateaux of hills. Large dolerite boulders occur in this community resulting in microhabitats with a moister environment than surrounding areas. The soil varies from rocky to sandy especially in the lower-lying areas.

In the presence of *Tarchonanthus camphoratus,* the occurrence of the grass, *Digitaria eriantha* (species group U), differentiates this sub-community (Table 4.1). Under normal circumstances this grass is regarded as indicative of good pasture (Van Oudtshoorn 1991). Other abundant grasses include *Aristida diffusa*, *Sporobolus fimbriatus*, *Cymbopogon plurinodis* (species group AF) and *Themeda triandra* (species group AJ). Woody species are limited and restricted to the trees *Tarchonanthus camphoratus* (species group Z), *Euclea crispa* and the shrubs *Rhus erosa* (species group AF) and *Rhus burchellii* (species group AJ), with *Felicia filifolia* (species group AF) being less abundant. The fern, *Cheilanthes eckloniana* (species group AF), is also abundant, especially in micro-habitats between large boulders.

Three distinct variants further characterize this sub-community (Table 4.1).

1.3.1.1 *Hermannia vestita-Protasparagus capensis* Variant

The habitat in which this limited variant occurs is generally dry and about 60% of the surface area covered by large roundish and sub-angular stones and rocks between 0.1 and 0.5 m in diameter. Rock sheets are also found.

Although not diagnostic, this variant is characterised by the scanty occurrences of *Hermannia vestita* and *Protasparagus capensis* (species group R). Trees are scarce and are restricted to *Tarchonanthus camphoratus* (species group Z) and *Euclea crispa* (species group AF). Shrubs present include *Rhus burchellii* (species group AJ) and the dwarf shrub *Felicia filifolia* (species group AF). The only conspicuous graminoids are *Themeda triandra* and *Heteropogon contortus* (species group AJ).

An average of 17 species/relevé was recorded for this variant (Table 4.1).

1.3.1.2 *Selago albida-Oxalis corniculata* Variant

This variant is associated with lowlands and less rocky soil than that of the *Hermannia vestita-Protasparagus capensis* Variant. Sandy soils are more common.

The differentiating species of this vegetation unit (species group S, Table 4.1) have low cover-abundance values and are inconspicuous. The slightly higher cover-abundance values of *Digitaria eriantha* (species group U), *Aristida diffusa*, *Rhus erosa*, *Sporobolus fimbriatus*, *Cymbopogon plurinodis*, the absence of *Heteropogon contortus* and *Stachys rugosa* (species group AJ), as well as the dominance of *Euclea crispa* (species group AF), characterize this variant (Table 4.1). The presence of the grass, *Aristida congesta* and the Karoo encroacher, *Chrysocoma ciliata* (species group AJ), also differentiates this community from the *Hermannia vestita-Protasparagus capensis* Variant (Table 4.1). *Walafrida saxatilis* often grows in association with *Chrysocoma ciliata* on sandy soils (See Chapter 7).

An average of 18 species/relevé was recorded for this variant (Table 4.1).

1.3.1.3 *Lightfootia albens-Eustachys paspaloides* Variant

This variant occurs mainly on rocky-sandy soil with fine gravel common on the soil surface.

This variant lacks exclusively diagnostic species and is inconspicuous. Except *Tarchonanthus camphoratus,* other woody species include *Euclea crispa, Rhus erosa, Felicia filifolia* (species group AF) and *Rhus burchellii* (species group AJ). The fern, *Cheilanthes eckloniana* (species group AF) has a higher cover-abundance here as in the *Selago albida-Oxalis corniculata* Variant (Table 4.1). Abundant grasses are restricted to *Themeda triandra* and *Heteropogon contortus* (species group AJ).

The *Lightfootia albens-Eustachys paspaloides* Variant recorded an average of 16 species/relevé (Table 4.1).

1.3.2 *Helichrysum zeyheri-Themeda triandra* Sub-community

The *Helichrysum zeyheri-Themeda triandra* Sub-community is present on the overutilized crests higher up on the north-facing slopes of hills. No boulders occur, but the soil is rocky and shallow (< 100 mm deep).

The differentiating species are listed in species group V, all of which have a low cover-abundance (Table 4.1). The tree, *Tarchonanthus camphoratus* (species group Z), is conspicuous. *T. camphoratus* is shrublike, generally not exceeding 2 m in height. A further characteristic of this vegetation unit is the dominance of *Themeda triandra* (species group AJ). *Heteropogon contortus* (species group AJ) is also abundant and is often characteristic of rocky habitats (Van Oudtshoorn 1991).

The *Helichrysum zeyheri-Themeda triandra* Sub-community recorded 14 species per sample plot (Table 4.1).

1.3.3 *Euryops multifidus-Tarchonanthus camphoratus* Sub-community

This sub-community is limited to the plateaux of hills with large rock plates covering 60-70% the soil surface.

Euryops multifidus (species group W) differentiates this sub-community (Table 4.1) and only a few other species occur. The tree *Euclea crispa* (species group AF) and the small shrub *Rhus ciliata* are the most important woody species. Grasses are virtually restricted to *Themeda triandra* (species group AJ) and *Aristida diffusa* (species group AF, Table 4.1). *Themeda triandra* has a restricted dominance, but is notably less abundant in this sub-community than in the *Helichrysum zeyheri-Themeda triandra* Sub-community (Table 4.1).

The *Euryops multifidus-Tarchonanthus camphoratus* Sub-community recorded 7 species per sample plot (Table 4.1).

1.3.4 *Rhigozum obovatum-Tarchonanthus camphoratus* Sub-community

This sub-community mainly occurs on the dry overgrazed and often trampled crests of north-facing slopes. The soil surface is rocky and covered with large boulders.

The diagnostic shrub, *Rhigozum obovatum* (generally not higher than 2 m) (species group Y), is the most conspicuous shrub and often completely dominates the vegetation. The tree, *Tarchonanthus camphoratus* (species group Z), is the only other abundant woody species present (Table 4.1). This sub-community is inconspicuous due to continuous overgrazing and the occurrence of only a few species (Table 4.1). Noteworthy is the absence of species in species group AF with the scanty occurrence of *Ehretia rigida* being the only exception (Table 4.1).

Two variants further divide this sub-community (Table 4.1).

1.3.4.1 *Stipagrostis namaquensis-Rhigozum obovatum* Variant

This variant occurs on trampled ground, covered with a thick (100 mm thick) layer of sand on north-facing slopes. Gravel and stones (50 mm or less in diameter) cover 50% of the soil surface.

The grass, *Stipagrostis namaquensis* and the forb, *Berkheya pinnatifida* (species group X) are diagnostic of this variant, but the dominant *Rhigozum obovatum* (species group Y) is more conspicuous. According to Coates Palgrave (1984), *R. obovatum* commonly occurs in dry rocky places and karroid scrub. *R. obovatum* is often heavily browsed on by game and stock so that plants are frequently kept down to a height of about 1 m (Coates Palgrave 1984). This was also the case here with the average height of *R. obovatum* not exceeding 1 m. *Kleinia longifolia* (species group AD) has a low cover-abundance in this variant, but is absent from the *Rhigozum obovatum-Heteropogon contortus* Variant (Table 4.1).

The *Stipagrostis namaquensis-Rhigozum obovatum* Variant recorded an average of 7 species/relevé (Table 4.1).

1.3.4.2 *Rhigozum obovatum-Heteropogon contortus* Variant

This variant occurs in virtually the same habitat conditions than the *Stipagrostis namaquensis-Rhigozum obovatum* Variant. Termite heaps are conspicuous on the soil surface. The vegetation is overgrazed and the soil surface trampled. The vegetation, especially *Rhigozum obovatum*, is much smaller (not higher than 1 m) than in the *Stipagrostis namaquensis-Rhigozum obovatum* Variant. *Rhigozum obovatum* also has a lower cover-abundance than in the *Stipagrostis namaquensis-Rhigozum obovatum* Variant (Table 4.1).

This variant lacks exclusive diagnostic species but is characterised by the presence of *Heteropogon contortus* (species group AJ) which is absent in the *Stipagrostis namaquensis-Rhigozum obovatum* Variant (Table 4.1). Also conspicuous is the absence of *Stipagrostis namaquensis* and *Berkheya pinnatifida* (species group X), diagnostic of the *Stipagrostis namaquensis-Rhigozum obovatum* Variant (Table 4.1).

1.4 *Euclea crispa-Themeda triandra* Community

This plant community occurs on west, north and north-west facing slopes of low hills in the central parts of the study area. The vegetation is often severely overutilized by livestock and the herbaceous layer is often limited or even completely destroyed. The slopes are mostly dry and warm due to the high solar radiation associated with northerly facing slopes (Rossouw 1983). Surface rocks are predominantly doleritic with layers of sandstone (often deeper than 150 mm) a common phenomenon on the footslopes.

This community lacks exclusive diagnostic species. *Euclea crispa* is the only woody species present with high cover-abundance values (species group AF, Table 4.1). The small shrub, *Rhus ciliata* (species group AJ), with a random distribution has a restricted dominance especially in the more rocky habitats.

Themeda triandra, Heteropogon contortus (species group AJ) and *Aristida diffusa* (species group AF) are the grasses most often encountered. *Sporobolus fimbriatus* and *Elionurus muticus* and the small fern *Cheilanthes eckloniana* (species group AF) have limited occurrences (Table 4.1).

This community is further divided into six distinct sub-communities (Table 4.1).

1.4.1 *Euclea crispa-Tragus berteronianus* Sub-community

This sub-community is encountered on the dry north-facing slopes of dolerite hills. The soil is rocky with stones covering 20-40% of the soil surface.

The small grass, *Tragus berteronianus* (species group AA), differentiates this sub-community, with the < 2 m high "shrubby" tree, *Euclea crispa* (species group AF) being the most abundant woody species. According to Van Oudtshoorn (1991), *T. berteronianus* is unpalatable to livestock and it is an indicator of degrading veld conditions. *Euclea crispa* (species group AF) is the most important woody species present. *Themeda triandra* and *Heteropogon contortus* (species group AJ) are the only commonly encountered grasses. The dwarf fern, *Cheilanthes eckloniana* (species group AF), has a patchy occurrence and is mostly restricted to crevices between rocks.

The *Euclea crispa-Tragus berteronianus* Sub-community recorded an average of 10 species/relevé (Table 4.1).

1.4.2 *Setaria sphacelata-Rhus ciliata* Sub-community

The *Setaria sphacelata-Rhus ciliata* Sub-community is also associated with north-facing slopes, but the habitat is cooler and standing water in the low-lying areas occurs for virtually weeks after good rains. The soil is less rocky with the clay content generally exceeding 40% (Land Type Survey Staff, In press).

Setaria sphacelata (species group AB) differentiates this vegetation unit. The absence of the small fern, *Cheilanthes eckloniana*, mentioned in the *Euclea crispa-Tragus berteronianus* Sub-community, the lower cover-abundance of *Heteropogon contortus* (species group AJ) as well as the presence of the dwarf shrub, *Rhus ciliata* (species group AJ), further differentiate this community. *Themeda triandra* (species group AJ) is the only other noteworthy grass (Table 4.1).

An average of 9 species/relevé was recorded for this sub-community (Table 4.1).

1.4.3 *Phyllanthus parvulus-Sesamum capense* Sub-community

The habitat conditions for this limited sub-community are virtually the same as for the *Setaria sphacelata-Rhus ciliata* Sub-community. The soil surface is covered with gravel and thus appears to have a more rocky surface.

Setaria sphacelata is absent from this plant community (Table 4.1) and the differentiating species are listed in species group AC (Table 4.1), all of which have a low cover-abundance value (Table 4.1). As with the *Setaria sphacelata-Rhus ciliata* Sub-community, *Euclea crispa* and *Rhus ciliata* are also abundant, but *Themeda triandra* (species group AJ) is less conspicuous (Table 4.1). *E. crispa* (species group AF) often forms dense stands. Besides *T. triandra*, other grasses such as *Aristida diffusa*, *Sporobolus fimbriatus* and *Elionurus muticus* (species group AF) are also present, but are inconspicuous (Table 4.1).

An average of 12 species/relevé was recorded for this sub-community (Tale 4.1).

1.4.4 *Kleinia longifolia-Themeda triandra* Sub-community

The distribution of this sub-community is restricted to the lower half of the north and west-facing rocky slopes. The soil surface is severely trampled and overgrazing is common. The soil is sandy and deep (> 300 mm deep).

This sub-community lacks exclusive diagnostic species but is rather characterised by the marginally greater frequency of *Kleinia longifolia* (species group AD) than in the *Phyllanthus parvulus-Sesamum capense* Sub-community. Although *K. longifolia* is regarded as highly unpalatable, it is often utilized by livestock, especially during the winter months (Vahrmeijer 1981). According to Vahrmeijer (1981) this species is extremely toxic, especially to horses and cattle. Other abundant species present include *Euclea crispa* (species group AF), *Themeda triandra, Rhus ciliata* and *Protasparagus laricinus* (species group AJ, Table 4.1).

The *Kleinia longifolia-Themeda triandra* Sub-community recorded an average of only 8 species/relevé (Table 4.1).

1.4.5 *Cymbopogon excavatus-Euclea crispa* Sub-community

The *Cymbopogon excavatus-Euclea crispa* Sub-community is encountered on the upper half of the westerly-facing slopes. The habitat is more rocky than in the *Phyllanthus parvulus-Sesamum capense-* and *Kleinia longifolia-Themeda triandra* Sub-communities. Large boulders are common, but no gravel is visible on the soil surface.

The grass, *Cymbopogon excavatus* (species group AE), is the only differentiating species (Table 4.1). The higher cover-abundance values of the grass, *Aristida diffusa* (species group AF), in this sub-community are also noteworthy (Table 4.1). Other grasses present include *Sporobolus fimbriatus* (species group AF), *Themeda triandra* and *Heteropogon contortus* (species group AJ). *Euclea crispa* (species group AF) is the most important tree encountered. The most important shrubs include *Rhus burchellii* and *R. ciliata* (species group AJ) with the dwarf shrub, *Protasparagus striatus* (species group AF), having a restricted dominance (species group AF, Table 4.1).

An average of 10 species/relevé was recorded for this sub-community (Table 4.1).

1.4.6 *Euclea crispa-Aristida diffusa* Sub-community

The *Euclea crispa-Aristida diffusa* Sub-community is found on clearly disturbed (at least in patches), dry north-west facing slopes.

This sub-community lacks diagnostic species as well as species which were encountered in all the sub-communities of the *Euclea crispa-Themeda triandra* Community. This is mainly a shrubby-grassland community with *Euclea crispa* (species group AF) the only important tree and *Rhus ciliata* (species group AJ) being the only abundant shrub. Among the grasses, *Aristida diffusa* (species group AF), *Themeda triandra* and *Heteropogon contortus* (species group AJ) are abundant. Other grass species present include *Sporobolus fimbriatus* and *Enneapogon scoparius* (species group AF, Table 4.1).

An average of 9 species/relevé was recorded for this sub-community (Table 4.1).

2 *Mohria caffrorum-Themeda triandra* Major-community

This major-community is predominantly associated with the flat areas on the ridges and hill plateaux. The habitat is generally dry and virtually unprotected from wind. The soil is shallow (< 100 mm deep) and rock slabs cover 60-80 % of the soil surface. The soil has a sandy-gravelly texture with dolerite stones visible on the surface.

The *Mohria caffrorum-Themeda triandra* Major-community is differentiated by the small fern, *Mohria caffrorum* (species group AI, Table 4.1). It is also differentiated by the limited occurrence of large trees and shrubs.

This community divides into two distinct units (Table 4.1).

2.1 *Eberlanzia spinosa-Mohria caffrorum* Community

This plant community is encountered on the dry plateaux of rocky hills and ridges, which often show signs of degradation due to continuous over utilization by livestock. The soil is very shallow (often < 50 mm deep) and rocky. Rock slabs cover 70-80 % of the soil surface and exposed soil is limited.

The thorny succulent, *Eberlanzia spinosa* (species group AG), is the only differentiating species for this sub-community but the fern, *Mohria caffrorum* (species group AI), completely dominates the vegetation. Other species with a limited distribution are the shrub, *Rhigozum obovatum* (species group Y), the grass, *Heteropogon contortus* and the Karoo-encroacher, *Chrysocoma ciliata* (species group AJ, Table 4.1).

2.2 *Felicia muricata-Mohria caffrorum* Community

The *Felicia muricata-Mohria caffrorum* Community is restricted to the more disturbed areas the crests of hills and on plateaux. The soil is less rocky than for the *Eberlanzia spinosa-Mohria caffrorum* Community and is often sandy. Fine gravel covers the soil surface.

Felicia muricata (species group AH) differentiates this community. *Mohria caffrorum* (species group AI) is also common, but far less dominant than in the *Eberlanzia spinosa-Mohria caffrorum* Community, while the grass, *Themeda triandra*, is more abundant within this community (Table 4.1). *Rhus ciliata* (species group AJ) is locally dominant and the grass *Aristida congesta* (species group AJ) is further indicative of the disturbed condition of this community.

ORDINATION

A DCA ordination of the relevés is given in Figure 4.2. The two major communities described here have noteworthy similarities and differences. The *Eberlanzia spinosa - Mohria caffrorum* - and *Felicia muricata - Mohria caffrorum* Community of the *Mohria caffrorum - Themeda triandra* Major-community (indicated by e and f respectively in the scatter diagram) are virtually restricted to the high-lying areas on crests and plateaux while the *Euclea crispa - Aristida diffusa* Major Community is restricted to the footslopes of hills, ravines and crests (Axis 1, Figure 4.2). No clear discontinuity is associated with axis 2 of the diagram (Figure 4.2).

DISCUSSION

The two major plant communities were all restricted to specific areas within the study area. In most cases, the ordination illustrates the similarities between the plant communities described. The vegetation of the rocky outcrops is in a state of continuous degradation because of relatively low rainfall for the last number of years, as well as the continuous over-utilization by livestock. This is in contrast to the findings of Stuart-Hill *et al.* (1984) in the climatic climax Grassland Biome where a strong presence of woody species on the rocky outcrops was recorded. According to Stuart-Hill *et al.* (1984) and Fuls (1993) the strong presence of woody species is ascribed to favourable moisture regimes associated with high percentages of surface rocks and rocks in the soil profile. Rainfall accumulation between rocks, concomitant with the volume of the soil profile occupied by sub-surface rocks, results in deeper rainfall infiltration, favouring species with a taproot system (Fuls *et al.* 1993).

The most important species associated with the rocky outcrops in the southern Free State include the woody species *Olea europaea, Buddleja saligna, Euclea crispa* subsp. *ovata, Rhus erosa, Felicia filifolia, Rhus burchellii, R. ciliata, Protasparagus laricinus, P. suaveolens* as well as the grasses *Themeda triandra* and *Heteropogon contortus.* Other woody species with restricted distribution include *Cussonia paniculata, Diospyros lycioides, Rhus lancea, Osyris lanceolata* and *Tarchonanthus camphoratus.*

Generally the south-facing slopes have a higher species diversity than the north-facing slopes. This is in accordance with Du Preez (1991), Eckhardt (1993), Kooij (1990), Malan (1992) and Fuls (1993). This is because of the warmer micro-climate of the northerly facing slopes (Rossouw 1983, Fuls 1993). According to Eckhardt (1993), aspect and topography and associated moisture regime are the overriding factors controlling the distribution of the thicket and woodland vegetation of the north-eastern Free State. This is also the case in the southern Free State as indicated in the ordination (Figure 4.2).

The restricted distribution of the majority of the plant communities associated with rocky outcrops, makes it imperative that conservation of these plant communities receive high priority. Future research will concentrate on the conservation status of these species and the shrubland communities of the southern Free State. This delineation of the plant communities and associated habitats of the rocky outcrops of the southern Free State should be used as the basis for future management and conservation of these areas. The restricted distribution of the majority of the plant communities associated with rocky outcrops, together with the low species diversity, resulted from degradation, makes it imperative that these areas receive high conservation priority.

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CHAPTER 5

Vegetation ecology of the southern Free State

Acacia and related shrub communities of the dry south-western Free State

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5.1 INTRODUCTION

Mentis & Huntley (1982) stated the necessity to determine the location and extent of the major vegetation types within the Grassland Biome. In this context the vegetation of the southern and south-western Free State was studied as part of the phytosociological research programme on the synthesis of the vegetation of the western Grassland Biome in South Africa (Bredenkamp *et al.* 1989; Bezuidenhout & Bredenkamp 1990; Kooij *et al.* 1990).

Plant communities are conceived as vegetation units that are characterized by their floristic composition (Whittaker 1978). Each plant community may thus be regarded as an unique entity with its own species composition and associated set of environmental factors. According to Westhoff (1971) the description of plant communities is essential to provide a scientific inventory for conservation and in general for the presentation of biotic diversity.

The aim of this study is to classify and ecologically interpret the *Acacia* communities in the arid south-western Free State by means of Braun-Blanquet procedures. Acacias are such a conspicuous feature of much of our vegetation that there is much demand for information about them (Carr 1976). According to Carr (1976), the genus *Acacia* is one of the most widespread and important genera in Africa. It was thus decided to describe the thornveld communities as a separate entity of the south-western Free State. Shrubland communities of the rocky outcrops (Chapter 4), the drainage channels (Chapter 6) and those communities associated with the high rainfall region (600-800 mm rainfall region) within the southern and south-western Free State (Chapter 3) are discussed elsewhere in this dissertation. This manuscript will contribute towards the final objective of compiling a synecological synthesis of the Grassland Biome Project (Scheepers 1986).

5.2 STUDY AREA

The study area (Figure 5.1) is part of the Nama-Karoo Biome (Rutherford & Westfall 1994) and falls within the 300-400 mm/annum rainfall interval (Weather Bureau 1965) and includes the Orange River Broken Veld (Veld Types 35, 36 and 40 respectively of Acocks 1988) and the Orange River Nama Karoo (Hoffman 1996).

The main stratigraphic unit is the Ecca Group (SACS 1980). Alluvium, sand and calcrete deposits also occur and are mainly situated in the north-western corner of the study area, south-west of Jacobsdal, as well as in the region of Luckhoff in the extreme south-western parts. Dolerite dykes frequently occur, especially in the region of the Vanderkloof Dam (Du Toit 1954).

SOILS

The most common soil group is lime rich and weakly developed on rock of the Kimberley and Plooysburg forms (Soil Classification Working Group 1991). Other soil groups include sands, combinations of red clays and undifferentiated rocks and lithosols. Many of the soil surfaces are easily eroded by water and wind. Natural vegetation is mostly confined to shallow, rocky, non-arable soils. According to Hoffman (1996) red and yellow apedal, freely draining young soils are prominent in the largest part of the Orange River Nama Karoo.

The Ae, Ag and Da land types are most prominent in the northern and western parts of the study area. These soils are mainly red with a high base status, (Ae and Ag land types). Duplex soils (clayish soils with a sandy layer on top) with red B-horizons also occur (Da land type). In the southern parts of the study area, the soil surface is more rocky, exposed rock covering 60-80% of the surface (Ib land type). The latter is prominent in the region of the Vanderkloof Dam (Land Type Survey Staff, in press).

A detailed description of the physical environment of the study area is presented elsewhere (Chapter 2).

5.3 METHODS

Relevés were compiled in 83 stratified random sample plots. Care was taken to avoid sampling of severely degraded vegetation and excessively disturbed areas. Rainfall was used as a first stratification of the study area with land type for a more detailed stratification.

Plot sizes were fixed at 100 m^2 which are in accordance with plot sizes used by Scheepers (1975), Bredenkamp & Theron (1978), Rossouw (1983), Van Wyk (1983), Müller (1986), Du Preez (1991), Bezuidenhout (1993) and Fuls (1993). For every plant species present in the sample plot, a cover-abundance value was estimated according to the Braun-Blanquet scale (Mueller-Dombois & Ellenberg 1974).

Two-way indicator species analysis (TWINSPAN) (Hill 1979 a) was applied to the floristic data set in order to derive a first approximation of the plant communities of the area. In order to determine vegetation gradients and the relationship with environmental variables, Detrended Correspondence Analysis (DECORANA) (Hill 1979 b) was applied to the floristic data set.

Taxon and author names comply with those of Arnold & De Wet (1993).

5.4 RESULTS AND DISCUSSION

The vegetation of the study area separates into distinct plant communities. The variation in topography creates a variety of habitats which in turn bear different plant communities. Different utilization patterns also contribute to this variety of communities. The hierarchical classification is as follows:

1 *Tarchonanthus camphoratus-Acacia mellifera* Major Community
1.1 *Acacia mellifera-Scmidtia pappophoroides* Community

1.2 *Acacia mellifera-Hermannia comosa* Community
1.3 *Rhus burchellii-Lantana rugosa* Community
1.4 *Barleria rigida-Fingerhuthia africana* Community
1.4.1 *Justicia cuneata-Barleria rigida* Sub-community
1.4.2 *Barleria rigida-Eriocephalus spinescens* Sub-community
1.5 *Melhania rehmannii-Justicia protracta* Community
1.5.1 *Melhania rehmannii-Justicia cuneata* Sub-community
1.5.2 *Melhania rehmannii-Acacia mellifera* Sub-community
1.6 *Cenchrus ciliaris-Hermannia vestita* Community

2 *Grewia flava-Cenchrus ciliaris* Major Community
2.1 *Grewia flava-Fingerhuthia africana* Community
2.2 *Cenchrus ciliaris-Helichrysum lineare* Community

3 *Acacia tortilis-Heteropogon contortus* Major Community
3.1 *Cheilanthes eckloniana-Tarchonanthus camphoratus* Community
3.1.1 *Protasparagus mucronatus-Rhus ciliata* Sub-community
3.1.2 *Cheilanthes eckloniana-Eragrostis echinochloidea* Sub-community
3.2 *Acacia tortilis-Maytenus polyacantha* Community
3.2.1 *Chrysocoma ciliata-Aristida congesta* Sub-community
3.2.2 *Eriocephalus ericoides-Acacia tortilis* Sub-community
3.2.3 *Schmidtia pappophoroides-Dimorphotheca zeyheri* Sub-community
3.2.4 *Acacia tortilis-Eragrostis obtusa* Community

4 *Rhigozum trichotomum-Acacia karroo* Major Community
4.1 *Enneapogon scaber-Rhigozum trichotomum* Community
4.2 *Sarcostemma viminale-Rhigozum trichotomum* Community
4.3 *Hertia pallens-Rhigozum trichotomum* Community
4.4 *Euryops multifidus-Rhigozum trichotomum* Community

DESCRIPTION OF THE COMMUNITIES

1 *Tarchonanthus camphoratus-Acacia mellifera* Major community

This major community is to be found on the rocky areas in the south western parts of the study area. These sites are usually situated on shallow soil on the slopes of hills, but are also associated with the dry plateau edges. Geologically, the area is underlain by the Tierberg Formation of the Ecca Group. Outcrops of Karoo dolerite mainly occur in the region of the Vanderkloof Dam. According to Werger (1973), the southern Kalahari represents a marginal savanna area on deep sandy soils. *Acacia mellifera* is especially abundant in the Vryburg area (Werger 1973).

Species group J of the phytosociological table (Table 5.1) differentiate this vegetation unit with *Acacia mellifera* (species group J), the shrub *Tarchonanthus camphoratus* and the thorny shrub *Protasparagus suaveolens* (species group P) the differentiating species. The constant occurrences of the grass, *Heteropogon contortus* (species group AB), further differentiate this plant community (Table 5.1).

Six distinct vegetation units further differentiate this major community (Table 5.1).

1.1 *Acacia mellifera-Schmidtia pappophoroides* Community

This vegetation unit is found on the plateaux of low dolerite hills. Big dolerite boulders (> 1 metre in diameter) are visible on the soil surface. The vegetation is partly overgrazed and veld fires occurred regularly. According to McCabe (1987), grazing is not the only method of defoliation in the Karoo. He suggests that fire is an "aid" to veld management and not a solution to problems and that the use of fire must always be linked to the management process occurring before and after the burn takes place.

This plant community lacks diagnostic species, but is rather characterized by the dominance of *Acacia mellifera* (species group J, Table 5.1). According to Carr (1976), *A. mellifera* is extremely drought resistant and has a preference for deep, sandy or gravelly soils. This was not the case here, as dolerite hills are mainly rocky with shallow soils. The *Acacia mellifera-Schmidtia pappophoroides* Community has a low species diversity with the shrub *Tarchonanthus camphoratus* (species group P) the only other noteworthy woody species present. *Schmidtia pappophoroides* (species group

S), *Heteropogon contortus, Enneapogon scoparius* and *Aristida diffusa* (species group AB) are the only noteworthy grasses found.

1.2 *Acacia mellifera-Hermannia comosa* Community

This plant community is found on the south-facing midslopes of dolerite hills. Large boulders are absent, but more than 50% of the soil surface is covered with rocks (< 1 m in diameter) and stones.

Hermannia comosa (species group A) is the only differentiating species. This species often grows in extremely rocky habitat and is absent from the *Acacia mellifera-Schmidtia pappophoroides* Community (Table 5.1). Woody species are scarce and only the thorn tree, *Acacia mellifera* (species group J), and the shrub, *Tarchonanthus camphoratus* (species group T), are present. The latter can reach heights of up to 6 metres, but seldom exceeds 2 metres in height here. Other woody species include *Acacia karroo* (species group AA). *Protasparagus suaveolens* (species group P) is the only noteworthy shrub (Table 5.1). The grasses *Heteropogon contortus* and especially *Themeda triandra* (species group AB) occasionally have high constancies (Table 5.1).

1.3 *Rhus burchellii-Lantana rugosa* Community

The *Rhus burchellii-Lantana rugosa* Community is encountered on relatively dry to dry north-facing slopes and on flat plateaux of low hills. The soils are generally shallow (< 100 mm deep) with a high percentage (often higher than 70%) of surface rock.

The diagnostic species of this vegetation unit are the shrub, *Rhus burchellii*, and the forb, *Lantana rugosa* (species group B). *R. burchellii* commonly occurs in rocky ravines and ridge veld (Venter & Joubert 1985). The grass, *Heteropogon contortus* (species group AB), is the only grass species occurring throughout the entire plant community (Table 5.1).

1.4 *Barleria rigida-Fingerhuthia africana* Community

This community frequently occurs on the relatively dry to dry and often disturbed/degraded footslopes of rocky ridges. The soil is of a calcareous nature and the surface is often covered with wind-blown sand.

There are no diagnostic species for this vegetation unit, but species of species groups C, D, F, J and P constantly occur. *Barleria rigida* (species group C), *Justicia cuneata* (species group D), *Fingerhuthia africana* (species group F), *Acacia mellifera* (species group J) and *Tarchonanthus camphoratus* (species group P) are the most abundant species differentiating this vegetation unit. Tree and shrub species are scarce and only *Acacia mellifera* (species group J) and *Tarchonanthus camphoratus* (species group P) are conspicuous.

Two distinct sub-communities further differentiate this plant community (Table 5.1).

1.4.1 *Justicia cuneata-Barleria rigida* Sub-community

This sub-community frequently occurs in bottomland situations with moderately to poorly drained calcareous soil. Fine gravel covers 60-70% of the soil surface.

This vegetation unit mainly differs from the *Justicia cuneata-Acacia mellifera* Sub-community by a lower cover-abundance of *Acacia mellifera* (species group J), but higher cover-abundances of *Barleria rigida* (species group C), *Justicea cuneata* (species group D) and *Tarchonanthus camphoratus* (species group P). *Lycium cinereum*, *Polygala uncinata* and *Abutilon pycnodon* (species group D) are exclusive to this vegetation unit (Table 5.1).

1.4.2 *Justicia cuneata-Acacia mellifera* Sub-community

This plant community is restricted to the well-drained, sandy soils which generally have a layer of clayey soil underneath (duplex soils). Exposed rocks cover 20-30% of the soil surface.

This plant community does not contain exclusive diagnostic species, but is rather differentiated by the high cover-abundance of particularly *Justicia cuneata* (species group E). Other species also regularly occurring, include the grasses, *Sporobolus fimbriatus* (species group G), *Fingerhuthia africana* (species group I) and *Enneapogon scoparius* (species group AE). Tree species are scarce and only *Acacia mellifera* (species group N), of which the average height do not exceed 1 m, is worth mentioning (Table 5.1).

1.5 *Melhania rehmannii-Justicia protracta* Community

This plant community is encountered on the footslopes of north- and west-facing hills where the vegetation was found to be disturbed throughout. Pieces of fine gravel from upslope virtually cover all of the exposed soil surface.

Melhania rehmannii and *Justicia protracta* (species group E) are exclusive to this vegetation unit. The thorn tree *Acacia mellifera* (species group J), generally not higher than 2 metres, is often extremely dominant and occurs throughout the community (Table 5.1).

Two distinct sub-communities further differentiate this vegetation unit (Table 5.1).

1.5.1 *Melhania rehmannii-Justicia cuneata* Sub-community

This sub-community is found on the footslopes of north-facing hills where soils of a calcareous nature are prominent. The well-drained sandy soils are often trampled. Pieces of fine gravel cover the soil surface.

This vegetation unit lacks diagnostic species (Table 5.1). The restricted dominance of *Justicia cuneata* (species group D), are differentiating with *Acacia mellifera* (species group J), the only conspicuous tree present. Like the woody species, grasses are also limited with only *Fingerhuthia africana* (species group F), *Themeda triandra, Heteropogon contortus* and *Enneapogon scoparius* (species group AB) having patchy occurrences. The forb, *Corbichonia decumbens* (species group F), is quite abundant, especially in crevices between rocks.

1.5.2 *Melhania rehmannii-Acacia mellifera* Sub-community

This sub-community is encountered on the footslopes of west-facing hills. Like in the *Melhania rehmannii-Justicia cuneata* Sub-community, this vegetation unit is overgrazed and disturbed. Fine gravel, covering the soil surface, and dolerite rock sheets are prominent. This vegetation unit does not contain diagnostic species which are restricted to this specific plant community (Table 5.1).

Acacia mellifera is the only conspicuous tree species and has, with the exception of one relevé (relevé 78), a high cover-abundance. This is a limited plant community with *Acacia mellifera* (species group J) more abundant than in the *Melhania rehmannii-Justicia cuneata* Sub-community (Table 5.1). Only a few other species occur of which the shrub *Ehretia rigida* (species group AB) are among the subordinate shrubs with a low cover-abundance. The grass *Enneapogon scoparius* (species group AB) are locally dominant (Table 5.1).

1.6 *Cenchrus ciliaris-Hermannia vestita* Community

This extensive community occupies a relatively wetter habitat than the *Melhania rehmannii-Justicia protracta* Community. It is restricted to the dolerite hills near the Vanderkloof Dam in the southern part of the study area.

Big dolerite boulders are a common sight and the soil of the often steep slopes (> 60°) is rocky.

This community is differentiated by *Acacia mellifera* (species group J) and *Cenchrus ciliaris* (species group I). *Acacia tortilis* (species group V) also frequently occurs (Table 5.1). *Heteropogon contortus* (species group AB) is the only frequently occurring grass species (Table 5.1).

2 *Grewia flava-Cenchrus ciliaris* Major Community

This vegetation unit is restricted to rocky habitat at the footslopes of hills and ridges. Gravel due to continuous erosion of the upper layers cover the soil surface. Trampling effect of livestock is obvious.

The shrub, *Grewia flava* (species group H), and the grass, *Cenchrus ciliaris* (species group I), are the differentiating species present (Table 5.1). Other abundant woody species include the thorn trees, *Acacia mellifera* (species group J) and *A. tortilis* (species group V) and to a lesser extent, the shrub, *Ehretia rigida* (species group AB, Table 5.1).

2.1 *Grewia flava-Fingerhuthia africana* Community

The *Grewia flava-Fingerhuthia africana* Community was found to be scarce, being mostly associated with rocky soil, covered by a thin layer of wind-blown sand. Calcareous stones are present and nearly covered by fine sand.

This vegetation unit lacks any diagnostic species (Table 5.1) and is differentiated by the constant occurrence of *Grewia flava* (species group H), as well as the restricted dominance of *Cenchrus ciliaris* (species group I) and *Acacia mellifera* (species group J). The thorn tree, *Acacia tortilis* (species group Y), also occurs, but seldom exceeds two metres in height.

2.2 *Cenchrus ciliaris-Helichrysum lineare* Community

This community is generally found on rocky soil among big boulders. The habitat is better protected by these big boulders than in the *Grewia flava-Fingerhuthia africana* Community. The habitat is lower-lying and the soil is of a clayey nature. Surface rocks are present and are more conspicuous than in the *Grewia flava-Fingerhuthia africana* Community.

Species of species groups G and H differentiate this vegetation unit - all of which have a low cover-abundance (Table 5.1). Noteworthy is the dominance of *Cenchrus ciliaris* (species group I) and the absence of *Fingerhuthia africana* (species group F, Table 5.1). Also conspicuous are the presence of species of species group K, which are absent in the *Grewia flava-Fingerhuthia africana* Community. Conspicuous woody species include *Grewia flava* (species group H), with a restricted dominance, *Acacia mellifera* (species group J) and *A. tortilis* (species group V).

3 *Acacia tortilis-Heteropogon contortus* Major Community

The *Acacia tortilis-Heteropogon contortus* Major Community is found in the north-western corner of the study area in the Jacobsdal District. This vegetation unit is mainly associated with the bottomlands at the footslopes of low hills and on the adjacent plains. These soils generally have a high base status (Land Type Survey Staff, in press). Two areas are distinguishable namely one to the north and one to the south of Jacobsdal. The soils of the southern part (Ae land type) are generally deeper (> 300 mm deep) (Land Type Survey Staff, in press). The soils of the Ag land type in the northern part are shallow (< 300 mm deep) and are often very rocky (Land Type Survey Staff, in press).

The Tierberg Formation of the Ecca group is the main geological formation. As in the *Acacia mellifera-Heteropogon contortus* Major Community, dolerite dykes occur, but to a much lesser extent and these are virtually restricted to the higher-lying areas.

The presence of the species of species group V in the phytosociological table (Table 5.1) together with the absence of *Acacia mellifera* (species group J, Table 5.1) differentiate this vegetation unit. *Acacia tortilis* is the only dominant tree species present. According to Venter & Joubert (1985) this species is common to dominant in the western thornveld of the Free State. According to Carr (1976), *A. tortilis* is more common in bushveld and lowveld but extends also to the highveld areas of South Africa.

Six distinct communities further divide this vegetation unit (Table 5.1).

3.1 *Cheilanthes eckloniana-Tarchonanthus camphoratus* Community

This community is mainly associated with the foot- and midslopes of low hills in the undulating landscape and adjacent plains. The soils of these situations are generally deeper than 300 mm at the feet of the hills, but are markedly shallower on the rocky slopes. The soil type is mostly of the Mispah form with a shallow orthic A-horizon (Land Type Survey Staff, in press).

The vegetation is differentiated by the species listed in species group N (Table 5.1) which randomly occur in the relatively dry rocky areas of the western Free State. Although not exclusive to this vegetation unit, *Tarchonanthus camphoratus* (species group N) and *Acacia tortilis* (species group V) are the two dominant tree species present. The grass species, *Heteropogon contortus* (species group AB), is often very abundant in extremely rocky localities, but is less common in the low-lying areas.

Two distinct sub-communities are distinguishable in this vegetation unit (Table 5.1).

3.1.1 *Protasparagus mucronatus-Rhus ciliata* Sub-community

This sub-community is associated with the footslopes of rocky hills with rocks covering 80-90% of the soil surface.

This sub-community is dominated by *Protasparagus mucronatus* and *Rhus ciliata* (species group L, Table 5.1). Other species also differentiating this vegetation unit include *Chenopodium album* (species group K), *Hermannia vestita* (species group L) and the fern, *Cheilanthes eckloniana* (species group N). Noteworthy is the high constancy of *Tarchonanthus camphoratus* (species group P). In contrast, *Acacia tortilis* (species group V), has a patchy occurrence. The herbaceous layer is well developed and prominent grasses are *Digitaria eriantha* (species group N), *Themeda triandra* and *Heteropogon contortus* (species group AB).

3.1.2 *Cheilanthes eckloniana-Eragrostis echinochloidea* Sub-community

This sub-community occurs on the low-lying plains at the footslopes of hills along drainage lines. The soil is calcareous and covered by a thin layer of sand. Overgrazing and trampling of the soil surface is a common phenomenon.

The small grass, *Eragrostis echinochloidea* (species group M), is the only diagnostic species present (Table 5.1). According to Van Oudtshoorn (1991), this species grows well in disturbed habitat and is indicative of habitat disturbance and overgrazed pasture. Other grasses are limited, probably due to habitat disturbance and are restricted to *Digitaria eriantha* (species group N) and *Heteropogon contortus* (species group AB). *Acacia tortilis* (species group V) is the only abundant tree and *Tarchonanthus camphoratus* (species group P) the only prominent shrub present (Table 5.1).

3.2 *Acacia tortilis-Maytenus polyacantha* Community

This community is associated with drainage channels on the low-lying footslopes of dolerite hills. The soil is clayey with fine gravel and pieces of eroded rock, eroded from upslope, covering the soil surface.

This vegetation unit is differentiated by the presence of the species listed in species group U (Table 5.1). Although not abundant, *Maytenus* *polyacantha,* the thorny karroid dwarf shrub, *Eriocephalus spinescens* and the grass, *Aristida congesta,* are the most important species. The presence of *Chrysocoma ciliata* is indicative of Karoo invasion (Anonymous 1968).

3.2.1 *Chrysocoma ciliata-Aristida congesta* Sub-community

This vegetation unit is situated on the low-lying sandy areas of dolerite hills. The soil is deep (> 400 mm deep) and virtually no rocks or stones occur on the soil surface. Habitat disturbance, due to overgrazing and trampling by livestock, is evident. These areas are particularly vulnerable to soil erosion.

Elephantorrhiza elephantina (species group O, Table 5.1) randomly grows in deep sandy soil and is the only diagnostic species. *Rhus ciliata* (species group L), *Tarchonanthus camphoratus* (species group P), and *Maytenus polyacantha* (species group U) and *Acacia tortilis* (species group V) are the most important representatives of the woody component. Conspicuous grasses are absent and only *Aristida congesta* (species group U) and *Heteropogon contortus* (species group AB) have a restricted distribution (Table 5.1).

3.2.2 *Eriocephalus ericoides-Acacia tortilis* Sub-community

This community is found on dry low-lying plains with calcareous soils. Calcareous - and dolerite stones cover the soil surface. The soil is poorly drained and patches of overgrazing are a common phenomenon.

The *Acacia tortilis-Eriocephalus ericoides* Community is differentiated by the presence of the species of species group Q with the karroid shrublet, *Eriocephalus ericoides* the most abundant, and which together with *Chrysocoma ciliata,* give this sub-community a karroid appearance.

The shrub, *Tarchonanthus camphoratus* (species group P), is absent from this vegetation unit. *Acacia tortilis* is the only dominant woody species present (Table 5.1). Grasses are scarce and only *Eragrostis curvula* (species group N) is worth mentioning (Table 5.1).

3.2.3 *Schmidtia pappophoroides-Dimorphotheca zeyheri* Sub-community

The *Schmidtia pappophoroides-Dimorphotheca zeyheri* Sub-community is to be found in the extreme northern parts of the study area where soil is generally deep (> 300 mm deep) and sandy. Limestone reefs occur in areas where habitat disturbance is common.

Schmidtia pappophoroides (species group R) is the only abundant diagnostic species. *Dimorphotheca zeyheri, Hermannia modesta* and the small grass *Chloris virgata* are also diagnostic of this sub-community, but are inconspicuous. *Acacia tortilis* (species group V) dominates this thornveld and is the only conspicuous tree species present (Table 5.1).

3.2.4 *Acacia tortilis-Eragrostis obtusa* Sub-community

Like the *Schmidtia pappophoroides-Dimorphotheca zeyheri* Sub-community, this vegetation unit is also very limited in area and generally has a low species diversity (Table 5.1). The *Acacia tortilis-Eragrostis obtusa* Sub-community also occurs on deep sandy soils of bottomland situations, but the habitat is marginally wetter than that of the *Schmidtia pappophoroides-Dimorphotheca zeyheri* Sub-community, indicating somewhat better habitat conditions.

Blepharis diversispina (species group T) differentiates this sub-community, but the presence of the grass *Eragrostis obtusa* (species group S) is more evident. The absence of species of species group R combined with the presence of *Blepharis diversispina* (species group T) also differentiate this vegetation unit from the *Schmidtia pappophoroides-Dimorphotheca zeyheri* Sub-community. *Acacia tortilis* (species group V) is the only conspicuous woody species present (Table 5.1).

4 *Rhigozum trichotomum-Acacia karroo* Major Community

This major community comprises overgrazed and trampled veld and is found on shallow, rocky lithosols of loamy sand on the plateaux and gentle slopes, rarely sloping more than 5°. It also occurs on sites where the calcrete plateaux are overlain by a thin layer of Kalahari sand. The latter is mainly situated in the region of Petrusville in the south-western parts of the study area. This woodland also occurs on the banks of some dry rivulets, especially in upland situations. According to Bezuidenhout (1993) areas occupied by *Acacia karroo* Woodland are often overgrazed and the advanced stage of degradation is indicated by large areas of bare, compacted soil. This major community is not to be confused with the *Acacia karroo-Protasparagus laricinus* Major Community mentioned in Chapter 6 which is associated with low-lying areas along public roads.

This vegetation unit is differentiated by the presence of only two species, namely *Rhigozum trichotomum* and *Acacia karroo* (species group AA, Table 5.1). According to Carr (1976), *Acacia karroo* is more widely distributed than any of our other acacias and occurs in varying climatic conditions in all provinces of South Africa, eastern Botswana, Swaziland and Lesotho.

The *Rhigozum trichotomum-Acacia karroo* Major Community subdivides into four distinct communities (Table 5.1).

4.1 *Enneapogon scaber-Rhigozum trichotomum* Community

An infrequent community which occurs only on the rocky outcrops of dolerite on the plateaux along the Orange River in the region of the Gariep Dam. The soil is covered with large rock slabs.

Enneapogon scaber (species group W) differentiates this community and grows extremely well between the rock slabs. *Acacia karroo* is infrequent and is generally not higher than 1 metre, probably due to the shallow and rocky soil. *Sporobolus fimbriatus* (species group D), *Fingerhuthia africana* (species group F) and *Cenchrus ciliaris* (species group I) especially, further differentiates this vegetation unit (Table 5.1). Also present, but less frequent, are *Heteropogon contortus* and *Enneapogon scoparius* (species group AB, Table 5.1).

4.2 *Sarcostemma viminale-Rhigozum trichotomum* Community

Downstream from Orania, (just outside the study area in the Northern Cape), the Ecca sandstones are frequently covered by sand which contains a fair amount of gravel. Calcareous concretions constitute an important component of these soils, and often the sand and gravel are completely cemented into thick calcrete strata. The vegetation is disturbed and the soil trampled.

Sarcostemma viminale (species group X) is the differentiating species. Only a few other species occur, of which *Rhigozum trichotomum* and *Acacia karroo* are occasionally abundant (species group AA, Table 5.1). Graminoids are conspicuously absent, probably due to the trampled condition of the habitat.

4.3 *Hertia pallens-Rhigozum trichotomum* Community

This vegetation unit occurs on the calcareous-rich soils of the flat pediplains of the south-western Free State. Dolerite and Ecca sandstone are overlain by a layer of loamy Kalahari sand, possibly somewhat mixed with wind-blown alluvial sand. It usually contains a small fraction of fine gravel. This soil is relatively compacted, compared to the majority of the Kalahari sands.

Hertia pallens (species group Y, Table 5.1) is the only species differentiating this plant community. This karroid species usually occurs under extremely dry conditions where the pasture is overgrazed and the soil trampled. Besides *H. pallens, Rhigozum trichotomum* and *Acacia karroo* are the only abundant species present.

4.4 *Euryops multifidus-Rhigozum trichotomum* Community

The *Euryops multifidus-Rhigozum trichotomum* Community is also associated with calcareous-rich soils of the low-lying areas. Surrounding dolerite boulders create a cooler and moister habitat than that of the *Hertia pallens-Rhigozum trichotomum* Community. No gravel is visible on the soil surface.

Rhigozum trichotomum (species group AA), conspicuously dominant in this vegetation unit, often forms very dense stands together with *Acacia karroo* over large areas of trampled veld. *Euryops multifidus* (species group Z) grows well in the low-lying areas, especially in areas where stagnant water occurs for long periods of time.

ORDINATION

The distribution of the syntaxa along the first and second axes of the DECORANA ordination (Hill 1979 b) is given in Figure 5.2. The first axis illustrates a gradient of habitat disturbance (Figure 5.2). Also illustrated along axis 1, is the distribution of plant communities associated with rocky and sandy soils. Along the second axis, plant communities of bottomlands and the footslopes of hills range at the top of the diagram, while communities restricted to the hills and ridges as well as the plateaux are to the bottom.

The *Grewia flava-Cenchrus ciliaris* Major Community is clearly a transition between the *Tarchonanthus camphoratus-Acacia mellifera* Major Community and the *Acacia tortilis-Heteropogon contortus* Major Community. The DECORANA ordination (Figure 5.2) supports the Braun-Blanquet classification (Table 5.1).

DISCUSSION

This is the first comprehensive ecological account of the *Acacia* communities in the dry south-western Free State. All the major vegetation types and associated plant communities could be related to specific environmental attributes. These communities all differ from one another, but certain similarities are also noticeable. The woodland vegetation of the *Acacia* communities are easily distinguishable and interpretable in the veld. The grassland is being overgrazed and burnt. Field fires occur regularly and play an important role in veld management. In this way the unpalatable grass component is destroyed and new pioneer grasses have the chance to establish.

The low species diversity and low successional status of the species are ascribed to the degradation of the grassland and to bush encroachment. In areas where thorn-bush encroachment is a problem, a cheap and effective method of assisting the recovery of bare areas is to cover such areas with brush which is cleared from the area before seeding. Normally such brush decomposes after a few seasons and the little patches thus protected then become available for grazing. However, in all cases of veld reclamation, whether by natural or chemical means, sufficient recuperative rest during the growing season in the ensuing years is essential if the reclaimed veld is to maintain itself (Tainton 1984).

Acacia mellifera, A. tortilis, A. karroo and *Rhigozum obovatum* are the most important differentiating species in the thornveld of the southern Free State. *Acacia mellifera* is common in the south-western thornveld, while *Acacia tortilis* is common to abundant in the western parts on calcareous habitat of the south-western Free State. *Acacia karroo* is widely distributed through the Free State and occurs especially along water courses and drainage channels (See Chapter 6). In exceptional cases, *Acacia karroo* encroachment may occur on overgrazed grassland vegetation. *Rhigozum obovatum* is a widely distributed karroid species and is common to abundant in stony veld and on hills. The most important grasses encountered in the thornveld include *Aristida congesta, A. diffusa, Enneapogon scoparius, Eragrostis lehmanniana, Fingerhuthia africana, Heteropogon contortus* and *Themeda triandra. Blepharis diversispina, Chrysocoma ciliata, Hertia pallens, Eriocephalus ericoides, E. spinescens, Lycium cinereum, Pentzia globosa* and *Salsola glabrescens* are all elements from the Karoo vegetation, indicating the strong relationship between these *Acacia* grassland communities and the encroaching Karoo.

Conservation of these areas should receive high priority and these present studies could be used as basis in doing so. The need to get a better understanding of the thornveld vegetation in order to apply constructive conservation techniques and in order to manage the resources in a better way is necessary and should be high on the list of priorities.

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CHAPTER 6

Vegetation ecology of the southern Free State

Vegetation ecology of the southern Free State: Riparian shrub communities

CHAPTER 6

VEGETATION ECOLOGY OF THE SOUTHERN FREE STATE: RIPARIAN SHRUB COMMUNITIES

6.1 INTRODUCTION

The necessity of detailed plant ecological studies as a basis for sound land-use planning, management and research is widely recognized (Pentz 1938; Codd 1949; Bayer 1970; Foran *et al.* 1986; Bosch *et al.* 1987). One of the major projects in this respect is the Grassland Biome Project. The Grassland Biome of South Africa covers approximately 27% of the country (Rutherford & Westfall 1994). As a result of intensive agricultural practices and urbanization, together with industrialization, the deterioration of the grassland led to concern amongst decision-makers, resulting in the launch of the Grassland Biome Project (Mentis & Huntley 1982).

One of the first priorities of this Project, was to determine the location and extent of the major vegetation types within the Biome (Mentis & Huntley 1982). The aim of this study was therefore to classify and describe the riparian shrub communities in the southern Free State. This study also fits in with a comprehensive phytosociological programme under the Grassland Biome Project (Mentis & Huntley 1982; Scheepers 1987).

The physical environment (Chapter 2), description of the plant communities of the Zastron Area (Chapter 3), those associated with the rocky outcrops of the dry south-western Free State (Chapter 4) and *Acacia* communities (Chapter 5), are discussed elsewhere in this dissertation. This report primarily deals with shrub communities associated with low-lying drainage channels and other relevant bottomland moist habitats. In contrast to the mountainous habitats the communities associated with the bottomlands display a generally lower species diversity. The habitat is fairly unstable, due to seasonal flooding and drying which, together with the frequent overgrazing of the area, have caused an advanced state of degradation of the vegetation. The soil is often severely eroded and the vegetation obviously disturbed.

Ross (1948) stated that continuous degradation of natural pasture in many parts of the world is visible. The Karoo and adjacent grasslands are also in a degradation phase (Tidmarsh 1948; Bezuidenhout 1993). Topsoil with low (< 0,5% organic Carbon) organic material content covers nearly 60% of the country, while sandy soil (< 10% clay) covers nearly 30% of the area (Van Oudtshoorn 1991). These soils are particularly vulnerable to wind and water erosion. A number of scientists previously refer to the continuous degradation of vegetation due to continuous erosion in South Africa (Robertson 1968).

According to Du Preez (1991) the *Acacietea karroo* in the southern and eastern Free State represents the thickets usually situated on well-developed levees along rivers, streams and drainage lines, and is also present on clayey soils on the low level terraces and flood plains adjacent to the rivers. Vegetation of this class may also be found on deep alluvial or colluvial soils on gradual footslopes of hills and ridges, usually situated near drainage lines and rivers (Bredenkamp *et al.* 1989; Bredenkamp & Bezuidenhout 1990). The *Acacia karroo-Rhigozum trichotomum* Community associated with higher-lying areas is discussed in Chapter 5 of this dissertation.

Rivers and flood plains in the interior of South Africa are periodically and seasonally flooded. This phenomenon results in erosion of top soils or deposition of sand, clay and silt on river banks and flood plains. In such disturbed habitats only pioneers and species with wide ecological amplitudes can survive (Du Preez 1991).

Fire as a controlling factor of *Acacia karroo* encroachment is not always successful (Trollope 1974). Evidence from the more arid thornveld of the Eastern Cape (Du Toit 1972) has shown conclusively that fire is not effective in killing *Acacia karroo*. Trollope (1974) has shown that only a small proportion (9.3%) of *A. karroo* is in fact killed by fire. The herbaceous layer of these riparian communities is usually without a dense grass cover. Dense stands of fire resistant mature tree and shrub species suppress the growth of grasses and fires thus looses its detrimental effect (Trollope 1974). Observations made in the eastern Cape show that *Acacia karroo* was able to survive eight years in succession by coppicing after each burn (Trollope 1974).

The widespread ploughing of arable land concomitant with livestock grazing pressure, further result in the destruction and degradation of large tracks of pristine vegetation and also play an important role in the continuous eroding of arable soil in the study area. The extent of vegetation retrogression, as well as the total land-area in question, is difficult to assess or to quantify. A more detailed identification, description and determination of the localities of the riparian shrub communities are thus needed.

6.2 STUDY AREA

The present study includes the southern Free State and is situated to the south of the 29° 00' S latitude and to the west of the 27° 00' E longitude, encompassing approximately 27 000 km^2.

Two biomes can be distinguished in the study area, namely the Grassland and Nama-Karoo Biomes (Rutherford & Westfall 1994). According to Acocks (1953, 1988) the vegetation of these biomes in the southern Free State is divided into six different veld types. Towns situated in the study area are (from north to south) Bloemfontein, Petrusburg, Fauresmith, Wepener, Zastron and Bethulie (Chapter 2).

The rainfall is erratic, especially in the western part of the study area from where it increases and increases in an easterly direction from a 300-400 mm/annum rainfall interval to a 600-800 mm/annum rainfall interval. Slow-draining streams are common owing to the flatness of the terrain.

A detailed description of the study area and environmental attributes is given in Chapter 2 of this dissertation.

6.3 METHODS

Relevés were compiled in 31 stratified random sample plots. Care was taken to avoid sampling of severely degraded vegetation and excessively disturbed areas.

Plot size was fixed at 100 m^2 which is in accordance with the plot size used by Scheepers (1975), Bredenkamp & Theron (1978), Rossouw (1983), Van Wyk (1983), Müller (1986), Du Preez (1991), Bezuidenhout (1993) and Fuls (1993). For every plant species present in the sample plot, a cover-abundance value was estimated according to the Braun-Blanquet scale (Mueller-Dombois & Ellenberg 1974).

Two-way indicator species analysis (TWINSPAN) (Hill 1979 b) was applied to the floristic data set in order to derive a first approximation of the plant communities of the area. In order to determine vegetation gradients and the relationship with environmental variables, Detrended Correspondence Analysis (DECORANA) (Hill 1979 a) was applied to the floristic data set.

Taxon and author names comply with those of Arnold & De Wet (1993).

6.4 RESULTS AND DISCUSSION

In the analysis of the vegetation, nine distinct vegetation units were identified. Two major communities, grouped into five distinct plant communities, were identified which are dominated by *Acacia karroo* and *Rhus lancea* respectively. The distribution pattern of the low thicket vegetation apparently depends primarily on the variations in irradiation (Fuls 1993) and rockiness of the soil surface. The hierarchical classification of the vegetation stresses the correlation between habitat and communities in the study area, as well as the relationships between communities. The communities are classified as follows:

1 *Acacia karroo-Diospyros lycioides* Major Community
1.1 *Acacia karroo-Salix babylonica* Community
1.2 *Ziziphus mucronata-Protasparagus laricinus* Community
1.2.1 *Rhus pyroides-Lycium hirsutum* Sub-community
1.2.1.1 *Setaria verticillata-Chenopodium album* Variant
1.2.1.2 *Crassula lanceolata-Acacia karroo* Variant
1.2.1.3 *Rhus pyroides-Protasparagus laricinus* Variant
1.2.2 *Heteromorpha trifoliata-Nidorella resedifolia* Community

2 *Rhus lancea-Rhus burchellii* Major Community
2.1 *Olea europaea-Rhus lancea* Community
2.2 *Rhus erosa-Rhus lancea* Community
2.2.1 *Diospyros austro-africana-Rhus lancea* Sub-community
2.2.2 *Heteropogon contortus-Rhus lancea* Sub-community
2.3 *Euclea crispa-Rhus lancea* Community

DESCRIPTION OF THE COMMUNITIES

1 *Acacia karroo-Protasparagus laricinus* Major Community

This widespread shrub community is mainly associated with the low-lying or slightly undulating plains along public roads. According to Carr (1976), *Acacia karroo* is more widely distributed than any other *Acacia* species and occurs in varying climatic conditions in all provinces of the Republic of South Africa, eastern Botswana, Swaziland and Lesotho. Although *Acacia karroo* is adaptable to a wide variety of conditions and soil forms (Carr 1976), the location of this major-community is restricted to areas where wind-blown sand and gravel eroding from higher-lying areas often cover the soil surface.

The vegetation is characterized by *Acacia karroo* (species group G, Table 6.1). According to Carr (1976), *A. karroo* was probably the first of the South African acacias to have drawn the attention of early botanists. Other widely spread trees include *Ziziphus mucronata* (species group F), *Olea* *europaea, Diospyros lycioides* (species group H) and *Rhus lancea* (species group M). *Protasparagus laricinus* (species group F) is the only abundant shrub (Table 6.1). The sedge *Cyperus longus* (species group F) is also common. Graminoids are scarce and are restricted to patchy occurrences of *Setaria verticillata* (species group B), *Eragrostis obtusa* (species group F), *Themeda triandra* and *Sporobolus fimbriatus* (species group M).

An average of 13 species per relevé was recorded for this major community.

Two distinct communities further characterize this major-community (Table 6.1).

1.1 *Acacia karroo-Salix babylonica* Community

This community represents azonal wetland-like vegetation and is present in depressions or other bottomland situations. These bottomland situations generally have soils with a higher clay content than those of upland areas. No rocks or large stones are visible on the soil surface. The soil is poorly drained and low-lying areas are inundated for long periods after rains.

Species of species group A (Table 6.1) characterize this community. The diagnostic woody species are the exotics *Salix babylonica, Schinus molle* and *Nicotiana glauca*, the reed *Phragmites australis*, the grass *Tetrachne dregei,* as well as the shrublets *Asclepias fruticosa* and *Melilotus alba* (Table 6.1). According to Stirton (1978), *Nicotiana glauca* is indigenous in north-western and central Argentina, Paraguay and Bolivia and commonly occurs along public roads in dongas and on river beds. The alkaloid present in *N. glauca*, nicotine, mainly causes nervous symptoms such as twitching, shaking and shivering. Abdominal pain and breathing difficulties and vision disturbancees may also occur (Tampion 1982). *Phragmites australis* sometimes is heavily grazed by livestock and generally does not exceed 1 metre in height. *Acacia karroo* (species group G) has an extremely high cover-abundance and completely dominates the vegetation, with *Diospyros lycioides* (species group H) also generally encountered (Table 6.1).

An average of eight species per relevé was recorded for this community

1.2 *Ziziphus mucronata-Protasparagus laricinus* Community

This plant community can be found on the relatively well-drained, clayey soils of riverbanks. The soil is drier than that of the *Acacia karroo-Salix babylonica* Community. Habitat disturbance due to continuous overgrazing and trampling of livestock and occasional flooding is reflected in the species composition (Table 6.1).

Species listed in species group F, with *Ziziphus mucronata* and *Celtis africana* the only exclusive diagnostic tree species, differentiate this vegetation unit (Table 6.1). *Protasparagus laricinus, P. suaveolens* and *Lycium cinereum* (species group F) are the most abundant shrubs. The reed, *Cyperus longus*, normally associated with wetlands (Eckhardt *et al.* 1993), the forb, *Tagetes minuta*, and the climber, *Clematis brachiata*, are the only other abundant and differentiating species (species group F, Table 6.1). Other conspicuous species include the trees, *Acacia karroo* (species group G), *Olea europaea, Diospyros lycioides* (species group H) and *Rhus lancea* (species group M). The height of these trees varies between 4-5 metres.

An average of 15 species per relevé was recorded.

This plant community is divided into two distinct sub-communities (Table 6.1).

1.2.1 *Rhus pyroides-Lycium hirsutum* Sub-community

This bottomland vegetation occurs on seasonally wet, well-drained sandy soils of riverbeds. The habitat is fairly unstable due to seasonal flooding and drying. Overgrazing of pasture and trampling of livestock frequently occurs.

Species listed in species group D differentiate this sub- community. *Lycium hirsutum* and *Rhus pyroides* (species group D) are the only abundant and differentiating shrubs and *Panicum maximum* the only differentiating grass (Table 6.1). Other conspicuous trees and shrubs include *Ziziphus mucronata* (species group F), *Acacia karroo* (species group G), *Diospyros lycioides* (species group H) and *Rhus lancea* (species group M) with *Celtis africana* (species group F) and *Olea europaea* (species group H) less abundant (Table 6.1).

Three distinct variants further characterize this plant community (Table 6.1).

1.2.1.1 *Setaria verticillata-Chenopodium album* Variant

The *Setaria verticillata-Chenopodium album* Variant occurs in full sun and is restricted to the disturbed and overgrazed zones of dry riverbeds. Duplex soils are prominent. Large trees are absent and the maximum height of tree species does not exceed two metres.

The two diagnostic species are pioneers which colonize disturbed habitats. They are the grass *Setaria verticillata* and the forb *Chenopodium album* (species group B, Table 6.1). The absence of *Olea europaea* (species group H) also characterizes this vegetation unit. *Acacia karroo* (species group G) is inconspicuous and has an average height of only 0.3 metres. Conspicuous species include the sedge, *Cyperus longus* (species group F), with *Rhus pyroides* (species group D) and *R. lancea* (species group M) small, but numerous. Forbs are inconspicuous and are restricted to *Chenopodium album* (species group B), *Tagetes minuta, Artemisia afra* and *Zinnia peruviana* (species group F), as well as the climber *Clematis brachiata* (species group F)

An average of 18 species per relevé was recorded (Table 6.1).

1.2.1.2 *Crassula lanceolata-Acacia karroo* Variant

This entity is associated with wet riverbeds at the footslopes of dolerite hills. The undergrowth of this vegetation unit occurs in the full shade of the tree canopy. The soil is sandy with fine gravel from upslope (often 200 mm deep) visible on the surface. This habitat is wetter than that of the *Setaria verticillata-Chenopodium album* Variant.

This variant is not well developed. *Crassula lanceolata* and *Pollichia campestris* (species group C) are the only differentiating species. *Acacia karroo* (species group G), the most abundant tree species, generally exceeds three metres in height. *Rhus pyroides* (species group D), *Celtis africana*, *Ziziphus mucronata* (species group F) and *Diospyros lycioides* (species group H) are more abundant here than in the *Setaria verticillata-Chenopodium album* Variant. The presence of *Olea europaea* (species group H) also differentiates this variant from the *Setaria verticillata-Chenopodium album* Variant (Table 6.1). *Olea europaea* is shrub-like and generally does not exceed two metres in height.

1.2.1.3 *Rhus pyroides-Protasparagus laricinus* Variant

This vegetation unit also occurs in dry riverbeds with a thick (50-100 mm) layer of gravel, which gives it a rocky appearance, covering the soil surface. The deeper soil layers are clayish, moist and deep (< 100 mm deep).

Diagnostic species are absent (Table 6.1). The most abundant shrubs are *Rhus pyroides* (species group D) and *Diospyros lycioides* (species group H). *Acacia karroo* (species group G) and *Rhus lancea* (species group M) are, although inconspicuous, the most abundant trees. The sedge *Cyperus longus* (species group F) often forms dense stands. Noteworthy is the absence of *Celtis africana* (species group F) and the scanty occurrence of *Acacia karroo* (species group G) and *Olea europaea* (species group H). Graminoids are scarce and restricted to *Panicum maximum* (species group D), *Themeda triandra* and *Sporobolus fimbriatus* (species group M).

An average of 15 species per relevé was recorded (Table 6.1).

1.2.2 *Heteromorpha trifoliata-Nidorella resedifolia* Sub-community

This community is restricted to moist bottomland situations where poorly drained calcareous soils occur. The soil is calcareous-clayey and calcareous stones are visible on its surface. The deeper soil layers associated with this sub-community were found to be generally more clayey than those associated with the *Rhus pyroides-Lycium hirsutum* Sub-community.

The vegetation is overgrazed and the shrub, *Heteromorpha trifoliata*, generally not higher than two metres, and the forb, *Nidorella resedifolia* (species group I), are diagnostic (Table 6.1). *Acacia karroo*, generally not exceeding two metres in height, and *Ziziphus mucronata* (2-4 metres) (species group F) are the most abundant tree species. Other tree species present, include *Olea europaea* (species group H) and *Rhus lancea* (species group M) with *R. ciliata* (species group J) the only locally abundant shrub (Table 6.1). The absence of *Diospyros lycioides* (species group H), as well as the absence of species from species groups A-D, I, K and L, also differentiates this sub-community from the *Rhus pyroides-Lycium hirsutum* Sub-community (Table 6.1).

2 *Rhus lancea-Rhus burchellii* Major Community

The *Rhus lancea-Rhus burchellii* Major Community is chiefly associated with drainage channels at the footslopes of low hills. The habitat is more rocky than that of the *Acacia karroo-Diospyros lycioides* Major Community. Big dolerite rocks from upslope often cover more than 50% of the soil surface. The soil surface is often severely eroded and dongas are conspicuously observable.

Rhus lancea and *R. burchellii* (species group M) are the only widely dispersed woody species. *Rhus erosa* (species group K) and *R. ciliata* have a more restricted distribution (Table 6.1). *R. erosa*, especially, is common to dominant on more arid mountain slopes and hills (Venter & Joubert 1985). Signs of overgrazing are obvious in some cases, with the pioneer species *Aristida diffusa* prominently present (species group I, Table 6.1). *Themeda triandra* and *Sporobolus fimbriatus* (species group M) are the only other relatively common graminoids (Table 6.1).

An average of seven species per relevé was recorded (Table 6.1).

Three communities are distinguishable (Table 6.1).

2.1 *Olea europaea-Rhus lancea* Community

This vegetation unit is restricted to the footslopes of rocky hills. The slopes face mainly in a southerly direction, explaining the higher moisture conditions of the soil. Soils of the Mispah Form is typical of this habitat with surface-rock percentages exceeding 20%. Big dolerite rocks are common, covering 20-50% of the soil surface. The soil is shallow (< 100 mm deep) and rocky.

Diagnostic species are absent, but the vegetation is rather characterized by the exceptional dominance of *Rhus lancea* (species group M, Table 6.1). *Olea europaea* and *Diospyros lycioides* (species group H) are the only other conspicuous tree species present. *Aristida diffusa* (species group I) and *Rhus burchellii* (species group M) are the only noteworthy grass and shrub species respectively (Table 6.1).

An average of seven species per relevé was recorded (Table 6.1.).

2.2 *Rhus erosa-Rhus lancea* Community

The *Rhus erosa-Rhus lancea* Community is also found along the footslopes of rocky hills. The aspects are south and south-west. The soil is well-drained and sandy with exposed rocks covering less than 20% of the soil surface.

Fine gravel virtually cover the soil surface, especially in the lower-lying areas.

Rhus erosa (species group K) is very conspicuous and the only differentiating species present (Table 6.1). *Rhus lancea* (species group M), together with *R. erosa* (species group K) and *R. burchellii* (species group M) often form dense stands, especially in the lower-lying areas (Table 6.1).

Two sub-communities further differentiate this plant community (Table 6.1).

2.2.1 *Diospyros austro-africana-Rhus lancea* Sub-community

This sub-community is encountered on well-drained sandy soils of south-west facing slopes where deep dongas are a common phenomenon. Signs of overgrazing are obvious. The different soil types to be found vary from shallow (< 100 mm) to deep (> 200 mm). The soil is less rocky than in the *Heteropogon contortus-Rhus lancea* Sub-community.

This sub-community lacks exclusive diagnostic species (Table 6.1). *Diospyros lycioides* (species group H) and *Rhus lancea* (species group M) are the most conspicuous tree species present. *R. lancea*, here less prominent than in the *Heteropogon contortus-Rhus lancea* Sub-community, generally does not exceed two metres in height. *Rhus erosa* (species group K) and *Diospyros austro-africana* (species group K) are the most prominent shrubs. The absence of *Heteropogon contortus* and *Rhigozum obovatum* (species group J), as well as the presence of *Diospyros lycioides* and *D. austro-africana* further differentiate this sub-community from the *Heteropogon contortus-Rhus lancea* Sub-community (Table 6.1).

2.2.2 *Heteropogon contortus-Rhus lancea* Sub-community

This sub-community is associated with well-drained sandy-rocky soils. The aspect is south. Rock slabs cover 60% of the soil surface. Fine gravel and dolerite stones are visible on the surface, leaving the rock slabs virtually unexposed.

Heteropogon contortus (species group J), absent in the *Diospyros austro-africana-lancea* Sub-community, is the only diagnostic grass present with the shrub, *Rhigozum obovatum* (species group J), the only diagnostic shrub (Table 6.1). This sub-community lacks species from species group H, which are evident in the *Diospyros austro-africana-Rhus lancea* Sub-community (Table 6.1). A further characteristic of this vegetation unit is the partial dominance of *Rhus lancea* and *R. burchellii* (species group M) respectively. *R. ciliata* (species group J) is widespread and is the only other prominent shrub. The grasses, *Themeda triandra* (species group M), and *Aristida diffusa* (species group I) are the only noteworthy graminoids present (Table 6.1).

2.3 *Euclea crispa-Rhus lancea* Community

The *Euclea crispa-Rhus lancea* Community is restricted to the rocky low-lying areas of the foot of dry north-facing hillslopes. Big dongas are common with a thick layer of gravel (100-200 mm) covering the soil surface. The soil is shallow (< 100 mm), rocky (> 60 %) and of the Mispah Form.

The shrub, *Euclea crispa* (species group L), differentiates this plant community (Table 6.1). *Rhus lancea* (species group P) is totally dominant and is the only conspicuous tree present (Table 6.1). Graminoids are poorly represented and only *Themeda triandra* and *Sporobolus fimbriatus* (species group M) are worth mentioning (Table 6.1).

ORDINATION

In the scatter diagram the distribution of syntaxa along the first and second axes of the DECORANA ordination is given (Figure 6.1). No clear discontinuity exists between the different communities. It was thus decided to restrict the ordination to the two major-communities. Clear discontinuity can be observed and the major plant communities are restricted to specific areas in the diagram. The first axis illustrates a gradient which may be related to altitude and rockiness of the soil surface. Plant communities associated with the rocky drainage channels and the footslopes of hills (*Rhus lancea-Rhus burchellii* Major Community) are to the right of the diagram while communities of the lowlands and undulating terrain with less rocky soil (*Acacia karroo-Diospyros lycioides* Major Community) are to the left of the diagram. Along the second axis a moisture gradient exists. Plant communities in wet areas are situated at the top. The moisture decreases towards the bottom with the communities associated with dry habitat situated at the bottom of the diagram (Figure 6.1).

DISCUSSION

The riparian shrub communities of the southern Free State is in a state of degradation, because of a relatively low rainfall for the last number of years and a continuous degradation of vegetation. Yet, all the plant communities could be related to specific environmental conditions in the field. It is important to note that, although some of these communities show strong affinities with the vegetation associated with rocky outcrops in the study area (Chapter 4), all these communities were encountered in bottomland situations and drainage channels. The habitat is fairly unstable, due to seasonal flooding and drying which, together with the frequent overgrazing of the area play an important role in the degradation of the vegetation. The strong presence of certain woody species within the drainage channels is ascribed to the favorable moisture regimes in these areas. Habitat disturbance (especially in areas along public roads) frequently occurs.

It is clear that plant communities are dynamic and may display changes in species composition according to the habitat. According to Eckhardt (1993) veld in a good condition is usually characterized by a high basal cover of high ecological status species. The low cover of ecological important grasses is further indicative of veld in a poor condition (Van Oudtshoorn 1991). The riparian shrub vegetation can therefore be described as veld in a poor condition. The most important woody species are *Acacia* *karroo, Diospyros lycioides, Protasparagus laricinus, Rhus burchellii, R. ciliata, Rhus lancea* and *Ziziphus mucronata. Acacia karroo, Diospyros lycioides* and *Rhus lancea* are the most important differentiating species. *Themeda triandra* and *Sporobolus fimbriatus* are the most abundant grasses. Signs of overgrazing are obvious in some cases with the pioneer species *Aristida diffusa* prominently present. According to Van Oudtshoorn (1991), *A. diffusa* is an unpalatable grass and can be seen as indicative of overgrazed pasture.

Ecologically sound conservation management programs should take this present delineation of the riparian shrub communities as the basis for future management planning. The restricted distribution of these communities emphasize the fact that these areas should be given higher conservation priority.

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CHAPTER 7

Vegetation ecology of the southern Free State

Phytosociology of the southern Free State: Overgrazed and retrogressed vegetation.

CHAPTER 7

PHYTOSOCIOLOGY OF THE SOUTHERN FREE STATE: OVERGRAZED AND RETROGRESSED VEGETATION.

7.1 INTRODUCTION

The fact that Acocks's (1988) broad description of the South African vegetation is one of the most noted classifications, indicates the necessity of vegetation classification. Many descriptions of Karoo veld have been given (Pole-Evans 1936, Potts & Tidmarsh 1937, Adamson 1938, De Klerk 1947, Werger 1978, Vorster & Roux 1983, Hoffman & Cowling 1990, Bond *et al.* 1994, Hoffman 1996 a, b, c, d, e, f) of which the vegetation map by Acocks (1953) is the most detailed. In a description of the Grassland Biome Project, Mentis & Huntley (1982) stated the necessity to identify and determine the location and extent of the major vegetation types and subtypes within the Biome and particularly in the Upper Nama Karoo (Vegetation type 50), Orange River Nama Karoo (Vegetation type 51) and the Eastern Mixed Nama Karoo (Vegetation type 52) (Hoffman 1996).

As very little is known about the phytosociology of the southern Free State, this description and ecological interpretation of the vegetation contribute significantly to the present knowledge of the Grassland Biome and the results should be useful in compiling a final synecological synthesis of the Grassland Biome (Scheepers 1986).

The fact that both the Nama-Karoo and Grassland Biomes occur within the study area indicates a major difference and an overlap of the major vegetation types (Chapter 2). The biggest part of the area studied lies within the Nama-Karoo Biome.

The vegetation of the Grassland Biome is physiognomically monolithic and is characterized by a strong dominance of hemicryptophytes of the Poaceae while the vegetation of the Karoo-Biome is dominated by chamaephytes and hemicryptophytes and can be described as grassy, dwarf shrubland (Edwards 1983). Presently, evidence more likely shows that there has existed a dynamic interface between the Nama-Karoo and Grassland Biomes, as discussed by Rutherford & Westfall (1994), and that the concept of a fluctuating boundary between the two biomes, rather than a replacement of pure grassland by almost pure Nama-Karoo, is appropriate at least during the last 1 000 years (Avery 1991).

Drought adaptation in plants in the study area happens more through drought tolerance than through drought avoidance by, for example storage of water, or through drought evasion. Many of the chamaephytes are facultatively deciduous in response to the high temporal variability of rainfall (Rutherford & Westfall 1994).

The border between moist and dry grassland is best expressed as ranging between the 500 and 700 mm rainfall isohyets (Rutherford & Westfall 1994). Changes in the vegetation relationship with increasing soil depth suggest that land use, and not climate, has driven the decline of grasses (Bond *et al.* 1994). Heavy grazing in the Karoo eliminates the palatable components, favors generally unpalatable grasses and also reduces fuel to carry fire (Stuart-Hill & Mentis 1982). According to Trollope (1980) burning in savanna areas is only practical in situations where sufficient grass fuel can be accumulated to ensure a high intensity fire. According to Opperman *et al.* (1974) *Elionurus muticus* tends to increase, and often dominates, under mismanagement of veld. Murray (1940) found that *E. muticus* dominated camps that have been grazed heavily for five years. Opperman *et al.* (1969) emphasized the necessity of an early summer rest for both *Themeda triandra* and *Cymbopogon plurinodis* if maximum dry yields are required, while *E. lehmanniana* shows a higher resistance to frequent defoliations. Veld management should thus be applied in relation to the condition of the veld.

The concept of veld condition refers to the condition of the vegetation in relation to some functional characteristics (Trollope *et al.* 1990). Droughts in the Karoo areas do not only have an effect on the vegetation, alone but seriously effects the farming community as a whole, especially in terms of socio-economic factors. Droughts are one of the main factors responsible for the depopulation of extensive areas and its resultant effects such as a higher incidence of unemployment, forces the impoverishment of certain sections of the population.

Carbon isotope analysis of soil organic matter supports Acocks's (1988) hypothesis for an increase in shrub cover at the expense of grasses across a wide expanse from the central and eastern Karoo through to the grasslands of the southern Free State (Bond *et al.* 1994). Acocks (1988) postulated that the pre-Trekboer veld cover in the Upper Karoo was dominated by grasses. This veld subsequently deteriorated to a so-called False Karoo dominated by shrubs (Sampson 1986). According to Hoffman & Cowling (1990) perennial grass cover has increased in the Karoo over the last 200 years. They also recorded that many perennial grasses appeared in greater abundance in 1989 than they did in the 1920's or the early 1960's. The increase in grass cover at these sites has probably occurred in response to increased summer rainfall (Hoffman & Cowling 1990). Tyson *et al.* (1975), Tyson (1986) and Vogel (1988, 1989) however proposed that the case for progressive desiccation is untenable. Fluctuations in grass and shrub cover may be temporary or permanent, depending on grazing treatments and erosion rates (Roux & Theron 1987). Roux (1966) and Novellie & Strydom (1987), however suggest that grazing treatment has little effect on the general response of grasses and shrubs, while Zedler (1981) suggests that in semi-arid regions, such fluctuations may influence community composition for decades. According to Avery (1991) the more generalized picture for the early period suggests that the vegetation cover mainly increased or decreased as a whole, rather than that grass and scrub cover periodically replaced each other either in whole or in part.

For successful propagation by seed, grass plants require an adequate time of unhampered growth for the completion of the reproductive process. This reproductive process extends from the time of elongation of the stem bearing the reproductive primordia until the seedling has become established. In the case of rooigras (*Themeda triandra*) this period may extend from March in one year to December the next year - a period of 21 months. For most grasses, however, a shorter period is sufficient (Edwards 1972).

Because veld varies considerably from farm to farm and even within each farm boundary, it is unlikely that any one grazing system will meet with optimum success under all conditions in any given area. For domestic livestock, especially in arid environments, water is a major limiting factor for survival and growth. Since water is usually available at only a few scattered point sources, these become the main foci of animal activities. The result is a zone of attenuating animal impact away from each watering point - a zone commonly known as the piosphere (Andrew 1988). Andrew (1988) further postulated that the piosphere has been a particularly useful framework for examining the effects of domestic livestock on ecological variables. However, if the natural characteristics of each unit of veld are taken into consideration, it should be possible, with the aid of the principles of veld management, to develop a beneficial veld management plan for any area. In order to do this it is necessary to classify and evaluate the veld on each farm. There is no standard recipe for veld management, but it is fundamental that any system is dependent for its success in the first instance on the basic subdivision of the veld into uniform units and secondly on adherence to the current carrying capacity of the veld (Edwards 1972). Because seasonal fluctuations are real events with possible long-term implication, Hoffman & Cowling (1990) recommended that a more meaningful approach to understanding vegetation change in the Karoo is to address questions such as:

(1) What happens to the shrubs when grass cover increases in response to summer rain?;
(2) Do these two growth forms compete for recourses or do grasses merely occupy space not utilized by shrubs?;
(3) Which grasses respond to which rainfall events?;
(4) Is the increased cover a result of new recruits or increased tussock size or both?; and
(5) How long do new recruits remain in the community?

Perhaps the most pressing need is to attempt to uncouple environmental (such as rainfall, temperature) from biotic (such as grazing) determinants of vegetation change. Although Roux (1966), Donaldson (1986) and Novellie & Strydom (1987) provides many useful insights, no general predictive model incorporating both environmental and biotic agents of vegetation change has emerged. Perhaps a first step is to acknowledge that the potentially dynamic seasonal response of grasses and shrubs is a vital component of any model seeking to explain long-term vegetation change in the Karoo. To date, this view has been largely ignored as the theory of an expanding Karoo attests (Hoffman & Cowling 1990).

7.2 STRATIFICATION

In a series of maps, Acocks (1953) postulated a major transformation from grasslands to karroid shrublands from the pre-European era (AD 1400) to the present. According to Fuls (1993), karroid shrubs as well as signs of Karoo invasion were quite often encountered in areas to the west of the 650 mm rainfall isohyet in the northern Free State. Le Roux (1978), however, indicated that rainfall as a proportion of evaporation is more significant than rainfall isohyet in influencing the distribution of pans. The 30% isoline was thus used as a first stratification of the study area. The area west of this 30% isoline is considered to be the driest and therefore has the most impoverished vegetation in the southern Free State (Figure 7.1).

7.3 STUDY AREA

The study area comprises the western and south-western part of the southern Free State and is situated west of the 30% isoline (Figure 7.1). A detailed description of the physical environment was given elsewhere in this dissertation (Chapter 2).

GEOLOGY AND SOILS

The study area is underlain by the Karoo System and Ecca & Beaufort Formations dominate the area. The Ecca Group mainly consists of shale. Red mudstone commonly occurs in the Beaufort, but is absent in the Ecca. The latter is dark-grey and carbon-rich. Layers of sandstone commonly occur within the Beaufort, but seldom in the Ecca. Intrusive Karoo dolerite frequently occurs. It is mechanically very hard, but unstable against chemical weathering (Eloff 1984).

According to Du Toit (1954) the soils are mainly desert soils with some Kalahari and Solonetic soils. The main soil forms are Mispah, Glenrosa, Hutton, Sterkspruit, Swartland and Valsrivier which generally occur on the plains and low hills, while the Dundee and Oakleaf soil forms are prominent in the watercourses. The soils are generally alkaline (pH 7,0 to 8,3) and shallow, especially on the plains and low hills. Soil depth has a profound effect on the distribution and productivity of the vegetation (Vorster & Roux 1983).

Many of the soils of the study area are easily eroded by water and wind. Where vegetation cover has been reduced by persistent overgrazing, erosion of soils has reached an advanced level of degradation. Where the sand veneer of some arid areas is eroded away, dwarf shrubs invade (Tinley 1977).

7.4 METHODS

Relevés were compiled in 89 sample plots. Stratification was based on rainfall as a proportion of evaporation, topography, aspect and geology. Plot sizes were fixed at 16 m^2 in accordance with Scheepers (1975), Bredenkamp & Theron (1978), Bezuidenhout & Bredenkamp (1990) and Bezuidenhout *et al.* (1993). In each sample plot, the cover-abundance of all species was recorded using the Braun-Blanquet scale (Mueller-Dombois & Ellenberg 1974). Other environmental variables which was recorded include soil type, land type, rockiness of the soil surface, erosion and degree of utilization by herbivores.

Two-way indicator species analysis (TWINSPAN) (Hill 1979 a) was applied to the floristic data set in order to derive a first approximation of the vegetation units of the area. Refinement was done by the application of Braun-Blanquet procedures and resulted in a phytosociological table (Table 7.1).

In order to determine possible vegetation gradients and the pattern of the plant communities on this gradient, the multivariate ordination technique, Detrended Correspondence Analysis (DECORANA) (Hill 1979 a) was applied to the floristic data set.

Taxa names conform to those of Arnold & De Wet (1993).

7.5 RESULTS AND DISCUSSION

In general the vegetation of the overgrazed areas in the southern Free State can be considered as a *Chrysocoma ciliata - Pentzia globosa* short closed shrubland (Edwards 1983). The vegetation is generally utilized as pasture for cattle and sheep. Most of the pasture is overgrazed and trampled. The Karoo encroacher species, *Chrysocoma ciliata,* is a typical karroid dwarf shrub and is considered to be an important element of Karoo invasion in the Grassland Biome (Du Preez 1979).

The species listed in species group L and R (Table 7.1) are characteristic of overgrazed or selectively grazed, degraded vegetation. The poor condition of the vegetation is emphasized by the presence of karroid shrubs such as *Pentzia globosa, Lycium cinereum, Melolobium candicans, Walafrida saxatilis,* as well as the grasses *Eragrostis lehmanniana, E. obtusa* and *Fingerhuthia africana*, usually associated with disturbed and trampled soil (Acocks 1979).

Most of the plant communities encountered have a low species diversity. The plant communities distinguished in the study area can be classified in a hierarchy as follows:

1 *Lycium cinereum-Salsola glabrescens* Major Community

1.1 *Protasparagus capensis-Eriocephalus spinescens* Community
1.1.1 *Panicum coloratum-Felicia filifolia* Sub-community
1.1.2 *Aristida canescens-Osteospermum spinescens* Sub-community

1.2 *Scirpus dioicus-Lycium cinereum* Community
1.2.1 *Juncus kraussii-Eragrostis echinochloidea* Sub-community
1.2.2 *Sporobolus ioclados-Scirpus dioicus* Sub-community

1.3 *Ruschia rigida-Protasparagus suaveolens* Sub-community

1.4 *Eriocephalus ericoides-Chrysocoma ciliata* Community
1.4.1 *Lightfootia albens-Eriocephalus ericoides* Sub-community
1.4.2 *Lightfootia nodosa-Chrysocoma ciliata* Sub-community
1.4.3 *Eriocephalus ericoides-Melolobium candicans* Sub-community

1.5 *Salsola glabrescens-Fingerhuthia africana* Community
1.5.1 *Galenia africana-Hertia pallens* Sub-community
1.5.2 *Hertia pallens-Pentzia globosa* Sub-community

1.6 *Rhigozum trichotomum-Stipagrostis obtusa* Community

2 *Chrysocoma ciliata-Aristida congesta* Major Community

2.1 *Stipagrostis ciliata-Aristida diffusa* Community

2.2 *Felicia muricata-Eragrostis lehmanniana* Community

2.3 *Eragrostis superba-Eragrostis lehmanniana* Community

2.4 *Asclepias fruticosa-Salsola kali* Community

DESCRIPTION OF THE PLANT COMMUNITIES

The floristic and associated environmental attributes of the respective plant communities are as follows:

1 *Lycium cinereum-Salsola glabrescens* Major Community

This major community was encountered on midslopes and low-lying areas in the southern Free State. A great variety of soil types are present and vary from sandy to clayish to rocky soils. The long-term utilization by herbivores was subjectively rated as extremely severe.

The *Lycium cinereum-Salsola glabrescens* Major Community is differentiated by the two mentioned species, listed in species group N (Table 7.1). Also conspicuous through the entire major community are the

Karoo bush, *Pentzia globosa* and the grasses, *Eragrostis lehmanniana, E. obtusa* and *Fingerhuthia africana* (species group R, Table 7.1). *Panicum coloratum* (species group A), *Scirpus dioicus* (species group F), *Ruschia rigida* (species group G), *Chrysocoma ciliata* and *Hertia pallens* (species group L) have restricted dominances (Table 7.1).

Six distinct communities, subdivided into nine sub-communities were recognized (Table 7.1).

1.1 *Protasparagus capensis-Eriocephalus spinescens* Community

This plant community is predominantly associated with the dry bottomland and midslopes of hills. Estcourt, Sterkspruit, Swartland and Valsrivier soil forms, generally with a clay content of 15-35% (Soil Classification Working Group 1991) are common.

The soil is sandy-rocky with loose gravel occurring on the soil surface. The long-term utilization by herbivores was subjectively rated as extremely severe.

The karroid dwarf shrub, *Eriocephalus spinescens*, the spinose *Protasparagus capensis* and the Karoo bush *Pentzia incana* (species group C, Table 7.1) characterize this plant community. *E. spinescens* can survive extremely dry conditions and mainly occurs in the zone between typical Karoo veld and dry grassland. This species is furthermore primarily associated with pasture degradation (Anonymous 1968). Also prominent are *Lycium cinereum* (species group N) and *Pentzia globosa* (species group R). *P. globosa* is according to Anonymous (1968) dominant in the Great Karoo and less prominent in areas adjacent to sweet grassland.

Two distinct sub-communities are distinguishable (Table 7.1).

1.1.1 *Panicum coloratum-Felicia filifolia* Sub-community

A sub-community which is restricted to the sandy deposits on the midslopes of low hills. This vegetation unit is moderately disturbed and is characterized by the presence of only a few species with *Panicum coloratum* (species group A) the most important. The presence of *Pentzia globosa* (species group R) and *Aristida congesta* (species group T) is further indicative of overgrazed and trampled areas (Van Oudtshoorn 1991).

An average of eight species per relevé was recorded (Table 7.1).

1.1.2 *Aristida canescens-Osteospermum spinescens* Sub-community

The *Aristida canescens-Osteospermum spinescens* Sub-community occurs on rocky areas of the midslopes. The soils are shallow (< 100 mm deep), of the Mispah form and mainly consist of hard rock layers, have a low clay content (> 40%) and a non-calcareous A-horizon (Soil Classification Working Group 1991).

The grass, *Aristida canescens*, is the most conspicuous among the differentiating species (species group B, Table 7.1). Other species present include the shrub, *Lycium cinereum* (species group N), karroid shrub, *Pentzia globosa* and the grass, *Eragrostis lehmanniana* (species group R). *Panicum coloratum* (species group A) and *Eriocephalus spinescens* (species group C) have lower cover-abundance values than in the *Panicum coloratum-Felicia filifolia* Sub-community, but *Lycium cinereum* (species group N) is more abundant. Also conspicuous are *Osteospermum spinescens, Ruschia hamata* (species group B) and *Eragrostis lehmanniana* (species group R) which are absent in the *Panicum coloratum-Felicia filifolia* Sub-community (Table 7.1). *O. spinescens*, commonly known as "Draaibos", is conspicuous in the central Karoo in brackish soil types. This species is regarded as unpalatable to sheep, but is more readily utilized by cattle in extreme dry regions. The presence of this species is normally indicative of a shallow water table (Anonymous 1968).

On average, ten species/relevé were recorded for this sub-community (Table 7.1).

1.2 *Scirpus dioicus-Lycium cinereum* Community

This *Scirpus dioicus-Lycium cinereum* Community is associated with relatively wet, low-lying drainage channels of the Db land type in the south-eastern corner of the study area. The soils are clayey, brackish and poorly drained.

Species listed in species group F differentiate this community (Table 7.1). *Scirpus dioicus* (species group F) dominates the vegetation and *Sporobolus ioclados* (species group D) only has a restricted dominance (Table 7.1). *Lycium cinereum* (species group N), also with a restricted dominance, is the only abundant shrub. *Helichrysum pentzioides* (species group F), commonly known as "Kerriebos", occurs widespread in the Karoo areas, but is more conspicuous in the western regions. This species is seldom dominant in karroid areas and is virtually restricted to low-lying areas (Anonymous 1968).

Two sub-communities are distinguishable in this vegetation unit (Table 7.1).

1.2.1 *Juncus kraussii-Eragrostis echinochloidea* Sub-community

An entity found on marginally moist soils of the lowlands where the vegetation is overgrazed. The soil is often trampled, especially near watering points for cattle and dams. The sedge, *Scirpus dioicus* (species group F), is characteristically dominant. The differentiating species are listed in species group E (Table 7.1) of which another sedge, *Juncus kraussii*, is the most abundant. Other abundant species are the karroid shrub *Lycium cinereum* (species group N) and the grass *Eragrostis lehmanniana* (species group R, Table 7.1).

An average of ten species/relevé was encountered (Table 7.1).

1.2.2 *Sporobolus ioclados-Scirpus dioicus* Sub-community

This retrogressed plant community was encountered in the low-lying areas with brackish soils bordering pans. The vegetation is heavily overgrazed and the soil surface is severely trampled. No exclusive diagnostic species occur and the sub-community is characterised by the absence of species from species group E (Table 7.1). The vegetation is dominated by *Scirpus dioicus* and the small grass, *Sporobolus ioclados* (species group D, Table 7.1). Although not abundant, *Helichrysum pentzioides* (species group F), *Lycium cinereum* (species group N) and *Pentzia globosa* (species group R) are also present (Table 7.1) - a sure sign of pasture degradation.

This sub-community comprises only ten species with an average of 7 species/relevé (Table 7.1).

1.3 *Ruschia rigida-Protasparagus suaveolens* Sub-community

The *Ruschia rigida-Protasparagus suaveolens* Sub-community is restricted to the moderately wet drainage lines along public roads. The soil is clayey. Gravel and stones cover the soil surface. The clay content of the B-horizon varies from 15-50% (Land Type Survey Staff, in press). Long-term utilization by herbivores was subjectively rated as moderately severe to severe.

Ruschia rigida, *Protasparagus suaveolens* and *Flaveria bidentis* (species group G) are the differentiating species. Besides the dominance of *Ruschia rigida*, the dwarf shrubs, *Eriocephalus ericoides* (species group J) and the Karoo bush *Pentzia globosa* (species group R) are the most important (Table 7.1).

1.4 *Eriocephalus ericoides-Chrysocoma ciliata* Community

The *Eriocephalus ericoides-Chrysocoma ciliata* karroid dwarf shrub community is primarily associated with calcareous-rocky soils in low-lying areas, especially in drainage channels. Pieces of fine gravel and calcareous stones occur on the surface. The vegetation is selectively and patchily overgrazed and the soil surface trampled.

This community is differentiated by the combined presences of *Eriocephalus ericoides* (species group J), *Chrysocoma ciliata* and *Hertia pallens* (species group L, Table 7.1). *E. ericoides*, commonly known as "Kapokbos", is only locally prominent. This species inhibits the growth of "sweet grasses" (Anonymous 1968) and is often extremely abundant in very dry bottomland situations. It can absorb water through its leaves and is drought resistant (Anonymous 1968). *Chrysocoma ciliata* and *Hertia pallens* (species group L) are also drought-resistant and widely dispersed throughout this plant community (Table 7.1). The presence of *Chrysocoma ciliata* and *Pentzia globosa* (species group R) is indicative of overgrazing and habitat disturbance (Anonymous 1968). According to Anonymous (1968), *C. ciliata* is unpalatable and degenerates in an area well covered with grasses. Species indicative of degradation occur in places throughout this vegetation unit.

Three distinct sub-communities further differentiate this plant community (Table 7.1).

1.4.1 *Lightfootia albens-Eriocephalus ericoides* Sub-community

This sub-community is typically found on the well-drained flat areas in drainage channels along public roads in the south-western Free State. The soil easily dries out and is of a clayey-calcareous nature. A high percentage of the soil surface is covered by calcareous stones.

Lightfootia albens (species group H) is diagnostic of this sub-community. The low cover-abundance of *Eriocephalus ericoides* (species group J, Table 7.1) as well as the higher cover-abundance of *Chrysocoma ciliata* (species group L) also differentiate this sub-community. According to Anonymous (1968), *C. ciliata*, can be seen as one of the most important and active invaders of overgrazed and trampled grassland. It can be seen as the leading species of Karoo invasion and increases in overgrazed pasture (Anonymous 1968).

An average of seven species/relevé was recorded (Table 7.1).

1.4.2 *Lightfootia nodosa-Chrysocoma ciliata* Sub-community

This sub-community occurs where a sandy deposit overlies the calcareous soils, especially in drainage channels and eroded areas. Doleritic and sandstone rocks occur on the surface.

Lightfootia nodosa (species group I) is the differentiating species which distinguishes this vegetation unit from the rest of the *Eriocephalus ericoides-Chrysocoma ciliata* Community (Table 7.1). The absence of *Lightfootia albens* differentiates this sub-community from the *Lightfootia albens-Eriocephalus ericoides* Sub-community (Table 7.1). The *Lightfootia nodosa-Chrysocoma ciliata* Sub-community has a low species diversity of only eleven species, with only *Lightfootia nodosa* (species group I), *Eriocephalus ericoides* (species group J) and *Chrysocoma ciliata* (species group L) occurring regularly (Table 7.1).

An average of five species/relevé was recorded (Table 7.1).

1.4.3 *Eriocephalus ericoides-Melolobium candicans* Sub-community

The *Eriocephalus ericoides-Melolobium candicans* Sub-community is mostly associated with disturbed and eroded areas in the southern parts of the study area, west of Luckhoff. These areas are mostly disturbed due to continuous overgrazing. Duplex soils with red B-horizons are the most prominent with red apedal soils (< 300 mm deep) also frequently occurring (Land Type Survey Staff, in press). Hutton and Glenrosa soil forms are the most prominent (Land Type Survey Staff, in press).

Of the 12 species encountered in this sub-community, none was diagnostic. This sub-community is recognized by the absence of *Lightfootia albens* and *L. nodosa.* Apart from *Eriocephalus ericoides* (species group J) and *Hertia pallens* (species group L), *Melolobium candicans, Chrysocoma ciliata* (species group L) and *Eragrostis obtusa* (species group R) are the most prominent species. The presence of *C.*

ciliata, especially is a definite sign of pasture degradation (Anonymous 1968). *Salsola glabrescens* (species group N) was recorded in only one plot, but was dominant (Table 7.1).

1.5 *Salsola glabrescens-Fingerhuthia africana* Community

The *Salsola glabrescens-Fingerhuthia africana* Community represents overgrazed and trampled areas on bottomland situations of the Ae land type in the southern Free State.

This vegetation type is differentiated by the constant presence of *Hertia pallens* and *Chrysocoma ciliata* (species group L). *Pentzia globosa, Eragrostis lehmanniana* and *Fingerhuthia africana* (species group R) are also important members. A total of 23 species were listed. The majority are typical karroid species. Only 5 grass species were listed - a clear indication of retrogressed habitat conditions (Vorster & Roux 1983). The absence of *Eriocephalus ericoides* differentiates it from the *Eriocephalus ericoides-Chrysocoma ciliata* Community.

Two distinct sub-communities further divide this community (Table 7.1).

1.5.1 *Galenia africana-Hertia pallens* Sub-community

The *Galenia africana-Hertia pallens* Sub-community is strongly associated with the rocky dolomite areas in and around sink holes. Soil types often associated with this vegetation unit include Hutton, Glenrosa, Oakleaf and Swartland (Land Type Survey Staff, in press). These soils are predominantly sandy with red B-horizons. The trampling effect of livestock is evident. Ant heaps are prominent.

Galenia africana (species group K, Table 7.1) dominates the vegetation and is the only diagnostic species present. Other regularly occurring species include the co-dominant *Hertia pallens, Chrysocoma ciliata* (species group L), *Lycium cinereum, Salsola glabrescens* (species group N) and the grasses *Eragrostis lehmanniana* and *Fingerhuthia africana* (species group R, Table 7.1). *Hertia pallens*, commonly known as "Springbokbos", is completely worthless as pasturage and also unpalatable. Under severely degraded conditions it may cause poisoning and especially affects the liver of livestock (Anonymous 1968).

An average of seven species/relevé was recorded (Table 7.1).

1.5.2 *Hertia pallens-Pentzia globosa* Sub-community

The *Hertia pallens-Pentzia globosa* Sub-community is primarily associated with red soils of high base status. The soils are generally deeper than 300 mm and no dunes occur. Inanda, Kranskop, Magwa, Hutton, Griffin and Clovelly soils are prominent (Land Type Survey Staff, in press). An average clay content of 35-55% is common (Soil Classification Working Group 1991). No ant or termite heaps were spotted.

This sub-community lacks diagnostic species and is recognized by the total absence of *Galenia africana* (species group K) and the scanty occurrence of *Lycium cinereum* (species group N, Table 7.1). Also noteworthy are the absences of *Walafrida saxatilis* and *Melolobium candicans* (species group L). Although six species of grass were listed, these are poorly represented. The most important species are *Eragrostis lehmanniana, E. obtusa,* and *Fingerhuthia africana* (species group R, Table 7.1). The high cover-abundance of particularly the dwarf shrub *Chrysocoma ciliata* (species group L) is a definite sign of pasture degradation (Anonymous 1968). *Walafrida saxatilis* (species group L), *Salsola glabrescens* (species group N) and *Pentzia globosa* (species group R) are the most abundant other karroid dwarf shrubs present (Table 7.1). *P. globosa,* commonly known as "Bitterkaroo", randomly occurs in the boundary zone between dry grasslands and karroid areas (Anonymous 1968).

On average, six species/relevé were recorded for this sub-community (Table 7.1).

1.6 *Rhigozum trichotomum-Stipagrostis obtusa* Community

This tall closed shrubland was encountered on the bottomlands and footslopes of hills. These areas, mainly in the western and south-western parts, are often overgrazed and trampled. The Ag-, Ae- and Da land types are the most prominent. The soils are primarily red, having a high base status. Duplex soils with red B-horizons are also present (Da land type). Inanda, Kranskop, Magwa, Hutton, Griffin and Clovelly soils, all having a generally high clay content (15-35% clay, Soil Classification Working Group 1991) are the most prominent (Land type Survey Staff, in press). Bezuidenhout (1995) described a similar community in the Vaalbos National Park on moderately deep, poorly drained, aeolian sands. According to him, the tree stratum is poorly developed with a canopy cover of 2%. Trees are absent, probably due to the low rainfall.

The shrub, *Rhigozum trichotomum* (species group M), is dominant over large areas of trampled veld in the Free State (Venter & Joubert 1985) and, together with *Stipagrostis obtusa*, constitute the differentiating species of this community (Table 7.1). According to Acocks (1979) the dominance of *R. trichotomum* is restricted to the southern variation of the False Arid Karoo and that this condition of dominance is artificial, resulting from elimination of effective competition by grasses. Acocks (1988) described the *Rhigozum trichotomum* Veld of the Plains under the Orange River Broken Veld (Veld type 32) on gravelly and stony plains. At the upper margin of the Orange River Broken Veld, where it merges into the Arid Karoo, this may be the only shrub present, but, as a rule, it is accompanied by a few other shrub species. *R. trichotomum* sometimes forms dense growths and is sometimes scattered, but usually tend to spread into clumps by means of its stolons (Acocks 1988). In sandy valleys it grows up to two metres tall, but is usually only one metre tall. Other widely distributed species include the shrub, *Lycium cinereum,* the dwarf shrub, *Salsola glabrescens* (species group N) and the Karoo encroacher *Chrysocoma ciliata* (species group L, Table 7.1). *Stipagrostis obtusa* (species group M), commonly known as fine "Twaa" by Bushmen, (Van der Walt 1993) is the only noteworthy grass present (Table 7.1). According to Van der Walt (1993), *S. obtusa* is commonly known as the pioneer of the sandy areas of the Kalahari.

Twenty species were listed for this community with an average of six species/relevé (Table 7.1).

2 *Chrysocoma ciliata-Aristida congesta* Major Community

This major community was encountered on low-lying areas in the southern Free State. A great variety of soil types are present and vary from sandy to clayish soils. The long-term utilization by herbivores was subjectively rated as extremely severe.

The *Chrysocoma ciliata-Aristida congesta* Major Community is differentiated by the stronger presence of *Aristida congesta* (species group T, Table 7.1). Trees and shrubs were found to be totally absent. The restricted dominance of *Stipagrostis ciliata* (species group O) is conspicuous, especially in the sandy areas. The dwarf shrubs *Chrysocoma ciliata, Hertia pallens, Walafrida saxatilis* (species group L), as well as the grasses *Eragrostis lehmanniana* and *E. obtusa* (species group R) occur widespread (Table 7.1).

Four distinct communities were identified (Table 7.1).

2.1 *Stipagrostis ciliata-Aristida diffusa* Community

The *Stipagrostis ciliata-Aristida diffusa* Community is associated with the dry low-lying sandy deposits of the Ag land type near Petrusville in the south-western part of the study area. A thick layer of sand (100-200 mm thick) covers the rocky soil surface (duplex soils). Wind erosion often is a common phenomenon, especially in the unprotected lowlands.

This grassland is dominated by bushmen-grass, *Stipagrostis ciliata* (species group O), a valuable sweet grass in the arid areas. According to Van der Walt (1993), bushmen-grassveld is our only true grassland, because it is independent of fire for survival. *S. ciliata*, commonly known as granular "Twaa" among Bushmen, is a highly palatable species and commonly occurs in areas with an average rainfall of less than 150 mm. per annum (Van der Walt 1993). Other graminoids are scarce and restricted to the somewhat patchy occurrences of *Aristida diffusa* (species group O), *Eragrostis lehmanniana* (species group R) and *Aristida congesta* (species group T, Table 7.1), a clear indication of the retrogressed condition of the veld.

An average of six species/relevé was recorded (Table 7.1).

2.2 *Felicia muricata-Eragrostis lehmanniana* Community

The *Felicia muricata-Eragrostis lehmanniana* Community is primarily a disturbed, overgrazed grassveld on the edges of pans where the clay content can vary considerably (15-55%, Soil Classification Working Group 1991). The soil surface is rocky and trampled. No sandy layer occurs and the habitat conditions are drier than in the *Stipagrostis ciliata-Aristida diffusa* Community.

This community lacks exclusive diagnostic or character species, but is rather characterized by the presence and often dominance of the grasses *Eragrostis lehmanniana* (species group R) and *Aristida congesta* (species group T), as well as the constant occurrence of *Felicia muricata* (species group P). Noteworthy is the virtual absence of *Stipagrostis ciliata* (species group O) from this community, probably due to the less sandy habitat. *Eragrostis superba* (species group Q) is absent in this community (Table 7.1). Although a strong grass component exists, Karoo elements such as *Felicia filifolia* (species group A), *Protasparagus suaveolens* (species group G), *Chrysocoma ciliata, Walafrida saxatilis* (species group L) are also present (Table 7.1).

On average, six species/relevé were recorded for this community (Table 7.1).

2.3 *Eragrostis superba-Eragrostis lehmanniana* Community

The *Eragrostis superba-Eragrostis lehmanniana* Community is found on sandy to clayey soils in drainage channels throughout the entire study area. These soils are often extremely rocky.

According to Van Oudtshoorn (1991), *Eragrostis superba* prefers sandy and rocky soil, but also grows in turfish soil. *Eragrostis superba* (species group Q), a nutritious grazing grass, differentiates this community and is the only widely dispersed species often forming dense stands in association with *Chrysocoma ciliata*, *Walafrida saxatilis* (species group L), *Eragrostis lehmanniana* (species group R) and *Aristida congesta* (species group T). *Salsola kali* (species group S) only has a restricted dominance (Table 7.1).

An average of only four species/relevé was recorded (Table 7.1).

2.4 ***Asclepias fruticosa-Salsola kali*** **Community**

The *Asclepias fruticosa-Salsola kali* Community is associated with severely degraded and disturbed areas in drainage channels along public roads. The soils are clayey and calcareous stones occur on the surface. The habitat is wetter than in the *Eragrostis superba-Eragrostis lehmanniana* Community.

The unpalatable forb, *Asclepias fruticosa* (species group S), which grows to about 1.5 m tall, is the only abundant species present. *A. fruticosa* occurs widespread in South Africa and is virtually restricted to sandy river courses, disturbed sandy soils, sandy bottomland situations, quicksand and along public roads (Anonymous 1968). *Salsola kali* and *Tagetes minuta* (species group S), both exotics, typical in overgrazed and trampled veld, together with the "steekgras", *Aristida congesta* (species group T), are the only other species worth mentioning (Table 7.1).

On average, only four species/relevé were recorded (Table 7.1).

ORDINATION

A DCA ordination (Hill 1979 b) was applied to the floristic data set in order to determine possible environmental gradients. No clear discontinuity in the distribution of a number of plant communities exists which is probably due to the overall retrogressed vegetation and disturbed habitat conditions. Most of the plant communities are poorly represented by only a few differentiating species and are not always easily distinguishable in the veld. Severe habitat degradation, such as erosion and overgrazing of natural vegetation was evident through the entire study area. It was thus decided that such an ordination should not complement the data.

DISCUSSION

The fundamental aspects set out here have primarily a bearing on the reaction of the vegetal cover to pasture and veld mismanagement. The removal of young growth of established plants by grazing during their renewal stages of growth - for example when plants are sprouting at the beginning of a growth cycle, or after a drought - results chiefly in physiological damage to the plant systems. This damage mainly includes the disruption and weakening of the vital processes and their activity, and especially exhaustion and weakening of the root system. Physiological damage to plants can also take place with grazing during the termination of their growth cycles when, for example, the replenishment of the root reserves of the plant takes place, which is essential for rapid and vigorous regrowth at the start of a new cycle (Hugo 1968).

In sweet grassveld, the most important adverse changes in the veld during the period of European settlement have been: (a) a reduction in total vegetal cover, causing high runoff and erosion; (b) a replacement of nutritious perennial grasses by inferior annual grasses and weeds; and (c) the increase of woody weeds, notably species of *Acacia*, *Chrysocoma* and *Pentzia* (Tainton 1984).

Grazing during the active growth stages of a plant results in vegetative damage and destruction of plant material. This can lead, in severe cases, to the complete absence of ecologically important plant species and thus seriously affects the whole environment by the invasion of ecologically less important species. This is clearly illustrated in the presence of species such as *Hertia pallens, Lycium cinereum,* the Karoo encroacher, *Chrysocoma ciliata, Pentzia globosa*, as well as the grasses *Aristida* *congesta* and *Eragrostis lehmanniana.* Trees and shrubs are virtually absent and are restricted to the patchy occurrences of *Rhigozum trichotomum*. This fact is supported by Van den Berg *et al.* (1975) who found that autumn grazing (when the seeds of climax grasses ripen) was the most detrimental in terms of the basal cover of climax grasses in the *Cymbopogon-Themeda* veld, while both spring and winter grazing resulted in only small detrimental changes in the vegetation. They also found that summer and autumn grazing resulted in much smaller climax grass tufts than those of spring and winter grazing. According to them, this decline in basal cover could thus be attributed mainly to a reduction in tuft size. The tuft size of pioneer grasses, however, remained reasonably constant during all the seasons (Van den Berg *et al.* 1975). According to them, an increase in basal cover of pioneer grasses could be attributed largely to the increase in the tuft density of pioneer grasses. According to Hoffman *et al.* (1990) an increase in grass basal cover may negatively influence shrub basal cover. They also suggest that a large increase in summer rain, relative to the tong-term mean, would result in an associated increase in the percentage change in grass basal cover (Hoffman *et al.* 1990). It should, however, be kept in mind that various other environmental factors, such as light intensity, temperature etc. are also involved in vegetation changes (Hoffman *et al.* 1990).

According to Hugo (1968) unpalatable grasses such as *Elionurus muticus* and *Eragrostis plana* often invade the veld under selective grazing. Animals concentrate on the palatable grasses which are consequently continually grazed short, lose their vigor and, as a result, use less plant food and water. These nutrients are then available for use by unpalatable types which thrive there and begin to dominate the veld. Roberts (1974) reported that large areas in the Willem Pretorius Game Reserve were changing to Karooveld as a result of the concentration of animals on certain areas of the reserve. He also noted the possibility of extensive future erosion if the situation is left unchanged. Resting of the eroded Karooveld during the growing season was considered to be of the utmost importance to allow recuperation of this potentially valuable grazing land (Roberts 1974).

If this condition is allowed to develop, it is extremely difficult and sometimes virtually impossible to find a practical way of getting rid of unpalatable species. This is why it is of the utmost importance that the veld should always be carefully managed. Certain unpalatable grass types such as *Cymbopogon* spp., however, represent different successional stages and may be removed by judicious application of veld management practices (Hugo 1968).

There are various management systems which give recognition to the principles of sour-veld management. It should, however, always be kept in mind that management systems (camp systems) aim at bringing about soil and veld stability under utilization conditions. Since soil and veld stability are also a function of the climate and the latter (rainfall in particular) varies from season to season and even within seasons, it is essential that the management be flexible so as to be adaptable to environmental changes. Factors such as grazing intensity, the number of rest camps, frequency of the rest periods and veld burning will require continual adjustment. At present, so-called multi-camp, open-rotation grazing systems are being propagated under widely divergent conditions. According to Grunow (1973) the object is to adapt to erratic rainfall, variable environment, veld condition and growth rate of the most important grazing grasses (indicator grasses). In very dry areas the management system tries to make provision for the resting of certain camps after rain, so that maximum benefit may be derived from the rest period during which various essential physiological processes take place (Grunow 1973). Grunow (1973) proposed three general methods for increasing the production of "natural" veld as a resource of feed for herbivores. These are by feld fertilization, by reinforcement with legumes and more productive grasses, and by veld replacement with better grass and legume species.

In situations where the undesirable grass species is lower in the grassland succession than the desirable species, controlled selective grazing is effective in reducing the abundance of the undesirable species. However, controlled selective grazing is ineffective when the undesirable grasses is higher in the grassland succession than the desirable species. Therefore the desirable grass species will always be at a competitive advantage to the undesirable grasses by virtue of their higher successional status and the preferential grazing treatment they receive in a system of controlled selective grazing (Trollope 1980). Continuous overstocking and overgrazing have affected the dry matter production potential and stability of veld (Fourie 1983) and, inevitably, animal production. Therefore, to maintain the livelihood of many South African farmers, efforts to stop the retrogression of veld and to increase the utilization to that of its full potential should be considered as top priority (De Waal 1986).

According to Vogel (1994) drought initiatives today are not markedly different from those of the past. The National Drought Committee still focuses its drought-relief efforts primarily on the livestock farmers. The most recent drought saw the usual crisis-driven response, with vast sums of money being diverted to assist debt-ridden farmers, the installation and repair of inadequate water supplies in rural areas, and the intensification of food-aid schemes, often poorly targeted.

Finally it may be added that plant succession goes hand in hand with soil changes. The development from the pioneer condition to the climax condition is accompanied by the general building up and improvement of the soil (higher moisture and nutrient status), while changes from the climax to the pioneer condition are accompanied by general deterioration and loss of soil. Soil, subject to erosion, or soil which has lost its structure, will cause plant succession to progress very slowly and so delay the whole process of veld improvement. Soil stability therefore forms one of the corner-stones of veld-pasture production (Hugo 1968). According to Morgan (1986), soil management is concerned with ways of preparing the soil to promote dense vegetation growth and improve its structure so that it is more resistant to erosion. Soil conservation must be based on the following:
(a) covering the soil to protect it from raindrop impact;
(b) improving the aggregate stability of the soil; and
(c) increasing surface roughness to reduce the velocity of runoff and wind (Morgan 1986).

Attempts to redress some of these problems resulted in the formation of the National Consultative Forum on Drought (Adams 1993 and Hobson & Short 1993) in June 1993. Attempts to formulate a comprehensive national early warning system, that focuses both on the physical and human indicators, including weather prediction and monitoring, water supply, health and nutrition, are being made (Walters 1993) and it is hoped that these will succeed in establishing an effective hazard-management plan. The expertise for an early warning system exists, but it needs to be co-ordinated, clearly targeted, interactive and given greater authority to be effective.

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CHAPTER 8

Vegetation ecology of the southern Free State

Vegetation ecology of the southern Free State: Grassland communities

CHAPTER 8

VEGETATION ECOLOGY OF THE SOUTHERN FREE STATE: GRASSLAND COMMUNITIES

8.1 INTRODUCTION

The major factor responsible for large scale natural vegetation changes is climate, especially rainfall and temperature (Rutherford & Westfall 1994). It is well documented that radical changes in climate and vegetation has taken place in South African vegetation in the past (Brooks 1926). In relatively recent times (50 000 to 12 000 B.P.) climatic change in southern Africa caused large scale expansions and contractions of Karoo vegetation with corresponding change in grassland (Van Zinderen-Bakker 1962). From these former, but gradual changes, it is reasonable to assume that climatic change, though extremely gradual, is inherent to the Karoo environment. It is therefore not inappropriate to assume that Karoo vegetation is at present being affected by a macroclimatic change and mostly towards the xeromorphic (Van Zinderen-Bakker 1962). Thorough analysis of meteorological data (50 000 - 12 000 B.P.) showed that no drastic change in climate could hitherto be statistically identified (Dyer & Tyson 1977). Vegetation change, as a result of climatic change, can thus be disregarded for consideration as a factor responsible for detectable changes in Karoo vegetation. It thus transpires that vegetation change over the last three centuries can be entirely ascribed to the activities of man and his agricultural pursuits, especially grazing by sheep (Roux & Opperman 1982).

The tropical elements of Karoo vegetation, mostly grass species, respond primarily to summer rainfall, while Karoo-bushes respond to autumn and spring rains (De Klerk 1947). A large number of important species (mostly those from an agricultural point of view considered as undesirable, unpalatable and encroaching types) may exhibit growth cycles of a high or low rate during any season of the year. This partly accounts for the greater success of these species during any season.

The variability of seasonal rainfall, e.g. a higher rainfall for a few successive summer seasons or alternately the cooler months, evokes growth responses according to phenological characteristics. The result of this regulating mechanism is that the physiognomy of Karoo vegetation may change considerably from grassy to shrub-like. This phenomenon is particularly noticeable in those types of veld such as the False Upper Karoo (Veld Type 36, Acocks 1988) where grasses are an important constituent of the vegetation, e.g. the development of a blanketing cover of *Aristida* spp. in 1950, following copious late summer rains, and *Eragrostis lehmanniana* occurring extensively in Karoo vegetation in 1975 following the overabundant rain in 1974 (Roux & Opperman 1982). The Karoo thus avails over vegetation and environmental elements which are conducive to the variability and instability of the vegetation. Coupled with the grazing factor, these characteristics can lead to profound and permanent changes in the vegetation composition.

The ecologically most important attributes of grasses are:

1. Their ability to cover the ground with a permanent mat of foliage dense enough to protect it against the eroding action of wind and water, so that a depth of soil can accumulate and be held by the mass of fibrous roots possessed by grass, and

2. the fact that it provides the principal food of the grazing animal, whether wild or domestic.

When selective grazing ceases, either through complete resting, or, better through application of an artificial form of non-selective grazing, a second environment appears, in which such of the pioneer grasses and climax grasses as have survived are free to try to re-establish a cover on eroding sub-soil (Acocks 1971). According to McNaughton (1985) selective grazing improves the nutrient status of regrowing plant tissue. The recycling of nutrients may be an important component of stimulation of productivity by grazing (McNaughton 1985).

According to Acocks (1971), *Themeda triandra* is ecologically the most important grass, both to the wild animal and to the domestic animal, and the most widely distributed of the climax dominants. This species has a north-eastern distribution of tropical and subtropical areas (Pattern 1, Acocks 1971). Danckwerts (1981) found that veld dominated by *Themeda triandra* in sweet thornveld areas of the eastern Cape had a higher grazing capacity than that dominated by pioneer species like *Aristida*. A good indicator of the physiognomic structure of the grass sward is the standing crop of grass as it describes the volume and density of plant material at ground level.

Continuous grazing throughout the winter period, and even during early summer, severely damages species such as *Themeda triandra, Eragrostis curvula* and *Digitaria eriantha* although it does not affect the total herbage yields (Coetsee 1975).

Sour veld is poorly utilized by animals during winter due to unpalatability and low feed value (Coetsee 1975). Coetsee (1975) further reports that grazing in autumn and early summer, tends to give significantly ($p < 0.01$) lower basal cover of *T. triandra* and results in an increase ($p < 0.01$) of *Cymbopogon plurinodis*, while lack of grazing results in a decrease ($p < 0.01$) of *C. plurinodis*.

Continuous grazing of summer rested veld during the whole winter period and during early summer causes severe damage to certain species, such as *T. triandra*, *E. curvula* and *D. eriantha*, while early summer grazing in particular stimulates undesirable species such as *Elionurus muticus* and can result in a very unpalatable sward (Coetsee 1975).

Kruger & Edwards (1972) have done research on the utilization and relative palatability of different grass species in the western variation of the Bakenveld and found that *Eustachys paspaloides* and *Themeda triandra* (in that order) are the two species which, irrespective of treatment, are the best utilized.

Evapotranspiration and water use efficiency were determined for each of seven grass species (*Cymbopogon plurinodis, Digitaria eriantha, Eragrostis* *chloromelas, E. lehmanniana, Panicum stapfianum, Sporobolus fimbriatus* and *Themeda triandra*) by Snyman (1989). According to him the differences of mean daily evapotranspiration over two years were not statistically significant. The average aboveground phytomass production and water use efficiency of *C. plurinodis, D. eriantha* and *T. triandra* was higher ($p \leq 0,01$) than that of the other species. He further concluded that aboveground phytomass production was the determining factor of water use efficiency. However, under conditions of moisture stress, the water use efficiency of these three species was low, with that of *Eragrostis chloromelas* the highest. Snyman (1989) further emphasized that water use efficiency in particular is an important factor in determining the distribution of grasses.

The study of the grasslands of the undulating plains in the southern Free State forms part of a comprehensive phytosociological research programme under the Grassland Biome Project (Mentis & Huntley 1982; Scheepers 1986). This paper primarily focuses on the Braun-Blanquet classification and plant-ecological interpretation of the grassland communities in the southern Free State. *Themeda triandra* is, according to Van Oudtshoorn (1991), the most important grass in South Africa and occurs in all veld types. *T. triandra* is evident through the entire southern Free State and is the differentiating species (Species Group V, Table 8.1).

8.2 STUDY AREA

In the Upper Orange River Valley, there is a climatic boundary approximately indicated by the 400 mm rainfall isohyet, which coincides remarkably well with the borderline between the true Karoo-Namib dwarf shrub communities, the *Pentzietea incanae*, and the more grassy karroid communities (Werger 1980). The 600 mm rainfall isohyet is indicated in Figure 8.1. To be in accordance with Chapter 7, the 30% isoline is considered to be a more accurate stratification of the study area. The area east of the 30% isoline was thus studied in this survey.

A broad description of the physical environment and major plant communities of the southern Free State is given elsewhere (Chapter 2).

8.3 METHODS

Relevés were compiled in 153 sample plots. Stratification was based on rainfall as a proportion of evaporation, topography, aspect and geology. Severely degraded areas were avoided in this survey. Long-term overgrazed and retrogressed vegetation is discussed elsewhere in this dissertation (Chapter 7). Plot sizes were fixed at 16 m^2 in accordance with Scheepers (1975), Bredenkamp & Theron (1978), Bezuidenhout & Bredenkamp (1990) and Bezuidenhout *et al.* (1993).

In each sample plot, the cover-abundance of all species was recorded using the Braun-Blanquet scale (Mueller-Dombois & Ellenberg 1974). Other environmental variables which was recorded include soil type, soil depth, land type, rockiness of the soil surface, erosion and degree of utilization by herbivores.

Two-way indicator species analysis (TWINSPAN) (Hill 1979 b) was applied to the floristic data set in order to derive a first approximation of the vegetation units of the area. Refinement was done by the application of Braun-Blanquet procedures and resulted in a phytosociological table (Table 8.1).

In order to determine possible vegetation gradients and the pattern of the plant communities on this gradient, the multivariate ordination technique, Detrended Correspondence Analysis (DECORANA) (Hill 1979 a), was applied to the floristic data set.

Taxa names conform to those of Arnold & De Wet (1993).

8.4 RESULTS AND DISCUSSION

The grassland of the southern Free State (Table 8.1) can be broadly classified as the *Themeda triandra-Eragrostis lehmanniana* Grassland. According to Acocks (1988) overgrazing causes *Themeda triandra* to be replaced by less palatable grasses such as *Eragrostis echinochloidea* with little or no reduction in the cover.

The Karoo has nearly overrun the Dry *Cymbopogon-Themeda* Veld in the southern Free State and is randomly increasing with time (Acocks 1988). The grass genera, *Themeda, Setaria, Panicum, Eragrostis* and *Aristida* are all of tropical origin (Acocks 1971) with wide ecological adaptabilities and therefore occur widespread. *Themeda triandra* is the most common grass species in South Africa and is found in all grass veld types of South Africa but is more common in undisturbed climax veld (Acocks 1988, Gibbs Russell *et al.* 1990).

The widespread occurrence of grasses such as *Aristida congesta* and the karroid shrublets *Chrysocoma ciliata* and *Pentzia globosa* is indicative of the expansion of disturbed veld at the expense of "sweet" grassland (Acocks 1988).

Shrubs and trees are seldomly encountered in the undulating grassland (Fuls 1993). The most important shrubs encountered include *Euclea crispa* subsp. *ovata, Rhigozum obovatum* and *Rhus ciliata*, all of which have patchy occurrences. The dwarf fern, *Cheilanthes eckloniana*, also has a patchy occurrence and randomly occurs in rocky habitat (Fuls 1993). All these woody and ferns species are restricted to areas where rocks occur on the soil surface. The hills are low, consist of sandstone and dolerite and the slopes are seldom in excess of four degrees.

CLASSIFICATION

A hierarchical classification of the plant communities of the *Themeda triandra-Eragrostis lehmanniana* Grassland is as follows:

1 *Nidorella resedifolia-Themeda triandra* Community
1.1 *Panicum schinzii-Salvia disermas* Sub-community
1.2 *Agrostis lachnantha-Protasparagus suaveolens* Sub-community

2 *Protasparagus laricinus-Felicia filifolia* Community

3 *Chloris virgata-Themeda triandra* Community
3.1 *Xanthium spinosum-Senecio consanguineus* Sub-community
3.2 *Helichrysum dregeanum-Urochloa panicoides* Sub-community

4 *Harpochloa falx-Elionurus muticus* Community

5 *Eragrostis gummiflua-Themeda triandra* Community
5.1 *Elionurus muticus-Triraphis andropogonoides* Sub-community
5.2 *Eragrostis gummiflua-Sporobolus fimbriatus* Sub-community

6 *Sporobolus fimbriatus-Themeda triandra* Community
6.1 *Cymbopogon plurinodis-Eragrostis curvula* Sub-community
6.2 *Sporobolus fimbriatus-Eragrostis lehmanniana* Sub-community

7 *Cymbopogon plurinodis-Themeda triandra* Community
7.1 *Panicum coloratum-Themeda triandra* Sub-community
7.2 *Themeda triandra-Aristida diffusa* Sub-community

8 *Heteropogon contortus-Themeda triandra* Community
8.1 *Cymbopogon plurinodis-Heteropogon contortus* Sub-community
8.2 *Heteropogon contortus-Themeda triandra* Sub-community
8.3 *Enneapogon scoparius-Hermannia vestita* Sub-community
8.3.1 *Protasparagus striatus-Euclea crispa* subsp. *ovata* Variant
8.3.2 *Stachys rugosa-Eustachys paspaloides* Variant

9 *Rhus ciliata-Themeda triandra* Community
9.1 *Heteropogon contortus-Chrysocoma ciliata* Sub-community
9.2 *Rhus ciliata-Chrysocoma ciliata* Sub-community

10 *Euryops empetrifolius-Eriocephalus spinescens* Community

11 *Digitaria eriantha-Themeda triandra* Community

12 *Themeda triandra-Eragrostis lehmanniana* Community

DESCRIPTION OF THE COMMUNITIES

1 *Nidorella resedifolia-Themeda triandra* Community

This plant community occurs on the low-lying areas of the Ca and Da land types varying from well-drained to poorly drained soils. The Da land type consists mainly of duplex soils with red B-horizons while the Ca land type consists of soils where upland duplex and/or margalitic soils are common. Estcourt, Sterkspruit, Swartland, Valsrivier and Kroonstad soils are the most prominent (Land Type Survey Staff, in press). The clay content of the B-horizon generally varies between 15% and 35% (Macvicar *et al.* 1977).

Nidorella resedifolia (species group C) differentiates this vegetation unit. The presence of the small grass, *Chloris virgata* (species group G) is indicative of overgrazed conditions (Van Oudtshoorn 1991). The high cover-abundance for *Themeda triandra* (species group W) is conspicuous (Table 8.1).

Two sub-communities are recognized within this community (Table 8.1).

1.1 *Panicum schinzii-Salvia disermas* Sub-community

This sub-community is restricted to the marginally overgrazed and trampled zones on flat bottomlands or floodplains along rivers and streams. Sandy clay loams are common.

The *Panicum schinzii-Salvia disermas* Sub-community has a infrequent occurrence (only three relevés were listed) with *Panicum schinzii* and *Salvia disermas* (species group A) differentiating this vegetation unit (Table 8.1). Other species are scarce and only the grasses *Eragrostis curvula, E. obtusa, Digitaria eriantha* (species group V), *Aristida diffusa* and *Themeda triandra* (species group W) are found in this sub-community (Table 8.1).

An average of seven species/relevé was encountered (Table 8.1).

1.2 *Agrostis lachnantha-Protasparagus suaveolens* Sub-community

The *Agrostis lachnantha-Protasparagus suaveolens* Sub-community is found in the lower-lying areas of the *Nidorella resedifolia-Themeda triandra* Community, adjacent to drainage channels. The clayey soils are poorly drained and generally wetter and less disturbed than in the *Panicum schinzii-Salvia disermas* Sub-community. These areas are normally submerged during the rainy season. The trampling effect of livestock often results in exposed areas.

This sub-community is characterized by the large hygrophytic grass, *Agrostis lachnantha*, the thorny dwarf shrub, *Protasparagus suaveolens*, and the forb, *Hibiscus trionum* (species group B). *Themeda triandra* (species group W) has a markedly lower cover-abundance, probably because of the wetter habitat conditions.

An average number of ten species was recorded per sample plot (Table 8.1).

2 *Protasparagus laricinus-Felicia filifolia* Community

This plant community is associated with the crests of the undulating karroid veld and calcareous-sandy deposits adjacent to lower-lying drainage channels where the soil is clayey. Exposed sandstone rocks are common.

The dwarf shrub, *Felicia filifolia*, and the shrub, *Protasparagus laricinus* (species group D), act as differentiating species (Table 8.1). The grasses *Aristida congesta, A. diffusa* and *Themeda triandra* (species group W) all have a restricted dominance. The presence of the two *Aristida* species indicates retrogression of the veld. Other grasses present, include *Eragrostis curvula* (species group V) and *Eragrostis lehmanniana* (species group W, Table 8.1). The thorny karroid shrub, *Protasparagus striatus* (species group P), is the most important shrub.

An average of five species/relevé was recorded (Table 8.1).

3 *Chloris virgata-Themeda triandra* Community

The *Chloris virgata-Themeda triandra* Community is encountered on relative poorly drained to well-drained, dry, lower-lying, calcareous and clayey soils of the study area. These clayey soils are often covered with a thin layer of wind-blown sand.

This community does not have exclusive diagnostic species, but it is characterized by the strong and continuous presence of the small pioneer grass, *Chloris virgata* (species group G). According to Van Oudtshoorn (1991) *C. virgata* is a fast-growing, palatable grass which is adapted to overgrazing and trampling. *Themeda triandra* (species group W) has a high cover-abundance throughout the entire community. The only other commonly occurring grasses, *Eragrostis lehmanniana* and *Aristida congesta*, have a low abundance value (species group W, Table 8.1).

Two sub-communities are distinguishable in this plant community (Table 8.1).

3.1 *Xanthium spinosum-Senecio consanguineus* Sub-community

This sub-community was encountered on the footslopes of hills where clayey deposits occur. Fine gravel and stones, primarily of sandstone, but also dolerite cover the moist soil surface.

The differentiating species of this sub-community, all with low cover-abundances, are listed in species group E (Table 8.1). *Chloris virgata* (species group G), *Aristida congesta* and *Themeda triandra* (species group W) are the only constantly occurring graminoids (Table 8.1). The karroid dwarf shrub, *Pentzia globosa* (species group W) is the noteworthy shrub present. *P. globosa* is an encroacher species and is especially abundant in the ecotone between dry grasslands and karroid areas (Anonymous 1968).

An average of ten species/relevé was recorded (Table 8.1.).

3.2 *Helichrysum dregeanum-Urochloa panicoides* Sub-community

This sub-community was encountered on black turfish soil with sandy deposits adjacent to drainage channels along public roads. No surface rock or gravel occurs. The soil is poorly drained and patches of water are visible for weeks after good rains.

Helichrysum dregeanum and *Urochloa panicoides*, and to a lesser extent *Panicum maximum* (species group G), are the differentiating species present. Only *H. dregeanum* is abundant. *H. dregeanum*, normally associated with grasses is drought resistant, but does not normally grow during dry seasons and droughts (Anonymous 1968). The pioneer grass, *Chloris virgata* (species group G), has an infrequent presence. The three grasses listed in species group W, especially *Themeda triandra* and *Aristida congesta*, have slightly higher cover-abundance values (Table 8.1).

An average of eight species/relevé was recorded (Table 8.1).

4 *Harpochloa falx-Elionurus muticus* Community

As indicated by Werger & Coetzee (1978), this grassland coincides largely with Acocks's (1988) *Cymbopogon-Themeda* Veld (Veld type 48), the Highland Sourveld to *Cymbopogon-Themeda* veld transition (Veld type 56) and the Southern Tall Grassveld (Veld type 65). Du Preez (1991) refers in Low & Rebelo (1996) to this grassland as Moist Cold Highveld Grassland. This sour grassland is localized, occurring only on deep sandy and leached soils of the sand stone terraces and plateaux in the south-eastern corner of the study area, near Zastron. Exposed rocks, however, give the habitat a rocky appearance. This area mainly falls within the 600-800 mm p.a. rainfall interval where Avalon and Clovelly soils are the most abundant. In some areas the vegetation is relatively undisturbed and utilization of grasses by livestock is restricted to the minimum. According to Roberts (1966), this type of grassland is associated with cool, moist conditions that usually occur at high altitudes. Similar communities were described by Du Preez (1991), Eckhardt (1993) and Fuls (1993).

The diagnostics are listed in species group H (Table 8.1). The most abundant grasses are *Harpochloa falx, Trichoneura grandiglumis, Brachiaria serrata, Cymbopogon dieterlenii, Tristachya leucothrix* and *Eragrostis capensis*. Other grasses present include *Setaria sphacelata* (species group I), *Elionurus muticus* (species group K), *Heteropogon contortus* (species group S), *Digitaria eriantha, Eragrostis curvula* (species group V) and *Themeda triandra* (species group W, Table 8.1).

A total of 37 species were recorded with an average of 29 species/relevé (Table 8.1).

5 *Eragrostis gummiflua-Themeda triandra* **Community**

The *Eragrostis gummiflua-Themeda triandra* grassland is primarily associated with moist habitats that vary from drainage channels with duplex soils to higher-lying areas where rocky soils are common. These areas also vary from moderately disturbed to relatively undisturbed. The habitat conditions are similar to that of the *Eragrostis gummiflua-Cynodon dactylon* Grassland described by Coetzee (1993) in the Pretoria-Witbank-Heidelberg Area. Deep Clovelly and Hutton soils (> 500 mm deep) with a clay content of 15%-20% are prominent. Although inconspicuous here, *Themeda triandra* is absent from the *Eragrostis gummiflua-Cynodon dactylon* Grassland (Coetzee 1993).

The presence of *Eragrostis gummiflua* differentiates this plant community (species group L, Table 8.1). This species often has a high cover-abundance and dominates the vegetation. According to Van Oudtshoorn (1991), *E. gummiflua* usually occurs in high rainfall areas and is often abundant in drainage channels. *E. gummiflua* prefers sandy and rocky soils and is regarded as unpalatable to livestock. Trees and shrubs are absent and the whole vegetation unit occurs in full sun. Other graminoids present include *Setaria sphacelata* (species group I), *Sporobolus fimbriatus* (species group M), *Cymbopogon plurinodis* (species group O), *Digitaria eriantha* (species group V) and *Themeda triandra* (species group W, Table 8.1).

Two distinct sub-communities are present (Table 8.1).

5.1 *Elionurus muticus-Triraphis andropogonoides* Sub-community

This sub-community occurs on moderately drained to well-drained, trampled rocky soil of the higher-lying areas.

The presence of the grasses *Elionurus muticus* and *Triraphis andropogonoides* (species group K) as well as the absence of *Sporobolus fimbriatus* (species group M) differentiate this sub-community from the *Eragrostis gummiflua-Sporobolus fimbriatus* Sub-community (Table 8.1). *Eragrostis gummiflua* (species group L) and *Themeda triandra* together often form dense stands (Table 8.1). Also noteworthy is the low presence of species from species group W with *T. triandra* the only representative (Table 8.1).

An average of six species/relevé was recorded (Table 8.1).

5.2 *Eragrostis gummiflua-Sporobolus fimbriatus* Sub-community

The *Eragrostis gummiflua-Sporobolus fimbriatus* Sub-community is primarily associated with the more stable veld of the *Eragrostis gummiflua-Themeda triandra* Community. The soils are clayey and covered by a layer of wind-blown sand (duplex soils).

Conspicuous is the constant dominance of *Eragrostis gummiflua* (species group L). The presence of the large graminoid, *Sporobolus fimbriatus* (species group M), further characterizes this plant community. *Cymbopogon plurinodis* (species group O), a large tufted graminoid, is widely distributed, but has a low dominance value (Table 8.1). According to Van Oudtshoorn (1991), *Cymbopogon plurinodis* often grows in association with *Themeda triandra*, but the latter only has a patchy occurrence in this sub-community (Table 8.1). *Setaria sphacelata* (species group I) is also present, but inconspicuous (Table 8.1).

An average of seven species/relevé was recorded (Table 8.1).

6 *Sporobolus fimbriatus-Themeda triandra* Community

This grassland is primarily associated with the higher-lying well-drained soils in sandy to rocky parts of the undulating landscape. Generally the soil structure varies from sandy to marginally clayey to rocky.

Sporobolus fimbriatus (species group M), a highly palatable grass with a high foliage production, acts as differentiating species (Table 8.1). According to Van Oudtshoorn (1991) this grass has a wide distribution in the Grassland Biome of South Africa and occupies a great variety of, often moist, habitats. This community is principally differentiated from the *Eragrostis gummiflua-Themeda triandra* Community by the total absence of *Eragrostis gummiflua* (species group L).

Other grasses present are *Panicum coloratum* (species group N), *Cymbopogon plurinodis* (species group O), *Eragrostis obtusa, E. curvula, Digitaria eriantha* (species group V), *Aristida diffusa, Eragrostis lehmanniana* and *Themeda triandra* (species group W, Table 8.1). Quite a number of forbs were found in this community, but are inconspicuous.

Two distinct sub-communities further subdivide this community (Table 8.1).

6.1 *Cymbopogon plurinodis-Eragrostis curvula* Sub-community

This grassland was encountered on the crests of the higher parts of the undulating terrain. The soils are rocky and well-drained.

The *Cymbopogon plurinodis-Eragrostis curvula* Sub-community is characterized by the combined presence and mostly high abundance of *Themeda triandra* (species group W), *Sporobolus fimbriatus* (species group M) and *Cymbopogon plurinodis* (species group O), as well as the restricted occurrence of *Panicum coloratum* (species group N). No diagnostic species occur. *Digitaria eriantha* (species group V) has a restricted dominance and *Eragrostis curvula* (species group V) are the only other abundant grasses present (Table 8.1). De Winter (1955) regards *E. curvula* as the most variable species in the genus, *Eragrostis*, in southern Africa. This species occurs naturally only as far north as Kenya, but cultivars have been introduced as pasture grasses throughout the tropics. It often occurs in disturbed situations as a pioneer species (Gibbs Russell & Spies 1988). The constant presence of *Chrysocoma ciliata* and *Pentzia globosa* (species group W) indicates Karoo-encroachment.

An average of seven species/relevé was encountered (Table 8.1).

6.2 *Sporobolus fimbriatus-Eragrostis lehmanniana* Sub-community

A type of grassland encountered on well-drained sandy deposits. The soil is rocky with eroding sandstone covering it. *Cymbopogon plurinodis*, normally a common site on rocky soil, is absent from this sub-community. A stronger presence of *Eragrostis lehmanniana* (species group W) further differentiates this sub-community. *Themeda triandra* (species group W) only has a patchy occurrence and is mostly non-conspicuous (Table 8.1). The presence of *Eragrostis obtusa* (species group V) is indicative of overgrazed pasture (Van Oudtshoorn 1991).

An average of five species/relevé was recorded for this sub-community (Table 8.1).

7 *Cymbopogon plurinodis-Themeda triandra* Community

The *Cymbopogon plurinodis-Themeda triandra* Community is associated with the moderately utilized to moderately under utilized, moist, rocky slopes of hills. The soils are mostly of doleritic origin, but patches of sandstone and clayey soil also occur. Big dolerite boulders on the slopes are a common sight. The *Eragrostis curvula-Themeda triandra* Grassland, described by Fuls *et al.* (1992 b) basically has the same habitat conditions than were encountered here.

Exclusive diagnostic species are absent, being rather characterized by the conspicuous dominance of *Themeda triandra* (species group W) and constant presence of *Cymbopogon plurinodis* (species group O, Table 8.1). This community is represented by 23 species of which only a few occur widespread. The presence of *Pentzia globosa* (species group W) especially in the low-lying areas is a sure sign of Karoo invasion and grassland degradation (Anonymous 1968).

Two distinct sub-communities further characterize this community (Table 8.1).

7.1 *Panicum coloratum-Themeda triandra* Sub-community

This grassland community is associated with the moist areas of east-facing hillslopes. The habitat is less rocky than that of the *Themeda triandra-Aristida diffusa* Sub-community. The soils are deep (> 200 mm) and clayey (> 40% clay in the B-horizon). Dolerite stones and rocks (> 0.5 m in diameter) are visible on the soil surface.

The presence of *Panicum coloratum* (species group N) differentiates this sub-community from the *Themeda triandra-Aristida diffusa* Sub-community. The dominance of *Themeda triandra* (species group W) is exceptional. The highly unpalatable grass, *Cymbopogon plurinodis* (species group O), is also widely distributed, but has a lower cover-abundance. Other grasses present are *Digitaria eriantha, Eragrostis curvula* and *E. obtusa* (species group V), all having patchy occurrences (Table 8.1).

An average of five species/relevé was recorded for this sub-community (Table 8.1).

7.2 *Themeda triandra-Aristida diffusa* Sub-community

This grassland is associated with the moderately utilized moist south- and east-facing rocky slopes. The soil is shallow (< 100 mm deep) and rocky. Big dolerite boulders (> 1 m in diameter) are a common phenomenon.

The *Themeda triandra-Aristida diffusa* Sub-community is dominated by the relatively large, tufted, perennial grass, *Themeda triandra* (species group W). Besides the absence of *Panicum coloratum* (species group N) from this sub-community, the patchy occurrence of *Aristida diffusa* further differentiates these sub-communities (Table 8.1). *Pentzia globosa* (species group W) was present in about half of the relevés and indicates pasture degradation and Karoo encroachment.

8 *Heteropogon contortus-Themeda triandra* Community

This grassland occurs on westerly, easterly, northern and to a lesser extent on southerly hillsides. The south-facing hill slopes characteristically are associated with larger shrubs and trees. The distribution pattern of this grassland apparently depends primarily on variations in irradiation. Variations in moisture and micro-climate are related to differences in irradiation due to different aspects and gradients (Fuls 1993). *Heteropogon contortus-Themeda triandra* Communities were described by Bredenkamp *et al.* (1989) in the Potchefstroom-Fochville-Parys area, Coetzee (1993) in the Pretoria-Witbank-Heidelberg area and Fuls *et al.* (1992 a) on the rocky outcrops of the northern Free State. The habitat conditions described by Fuls *et al.* (1992 a) under the *Aristido canescentis-Themedatalia triandrae* are similar to the conditions found here. The soils are generally shallow and rocky. Sandy deposits occur in the lower-lying areas.

The north-facing slopes were, in general, found to be drier and often severely overutilized by livestock. The *Heteropogon contortus-Themeda triandra* Community thus occurs primarily in areas more utilized than the *Cymbopogon plurinodis-Themeda triandra* Community. This confirms the fact that *C. plurinodis* is a notably unpalatable species which tends to increase in underutilized areas, being referred to as a souring process (Bosch 1989).

The most common, often co-dominant grasses encountered in this grassland are the medium to large tufted perennials *Heteropogon contortus* (species group S), *Digitaria eriantha* (species group V), *Eragrostis lehmanniana, Aristida congesta, A. diffusa* and *Themeda triandra* (species group W, Table 8.1). *H. contortus* is known from tropical and warm regions throughout the world, where it is a common component of grassland and savanna (Gibbs Russell & Spies 1988). Clayton & Renvoize (1986) report that it is a most variable species, which previously has been subdivided into intraspecific categories according to the hairiness of the pedicelled spikelets. In South Africa, Chippindall (1955) comments on the considerable variation of *H. contortus* in habitat, size and hairiness. This species tends to dominate in the eastern regions of South Africa and is especially abundant in Gauteng, the Northern Province and Mpumalanga. Shrubs encountered were *Euclea crispa* subsp. *ovata*, the thorny shrub *Protasparagus striatus* (species group P) and *Rhigozum obovatum* (species group Q, Table 8.1).

Three distinct sub-communities are recognizable (Table 8.1).

8.1 *Cymbopogon plurinodis-Heteropogon contortus* Sub-community

This sub-community is associated with undisturbed, rocky, east-facing slopes of hills. The stronger presence of *Cymbopogon plurinodis* (species group O) is indicative of a souring process, previously mentioned.

No exclusive diagnostic species occur and only a few species are abundant (Table 8.1). The grasses *Cymbopogon plurinodis* (species group O), *Heteropogon contortus* (species group S) and *Themeda triandra* (species group W) dominate this grassland. Also present, but inconspicuous, are other grasses such as *Eragrostis curvula, E. obtusa* (species group V), *Aristida congesta* and *Eragrostis lehmanniana* (species group W, Table 8.1).

An average of six species/relevé was recorded for this sub-community (Table 8.1).

8.2 *Heteropogon contortus-Themeda triandra* Sub-community

The *Heteropogon contortus-Themeda triandra* Sub-community occurs on the north-facing midslopes and plateaux of hills where big dolerite boulders are common. The soil is extremely shallow (< 100 mm deep) and is often covered by flat rock slabs. Isolated patches of this grassland were also found on dry, disturbed west-facing slopes.

This grassland sub-community is primarily characterized by the absence of diagnostic species and it also lacks *Cymbopogon plurinodis* which is prominent in the *Cymbopogon plurinodis-Heteropogon contortus* Sub-community (Table 8.1). *Heteropogon contortus* (species group S) and *Themeda triandra* (species group W) are the only two abundant and dominant grasses present (Table 8.1).

An average of five species/relevé was recorded for this sub-community (Table 8.1).

8.3 *Enneapogon scoparius-Hermannia vestita* Sub-community

The distribution of this plant community is restricted to the southern and south-western parts of the study area in the region of the Vanderkloof Dam. The substratum is formed by Ecca and Dwyka deposits and, in the westernmost section of the Orange River, by Ventersdorp lavas. Only the upper parts of the isolated hills consist of Beaufort deposits and dolerite. Soils are usually lithosols or of a sandy loam type except in some localities north of the river where extensive deposits of Kalahari sand have accumulated (Werger 1980).

This sub-community is characterized by the species listed in species group R (Table 8.1). *Enneapogon scoparius* and *Cenchrus ciliaris* (species group R) are the differentiating grass species, while *Stachys rugosa* and *Hermannia vestita* are the differentiating forb species (Table 8.1). According to Gibbs Russell & Spies (1988), *C. ciliaris* is a common savanna species which occurs throughout Africa to Arabia and India. According to them this species has a wider distribution than the most other important pasture grasses in South Africa. *C. ciliaris* is usually found in rocky places, which may be its natural habitat in the cooler parts of its range, but there are indications that in warmer parts it was of general occurrence and of great importance (Acocks 1971). *Heteropogon contortus* (species group S, Table 8.1) is the dominant, but *Themeda triandra* (species group W) only has an infrequent occurrence. Other grasses present, but less common, include *Digitaria eriantha* (species group V) and *Aristida diffusa* (species group W, Table 8.1).

Two variants were distinguished. (Table 8.1).

8.3.1 *Protasparagus striatus-Euclea crispa* subsp. *ovata* Variant

The *Protasparagus striatus-Euclea crispa* subsp. *ovata* Variant is primarily associated with the upper slopes and crests of hills near the Vanderkloof Dam. The habitat is rocky and the vegetation overgrazed.

This variant contains 15 species (Table 8.1). The small, thorny shrub, *Protasparagus striatus* and *Euclea crispa* subsp. *ovata* (species group P) are the differentiating species. The dominance of *Heteropogon contortus* (species group S) and the scanty occurrence of *Themeda triandra* (species group W), furthermore, characterize this vegetation unit (Table 8.1).

8.3.2 *Stachys rugosa-Eustachys paspaloides* Variant

This variant is found along crests and plateaux of hills. Big boulders are a common sight on the crests while flat rock slabs are more common on the plateaux. The soil is shallow (< 100 mm) and covered with eroded dolerite stones.

The hardy, small, drought resistant fern, *Cheilanthes eckloniana*, and the forb *Stachys rugosa* (species group R) grow very well in the crevices between the rocks. *Euclea crispa* subsp. *ovata* and *Protasparagus striatus* (species group P) are absent but the grasses *Enneapogon scoparius, Cenchrus ciliaris,* (species group R), *Heteropogon contortus* (species group S), *Digitaria eriantha* (species group V) and *Aristida diffusa* (species group W) are important (Table 8.1). Also conspicuous is the absence of *Themeda triandra* (Table 8.1).

9 *Rhus ciliata-Themeda triandra* Community

The *Rhus ciliata-Themeda triandra* Community was encountered on the footslopes of dolerite hills. According to Fuls (1993) the habitat of the footslopes in the northern Free State was found to be markedly homogeneous, which was also true of the present study. The soils of the footslopes are mostly eroded and covered with sand, pieces of fine gravel and stones.

The dwarf shrub, *Rhus ciliata* (species group T), differentiates this community and is also sub-dominant after *Themeda triandra* (Table 8.1). The Karoo-encroacher, *Chrysocoma ciliata* (species group W), is a typical karroid shrublet and is considered to be an important element of Karoo invasion in the Grassland Biome (Du Preez 1979). This unpalatable dwarf shrub is associated with veld degradation and increases with heavy overgrazing (Anonymous 1968). Sixteen species were listed in this community.

Two sub-communities were recognized (Table 8.1).

9.1 *Heteropogon contortus-Chrysocoma ciliata* Sub-community

The distribution of this sub-community was found to be restricted to areas where no rocks or stones are visible on the soil surface. Fine gravel, however, is common.

Heteropogon contortus (species group S) differentiates it from the *Rhus ciliata-Chrysocoma ciliata* Sub-community. Besides *H. contortus, Chrysocoma ciliata* and *Themeda triandra* (species group W) are the only other noteworthy species present (Table 8.1).

An average of five species/relevé was recorded (Table 8.1).

9.2 *Rhus ciliata-Chrysocoma ciliata* Sub-community

Besides gravel covering the soil surface and conspicuous big rocks present, this sub-community was found under virtually the same habitat conditions as the *Heteropogon contortus-Chrysocoma ciliata* Sub-community. The grass *Heteropogon contortus* is absent and *Themeda triandra* (species group W) has a higher cover-abundance (Table 8.1). Also present is a patchy occurrence of *Eragrostis lehmanniana* (species group W).

An average of four species/relevé was recorded (Table 8.1).

10 *Euryops empetrifolius-Eriocephalus spinescens* Community

The *Euryops empetrifolius-Eriocephalus spinescens* Community is primarily associated with the stony, dry upper east-facing slopes of hills where big sandstone rocks virtually cover the soil. Continuous weathering of these rocks gives the habitat a sandy appearance.

The diagnostic species are the karroid dwarf shrubs, *Euryops empetrifolius* and the thorny *Eriocephalus spinescens* (species group S, Table 8.1). The community is, furthermore, completely dominated by *Euryops empetrifolius* (Table 8.1). This grassland is also characterized by the presence of the grasses *Digitaria eriantha* (species group V), *Eragrostis lehmanniana, Aristida diffusa* and *Themeda triandra* (species group W), however only *T. triandra* is abundant (Table 8.1).

An average of four species/relevé was recorded (Table 8.1).

11 *Digitaria eriantha-Themeda triandra* Community

This grassland is predominantly associated with the slightly moist to dry, slopes and plateaux of hills in the central parts of the study area. The aspects were found to be exclusively westerly and easterly. Big dolerite rocks are a common sight.

This plant community lacks diagnostic species and generally has a low species diversity. The grasses *Digitaria eriantha* (species group V) and *Themeda triandra* (species group W), however, dominate the vegetation. The regular occurrence of the Karoo-encroacher, *Chrysocoma ciliata*, and the small grass *Eragrostis obtusa* (species group V) is a sure sign of veld and pasture degradation. Other grasses also commonly present include *Eragrostis curvula* (species group V) and *Eragrostis lehmanniana* (species group W, Table 8.1).

An average of five species/relevé was recorded (Table 8.1).

12 *Themeda triandra-Eragrostis lehmanniana* Community

This community occurs on dry, moderately utilized to underutilized rocky plains and slopes of low to moderately high hills in the southern parts of the study area, north-west of Zastron. The Clovelly soil form is the most prominent.

The *Themeda triandra-Eragrostis lehmanniana* grassland has no exclusively diagnostic species, being rather characterized by the high cover-abundance of *Themeda triandra* (species group W, Table 8.1). According to Van Oudtshoorn (1991) and Eckhardt (1993) well-managed fields are principally characterized by dense stands of *T. triandra*. Other grasses present include *Eragrostis lehmanniana* and *Aristida congesta* (species group W, Table 8.1). The total absence of *Digitaria eriantha* is a sign of pasture degradation.

An average of four species/relevé was recorded (Table 8.1).

ORDINATION

The scatter diagram illustrates the distribution of the major syntaxa along the first and second axes (Figure 8.2). Although no distinct discontinuity occurs, the syntaxa are restricted to specific spatial areas in the ordination diagram. Along the first axis a gradient is illustrated which may be related to moisture, altitude and habitat disturbance. Plant communities to the left of the diagram are adapted to a much drier and more disturbed habitat than those to the right. Also illustrated on axis 1 is a gradient of altitude. The sour high altitude *Harpochloa falx-Elionurus muticus* Grassland are to the right and those communities associated with lower altitudes are to the left. Axis two in the ordination diagram accommodates a soil structure gradient. Plant communities found on clayey and calcareous soils are to the top of the diagram. Communities associated with clayey-sandy (duplex) and rocky soils are grouped to the middle and sandy soils to the bottom of the diagram (Figure 8.2).

DISCUSSION

The southern Free State offers a wide variety of habitats and micro-climates due to variation in environmental factors (Figure 8.2) and are therefore ecologically interpretable. Inadequate soil moisture is considered the overriding factor limiting dry matter production in the arid and semi-arid grasslands of South Africa. Thus in these areas, efficiency of water use by natural grazing plants is critically important in relation to the production potential of the veld (Coetsee 1975). According to Snyman (1989), the aboveground phytomass production is the determining factor of water use efficiency of grasses. The water use efficiency of natural pasture can increase by using the correct managing principles and by ensuring that the vegetation composition is correct (Snyman 1989).

Acocks (1988) suggests that the boundary between Karoo shrublands and grasslands lies east of about 24° latitude and north of about 33° longitude. Widespread deterioration in all veld types over the last 500 years is evident and the extent to which such damage can be repaired by relatively simple methods, such as resting and rotational grazing, depends on how far the deterioration has progressed (Acocks 1988).

The grasslands of the southern Free State can be broadly classified as the *Themeda triandra-Eragrostis lehmanniana* Grassland. *Themeda triandra,* especially associated with climax grasslands on the highveld (Van Oudtshoorn 1991), followed by *Digitaria eriantha, Eragrostis curvula, E. lehmanniana, E. obtusa* and *Sporobolus fimbriatus* are the most prominent sweet grasses present. *Cymbopogon plurinodis* has a turpentine smell (Van Oudtshoorn 1991) and is regarded as unpalatable in sweet grasslands and represents a sub-climax to climax stage in grassland succession and where rainfall is adequate will give way to woody communities. The sweet grassland is more disturbed than the sour high altitude *Harpochloa falx-Elionurus muticus* Grassland as indicated by the numerous karroid species present. Sourveld is poorly utilized by animals during winter due to unpalatability and low feed value (Coetsee 1975).

Bezuidenhout (1993) identified five phytosociological classes in the western Transvaal grasslands. The most important grasses encountered include (in order of importance) *Eragrostis curvula, Themeda triandra, Aristida congesta, Elionurus muticus, Cymbopogon plurinodis, Heteropogon contortus, Cynodon dactylon, Aristida diffusa, Cymbopogon excavatus, Setaria flabellata, Eragrostis superba, Eragrostis gummiflua, Triraphis andropogonoides, Melinis repens, Pogonarthria squarrosa, Panicum coloratum, Sporobolus africanus, Eragrostis lehmanniana* and *Setaria nigrirostris*.

The rainfall of the western Transvaal grasslands is erratic and varies between 450 mm p.a. in the west to 770 mm p.a. in the east. The relatively heterogeneous geology is represented by the Witwatersrand and Ventersdorp Supergroups and the Transvaal Sequence with isolated occurrences of old Archaic granites and Karoo Sequence sediments. Soils in this area are heterogeneous and vary from clayey, due to great variation in parent rock material (Bezuidenhout 1993). Bezuidenhout (1993) considered available soil moisture, topographical position in relation to altitude, soil depth, drainage, percentage of stones or rocks on the soil surface and to a lesser extent percentage clay content the main contributing abiotic factors influencing the distribution of the of the vegetation.

Eckhardt (1993) described three major grassland communities in the north-eastern Free State, namely the *Aristida junciformis-Themeda triandra-*, *Eragrostis plana-Themeda triandra-* and *Monocymbium ceresiforme-Tristachya leucothrix* Grassland. The most important and conspicuous species is *Themeda triandra*. Other important grasses include *Andropogon appendiculatus, Aristida junciformis, Elionurus muticus, Eragrostis curvula, E. plana, Harpochloa falx, Heteropogon contortus, Paspalum dilatatum, Pennisetum sphacelatum* and *Tristachya leucothrix*.

The area studied by Eckhardt (1993) in the north-eastern corner of the Free State is situated in the summer rainfall zone with an average annual rainfall of 750 mm. The Karoo Sequence occupies almost the total study area. Two important groups which can be distinguished here, are the Ecca and Beaufort Groups. The Beaufort Group covers more than 80% of the study area (Eckhardt 1993). According to Eckhardt (1993) the combined influence of soil form, soil depth, moisture regime, altitude, aspect and topography is determining the occurrence of a certain community rather than a single factor on its own. In the southern Free State, soil moisture, habitat disturbance and altitude and soil type determine the distribution of grassland communities (Figure 8.2). According to O' Connor (1985) limited data illustrate that long-term rainfall variability, independent of grazing regime, has an overriding effect on compositional trends of grasslands in the savanna regions of southern Africa. Because of the influence of rainfall, the influence of grazing varies from the semi-arid to the more mesic savannas. O' Connor (1985), however, emphasized that different species respond in a markedly different manner to the same treatment under the same set of conditions. In the Karoo, however, it seems that the activities of man play a more important role in the determination of vegetation changes (Roux & Opperman 1982). Heavy grazing in the Karoo eliminates the palatable components, sometimes leaving only five or six poorly acceptable species (Stuart-Hill & Mentis 1982).

According to Fuls (1993) prominent grasses encountered throughout the northern Free State include *Eragrostis curvula, Themeda triandra, Cymbopogon plurinodis, Setaria sphacelata, Digitaria eriantha, Hyparrhenia hirta, Eragrostis plana, Cynodon dactylon, Aristida congesta, Microchloa caffra, Heteropogon contortus* and *Elionurus muticus*. *T. triandra* is by far the most dominant grass.

The north-eastern Free State is situated in the 600-700 mm p.a. rainfall zone of the semi-arid climatic climax grassland of the Grassland Biome of southern Africa. Geologically the area is underlain by the Ecca and Beaufort Groups of the Karoo Sequence with dolerite dykes and sills occurring throughout the area (Fuls 1993). According to Fuls (1993), the phytosociology of the vegetation is primarily influenced by soil moisture variations on a macro- and micro-scale, utilization by herbivores and terrain morphology. Soil type has a lesser influence on the vegetation distribution than soil depth, soil moisture and rockiness. This was also the case here as can be seen in the ordination (Figure 8.2).

Grasslands are generally considered as the most important vegetation units for livestock farming. Invasion of karroid species is evident throughout the entire southern Free State. *Chrysocoma ciliata* and *Pentzia globosa* are good examples (See Chapter 7). It is therefore necessary to manage them according to ecological principles to maintain optimum floristic composition and subsequently achieve a high production per unit area (Eckhardt 1993). According to Grunow (1973) the establishment of pastures on arable lands, particularly on small farms and where veld is degraded, raises the production potential of the farm. The practice of grazing summer-rested veld continuously during the whole winter period and even during early summer cannot be recommended as it can cause severe damage to certain species, such as *Themeda triandra* and *Eragrostis curvula* (Coetsee 1975). On low rainfall sweetveld it enables the veld to be adequately rested during the rainy season. According to O' Connor (1985) **stocking rate, rather than the system of grazing,** has a far greater influence on compositional trends of grasslands in the savanna regions of southern Africa.

In spite of all this, natural grasslands are being increasingly disturbed or purposefully altered by man-made processes. Many of these lead to a degradation of the natural vegetation, and for this reason there is an urgent need for more effective management of our natural resources. The presented delineation of the grassland communities and associated habitats should be used as a basis for future management and conservation of these areas.

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CHAPTER 9

Vegetation ecology of the southern Free State

Phytosociology of the southern Free State: Riparian and Streambed Vegetation

CHAPTER 9

PHYTOSOCIOLOGY OF THE SOUTHERN FREE STATE: RIPARIAN AND STREAMBED VEGETATION

9.1 INTRODUCTION

Begg (1986) defined a wetland as an area where excess of water is the dominating factor determining the nature of soil development and types of plant and animal communities living at the soil interface. Wetlands are therefore water-dominated areas with impeded drainage where soils are saturated with water (at least periodically) and where there is a characteristic flora and fauna (Coetzee 1993). The Ramsar Convention (Convention on Wetlands of International Importance especially as Waterfowl Habitat) was adopted in February 1971 by the International Conference on the Conservation of Wetlands and Waterfowl at the town of Ramsar in Iran. Article 1.1 of this Convention defines wetlands as follows: "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres".

The World Conservation Strategy identified wetlands as one of the most important life support system on this planet (Cowan 1991). Like many countries of the world, South Africa is rapidly approaching the position of maximum exploitation of its conventional water resources (Alexander 1985, Walmsley 1988). South Africa is categorized as an arid country with 65% of the land-surface area receiving a mean annual precipitation of less than 500 mm (Cowan 1991). In South Africa, a country with very few wetlands, it has been estimated that over half of the wetlands have been destroyed and lost (Breen & Begg 1989). Wetlands are therefore a scarce commodity in South Africa and the remaining wetlands should be high on the list of areas to be conserved.

Although South Africa is involved in the Ramsar Convention for some time now (Cowan 1991), many wetlands are still being destroyed beyond rehabilitation, making them one of South Africa's most endangered ecosystem types (Walmsley 1988). The widespread ploughing of arable land concomitant with livestock grazing pressure resulted in the destruction of large portions of pristine vegetation in the southern Free State. The sensitivity of hydrophilic vegetation makes the watercourses especially vulnerable to degradation. In many cases the trampling effect at these sites is so serious that most of the riverbank vegetation is completely destroyed by erosion.

From a phytosociological viewpoint, very little is known about the wetland vegetation in the southern Free State. As yet no research has been done on the vegetation composition and condition of the wetland habitats of the southern Free State to determine the state of health of these habitats. To facilitate optimal resource utilization in general, a detailed survey of the region has been undertaken. This survey forms an integral part of the ultimate goal to compile a comprehensive synecological synthesis of the Grassland Biome of South Africa (Scheepers 1986).

9.2 STUDY AREA

The present study includes the southern Free State and is situated to the south of the 29° 00' S latitude and to the west of the 27° 00' E longitude, encompassing approximately 27 000 km^2. Towns situated in the study area are Bloemfontein, Bethulie, Luckhoff, Petrusburg, Fauresmith, Wepener and Zastron (Figure 9.1). Figure 9.1 also portrays the rivers and dams in the southern Free State. The names of important dams changed during 1994. To be in line with Figure 9.1, the Hendrik Verwoerd Dam should read Gariep Dam and the P.K. le Roux Dam, the Van der Kloof Dam.

Wetlands in the southern Free State are mostly riparian wetlands along rivers and streams. Floodplains and vleis are mainly found in bottomland situations (Van Zyl 1966). Permanently waterlogged soils are scarce and seasonally standing water is mostly restricted to slow-draining watercourses of flat terrain. Slow-draining streams are common owing to the flatness of the terrain in most of the study area (Land Type Survey Staff, in press).

According to Strahler (1975), climate plays an important role in the land- and soil forming processes and also has a major influence on the distribution of vegetation (Acocks 1988).

Schulze & McGee (1978) and Woodward & Williams (1987) allege that precipitation and temperature are the most significant climatic factors in vegetation development.

The entire study area is subjected to a summer rainfall climate, although there are significant differences along the east-west gradient. The rainfall is erratic, especially in the western part of the study area (300-400 mm/a) and increases along a gradient eastwards to 700 mm/a. This is caused by the increasing relief from west to east and a decrease of average daily temperatures from west to east (Van der Wall 1976, Schultze & McGee 1978). According to Eloff (1984) the depth of the A-horizons of soils increase from west to east.

The main drainage basin of the study area is the Orange River. Other smaller rivers include the Caledon, Riet and Modder Rivers.

Topography has a definite influence on the temperature of the study area, especially along rivers (Barker 1985). The hottest months of the year are from December to February with July the coldest month of the year.

A more detailed description of the physical environment and climate is given elsewhere (Chapter 2).

9.3 METHODS

Relevés were compiled in 70 stratified random sample plots. Stratification was based on terrain morphology (riverbanks, streambanks, bottomlands such as vleis), and land types. Pan vegetation of the dry south-western Free

State is discussed in Chapter 10 of this dissertation. Care was taken to place sample plots on all the different terrain morphological units. Plot sizes were fixed at 100 m^2 (Scheepers 1975, Bredenkamp 1982, Eckhardt *et al.* 1993, Fuls 1993). In each sample plot a list of all species present was made and the cover-abundance of each species noted using the Braun-Blanquet scale (Mueller-Dombois & Ellenberg 1974).

Two-way indicator species analysis (TWINSPAN) (Hill 1979 b) was applied to the floristic data set in order to derive a first approximation of the vegetation types of the area. Refinement was done by means of Braun-Blanquet procedures (Bredenkamp *et al.* 1989). The floristic data set was further subjected to an ordination algorithm, Detrended Correspondence Analysis (DECORANA) (Hill 1979 a), to determine vegetation gradients and the relationship with environmental variables. Plant names conform to those of Arnold & De Wet (1993). Other relevant information such as habitat disturbance, degradation of vegetation, rockiness of the soil surface and human impact on the habitat were also noted.

Herbarium specimens collected during this survey are housed at the Geo Potts Herbarium (BFLU), Department of Botany and Genetics, UOFS, Bloemfontein.

All relevant soil information was collected from the Land Type Survey Staff (In Press), Soil Classification Working Group (1991) and Eloff (1984).

9.4 RESULTS AND DISCUSSION

The watercourses and adjacent areas of the southern Free State were often found to be disturbed and the vegetation overutilized and trampled by livestock. These areas generally do not have a high species diversity and are dominated by only a few forb species (Table 9.1). The wetland habitat of the study area can be broadly classified as the *Asclepias fruticosa-Cirsium vulgare* Wetland. *Asclepias fruticosa* and *Cirsium vulgare* (species group Y) are generally found in the wetlands in the southern Free State. Only a few dominant species occur and are mainly associated with seasonally flooded areas of the flat undulating plains including streams and riverbanks. The hierarchical classification of the Wetland vegetation type is as follows:

1 *Cyperus longus-Cyperus marginatus* Riparian Vegetation
1.1 *Cyperus longus-Agrostis lachnantha* Streambed Vegetation
1.2 *Cyperus rupestris-Mariscus congestus* Sub-community
1.3 *Cyperus longus-Cynodon incompletus* Sub-community
1.4 *Cyperus longus-Portulaca oleracea* Riparian Vegetation
1.4.1 *Cyperus longus-Medicago laciniata* Riparian Vegetation
1.4.2 *Cyperus longus-Persicaria serrulata* Riparian Vegetation
1.5 *Fuirena hirsuta-Wahlenbergia androsacea* Riparian Vegetation
1.5.1 *Cyperus marginatus-Fuirena hirsuta* Riparian Vegetation
1.5.2 *Sporobolus fimbriatus-Cirsium vulgare* Riparian Vegetation
1.6 *Sporobolus ioclados-Scirpus dioicus* Riparian Vegetation
1.7 *Chenopodium cristatum-Cyperus marginatus* Riparian Vegetation

2 *Scirpus nodosus* Riparian and Streambeds Vegetation
2.1 *Scirpus nodosus-Cyperus longus* Streambed Vegetation
2.2 *Scirpus nodosus-Cyperus laevigatus* Streambed Vegetation
2.3 *Juncus kraussii-Chrysocoma ciliata* Streambed Vegetation
2.4 *Scirpus nodosus-Juncus kraussii* Riparian Vegetation
2.5 *Scirpus nodosus-Cirsium vulgare* Riparian Vegetation

3 *Typha capensis-Senecio consanguineus* Streambed Vegetation
3.1 *Juncus exsertus-Helichrysum turgudulum* Riparian Vegetation
3.2 *Rumex lanceolatus-Juncus rigidus* Streambed Vegetation

4 *Phragmites australis-Protasparagus laricinus* Streambed Vegetation

5 *Protasparagus laricinus-Phyla nodiflora* Riparian Vegetation

6 *Salix babylonica-Lactuca dregeana* Streambed Vegetation

7 *Miscanthus capensis-Typha capensis* Riverbank Vegetation

8 *Agrostis lachnantha* Wetlands of the drainage channels

8.1 *Pennisetum sphacelatum-Miscanthus capensis* Wet drainage channels

8.2 *Cyperus eragrostis-Paspalum dilatatum* Drainage channels

DESCRIPTION OF THE COMMUNITIES

1 *Cyperus longus-Cyperus marginatus* Riparian Vegetation

The *Cyperus longus-Cyperus marginatus* Riparian Vegetation is strongly associated with poorly drained, moderately deep, clayey (> 25% clay content - A - & B-horizons) soils with alluvium often occurring. Less than 10% of the soil surface is covered by stones or rocks. This plant community is encountered on flat bottomlands and floodplains along rivers and streams.

The hygrophytes, *Cyperus longus* and *C. marginatus* (species group I), characterize this wetland type (Table 9.1). These species were often encountered growing in or adjacent to watercourses. Other frequently occurring species include *Asclepias fruticosa* and *Cirsium vulgare* (species group X, Table 9.1).

Seven distinct sub-communities further divide this wetland (Table 9.1)

1.1 *Cyperus longus-Agrostis lachnantha* Streambed Vegetation

This streambed sub-community is either growing in water or adjacent to open or flowing water. The riverbanks consist partly of rocks and gravel and are generally characterized by the Dundee soil form, consisting of stratified alluvium. The relatively low clay content in the upper layers in some areas can be ascribed to the flowing of gravel and sand particles from upstream.

This streambed has no exclusive diagnostic species group and is represented by only a few species with the sedges, *Cyperus longus* and *C. marginatus* (species group I) and the grass, *Agrostis lachnantha* (species group X), the most abundant (Table 9.1).

1.2 *Cyperus rupestris-Mariscus congestus* Sub-community

A sub-community occurring on the banks of perennial rivers and streams which are occasionally in flood. No rocks and gravel are visible on the clayey (> 35% clay) soil surface. A layer of river sand covers the soil surface. Little habitat disturbance occurs although patches of overgrazing can be encountered.

This sub-community is characterized by the species listed in species group A (Table 9.1). The differentiating species are the hygrophytes *Cyperus rupestris* and *Mariscus congestus* and the widespread couch grass *Cynodon incompletus*. Of note is the restricted dominance of *Cyperus longus* (species group I) and the frequent occurrence of *Asclepias fruticosa* (species group Y). *A. fruticosa*, commonly known as "milkweed" is virtually restricted to sandy deposits (Anonymous 1968). It is unpalatable, but is regularly eaten by insects and worms (Anonymous 1968). Trees and shrubs are infrequent, but the presence of *Protasparagus laricinus* (species group R) and *Diospyros lycioides* (species group S) further differentiates this wetland from the *Cyperus longus-Agrostis lachnantha* Streambeds. *Cirsium vulgare* (species group Y) was locally totally dominant (Table 9.1).

1.3 *Cyperus longus-Cynodon incompletus* Sub-community

This infrequent wetland is restricted to the relatively dry undulating landscape and drainage channels. Fine gravel cover 10-40% of the surface.

Species of species groups A and B characterize this sub-community and are indicative of habitat degradation (Table 9.1). The absence of *Cyperus rupestris, Mariscus congestus* (species group A), as well as *Asclepias fruticosa* (species group Y), differentiate this sub-community from the *Cyperus rupestris-Mariscus congestus* Riparian Sub-community (Table 9.1). *Cyperus longus* (species group I) is less conspicuous and the only other noteworthy species present (Table 9.1).

1.4 *Cyperus longus-Portulaca oleracea* Riparian Vegetation

This riparian sub-community is encountered on flat bottomlands or floodplains along the beds of seasonally flowing rivers and streams. The soils are deep (> 500 mm) and clayey (> 35%). The trampling effect of livestock often results in denuded areas along the watercourses.

The sedge, *Cyperus longus* (species group I), dominates the vegetation with *Portulaca oleracea* (species group D) also conspicuous. The latter is a pioneer and grows equally well in full sun as in the shade.

Two distinct variants further differentiate this wetland (Table 9.1).

1.4.1 *Cyperus longus-Medicago laciniata* Riparian Vegetation

This vegetation unit is restricted to the floodplains of seasonally flowing rivers. The soil is clayey and its surface covered with a layer of river sand (>100 mm thick) (duplex soils).

The reeds *Medicago laciniata*, *Xanthium strumarium* and *Atriplex semibaccata* (species group C) differentiate the vegetation with *Portulaca oleracea* (species group D) also prominent. The variant is dominated by *Cyperus longus* (species group I, Table 9.1). Other prominent species are scarce. The sprawling grass, *Cynodon incompletus* (species group A), grows particularly well in the mud in the shade of *Cyperus longus.*

1.4.2 *Cyperus longus-Persicaria serrulata* Riparian Vegetation

The *Cyperus longus-Persicaria serrulata* Riparian Vegetation occurs along the beds of rivers with shallow clayey (< 100 mm deep) soil. No sandy deposits overly the clay surface, but a layer of fine gravel (often > 100 mm thick) occurs. Habitat disturbance due to human impact is noticeable. Littering, especially, is common.

Species of species groups D, I and Y occur with *Cyperus longus* (species group I) the only conspicuous species (Table 9.1). The absence of species from species groups A, B and C differentiates this variant from the *Cyperus longus-Medicago laciniata* riparian vegetation (Table 9.1).

1.5 *Fuirena hirsuta-Wahlenbergia androsacea* Riparian Vegetation

Certain species of this sub-community are either growing in water or occur directly adjacent to open or flowing water. These seasonal watercourses are generally flowing during the rainy season. Habitat disturbance frequently occurs and trampling by livestock often results in denuded areas. The soil is clayey with big rocks (> 0.5 m in diameter) exposed on the soil surface.

Species of species group E are diagnostic of this sub-community with the sedge *Fuirena hirsuta* the most prominent. *Cyperus marginatus* (species group I) and *Cirsium vulgare* (species group Y) are also conspicuous, especially on riverbeds. Other species present, but less-conspicuous, include *Wahlenbergia androsacea, Ranunculus multifidus* (species group E), *Lobelia thermalis* and *Juncus kraussii* (species group M). The presence of *J. kraussii* indicates brackish conditions.

Two distinct variants further divide this wetland (Table 9.1).

1.5.1 *Cyperus marginatus-Fuirena hirsuta* Riparian Vegetation

The *Cyperus marginatus-Fuirena hirsuta* Riparian Vegetation occurs adjacent to slow-flowing water bodies such as dams and seasonally waterlogged streams. The soil is clayey and the surface trampled by cattle and sheep. Exposed rocks cover 20-40 % of the soil surface.

This variant lacks exclusive diagnostic species, but the vegetation is rather characterized by the strong presence of *Fuirena hirsuta* (species group E) and *Cyperus marginatus* (species group I, Table 9.1).

1.5.2 *Sporobolus fimbriatus-Cirsium vulgare* Riparian Vegetation

The vegetation associated with this variant of the *Fuirena hirsuta-Wahlenbergia androsacea* Riparian Vegetation is trampled by cattle. No rocks are visible on the soil surface.

This variant also lacks exclusive diagnostic species and is differentiated from the *Cyperus marginatus-Fuirena hirsuta* Variant by the presence of the species from species group H and the dominance of *Cirsium vulgare* (species group Y). Other species present, most of which are inconspicuous, include *Fuirena hirsuta*, *Ranunculus multifidus* (species group E), *Sporobolus virginicus* and *S. fimbriatus* (species group H, Table 9.1).

1.6 *Sporobolus ioclados-Scirpus dioicus* Riparian Vegetation

This infrequent vegetation group occurs on trampled soil, but to a lesser extent than the *Fuirena hirsuta-Wahlenbergia androsacea* Riparian Vegetation. No rocks occur on the surface. Fine gravel, almost as fine as river sand, cover the soil surface.

Diagnostic species are those listed in species group F (Table 9.1). According to Van Oudtshoorn (1991), *Sporobolus ioclados* generally grows well in brackish soil. *Scirpus dioicus* (species group F) is the only other diagnostic species present, but the restricted dominance of *Juncus kraussii* (species group M) is more noteworthy and further indicates brackish habitat (Table 9.1).

1.7 *Chenopodium cristratum-Cyperus marginatus* Riparian Vegetation

The habitat of this infrequent sub-community is not clearly distinguishable from the previous two wetlands. Habitat disturbance also occurs, but to a lesser extent. Littering, especially with plastic bags and bottles are a common phenomenon. Alluvium and gravel occur on the surface and the soil appears to be more calcareous in nature. Footprints of cattle are conspicuous in the mud.

Chenopodium cristatum (species group G), rather inconspicuous, is diagnostic of this vegetation unit (Table 9.1). Other species which frequently occur, include *Sporobolus virginicus, S. fimbriatus* (species group H), *Cyperus longus* (species group I), *Scirpus nodosus* (species group L), *Lobelia thermalis* (species group M) and *Cirsium vulgare* (species group Y). *S. fimbriatus* and *C. longus* are often conspicuously dominant (Table 9.1).

2 *Scirpus nodosus-Cirsium vulgare* Riparian and Streambed Vegetation

This community occurs on the periodically dry streambeds and on edges of pans. The riverbanks consist mainly of calcareous soil and is often clayey, especially in the lower-lying areas which receive more moisture. Big rocks are absent, but gravel gives these sites a stony appearance. The pans are without any rocks. The zone of vegetation on the edges of pans is clearly recognizable and can easily be distinguished by its structural appearance from the vegetation found deeper in the pans. The erect vegetation is in direct contrast to the creeping, carpet-like appearance of the vegetation in the central areas of pans where the rhizomatous swamp grass, *Diplachne fusca*, frequently occurs. Pan vegetation is discussed in Chapter 10 of this dissertation.

Species of species groups I, J, K, L, M and Y characterize this vegetation unit with *Scirpus nodosus* (species group L, Table 9.1) the differentiating species. Also conspicuous are the scanty occurrence of species of species groups A-H and N-V (Table 9.1).

Five distinct sub-communities divide this plant community (Table 9.1).

2.1 *Scirpus nodosus-Cyperus longus* Streambed Vegetation

This sub-community is associated with less disturbed drier streambeds with water patches occurring in the low-lying areas. The soil is clayey and no rocks are visible on the surface.

The *Scirpus nodosus-Cyperus longus* Streambed Vegetation lacks diagnostic species but is rather characterized by the restricted dominance of *Cyperus longus* (species group I) and *Scirpus nodosus* (species group L, Table 9.1). This streambed community is not particularly rich in species with *Juncus kraussii* (species group M), *Miscanthus capensis* (species group V) and *Asclepias fruticosa* (species group Y) the only other conspicuous species (Table 9.1).

2.2 *Scirpus nodosus-Cyperus laevigatus* Streambed Vegetation

The *Scirpus nodosus-Cyperus laevigatus* Streambed Vegetation is associated with less moist watercourses and often more sandy streambeds in comparison to the *Scirpus nodosus-Cyperus longus* Sub-community. This vegetation unit lacks clear diagnostic species. Only the sedge *Cyperus laevigatus* (species group J) occurs as such. *Cirsium vulgare* (species group Y) is the only conspicuous species and completely dominates the vegetation (Table 9.1). *C. vulgare* stands are often very dense. Other abundant species include *Scirpus nodosus* (species group L), *Lobelia thermalis* (species group M) and the swamp grass *Agrostis lachnantha* (species group X).

2.3 *Juncus kraussii-Chrysocoma ciliata* Streambed Vegetation

The *Juncus kraussii-Chrysocoma ciliata* Streambed Vegetation is associated with slow-flowing perennial or seasonally perennial streams and vleis with shallow streambed-incision. The calcareous-sandy soil of these streambeds is moist and fine gravel occurs on the surface. This vegetation is heavily overgrazed and the soil surface trampled.

The Karoo-encroacher, *Chrysocoma ciliata* (species group K), is the sole diagnostic species (Table 9.1). *Scirpus nodosus* (species group L) and

Juncus kraussii (species group M) have restricted dominances and *Asclepias fruticosa* (species group Y) also occurs, especially in the less sandy places (Table 9.1).

2.4 *Scirpus nodosus-Juncus kraussii* Riparian Vegetation

The *Scirpus nodosus-Juncus kraussii* Riparian Vegetation is restricted to higher-lying areas adjacent to pans. The soil is clayey and no rocks are visible on the surface.

Only a few species occur and none of these is diagnostic. *Scirpus nodosus* (species group L) and *Juncus kraussii* (species group M) are dominant in places, with *Lobelia thermalis* (species group M), *Protasparagus laricinus* (species group R), *Miscanthus capensis* (species group V), *Agrostis lachnantha* (species group X) also partly prominent (Table 9.1).

2.5 *Scirpus nodosus-Cirsium vulgare* Riparian Vegetation

This riparian vegetation is a transitional sub-community encountered on the peripheral zone of pans and is not to be confused with the vegetation found deeper in these pans. The soil is of a clayey nature with water patches in the low-lying areas. This sub-community is similar to the *Senecio inaequidens-Cynodon transvaalensis* Pan Community described by Eckhardt *et al.* (1993) in the Vrede-Memel-Warden Area in the north-eastern Free State.

No diagnostic species occur and the vegetation is dominated by *Scirpus nodosus* (species group L) and *Cirsium vulgare* (species group Y). The vegetation, especially where *C. vulgare* dominates, is often very dense. Other species are scarce, only *Portulaca oleracea* (species group D) and *Juncus kraussii* (species group M) being present (Table 9.1).

3 *Typha capensis-Senecio consanguineus* Streambed Vegetation

The *Typha capensis-Senecio consanguineus* Streambed Vegetation is associated with shallow streambeds where a mixture of clayey and clayey-sandy soil occurs. Habitat disturbance due to trampling of livestock is a common phenomenon.

The bullrush, *Typha capensis*, forming often very dense, homogeneous stands and the forb *Senecio consanguineus* (species group P) are the only differentiating species (Table 9.1).

Two distinct sub-communities characterize this plant community (Table 9.1).

3.1 *Juncus exsertus-Helictotrichon turgudulum* Riparian Vegetation

This wetland is encountered on vlei-edges which are not permanently waterlogged. The soil is of a clayey nature. The surface is rock-less. Habitat disturbance from trampling frequently occurs.

The diagnostic species of the *Juncus exsertus-Helictotrichon turgudulum* Sub-community are those listed in species group N (Table 9.1). *Juncus exsertus* are the most prominent and has a restricted dominance. *Typha capensis* (species group P), the sedge *Mariscus congestus* (species group A) and the grasses *Helictotrichon turgudulum* (species group N) and *Agrostis lachnantha* (species group X) are the most frequently occurring species. The noxious weed *Xanthium strumarium* (species group C) and the grass *Hyparrhenia dregeana* (species group N) grow especially well in deep clayey soil.

3.2 *Rumex lanceolatus-Juncus rigidus* Streambed Vegetation

This streambed community is associated with slower draining, waterlogged streambeds. Distinctive pools are absent. Habitat disturbance does occur, but to a much lesser extent than in the *Juncus exsertus-Helictotrichon* *turgudulum* Riparian Vegetation. Sandy-clayey soil occurs in the middle of these streambeds.

Rumex lanceolatus and *Juncus rigidus* (species group O) are the only two differentiating species. This sub-community lacks *Mariscus congestus* (species group A) and those species of species group N differentiating the *Juncus exsertus-Helictotrichon turgudulum* Riparian Vegetation (Table 9.1). *Typha capensis* (species group P) has a exceptionally high cover-abundance and the vegetation often is very dense. These sites are popular nest-building sites for water birds. *Phragmites australis* (species group Q) and *Asclepias fruticosa* (species group Y) were found to be co-dominant of this streambed vegetation (Table 9.1).

4 *Phragmites australis-Protasparagus laricinus* Streambed Vegetation

The *Phragmites australis-Protasparagus laricinus* Streambed Vegetation is primarily associated with the banks of perennial rivers and streams. Streamflow is generally slow, but may accelerate between pools. Rapids frequently occur and play a further role in the faster movement of water.

This vegetation unit lacks exclusive diagnostic species, but is rather differentiated by the dominance of the reed, *Phragmites australis* (species group Q). *P. australis* is the most widespread flowering plant on earth (Good 1974; Gibbs Russell *et al.* 1990). *Salix mucronata* and *Phyla nodiflora* (species group Q) further differentiate this community with *Protasparagus laricinus* (species group R), the exotic *Salix babylonica*, and *Diospyros lycioides* (species group S) the only other noteworthy species present (Table 9.1).

5 *Protasparagus laricinus-Phyla nodiflora* Riparian Vegetation

A vegetation group associated with shallow streambed incision and moist to wet streambanks. The subsoil of the streambanks are at least periodically waterlogged during the rainy season. The soil is clayey with sandy areas also abundant.

Only three species, *Protasparagus laricinus* (species group R), *Phyla nodiflora* (species group Q) and *Cirsium vulgare* (species group Y), are worth mentioning (Table 9.1). Species of species groups A, C, I, O and S are also present, but they are inconspicuous (Table 9.1). *Cirsium vulgare* (species group Y) is often dominant, especially in areas with sandy deposits.

6 *Salix babylonica-Lactuca dregeana* Streambed Vegetation

This, relatively undisturbed streambed vegetation type, is associated with moist riverbanks. No standing water occurs and the soil is clayey (< 20 % clay) or sandy, especially in the lower-lying areas. The exotic woody species *Salix babylonica* (species group S) completely dominates the vegetation, with *Diospyros lycioides* (species group S) the only other woody species present. Other species present include the grass *Cynodon incompletus* (species group A), the Karoo-encroacher *Chrysocoma ciliata* (species group K), *Lactuca dregeana*, *Artemisia afra* (species group S) and *Cirsium vulgare* (species group Y), all occurring in the shade of big *S. babylonica*.

7 *Miscanthus capensis-Typha capensis* Riverbank Vegetation

The *Miscanthus capensis-Typha capensis* Riverbank Vegetation is associated with duplex soils on riverbanks. The soils of the bottomlands are clayey and covered with a layer of sand (duplex soils). These soils are generally non-rocky (< 10% rocks). Habitat disturbance frequently occurs and signs of human impact (litter) are clearly visible.

Differentiating species are those listed in species group T, all of which have a low cover-abundance, but *Miscanthus capensis* (species group V) completely dominates the vegetation (Table 9.1).

8 *Agrostis lachnantha* Wetlands of the drainage channels

The habitat of the drainage channels occupied by this community is periodically eroded and disturbed. The soils are predominantly clayey but patches of calcareous soil do occur. Standing water is often visible, virtually for weeks after good rains.

Agrostis lachnantha (species group X), one of the most widespread of all grasses (Gibbs Russell *et al.* 1990), occurs frequently and differentiates this wetland community. This community has a low species diversity with species listed in species groups A-T (Table 9.1) just about absent. The only exception is *Artemisia afra* (species group S) which regularly occurs.

Two distinct sub-communities further divide this wetland (Table 9.1).

8.1 *Pennisetum sphacelatum-Miscanthus capensis* Wet drainage channels

This wetland is associated with periodically waterlogged drainage channels, where predominantly clayey soil prevails.

Pennisetum sphacelatum is the only diagnostic species and completely dominates the vegetation (species group U, Table 9.1). Due to the dominance of this grass, other forbs are scarce and only grasses such as *Miscanthus capensis* (species group V) and *Agrostis lachnantha* (species group X) occur, both having fairly high cover-abundance values.

8.2 *Cyperus eragrostis-Paspalum dilatatum* Drainage channel community

The *Cyperus eragrostis-Paspalum dilatatum* Sub-community is associated with drainage channels along public roads. The habitat is usually disturbed, not waterlogged and the soil is of a calcareous nature.

The sedge, *Cyperus eragrostis* and the perennial, rhizomatous grass, *Paspalum dilatatum* (species group W), are the most dominant of the diagnostic species (species group W, Table 9.1) with *Asclepias fruticosa* also frequently occurring (species group Y, Table 9.1). Where *Pennisetum sphacelatum* completely dominates the *Pennisetum sphacelatum-Miscanthus capensis* Wetland, it is absent from this sub-community where *C. eragrostis* dominates (Table 9.1).

ORDINATION

In the scatter diagram the distribution of the major syntaxa along the first and second axes of the ordination is given (Figure 9.2). Along the first axis, which presents a soil texture gradient, the plant communities associated with rocky soil (> 10% rocks) are situated to the left of the diagram and those communities associated with less rocky soil (< 10% rocks) towards the right. Also along the first axis is a gradient of habitat disturbance. Relatively undisturbed plant communities are to the left of the diagram with the more disturbed communities to the right. A habitat gradient illustrates the distribution of the plant communities along the second axis of the diagram. Plant communities to the top of the diagram are primarily associated with drainage channels while those to the middle and bottom of the diagram are primarily associated with rivers and streambeds (Figure 9.2).

9.5 DISCUSSION

All plant communities could be related to specific environmental conditions (Figure 9.2) and are therefore ecologically interpretable. Soil moisture and the type of grazing management applied in a certain area, play an important role by determining the type of vegetation in a that area (Eckhardt *et al.* 1993). According to them, the low species diversity of the wetland plant communities of the Vrede-Memel-Warden Area is mainly due to regular flooding, droughts and grazing of livestock. This was also the case within the wetlands of the southern Free State. According to Van der Walt (1992), numerous water birds were spotted in the pans and vleis of the north-eastern Free State. This was not the case here with most water birds spotted in the open pan communities (Chapter 10).

The most important species associated with the wetlands of the southern Free State are the grass *Agrostis lachnantha,* the sedges *Cyperus longus, C. marginatus* and *Juncus kraussii* and the forbs *Asclepias fruticosa, Cirsium vulgare* and *Lobelia thermalis*.

Wetlands are considered as sensitive areas (Eckhardt 1993) and require special attention as far as their management is concerned. Sound ecological principles seem to be the only way to manage these areas. This implies inter alia the delimitation of the different wetlands, implementation of ecologically sound veld management programmes, including the partial withdrawal of livestock and veld burning programmes, and the process of drainage being halted (Eckhardt 1993). Over utilization of vegetation and especially the accompanying habitat degradation of these areas should be minimized in order to ensure that the vegetation have more time to recover.

Human growth and utilization of fresh water on a sustained exponential basis are pre-eminent components of any analysis of inland water resources. Man must be recognized for what he is: an animal whose population growth is in an exponential phase (Wetzel 1983). The unfortunate effect of essentially uncontrolled growth is that consumption increases in response to rising supply. Every increase in supply is met by a corresponding increase in consumption, because in contemporary society, voluntary control over consumption is ineffective (Wetzel 1983). Fresh waters are a finite resource and if we are not able to manage it properly the consequences will be disastrous.

This delineation of the wetland communities of the southern Free State should be used as the basis for future conservation strategies of these areas. Because of the sensitivity of these areas and the continuous degradation of wetland habitats one should hope that future management and conservation strategies should be given higher priority.

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CHAPTER 10

Vegetation ecology of the southern Free State

Vegetation ecology of the southern Free State: Pan vegetation

CHAPTER 10

VEGETATION ECOLOGY OF THE SOUTHERN FREE STATE: PAN VEGETATION

10.1 INTRODUCTION

South Africa is an arid country of which 65% of the total area receives a mean annual precipitation of less than 500 mm (Cowan 1991). According to Morant (1983), wetland habitats in southern Africa have received little attention in the past. Little research or conservation efforts have been focused on pan ecosystems and despite their unique nature there has been an underestimation of their conservation value.

Pans are common in many of the world's arid zones. In Africa, south of the equator, pans occur from Zaïre in the north to South Africa in the south and from Namibia in the west to Mozambique in the east. The greatest concentration is, however, to be found in the southern Kalahari/northern Cape/western Free State region (Seaman 1987) where the mean annual precipitation is less than 500 mm.

To the casual traveller through the drier, western parts of South Africa, the shallow and usually waterless depressions in the veld are of little interest. But appearances can be deceptive. Such depressions can be surprisingly common. In fact, in pioneer days transport routes in the western Free State followed lines of pan abundance because of the water which they provided. They are important components of the terrestrial ecosystems of the region and, when they hold water, contain a uniquely fascinating biota. Despite the ecological importance of such temporary water-bodies, one can find very little about them in either learned or popular texts. It is obvious, however, that the relative lack of permanent waters in arid regions makes temporary water-bodies very important to the ecological functioning of such regions (Seaman 1987).

DEFINITION OF PANS

Some controversy has surrounded the definition of various wetland types (Morant 1983, Walmsley & Botten 1987), but endorheic (closed or no outlet) pans (Hutchinson *et al.* 1932, Geldenhuys 1982, Noble & Hemens 1978) are relatively easily defined ecosystems. Pans are shallow, even when fully inundated and are seldom more than about three metres deep. Typically their shape is circular to oval (Zaloumis 1987). Goudie & Thomas (1985) refer to pans as "small closed basins". Lancaster (1979) described southern Kalahari pans as "dry or ephemeral lakes, 0.3 - 7 km^2 in area which may have bare clay or more or less vegetated surfaces, contained in isolated enclosed depressions of 5-20 m deep with sizes of 2 - 16 km^2."

An early attempt to classify pans was based simply on their distance from the coast. Du Toit (1927) classified pans of South Africa as being either coastal or inland pans. The first classification of pans in relation to vegetation was applied to the pans in the Lake Chrissie area (Hutchinson *et al.* 1932). The following categories were distinguished: *Scirpus* pans, reed (*Phragmites*) pans, *Melosira*-Cyanophyceae pans, *Potamogeton livingstonei* pans, *Nodularia* pans and vegetation-less pans.

Noble and Hemens (1978) gave a general overview of several pan types in South Africa on the basis of physical characteristics and faunal and floral composition. These included salt-pans, temporary pans, grass pans, sedge pans, reed pans and semi-permanent pans. A more comprehensive classification of pans was devised by Geldenhuys (1982). He distinguished six types of pans in the Free State on the basis of presence of emergent-vegetation and in relation to utilization of the pans by water birds, both of which are dependent on the average duration of inundation. These are bare, sedge, scrub, mixed grass, closed and open *Diplachne* pans.

It is clear that though relatively little work has been done on pans, they are of ecological value and scientific interest. According to Geldenhuys (1982), annual rainfall is the best indicator of the number of pans being flooded for a significant period of time. The existence of pans depends entirely on the water regime and factors such as rainfall intensity, evaporation rate and groundwater level, all influence the duration of inundation (Cowan 1995).

THE FLORA OF PANS

Although several of the above classification schemes have been loosely based on the vegetation associated with pans, no published analyses of the vegetation of pans in South Africa exist. The only comprehensive, although unpublished, survey of the vegetation of a pan is that of Zimbatis (1975) covering Baberspan.

Geldenhuys (1982) found the less vegetated pan types to be more common in the drier south-western Free State, while the more vegetated types were more common in wetter areas, although both types occurred throughout, often in close proximity.

DISTRIBUTION OF PANS

According to Le Roux (1978) most of the pans in the Free State are situated on the arid side of the 550 mm annual rainfall isohyet. Le Roux (1978), however, considered rainfall as a proportion of evaporation to be more significant in influencing the maintenance of pans. He felt that these isolines correlated more closely with pan distribution (Cowan 1995). Seaman (1987) compiled a map indicating the greatest concentration of natural pans in the Free State. According to him most of the pans in the southern Free State are situated in the dry south-western Free State between Bloemfontein, Petrusburg and Fauresmith (Figure 10.1). Also indicated in Figure 10.1 are 20%, 30% and 40% isolines indicating annual rainfall expressed as a percentage of the annual evaporation (Le Roux 1978).

Concerning geology, most pans in the Free State are on Ecca Series, followed by Beaufort and Stormberg Series (Le Roux 1978). According to

Acocks (1988), the soil on the flats around pans in the western Free State is turfy with little or no rocks present. In his survey on the origin and forming of pans in the western Free State, De Bruiyn (1971) came to the following conclusion: "Of prime importance in the formation of pans is the presence of dolerite basin structures which, due to the resistance of dolerite to weathering, lead to the development of local inward drainage patterns. The inward drainage causes rainwater to accumulate in these basins and dissolved salts are concentrated when the water evaporates. The high concentration of salts causes mechanical weathering of the sediments due to crystallization and thermal expansion, thus producing disaggregated debris for removal by wind or water action. The prevailing low rainfall and high temperatures cause a rapid concentration of salts derived from those originally present in the Dwyka and Ecca sediments. After weathering the debris is removed by wind or water, thus exposing the next layer to weathering and erosion. This is the process that produces the typical flat floors of the pans, parallel to the bedding of the underlying sedimentary rocks."

10.2 STUDY AREA

The study area is located in the dry western parts of the southern Free State where annual rainfall expressed as a percentage of the annual evaporation is half of that in the south-eastern parts. The location of the study area in relation to towns in the southern Free State is shown in Figure 10.1.

Slow-draining streams and waterbeds are scarce owing to the flatness of the study area. The topography comprises a mosaic of flat, slightly undulating and undulating terrain (Land Type Survey Staff, in Press). Isolated hills and ridges occur. A detailed description of the study area was given elsewhere in this dissertation (Chapter 2).

10.3 METHODS

Relevés were compiled in 35 stratified sample plots. Plot sizes were fixed at 25 m^2. In each sample plot, the total floristic composition, using the Braun-Blanquet cover-abundance scale (Mueller-Dombois & Ellenberg 1974) was noted. Environmental information included geological formation, soil type and rockiness of the soil surface.

Two-way indicator species analysis (TWINSPAN) (Hill 1979 b) was applied to the floristic data set in order to derive a first approximation of the vegetation types of the area. Refinement of this classification was done by the application of Braun-Blanquet procedures. The results are presented in a phytosociological table (Table 10.1). The floristic data set was further subjected to an ordination algorithm, Detrended Correspondence Analysis (DECORANA) (Hill 1979 a), to determine vegetation gradients and the relationship with environmental variables. Taxon and author names conform to those of Arnold & De Wet (1993) and water birds were identified from Sinclair (1987).

10.4 RESULTS AND DISCUSSION

The analysis resulted in the recognition of nine plant communities, which can be grouped into three major community types. The hierarchical classification is as follows:

1 *Diplachne fusca* Community in non-saline pans
1.1 *Diplachne fusca-Eragrostis curvula* Sub-community
1.2 *Diplachne fusca* Sub-community

2 *Salsola glabrescens* Community in saline pans
2.1 *Salsola glabrescens* Sub-community
2.2 *Salsola glabrescens-Atriplex nummularia* Sub-community
2.3 *Salsola glabrescens-Suaeda fruticosa* Sub-community
2.4 *Salsola glabrescens-Eragrostis bicolor* Sub-community
2.5 *Salsola glabrescens-Sporobolus tenellus* Sub-community

3 *Sporobolus tenellus-Chenopodium album* Community

DESCRIPTION OF THE COMMUNITIES

1 *Diplachne fusca* Community in non-saline pans

This community is generally found in the central zones of pans and is the first to be submerged after good rains. The landscapes are mostly flat with no rocks visible on the ground surface. The trampling effect and grazing pressure exerted on this community by cattle and sheep is clearly recognizable. The soil is generally moderately to well drained. According to Fuls (1993), the *Diplachne fusca* pan and vlei vegetation in the Wesselsbron-Welkom area is characterized by the predominance of silt and non-swelling kaolinitic clays. This is also the case in the southern Free State.

According to Cowan (1995), the differences in bird communities between the three pan types (reed, sedge and open pans) in the Lake Chrissie area relate to differences in the habitats offered by each pan type. Numerous water birds were spotted within the *Diplachne fusca* Pan Community and include Egyptian Goose (*Alopochen aegyptiacus*), South African Shellduck (*Tadorna cana*), Yellow-billed duck (*Anas undulata*) and Red-billed Teal (*Anas erythrorhyncha*). The presence of these birds conform to that spotted by Geldenhuys (1982) in open *Diplachne* pans in the western Free State.

The rhizomatous swamp grass, *Diplachne fusca* (species group B, Table 10.1), is the only dominant species present. *D. fusca* is also prominent in the pans in the northern Free State described by Fuls (1993). This mat-forming, stoloniferous species appears to be annual, "disappearing" during the dry season or prolonged dry spells, only to re-appear within a week or so after substantial rain (Fuls 1993).

Two distinct sub-communities characterize this community (Table 10.1).

1.1 *Diplachne fusca-Eragrostis curvula* Sub-community

This grassland is generally found on the edges of clay pans where loose sand overlies the clayey soil (duplex soils). The soil is calcareous-clayey with a high base status and generally deeper than 300 mm (Ae land type). Standing water occurs periodically for weeks after good rains.

Although degradation of the vegetation is evident, *Diplachne fusca* (species group B) has a high cover-abundance. Only five species, with *Eragrostis curvula* and *Setaria incrassata* the most abundant, differentiate this sub-community (species group A, Table 10.1). The above-mentioned water birds were all observed in this sub-community.

1.2 *Diplachne fusca* Sub-community

This sub-community is found in the central areas of pans where the soils are generally deep (> 500 mm deep) and clayey. The sandy layer mentioned within the *Diplachne fusca-Eragrostis curvula* Pan Grassland is absent here. Bezuidenhout (1995) described a similar plant community in the Graspan-Holpan section of the Vaalbos National Park, near Kimberley in the Northern Cape. The *Diplachne fusca* Variant, he described, is associated with the poorly drained, moderately deep, clayey (> 25% clay content - A- & B-horizons) soil of the pans. According to Gibbs Russell *et al.* (1990) and Van Oudtshoorn (1991), *D. fusca* is always found near to or in fresh or brackish water. Periodically standing water occurs and the soil is poorly drained. Noteworthy is the exceptionally low species diversity with homogeneous dominance of *Diplachne fusca* (species group B). This sub-community differs from the *Diplachne fusca-Eragrostis curvula* Pan Grassland by the total absence of species from species group A (Table 10.1). The habitat is fairly unstable, owing to seasonal flooding and drying, which, together with the frequent overgrazing of these sites caused the advanced state of degradation of the vegetation present. No water birds were spotted.

2 *Salsola glabrescens* Community in saline pans

The *Salsola glabrescens* Pan Vegetation occurs on relatively poorly drained situations on the fringes of wetter drainage lines and other pan-bottomland situations. The soils of the undulating areas are shallower (< 300 mm deep) and the surface is often covered with calcareous stones.

This community is characterized by the absence of *Diplachne fusca* (species group B) and the strong presence of *Salsola glabrescens* (species group F, Table 10.1).

Six distinct sub-communities are recognizable (Table 10.1).

2.1 *Salsola glabrescens* Sub-community

The *Salsola glabrescens* dry pan vegetation occurs on saline-calcareous soil which is virtually covered with fine gravel. The vegetation is heavily overgrazed and the surface trampled. Road-building operations (road construction) affect most of the vegetation. According to Cowan (1995), over 40% of the pans in the Gauteng (the former PWV region in the central Transvaal) are affected by this practice. According to him pans are frequently seen as "lines of least resistance" by road planners.

The small woody shrublet, *Salsola glabrescens* (species group F), is the only species present. The average height of these shrublets do not exceed 0.3 m. Overgrazing of vegetation frequently occurs and the habitat is infested by termites.

2.2 *Salsola glabrescens-Atriplex nummularia* Sub-community

The *Salsola glabrescens-Atriplex nummularia* Sub-community occurs on flat landscapes on the edges of salt pans with fine gravel and calcareous stones visible on the surface. The vegetation is severely disturbed and standing water occurs in lower-lying areas. These environmental conditions provide a moist environment and only three diagnostic species occur (species group C, Table 10.1). *Atriplex nummularia* and *A. semibaccata* seldom grow higher than 0.3 m.

2.3 *Salsola glabrescens-Suaeda fruticosa* Sub-community

This sub-community is encountered in the lower-lying areas of salt pans (brackish soil). Like the *Salsola glabrescens-Atriplex nummularia* Pan Vegetation, this sub-community is severely disturbed and trampled. Erosion also occurs, but no stones are visible on the surface.

Diagnostic species include those listed in species group D (Table 10.1) with *Suaeda fruticosa, Atriplex erosa* and *Zygophyllum simplex* the most important (Table 10.1).

2.4 *Salsola glabrescens-Sporobolus ioclados* Sub-community

This pan grassland is restricted to seasonally wet, poorly drained situations. The calcareous soils are brackish and often show vertic or melanic properties. Alluvium, silt and gravel can be observed at many localities. The habitat is fairly unstable owing to seasonal flooding and drying. No gravel occurs on the soil surface.

The vegetation is characterized by the absence of species of species groups A-D and the presence of species of species groups E, F and H (Table 10.1). *Eragrostis bicolor, Sporobolus ioclados* (species group E), *Salsola glabrescens* (species group F) and *Sporobolus tenellus* (species group H) characterize this vegetation unit.

2.5 *Salsola glabrescens-Sporobolus tenellus* Sub-community

This grassland is found in severely eroded pans where wet calcareous soil occurs. During the rainy season, this sub-community is seasonally waterlogged. The vegetation is mostly disturbed and moderately over-utilized.

Salsola glabrescens (species group F) and *Sporobolus tenellus* (species group H) dominate the vegetation. This sub-community has virtually the same species composition as the *Salsola glabrescens-Sporobolus ioclados* Sub-community with the absence of *Eragrostis bicolor* (species group E) the only exception (Table 10.1).

3 *Sporobolus tenellus-Chenopodium album* Community

The *Sporobolus tenellus-Chenopodium album* Community is found on the edges of permanently waterlogged pans. The depth of these pans varies from 100 mm to 300 mm. The vegetation of these areas is usually overgrazed and the calcareous-stony soil trampled. The predominant soil type is the vertic Rensburg form.

This community is characterized by the species listed in species group G (Table 10.1) of which *Chenopodium album, Portulaca oleracea* and the small sedge, *Cyperus laevigatus*, are the most conspicuous differentiating species. The dwarf grass species *Sporobolus tenellus* (species group H) is also conspicuous.

ORDINATION

The distribution of all the plant communities along the first and second axes of the ordination is presented in Figure 10.2. The third and fourth axes contribute very little to the environmental interpretation of the communities and are therefore omitted. The vegetation gradient on the first axis is primarily associated with a soil texture gradient. *Diplachne* *fusca* Pan Vegetation to the left occurs on sandy-clayey (duplex) soils with a rockiness of less than 10%. Communities associated with rocky-clayey soils with a rockiness of > 20 % are to the right. Dry and moderately dry plant communities are to the top of the diagram. Plant communities which are more adapted to moist and wet conditions with poorly drained soils are to the bottom of the diagram (axis 2).

In the second ordination (Figure 10.3), the same data set was applied but relevés containing *Diplachne fusca* (indicated by "a" in Figure 10.2) on clayey soil were excluded. This was done because of the big difference between clay pans (indicated by "a in Figure 10.1) and the rest of the pan vegetation (Figure 10.2). The distribution of the plant communities is illustrated along the first and second axes of the ordination. Axis 1 illustrates a moisture gradient with the permanently waterlogged plant communities on poorly drained soils to the right of the diagram. Dry and seasonally waterlogged plant communities on well-drained soils are the left. The soils to the right of the diagram are generally deeper than those to the left. No clear discontinuity is associated with axis 2 of the diagram (Figure 10.3).

DISCUSSION

The eight plant communities identified are not strictly related to specific environmental variables, but are rather the products of combinations of variables such as soil depth, moisture, soil type and clay contents. A clear difference, however, between *Diplachne fusca* pans (clayey soils) and mixed grassland pans on rocky-clayey soils exists (Figures 10.2).

Diplachne fusca, Salsola glabrescens and *Sporobolus tenellus* are the most prominent species associated with pans in the southern Free State.

Much remains to be done concerning the conservation of pans. Management strategies aimed at land in private ownership, as suggested by Geldenhuys (1982), is as important as land acquisition for formal nature reserves. But how does one conserve pans? On the one hand, farmers (because most pans are on their land) and the public in general should be encouraged to regard pans as vital and interesting parts of the ecosystem. On the other hand, "panveld", as it is colloquially called, deserves to be conserved as part of a larger terrestrial-aquatic unit. This latter course has, to an extent, been followed inadvertently in the private conservation areas like Rooipoort near Kimberley in the North Cape. This is also the case on the Defence Force property, De Brug, west of Bloemfontein. Both properties are close to 30 000 hectares in size (Seaman 1987). However, some of the larger, and perhaps a suite of representative, pans should be given formal conservation protection if for no other reason than for their tourism and education potential. These protected pans could also provide baseline information against which status of pans in unprotected areas could be compared. Therefore consideration should be given for including many of the more important pans in the formal nature reserve system, including municipal reserves (Cowan 1995). Long-term resource conservation will only be effective if ecological boundaries are incorporated first and a proper management and conservation strategy be applied to these areas.

This delineation of the plant communities and associated habitats of the pans in the southern Free State should be used as the basis for future management and conservation of these areas.

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CHAPTER 11

Vegetation ecology of the southern Free State

Vegetation classes of the southern Free State

CHAPTER 11

VEGETATION CLASSES OF THE SOUTHERN FREE STATE

11.1 INTRODUCTION

Despite a number of broad classifications of the vegetation of southern Africa (Bolus 1886, 1905; Marloth 1906; Pole-Evans 1936; Acocks 1953, 1988; White 1976, 1983; Werger 1978; Rutherford & Westfall 1986, Low & Rebelo 1996), there is still a shortage of more detailed phytosociological studies of the South African flora (Scheepers 1986).

There were numerous attempts to distinguish vegetation units in South Africa (Werger 1978). Each vegetation map differed from the previous one, as the knowledge on the flora expanded and different classification approaches were developed. The present floristic knowledge has lead to the phytochorological subdivision of the continent (Werger 1978), but there is still the need for more detailed studies on the phytosociology of the South African flora (Scheepers 1986). Since Mentis & Huntley (1982) stated the necessity of research work in the Grassland Biome, a phytosociological research programme on the phytosociology and syntaxonomy of the Biome has been conducted.

The existing broad classifications are inadequate for detailed or regional agricultural and conservational planning and management of the biotic resources. Reclassification and mapping of the vegetation according to applicable scales is a priority (Scheepers 1986) and has been identified as such by the Grassland Research Centre (Department of Agricultural Development).

Subsequently a research programme on the detailed phytosociological synthesis of the vegetation of the Grassland Biome was initiated in 1986 (Scheepers 1986) and several phytosociological studies were launched to describe the vegetation of the Grassland Biome (i.e. Bezuidenhout 1988, 1993; Turner 1989; Kooij 1990 (a, b & c); Du Preez 1991; Matthews 1991;

Breytenbach 1991; Malan 1992; Coetzee 1993; Eckhardt 1993; Fuls 1993 and Myburgh 1993). The vegetation of the southern Free State represents a major part of this biome.

The phytosociological synthesis of the vegetation of the southern Free State forms part of the final objective to compile a comprehensive synecological and syntaxonomical synthesis of the vegetation of the Grassland Biome of South Africa. Several major vegetation classes were identified and these classes should form the basis for future detailed synecological and syntaxonomical studies.

11.2 METHODS

Compatible phytosociological data done by other phytosociologists, were obtained from the entire study area. These included:

* Association analysis of Thaba 'Nchu mountain (Roberts 1966);
* Braun-Blanquet classification of the Botanical Gardens of the Free State (Müller 1970);
* Compatible Braun-Blanquet classifications of the Upper Orange River Valley and the Tussen die Riviere Game Farm (Werger 1973 a & b);
* Vegetation ecology of Naval Hill (Du Preez 1979);
* Phytosociology of the Rolfontein Nature Reserve (Jooste 1980);
* Tree communities in the Bloemfontein area (Rossouw 1983);
* Phytosociology of the Bloemfontein west District (Malan 1992);
* Relevés encountered in the Soetdoring Nature Reserve; and
* New relevés compiled in the southern Free State by the present author.

The association analysis carried out by Roberts (1966) on the Thaba 'Nchu mountain is not comparable to a Braun-Blanquet classification. His data was therefore only used as presence-absence data in the synoptic data of the synthesis. Du Preez (1991) also made use of the presence-absence data of the association analysis association analysis carried out by Scheepers (1975) in the Bethlehem area.

All the above individual classifications resulted in the identification of 394 plant communities, compiled from 2 370 relevés, including more than 700 species (species list is stored in the database of the Main Frame Computer System, University of the Orange Free State). A procedure of successive approximation, including the recently proposed method for large data sets (Bredenkamp & Bezuidenhout 1995), was applied in this study:

Synoptic tables were constructed for each individual phytosociological classification, using the standard constancy classes (Whittaker 1978). In this way each community from each individual phytosociological classification was summarized as a single column (synrelevé) in a synoptic table. Rearrangement of this table by TWINSPAN (Hill 1979 a) and refinement of the resulting synrelevé classification by Braun-Blanquet procedures (Bredenkamp & Bezuidenhout 1995), brought all the related synrelevés (plant communities), identified by different researchers, in different studies from different regions in the southern Free State, effectively together in a single synoptic table (Table 11.1) comprising 394 communities identified in the various investigations over the entire study area.

Sixteen major vegetation types were identified and considered to represent phytosociological classes. Due to the enormous dimensions of the synoptic table (394 synrelevés), each of the 16 vegetation types was further reduced to a single column by using 20% frequency intervals for the species encountered in the various synrelevés within a vegetation type.

Table 11.1 clearly reveals the differential and character species of each class. Differential species are those preferential to a specific community and therefore distinguish that particular community from other floristically related communities, but these species may at the same time, be equally well or even better represented in other communities (Werger 1973 a). The differential species are indicated by shaded columns.

Character species are but a special case of differentiating species. These character species are of great diagnostic importance and can be classified into exclusive, selective and preferential species (Werger 1973 a). The character species, referred to as diagnostic species in text, are restricted to a particular class and are indicated by a single column (Table 11.1).

Species which do not differentiate between the communities are called accompanying species (Werger 1973 a).

An ordination algorithm, DECORANA (Hill 1979 b), was also applied to the synoptic data set to show environmental gradients between the different communities.

Taxa names conform to those of Arnold & De Wet (1993). No syntaxonomic names are attached to these classes pending better research.

11.3 RESULTS AND DISCUSSION

The vegetation of the southern Free State is broadly classified as the *Themeda triandra-Eragrostis lehmanniana* Grassland (Table 11.1). This grassland represents the natural climatic climax over most of the central and western Free State (Bayer 1955, Tainton 1984). The vegetation of the Grassland Biome is physiognomically monolithic and is characterized by strong dominance of hemicryptophytes of the Poaceae. Canopy cover is moisture dependent and decreases with mean annual rainfall (Rutherford & Westfall 1994). According to Rutherford & Westfall (1994) the vegetation of the Nama-Karoo Biome is dominated by chamaephytes and hemicryptophytes and can be described as a grassy, dwarf shrubland (Edwards 1983). The dominance of graminoids is consistent throughout, except for some rocky outcrops which are generally dominated by woody species. Grassland and karroid vegetation dominate the biggest part of the study area, with disturbed/overgrazed areas also prominent. The Grassland-Nama-Karoo interface (ecotone) is characterized by grassland which is invaded by karroid dwarf shrubland. According to Vorster & Roux (1983) succession of plant composition in the Nama-Karoo-Biome is usually taken to start after disturbance by overgrazing. The usual progression, given a significant reduction in grazing pressure and a suitable distribution of rainfall

(Vorster & Roux 1983), is a steady increase in hemicryptophyte cover and a more variable decrease in chamaephyte cover (Rutherford & Westfall 1994).

Three grassland types are distinguishable in the southern Free State: Dry Sandy Highveld Grassland of the plains in the dry western parts (Bredenkamp & Van Rooyen 1996 a), Moist Cool Highveld Grassland in the central-eastern part of the highveld in the Free State (Bredenkamp & Van Rooyen 1996 b) and Moist Cold Highveld Grassland (Bredenkamp *et al.* 1996).

The Dry Sandy Highveld Grassland occurs where the summer rainfall is erratic with an average of 450 mm per annum. Temperatures vary between -11 °C and 41 °C with an average of 18 °C. The soils are deep, red to yellow, apedal, aeolian sand, often covering limestone. This is a grassland which merges with the bordering Kalahari Thornveld to the west. A few *Acacia karroo* trees occur only occasionally along watercourses. West of Bloemfontein, affinity to Karoo vegetation can be seen in plant communities dominated by dwarf shrubs, including *Chrysocoma ciliata, Felicia muricata, Helichrysum pentzioides, Nenax microphylla, Pentzia incana, Rhus ciliata, Salsola kali, Walafrida densiflora* and *W. saxatilis.* The presence of Karoo elements in the western parts probably represent outliers of Karoo vegetation, but this should not necessary be considered as encroachment (Bredenkamp & Van Rooyen 1996 a).

The Moist Cool Highveld Grassland, generally referred to as *Cymbopogon-Themeda* Veld (Acocks 1988) occurs in areas where the rainfall varies from 600-700 mm per annum, occurring in summer. Temperatures vary from -11 °C to 38 °C, with an average of 17°C. Deep, red (Hutton) and yellow (Clovelly) soils predominate. Grazing here is important, but overgrazing converts this grassland to a Karoo type. The presence of Karoo elements in degraded sites is often seen as signs of Karoo encroachment into the Grassland Biome. In pristine condition *Themeda triandra* dominates entirely (Bredenkamp & Van Rooyen 1996 b). Other grasses often encountered include *Triraphis andropogonoides, Eragrostis superba, Brachiaria serrata, Elionurus muticus, Heteropogon contortus, Cymbopogon plurinodis* and *Setaria sphacelata*.

This grassland was studied by numerous phytosociologists like Bredenkamp *et al.* (1989), Kooij *et al.* (1992), Fuls *et al.* (1993), Eckhardt *et al.* (1993 a) and Coetzee *et al.* (1994).

The Moist Cold Highveld Grassland of the southern Free State is restricted to the Zastron Area. The rainfall ranges from 700-800 mm per annum, occurring mainly in summer. Temperatures vary between -13 °C and 35 °C, with an average of 14 °C. The soils are generally deep (deeper than 300 mm) yellow and grey sandy-loam soils derived from sandstones and shales of the Beaufort Group. This is a moderately dense grassland dominated by *Cymbopogon plurinodis, Elionurus muticus, Eragrostis curvula, Setaria sphacelata* and *Themeda triandra*. Typical grasses of this grassland include *Andropogon appendiculatus, Aristida junciformis, Eragrostis capensis, E. plana, Helictotrichon turgidulum, Microchloa caffra* and *Tristachya leucothrix* (Bredenkamp *et al.* 1996).

This grassland was surveyed by phytosociologists like Lubke *et al.* (1988), Du Preez (1991), Du Preez & Bredenkamp (1991), Eckhardt *et al.* (1993 a) and Fuls (1993).

The most prominent grass species encountered throughout the southern Free State are *Aristida congesta, A. diffusa, Digitaria eriantha, Eragrostis curvula, E. lehmanniana, E. obtusa, Eustachys paspaloides, Themeda triandra* and *Tragus koelerioides*. Also present but less prominent are *Cymbopogon plurinodis, Eragrostis chloromelas, E. nindensis, E. superba, Heteropogon contortus* and *Sporobolus fimbriatus* (Table 11.1).

Among the karroid vegetation *Berkheya onopordifolia, B. pinnatifida, Chrysocoma ciliata, Felicia muricata, Hertia pallens, Melolobium candicans, Protasparagus laricinus* and *Walafrida saxatilis* are the most prominent (Table 11.1).

Trees and shrubs occur widespread but scattered in the southern Free State. The most important are *Acacia karroo, A. mellifera, Boscia albitrunca, Buddleja saligna, B. salviifolia, Diospyros austro-africana, D.*

lycioides, Ehretia rigida, Euclea crispa subsp. *ovata, Olea europaea, Rhus burchellii, R. lancea, Rhigozum obovatum, R. trichotomum* and *Ziziphus mucronata* (Table 11.1).

CLASSIFICATION

The classification resulted in the recognition of 16 phytosociological classes (Table 11.1):

Class 1: *Leucosidea sericea-Stoebe plumosa* Mixed Afro-montane fynbos vegetation of the eastern mountains
Class 2: *Rhus erosa* shrubland of the rocky outcrops of the dry south-western Free State
2.1: *Rhus erosa-Aloe ferox* transitional shrubland between the Afro-montane fynbos vegetation and the shrubland communities of the extreme dry western Free State shrubland
2.2: *Euclea crispa-Buddleja saligna* woodland of the dry south-western Free State
2.3: *Argyrolobium lanceolatum-Anacampseros lanceolata* shrubland of the False Upper Karoo
3: *Eragrostis lehmanniana-Chrysocoma ciliata* karroid vegetation
3.1: *Rosenia humilis-Duthiastrum linifolium* dwarf shrubland
3.2: *Hermannia erodioides-Syncarpha argyropsis* dwarf shrubland of the Rolfontein Nature Reserve
Class 4: *Phaeoptilum spinosum-Zygophyllum gilfillanii* shrub and dwarf shrub communities of the rocky soils of the western Upper Orange River Valley
Class 5: *Acacia karroo* riparian thicket
Class 6: *Acacia mellifera-Tarchonanthus camphoratus* shrubland of the rocky outcrops
6.1: *Acacia tortilis-Acacia hebeclada* shrubland of the low-lying rocky outcrops
6.2: *Phyllanthus parvulus-Abutilon pycnodon* shrubland of the higher lying areas
Class 7: *Aristida bipartita-Lactuca serriola* moist grassland of Thaba 'Nchu

Class 8: *Eragrostis plana-Cymbopogon dieterlenii* moist grasslands of the eastern plains
Class 9: *Themeda triandra-Cymbopogon plurinodis* grasslands of the western plains.
Class 10: *Hertia pallens-Prosopis velutina* karroid vegetation of the dry western Free State
Class 11: *Oropetium capense-Anacampseros filamentosa* communities on very shallow soils on dolerite outcrops
Class 12: *Phragmites australis-Salix babylonica* Riparian vegetation
Class 13: *Mariscus congestus-Persicaria serrulata* Riparian vegetation
Class 14: *Juncus kraussii-Phragmites mauritianus* wetland and pan vegetation
Class 15: *Diplachne fusca-Setaria incrassata* Pan vegetation
Class 16: *Fingerhuthia africana-Helichrysum pentzioides* pan grassland

DESCRIPTION OF THE CLASSES

CLASS 1: *LEUCOSIDEA SERICEA-STOEBE PLUMOSA* MIXED AFRO-MONTANE FYNBOS VEGETATION OF THE EASTERN MOUNTAINS

The *Leucosidea sericea-Stoebe plumosa* Mixed Afro-montane fynbos vegetation is restricted to the hills and ridges of the Zastron area in the south-eastern part of the study area. Twelve plant communities encountered in the south-eastern Free State were included in this class.

This Mixed Afro-montane fynbos vegetation lies in the Moist Cold Highveld Grassland (Vegetation Type 40, Bredenkamp *et al.* 1996). The rainfall is relatively high and varies between 600 and 800 mm per annum.

Geologically the area is characterized by Molteno and Elliot Formations. The uppermost formation, namely the Clarens Formation, forms a prominent cliff on the northern side of Aasvoëlberg Mountain. The endangered Cape Vulture (*Gyps coprotheres*) used to breed here. The Molteno Formation, the first of the Stormberg Group, lies on top of the Beaufort Group. The Elliot Formation follows conformably on the Molteno Formation (Dingle *et al.*

1983). The topography of the area consists mainly of continuous hills and mountains with moderate and high relief, allowing only stock farming and small-scale crop production.

Generally the soils in the Zastron area are referred to as "Podsolic" (pH < 7) soils. These soils are generally deeper than "solonetic" [pH > 7 and contain a high salt (especially Sodium compounds) content] soils and also comprises well-developed horizons. Donga and surface erosion are a common phenomenon of these soils (Potgieter *et al.* 1995).

No reconcilable phytosociological classification of this Mixed Afro-montane fynbos class exists in the southern Free State. Roberts (1966) mentions Afro-montane fynbos communities from Thaba 'Nchu mountain, but his classification is derived from an association analysis, which is not comparable to a Braun-Blanquet classification.

This class, however, is in accordance with the *Passerina montana* Afro-montane fynbos communities of the eastern mountains of the Korannaberg, Thaba 'Nchu mountain and the Drakensberg range described by Du Preez (1991). The altitude varies between 1 800 - 2 800 m.

The *Leucosidea sericea-Stoebe plumosa* Mixed Afro-montane fynbos communities are characterized by species groups 1 & 2 (Table 11.1). The most important differentiating species with constancies higher than 40% are *Leucosidea sericea, Cussonia paniculata, Helichrysum rugulosum* and the exotic rose *Rosa eglanteria*. The diagnostic species are listed in species group 2 (Table 11.1). Species with a constancy of higher than 40% include *Euclea crispa* subsp. *crispa*, *Passerina montana* and *Stoebe plumosa*. Other frequently occurring species include *Rhus erosa, Olea europaea* subsp. *africana*, *Diospyros austro-africana*, the small ferns, *Cheilanthes eckloniana* and *Pellaea calomelanos, Osyris lanceolata* (species group 14), *Oxalis corniculata* (species group 32), *Felicia filifolia* (species group 55), the grasses *Heteropogon contortus, Aristida diffusa* (species group 61), *Themeda triandra*, the trees *Rhus burchellii* (species group 65) and *Diospyros lycioides* (species group 71) and the shrub *Protasparagus laricinus* (species group 76).

CLASS 2: *RHUS EROSA* SHRUBLAND OF THE ROCKY OUTCROPS OF THE DRY SOUTH-WESTERN FREE STATE

This shrubland includes the shrubland communities of the rocky outcrops of the relatively dry hills, ridges and slopes to the west of the 500 mm rainfall isohyet. Also included is the transitional zone between Afro-montane fynbos vegetation previously mentioned and the usually much drier hills and ridges in the extreme dry western Free State. The *Rhus erosa* shrubland of the western Free State is in accordance with the multistratal shrubby *Rhus erosa* shrubland described by Du Preez (1991).

The typical habitat consists of dry hills and ridges which are primarily of dolerite and are underlain by Beaufort and Ecca Formations.

This shrubland includes:

* the syntaxa described by Werger (1973 a) under the *Rhoetea erosae*;
* the *Rhus erosa-Melinis repens* communities, *Rhus erosa - Stachys burchelliana* Community and the *Olea europaea-Maytenus heterophylla* communities of the Tussen die Riviere Game Reserve (Werger 1973 b);
* syntaxa described by Rossouw (1983) from the Bloemfontein area under the *Olea africana* Community;
* communities derived from relevés of the Bloemfontein area (Malan 1992);
* Soetdoring Nature Reserve; and
* communities derived from relevés encountered in the southern Free State by the present author.

The most important species associated with this class are listed in species groups 14, 47, 54, 60, 61, 64, 65, 71, 75, 76, 77 and 79 of Table 11.1. Among the woody species *Rhus erosa, Olea europaea, Celtis africana, Diospyros austro-africana, Rhigozum obovatum, Maytenus polyacantha, Rhamnus prinoides, Osyris lanceolata, Grewia occidentalis, Rhus pyroides* subsp. *gracilis* (species group 14), *Ziziphus mucronata, Ehretia rigida* (species group 54), *Felicia filifolia, F. muricata, Rhus ciliata* (species group 55), *Rhus burchellii, R. lancea* (species group 65), *Diospyros lycioides* (species group 71), *Chrysocoma ciliata, Protasparagus laricinus* (species group 76), *P. suaveolens, Walafrida saxatilis* (species group 77) are the most important (Table 11.1).

Among the grasses *Cymbopogon excavatus* (species group 14), *C. plurinodis* (species group 47), *Enneapogon scoparius* (species group 55), *Heteropogon contortus, Aristida congests, A. diffusa* (species group 61), *Themeda triandra* (species group 65), *Hyparrhenia hirta* (species group 71), *Eragrostis obtusa* (species group 76), *Eragrostis lehmanniana* (species group 77) and *E. curvula* (species group 80) are abundant (Table 11.1).

The only abundant ferns include *Cheilanthes eckloniana* and *Pellaea calomelanos* (species group 14).

This class divides into three different vegetation units (Table 11.1).

2.1: *RHUS EROSA-ALOE FEROX* TRANSITIONAL SHRUBLAND BETWEEN THE AFRO-MONTANE FYNBOS VEGETATION AND THE SHRUBLAND COMMUNITIES OF THE EXTREME DRY WESTERN FREE STATE SHRUBLAND

This vegetation unit represents the transitional shrubland communities between the Afro-montane fynbos vegetation and the shrubland communities of the extreme dry western Free State. This vegetation unit consists of ten communities which were encountered near Mayaputi bridge south of Zastron. Deep Molteno sandstone slopes, nearly always exceeding 15° occur. Southerly and south-easterly facing slopes are the most prominent habitats. Werger (1973 a), however, found the *Rhoo-Aloetum ferocis* mainly on Molteno sandstone and occasionally on Red Beds on northerly-facing slopes. Werger (1973 a) refers to this vegetation as the *Grewio-Rhoetalia erosae*.

Aloe ferox (species group 3), commonly between 1 and 4 m high, finds its furthest inland distribution in this area (Werger 1973 a) and serves as the most important differentiating species. Woody species with constancies higher than 40% include *Euclea crispa* subsp. *ovata* (species group 4), *Rhus erosa, Olea europaea, Celtis africana, Diospyros austro-africana, Rhigozum obovatum, Rhamnus prinoides, Grewia occidentalis* (species group 14), *Rhus burchellii, R. lancea* (species group 65), *Diospyros lycioides* (species group 71), *Chrysocoma ciliata* (species group 76), *Protasparagus suaveolens, Walafrida saxatilis* (species group 77).

The most important grasses are *Heteropogon contortus* (species group 61), *Themeda triandra* (species group 65) and *Eragrostis curvula* (species group 80).

2.2: *EUCLEA CRISPA-BUDDLEJA SALIGNA* WOODLAND OF THE DRY SOUTH-WESTERN FREE STATE

The typical habitat consists of relatively dry hills and ridges and slopes to the west of the 500 mm rainfall isohyet.

93 Communities were included in this vegetation unit and are:

* the syntaxa described by Rossouw (1983) from the Bloemfontein area under the *Olea africana* Community;
* communities derived from relevés of the Bloemfontein area (Malan 1992);
* relevés encountered in the Soetdoring Nature Reserve; and
* communities derived from relevés encountered in the southern Free State.

The diagnostic species restricted to this vegetation unit are listed in species group 5 and include *Kleinia longiflora, Sisymbrium capense, S. thellungii* and *Trachyandra asperata* (Table 11.1). Woody species with constancies of higher than 40% are *Euclea crispa* subsp. *crispa, Buddleja saligna* (species group 4), *Rhus erosa, Olea europaea, Diospyros austro-africana* (species group 14), *Rhus ciliata, Felicia filifolia* (species group 55), *Rhus burchellii* (species group 65), *Chrysocoma ciliata* (species group 76) and *Protasparagus suaveolens* (species group 77).

Important grasses include *Digitaria eriantha* (species group 59), *Heteropogon contortus, Aristida congesta, A. diffusa* (species group 61), *Themeda triandra* (species group 65) and *Eragrostis lehmanniana* (species group 77).

2.3: *ARGYROLOBIUM LANCEOLATUM-ANACAMPSEROS LANCEOLATA* SHRUBLAND OF THE FALSE UPPER KAROO

The typical habitat of this vegetation unit is steep hillsides. Slopes generally vary between 15° and 40°, where the bedrock consists of dolerite. Geologically the area is underlain by the Beaufort Series, interrupted by dolerite layers. 31 Communities were included in this vegetation unit and are:

* communities derived from the association analysis of the vegetation of Thaba 'Nchu Mountain (Roberts 1966);
* communities described by Werger (1973 a) under the *Grewio-Rhoetalia erosae*;
* communities described under the *Pentzietea incanae* (Werger 1973 a);
* communities described under the *Rhoetalia ciliato-erosae* (Werger 1973 a);
* communities from the Rolfontein Nature Reserve (Jooste 1980); and
* communities encountered in the Soetdoring Nature Reserve.

The differentiating species of this vegetation unit are listed in species group 8 (Table 11.1). Species with higher than 40% constancy are *Argyrolobium lanceolatum, Lotononis laxa, Brachiaria serrata, Hermannia linearifolia, Phyllanthus maderaspatensis, Helichrysum lucilioides* and *Sutera halimifolia* (species group 8, Table 11.1).

The diagnostic species are listed in species group 9 (Table 11.1). *Anacampseros lanceolata* and *Pelargonium aridum* are the most important (Table 11.1).

Numerous woody species occur. A few conspicuous (constancies higher than 60 %) species are *Euclea crispa* subsp. *ovata* (species group 4), *Hermannia cuneifolia* (species group 10), *Rhus erosa, Olea europaea, Diospyros austro-africana* (species group 14), *Helichrysum dregeanum, Solanum supinum, Plexipus pinnatifidus, Helichrysum zeyheri, Lightfootia albens* (species group 19), *Melolobium microphyllum, Pegolettia retrofracta* (species group 26), *Tarchonanthus camphoratus* (species group 38), *Gazania krebsiana, Ehretia rigida* (species group 53), *Felicia muricata, Rhus ciliata* (species group 55), *Rhus burchellii* (species group 65), *Diospyros lycioides* (species group 71), the Karoo encroacher *Chrysocoma ciliata* (species group 76), *Protasparagus suaveolens, Walafrida saxatilis* (species group 77) and *Pentzia globosa* (species group 83).

Some prominent grasses include *Sporobolus fimbriatus, Enneapogon scoparius* (species group 55), *Tragus koelerioides, Digitaria eriantha* (species group 59), *Eustachys paspaloides* (species group 60), *Heteropogon contortus, Aristida congesta, A. diffusa* (species group 61), *Themeda triandra* (species group 65), *Eragrostis lehmanniana* (species group 77) and *Eragrostis curvula* (species group 80).

A few ferns occur and include *Cheilanthes hirta* (species group 11), *C. eckloniana* and *Pellaea calomelanos* (species group 14).

CLASS 3: *ERAGROSTIS LEHMANNIANA-CHRYSOCOMA CILIATA* KARROID VEGETATION

The *Eragrostis lehmanniana-Chrysocoma ciliata* karroid vegetation includes:

* Communities derived from the Soetdoring Nature Reserve and adjacent areas;
* the *Hermannio coccocarpae-Nestleretum confertae* (Werger 1973 a) along the Upper Orange River Valley;
* *Rhoetalia ciliato-erosae* (Werger 1973 a) along the Upper Orange River Valley; and

* plant communities from the Rolfontein Nature Reserve (Jooste 1980).

The typical habitat consists of koppies and ridges in the Soetdoring Nature Reserve and in the wide stretch of land from Aliwal North to Petrusville in the Upper Orange River Valley (Werger 1973 a). The slopes are gentle and varies between 0° and 9°. It is also found on sites that were ploughed several years ago and had been left unused since. Badly eroded areas are common and are recovering slowly. According to Werger (1973 a), this vegetation unit is usually poor in species, and *Eragrostis lehmanniana* scores constantly high cover values. This vegetation type is transitional between shrubland and grassland and usually occurs on shallow lithosols.

The vegetation includes 26 karroid shrubby communities occurring on sloping terrains of the hills. Exclusive diagnostic species are absent from this vegetation unit which is dominated by graminoids.

Prominent woody and semi-woody species include *Rosenia humilis* (species group 15), *Hermannia erodioides* (species group 21), *Gnidia polycephala, Helichrysum asperum, Melolobium microphyllum* (species group 26), *Gazania krebsiana* (species group 54), *Felicia muricata* (species group 55), *Hermannia coccocarpa, Geigeria filifolia* (species group 60), *Salsola glabrescens* (species group 75), *Chrysocoma ciliata* (species group 76), *Protasparagus suaveolens* (species group 77), *Pentzia globosa* and *Thesium hystrix* (species group 83).

Important grasses include *Enneapogon desvauxii* (species group 26), *Eragrostis chloromelas, Cynodon dactylon* (species group 41), *Tragus koelerioides, Digitaria eriantha* (species group 59), *Heteropogon contortus, Aristida congesta* (species group 61), *Themeda triandra* (species group 65), *Eragrostis obtusa* (species group 76), *Eragrostis curvula* (species group 80), *Fingerhuthia africana* (species group 83).

The data suggest that the vegetation is heterogeneous and that a comprehensive revision of this class is necessary. The ecotone between the

Grassland and Nama-Karoo Biomes contains many of the mentioned species and need to be studied in detail.

This class divides into two distinct orders (Table 11.1)

3.1: *ROSENIA HUMILIS-DUTHIASTRUM LINIFOLIUM* DWARF SHRUBLAND

The *Rosenia humilis-Duthiastrum linifolium* dwarf shrubland consists of 17 plant communities and includes:

* communities derived from the Soetdoring Nature Reserve and adjacent areas;
* the *Hermannio coccocarpae-Nestleretum confertae* (Werger 1973 a) along the Upper Orange River Valley; and
* *Rhoetalia ciliato-erosae* (Werger 1973 a) along the Upper Orange River Valley.

The typical habitat consists of hills and ridges of the Soetdoring Nature Reserve and the stretch of land from Aliwal North to Petrusville in the Upper Orange River Valley (Werger 1973 a). Here the grasslands degrade due to anthropogenic influences, particularly overgrazing by sheep, resulting in the floristically poor *Hermannio coccocarpae-Nestleretum confertae* (Werger 1973 a), typical of the False Upper Karoo. The soils are sandy loams, usually more than 1 m deep and of the solonetic type (Werger 1973 a).

This vegetation unit is characterized by the species listed in species group 15 and 16 (Table 11.1).

Among the differentiating species, listed in species group 15, *Rosenia humilis, Conyza bonariensis,* the reed *Cyperus usitatus* and the grass *Sporobolus ludwigii* are the most abundant (Table 11.1).

Species listed in species group 16 are exclusive to this vegetation order and are *Duthiastrum linifolium, Menodora africana, Kyllinga alata, Brachiaria* *serrata, Gethyllis undulata, Moraea polystachya* and *Oenothera tetraptera* (Table 11.1).

Strong affinities between this vegetation unit and the *Argyrolobium lanceolatum-Anacampseros lanceolata* Order of the *Rhus erosa-Olea europaea* Class exist and are clearly illustrated in species groups 17, 18 and 19 (Table 11.1).

Other prominent woody and semi-woody species included in this vegetation order are *Solanum supinum* (species group 19), *Melolobium microphyllum* (species group 26), *Indigofera alternans* (species group 27), *Hermannia comosa* (species group 47), *Pterothrix spinescens* (species group 53), *Gazania krebsiana* (species group 54), *Felicia muricata* (species group 55), *Hermannia coccocarpa, Geigeria filifolia, Nenax microphylla* (species group 60), *Nidorella resedifolia* (species group 69) and *Chrysocoma ciliata* (species group 76).

The most important grasses are *Sporobolus ludwigii, Digitaria argyrograpta, Eriochloa parvispiculata* (species group 15), *Enneapogon desvauxii* (species group 26), *Eragrostis chloromelas* (species group 41), *Cymbopogon plurinodis* (species group 47), *Eragrostis superba, Enneapogon scoparius* (species group 55), *Oropetium capense* (species group 56), *Tragus koelerioides, Digitaria eriantha* (species group 59), *Heteropogon contortus, Aristida congesta, A. diffusa* (species group 61), *Themeda triandra* (species group 65), *Eragrostis obtusa* (species group 76); *E. lehmanniana* (species group 77), *Eragrostis curvula* (species group 80) and *Panicum coloratum* (species group 84).

The presence and abundance of *Themeda triandra* (species group 65) and *Eragrostis curvula* (species group 80) in this association on sites that have been withdrawn from grazing for some time, support the suggestion of Werger (1973 a) that these species are relicts of a former grassland vegetation in these areas (Du Preez 1991).

3.2: *HERMANNIA ERODIOIDES-SYNCARPHA ARGYROPSIS* DWARF SHRUBLAND OF THE ROLFONTEIN NATURE RESERVE

The *Hermannia erodioides-Syncarpha argyropsis* dwarf shrubland of the Rolfontein Nature Reserve near the Vanderkloof Dam includes nine communities and is situated on the pediplains between the mesas (Jooste 1980).

Species from species group 21 differentiate this order. *Hermannia erodioides, Salvia disermas, Salsola calluna* and the grass *Stipagrostis uniplumis* are the most important (Table 11.1). This vegetation unit is distinguished from all other vegetation units by the presence of *Syncarpha argyropsis* (species group 22). Affinities with the *Argyrolobium lanceolatum-Anacampseros lanceolata* Order are illustrated by the presence of species from species group 21 (Table 11.1).

Woody and semi-woody species often encountered are *Gnidia polycephala, Helichrysum asperum* (species group 26), *Hermannia vestita* (species group 55), *H. coccocarpa* (species group 60), *Rhus burchellii* (species group 65), *Lycium hirsutum* (species group 70), *Chrysocoma ciliata* (species group 76), *Protasparagus suaveolens* (species group 77) and *Pentzia globosa* (species group 83).

Important grasses frequently encountered include *Enneapogon desvauxii* (species group 26), *Cynodon dactylon* (species group 41), *Tragus koelerioides* (species group 59), *Heteropogon contortus, Aristida congesta* (species group 61), *Themeda triandra* (species group 65), *Eragrostis obtusa* (species group 76), *E. lehmanniana* (species group 77), *E. curvula, Chloris virgata* (species group 80) and *Fingerhuthia africana* (species group 83).

A comprehensive formal syntaxonomical review of these syntaxa is needed.

CLASS 4: *PHAEOPTILUM SPINOSUM-ZYGOPHYLLUM GILFILLANII* SHRUB AND DWARF SHRUB COMMUNITIES OF THE ROCKY SOILS OF THE WESTERN UPPER ORANGE RIVER VALLEY

This shrubland includes:

* The syntaxa described by Werger (1973 a) under the class *Pentzietea incanae* and the order *Stipagrostion*.

The typical habitat consists of a flat monotonous landscape, west of Petrusville in the western Upper Orange River Valley. The substrata are formed by Ecca and Dwyka deposits and, in the westernmost section of the Upper Orange River, by Ventersdorp lavas. Soils are usually lithosols or of a sandy loam type except in some localities north of the river and in lees south of the river where thick deposits of Kalahari sand have accumulated. These habitats characteristically bear a vegetation dominated by *Stipagrostis* spp. Because of severe overgrazing for just over a century the dominance of *Stipagrostis* spp. have locally given way to an abundant growth of *Rhigozum trichotomum* in particular (Werger 1973 a).

Species listed in species groups 23 and 24 differentiate this class (Table 11.1). *Phaeoptilum spinosum, Dicoma macrocephala, Plinthus karooicus, Schizoglossum capitatum,* the grass *Eragrostis porosa, Pentzia calcarea, Peliostomum leucorrhizum, Aptosimum spinescens, Plinthus cryptocarpus, Hermannia spinosa* and *Monechma incanum* (species group 23) are the most important among the differentiating species. Species exclusive to this class are listed in species group 24 and are *Nolletia arenosa, Zygophyllum gilfillanii, Aptosimum albomarginatum, Euphorbia aequoris, Coelachyrum yemenicum, Hoodia gordonii* and *Rhynchopsidium pumilum.*

Important dicotyledons frequently encountered include *Gnidia polycephala, Aptosimum marlothii, Lessertia pauciflora, Kyphocarpa angustifolia, Eriocephalus pubescens, Polygala leptophylla* (species group 26), *Indigofera alternans* (species group 27), the thorn tree *Acacia mellifera* (species group 38), *Gazania krebsiana* (species group 54), *Eberlanzia spinosa* (species group 56), *Geigeria filifolia* (species group 60), *Salsola* *glabrescens* (species group 75), *Chrysocoma ciliata, Protasparagus laricinus* (species group 76), *P. suaveolens* (species group 77), *Lycium pilifolium* (species group 81), *Eriocephalus spinescens* (species group 82), *Barleria rigida, Pentzia incana, Thesium hystrix* and *Rhigozum trichotomum* (species group 83).

Important grasses are *Enneapogon desvauxii, Aristida adscensionis* (species group 26), *Tragus koelerioides* (species group 59), *Aristida congesta* (species group 61), *Tragus berteronianus, Eragrostis obtusa* (species group 76), *E. lehmanniana* (species group 77), *Fingerhuthia africana, Stipagrostis ciliata* and *Stipagrostis obtusa* (species group 83, Table 11.1).

The data suggest that the vegetation is heterogeneous and that a comprehensive revision of this class is necessary.

CLASS 5: *ACACIA KARROO - HEBENSTRETIA INTEGRIFOLIA* SHRUBLAND OF THE RIVER BANKS AND FLOODPLAINS

Ten Plant communities included in this class are the following:

* *Diospyrion lycioidis* (Werger 1973 a) along the entire Upper Orange River;
* *Acacia karroo-Celtis africana* Community described by Werger (1973 b) from the Tussen die Riviere Game Farm;
* *Salix mucronata* Community from the islands in the Modder River (Rossouw 1983); and
* *Acacia karroo* Communities from the banks of the Modder River, along dry rivulets, on flat plains and floodslopes and on mechanically disturbed, overgrazed and trampled areas in the Bloemfontein area (Rossouw 1983).

The habitat conditions associated with this vegetation unit are the same as in the *Acacia karroo* riparian thicket, described by Du Preez (1991). According to Werger (1973 a) true vascular waterplant communities are virtually absent from the Orange River, probably due to the high silt load of the water, although the large, sudden floods of this river might also be an important factor in this respect (Butcher 1933, Edwards 1969). The special adaptation of these vascular waterplants to their habitat, which is subject to flooding, silting and alternating dry and wet conditions, is discussed by Ambasht (1968) in a paper on a floristically similar community on the banks of the Ganges.

This class is characterized by species groups 28 and 29 (Table 11.1).

The most important differentiating species are the grasses *Melica decumbens, Setaria verticillata, Bromus catharticus, Lepidium africanum* and *Urochloa panicoides* (species group 28). Differentiating woody and semi-woody species are *Rhus pyroides* subsp. *pyroides, Protasparagus cooperi* (species group 28).

Other differentiating species include *Antizoma angustifolia, Bidens bipinnata, Pentarrhinum insipidum, Solanum retroflexum, Sonchus oleraceus, Delosperma cooperi, Silene undulata, Opuntia vulgaris, Rubia petiolaris, Protasparagus setaceus* and the small forb *Alternanthera pungens* (species group 28).

The diagnostic species exclusive to this class are the species listed in species group 29 and include *Chenopodium murale, Hebenstretia integrifolia, Rubia horrida* and *Verbena officinalis* (Table 11.1).

Other woody and semi-woody species of importance are *Ziziphus mucronata* (species group 54), *Felicia muricata* (species group 55), *Acacia karroo* (species group 64), *Atriplex semibaccata* (species group 69), *Lycium hirsutum* (species group 70), *Diospyros lycioides* (species group 71), *Protasparagus laricinus* (species group 76), *P. suaveolens* (species group 77), *Lycium cinereum* and the karroid *Pentzia globosa* (species group 83).

In the lower stratum *Sporobolus fimbriatus* (species group 55) and *Eragrostis curvula* (species group 80) tend to dominate (Table 11.1).

Similar *Acacia karroo* communities, representative of this class, have been described outside the study area, especially in the Bankenveld (Acocks

1988) and the western Transvaal *Cymbopogon-Themeda* Veld (Acocks 1988). Examples are communities described by Bredenkamp *et al.* (1989) from the Potchefstroom area, Bredenkamp & Bezuidenhout (1990) from the Faan Meintjes Nature Reserve, Bezuidenhout & Bredenkamp (1990) from the western Transvaal dolomitic area, Du Preez & Venter (1990) from the Vredefort Dome area and Kooij *et al.* (1990 a, b, c) from the north-western Free State.

CLASS 6: *ACACIA MELLIFERA-TARCHONANTHUS CAMPHORATUS* SHRUBLAND OF THE ROCKY OUTCROPS

This woodland includes:

* *Acacia* communities described by Malan (1992);
* *Acacia karroo* Community described by Rossouw (1983);
* communities derived from relevés in the Bloemfontein area and the southern Free State; and
* communities described by Jooste (1980).

The typical habitat consists of relatively dry hills, ridges and slopes, mainly west of the 500-600 mm per annum rainfall interval. Communities described by Jooste (1980) are associated with rocky habitat in which 60% of the surface is covered with roundish and sub-angular stones of between 0.3 and 0.7 m in diameter while the vegetation in the Jacobsdal area includes multistratal shrubby communities on Kalahari sand.

Conspicuous woody species associated with this class are *Acacia tortilis* (species group 33), *A. mellifera*, *Tarchonanthus camphoratus* (species group 38), *Ehretia rigida* (species group 54), the Karoo encroacher *Chrysocoma ciliata* (species group 76), *Protasparagus suaveolens* (species group 77) and the karroid shrublet *Pentzia globosa* (species group 83).

Prominent grasses include *Heteropogon contortus*, *Aristida congesta*, *A. diffusa* (species group 61), *Themeda triandra* (species group 65), *Eragrostis curvula* (species group 80) and *Fingerhuthia africana* (species group 83).

The *Acacia mellifera-Tarchonanthus camphoratus* shrubland of the rocky outcrops divides into two distinct vegetation units (Table 11.1).

6.1: *ACACIA TORTILIS-ACACIA HEBECLADA* SHRUBLAND OF THE LOW-LYING ROCKY OUTCROPS

This thorny shrubland order is primarily associated with the relatively low-lying woodland vegetation at the footslopes and protected areas of the Rolfontein Nature Reserve near the Vanderkloof Dam. Twenty-one communities were included and are:

* *Acacia* communities in the Rolfontein Nature Reserve; and
* Additional relevés encountered in the region between the Gariep and Vanderkloof Dams by the present author.

This area nearly always consists of dolerite slopes, sometimes interrupted by layers of Beaufort or Ecca sandstones, mudstones or shales covered by a shallow lithosol, which contain a large amount of gravel (Werger 1973 a). Surface rocks are predominantly doleritic.

The differentiating species of this thorny shrubland are listed in species group 33. *Acacia tortilis* is the only dominant species. Exclusive to this vegetation unit are the species listed in species group 34. *Acacia hebeclada, Heliophila carnosa* and *Hermannia modesta* are unique to this order (Table 11.1). Other frequently occurring species include the thorn tree *Acacia mellifera, Tarchonanthus camphoratus* (species group 38), the shrub *Ehretia rigida* (species group 54), the Karoo encroacher *Chrysocoma ciliata* (species group 76), *Protasparagus suaveolens* (species group 77), and karroid dwarf shrub *Pentzia globosa* (species group 83, Table 11.1).

Important grasses include *Cenchrus ciliaris* (species group 38), *Enneapogon scoparius* (species group 55), *Heteropogon contortus, Aristida diffusa* (species group 61), *Eragrostis curvula* (species group 80) and *Fingerhuthia africana* (species group 83).

6.2: *PHYLLANTHUS PARVULUS-ABUTILON PYCNODON* SHRUBLAND OF THE HIGHER LYING AREAS

This shrubland is situated on higher-lying areas on the slopes and plateaux of dolerite hills in the region of the Vanderkloof Dam. Dolerite hills covered by shallow lithosols occur. Twenty-one communities encountered were included.

The differentiating species are poorly developed and are listed in species group 36 (Table 11.1). *Abutilon pycnodon, Cullen obtusifolia* and *Justicia protracta* (species group 37) are the only diagnostic species characterizing this vegetation unit (Table 11.1).

Prominent woody and semi-woody species with constancies of 60% and higher, occasionally associated with this order include the thorn tree *Acacia mellifera,* the shrubs *Tarchonanthus camphoratus* (species group 38), and *Ehretia rigida* (species group 54), the Karoo encroacher *Chrysocoma ciliata* (species group 76) and the shrub *Protasparagus suaveolens* (species group 77).

Grasses include *Digitaria eriantha* (species group 59), *Heteropogon contortus, Aristida diffusa* (species group 61), *Themeda triandra* (species group 65), *Eragrostis lehmanniana* (species group 77) and *Fingerhuthia africana* (species group 83).

CLASS 7: *ARISTIDA BIPARTITA - LACTUCA SERRIOLA* MOIST GRASSLAND OF THABA 'NCHU

Plant communities included in this class are derived from the association analysis of 12 grassland communities of Thaba 'Nchu Mountain area, approximately 60 km east of Bloemfontein (Roberts 1966).

This moist grassland vegetation occurs east of the 500 mm rainfall isohyet with the largest part falling within the 600-800 mm rainfall interval (See Chapter 2).

The *Aristida bipartita-Lactuca serriola* moist grassland of the eastern plains is characterized by *Lactuca serriola* (species group 40) that distinguishes this class from all the other classes in the study area.

The vegetation is mostly dominated by grasses with trees and shrubs less conspicuous. The most prominent grasses are *Aristida bipartita* (species group 39), *Eragrostis chloromelas, Cynodon dactylon* (species group 41), *Eragrostis plana, Trichoneura grandiglumis, Eragrostis gummiflua, Microchloa caffra* (species group 44), *Cymbopogon plurinodis, Elionurus muticus* (species group 47), *Setaria sphacelata* (species group 55), *Tragus koelerioides* (species group 59), *Heteropogon contortus, Aristida congesta* (species group 61), *Themeda triandra* (species group 65), *Eragrostis obtusa, Tragus berteronianus* (species group 76), *Chloris virgata* (species group 80) and *Aristida canescens* (species group 81).

The presence of species such as the forbs *Berkheya onopordifolia* (species group 76) and *B. pinnatifida* (species group 77) and grasses such as *Aristida bipartita, Eragrostis chloromelas, Cynodon dactylon, Eragrostis gummiflua, Elionurus muticus, Tragus koelerioides, Aristida congesta, Eragrostis obtusa, Tragus berteronianus, Chloris virgata, Aristida canescens* is normally indicative of overgrazed and retrogressed vegetation (See Van Oudtshoorn 1991 & Fuls 1993).

This class is in accordance with the *Themeda triandra-Eragrostis plana* moist grasslands of the eastern plains, described by Du Preez (1991) where *Themeda triandra* is dominant, but due to overgrazing, the vegetation deteriorated to variations where *Elionurus muticus, Aristida junciformis, Eragrostis chloromelas* and *E. plana* dominate (Du Preez 1991).

Diospyros lycioides (species group 71) is inconspicuous, but virtually the only shrub species present, with *Lycium cinereum* and *Pentzia globosa* (species group 83) the only abundant dwarf shrubs.

CLASS 8: *ERAGROSTIS PLANA-CYMBOPOGON DIETERLENII* MOIST GRASSLANDS OF THE EASTERN PLAINS

This vegetation class occurs south-east of the *Themeda triandra-Cymbopogon plurinodis* dry grassland plains at a higher altitude and with a higher rainfall, described by Werger & Coetzee (1978) as Moist Temperate grassland.

Plant communities in this class are the following:

* the *Brachiaria serrata-Elionurus muticus*;
* *Eragrostis plana-E. gummiflua*; and
* *Pentzia globosa-Eragrostis curvula* communities described by Werger (1973 a) from the eastern Upper Orange River Valley; and
* communities derived from relevés encountered on Molteno sandstone on the Aasvoëlberg Mountain near Zastron in the southern Free State.

The *Brachiaria serrata-Elionurus muticus* Community occurs on sites mainly in the area covered by the sandy *Cymbopogon-Themeda* Veld (Acocks 1953), which are not too severely overgrazed and trampled. The soils are deep pseudopodzolic soils with a slightly acid topsoil of loamy sand on nearly horizontal layers of Molteno sandstone (Werger 1973 a).

The *Eragrostis plana-Eragrostis gummiflua* Community is encountered on damp sites with a deep soil of loamy sand on gentle slopes and plains of Molteno sandstone, upstream from Aliwal North (Werger 1973 a).

The *Pentzia globosa-Eragrostis curvula* Community occurs in the vicinity of Aliwal North, where the False Upper Karoo merges into the grassland vegetation. The soils are acid loamy sands and sandy loams on level to slightly sloping Molteno and Beaufort sandstones (Werger 1973 a).

According to Scheepers (1975) variation in vegetation is mostly determined by geology, position in the landscape and biotic factors, especially grazing. In this region the rainfall exceeds 600 mm/a and falls within the 600-800 mm rainfall interval (Chapter 2). This high rainfall tends to smooth out the variations in the physical factors of the environment, so that gradual transitions in the vegetation become the rule and abrupt discontinuities the exception (Du Preez 1991). According to Acocks (1988) these areas are too dry and/or too frosty for the development of any kind of forest. Shrubs are restricted to the rocky hills and mountains. Daubenmire (1968) stated that fire is the most important factor in preventing the development of woody vegetation in this type of area.

This class is distinguished from all the other classes by the presence of species listed in species group 43 (Table 11.1). The diagnostic species are the perennial, tufted grass *Cymbopogon dieterlenii, Ficinia* sp., *Hermannia geniculata* and the forb *Selago galpinii* (Table 11.1). Species differentiating this grassland are listed in species group 42 (Table 11.1). Strong affinities with the *Aristida bipartita-Lactuca serriola* moist grassland of Thaba 'Nchu are shown in species group 44 (Table 11.1). The grasses *Eragrostis plana, Trichoneura grandiglumis, Eragrostis gummiflua* and *Microchloa caffra* show the strongest affinities between the two classes. The grasses *Eragrostis chloromelas* (species group 41), *Tragus koelerioides* (species group 59) and *Eragrostis obtusa* (species group 76) have lower presences here as in the *Aristida bipartita-Lactuca serriola* moist grassland of Thaba 'Nchu. The absence of *Cynodon dactylon* (species group 41), *Chloris virgata* (species group 80) and *Panicum coloratum* (species group 84) in this grassland is also noteworthy. Grasses with higher frequencies in this moist grassland include *Eragrostis capensis* (species group 44), *Elionurus muticus* (species group 47), *Sporobolus fimbriatus* (species group 55), *Digitaria eriantha* (species group 59), *Heteropogon contortus* (species group 61) and *Eragrostis curvula* (species group 80).

Prominent woody species are *Rhus erosa* (species group 14) and the karroid shrub *Felicia filifolia* (species group 55).

The most abundant grasses include *Eragrostis racemosus, Panicum stapfianum* (species group 42), *Eragrostis plana, Trichoneura grandiglumis, Eragrostis gummiflua, Microchloa caffra, Eragrostis capensis* (species group

44), *Cymbopogon plurinodis, Elionurus muticus* (species group 47), *Setaria sphacelata, Sporobolus fimbriatus* (species group 55), *Digitaria eriantha* (species group 59), *Heteropogon contortus, Aristida congesta* (species group 61), *Themeda triandra* (species group 65), *Eragrostis obtusa* (species group 76), *E. lehmanniana* (species group 77), *Eragrostis curvula* (species group 80) and *Fingerhuthia africana* (species group 83).

The most prominent forbs are *Berkheya discolor* (species group 42), *Gazania krebsiana* (species group 54) and *Walafrida saxatilis* (species group 77).

Some of the association analysis end groups of Roberts' study of Thaba 'Nchu (1966), particularly end group 4, show strong floristic affinities with the *Brachiaria serrata-Elionurus muticus* Community and it is possible that the same community occurs in the Upper Orange River Valley and at Thaba 'Nchu (Werger 1973 a).

A comprehensive formal syntaxonomical review of these syntaxa including communities from outside the study area, is needed.

CLASS 9: *THEMEDA TRIANDRA-CYMBOPOGON PLURINODIS* GRASSLANDS OF THE WESTERN PLAINS

The vegetation of the Grassland Biome follows a rainfall gradient which generally corresponds to the relative contributions to the plant cover by "sweet" and "sour" grasses (Rutherford & Westfall 1994). "Sweet" grasses, in contrast to "sour" grasses, usually have a lower fibre content, maintain a higher above-ground nutrient level into winter and tend to be more palatable to stock. "Sweet" grasses (e.g. *Panicum coloratum*) are more common in areas with a mean annual rainfall below 625 mm, while sour grasses (e.g. *Aristida junciformis*) tend to dominate in areas with a mean annual rainfall of above 625 mm (Rutherford & Westfall 1994). The border between moist and dry grassland is best expressed as ranging between the 500 and 700 mm isohyet (Rutherford & Westfall 1994).

This class is encountered to the east of the 600 mm rainfall isohyet in the southern Free State and is dominated by *Themeda triandra, Digitaria eriantha* and *Eragrostis lehmanniana*. Grasslands with *Themeda triandra* occur widespread over Africa (Lebrun 1947; Volk & Leippert 1971). The *Themedetalia triandrae* described by Lebrun (1947) for East Africa are, however, absent in South Africa. It therefore seems that the southern African *Themeda triandra* communities do not belong to this order (Du Preez 1991). This class is in accordance with the *Aristida junciformis-Eragrostis plana* Grassland described by Fuls (1993), where *Themeda triandra* and *Eragrostis curvula* dominate. According to Werger (1973 a) the presence and abundance of *Themeda triandra* and *Eragrostis curvula* on sites that have been withdrawn from grazing for some time suggests that these species are relics of a former grassland vegetation. The development of woody vegetation is probably prevented by regular frosts (Acocks 1988, Werger 1973 a) and fire (Walter 1973, Scott 1970).

The topography is flat to undulating with isolated hills and ridges occurring occasionally. The soils of the moist grasslands are usually more leached by the higher rainfall and tend to be dystrophic in comparison with the generally eutrophic soils of the dry grasslands (Rutherford & Westfall 1994). The area in which this class occurs is mainly underlain by the Beaufort and Ecca Groups.

According to Acocks (1988) the grasslands of the Upper Orange River Valley merge into False Karoo vegetation towards the drier west and south. This is mainly due to anthropogenic influences, particularly overgrazing by sheep (Du Preez 1991).

Thirty-eight Plant communities are included in this class and are derived from relevés in the Bloemfontein West District (Malan 1992), the Upper Orange River Valley (Werger 1973 a) and additional relevés compiled in the southern Free State by the present author.

This grassland is characterized by the diagnostic species listed in species group 46 (Table 11.1) and are *Arctotis arctotoides, Dipcadi glaucum, Hypoxis filiformis* and *Tragopogon dubius*.

Trees and shrubs are virtually absent and the vegetation is dominated by grasses. Grasses with constancies of 60% and higher include *Cymbopogon plurinodis* (species group 47), *Digitaria eriantha* (species group 59), *Aristida congesta* (species group 61), *Themeda triandra* (species group 65), *Eragrostis obtusa* (species group 76), *Eragrostis lehmanniana* (species group 77), *Eragrostis curvula* (species group 80) and *Fingerhuthia africana* (species group 83).

The presence of the Karoo encroacher *Chrysocoma ciliata* (species group 76) is a clear indication of veld deterioration.

CLASS 10: *HERTIA PALLENS-PROSOPIS VELUTINA* KARROID VEGETATION OF THE DRY WESTERN FREE STATE

The *Hertia pallens-Prosopis velutina* karroid vegetation of the dry western Free State is encountered to the west of the 600 mm rainfall isohyet. This area includes the ecotone between the Grassland and Nama-Karoo Biomes. This class comprises 61 plant communities and includes:

* relevés encountered in the Bloemfontein West District (Malan 1992);
* communities of generally limited spatial extent (minor communities) in the Upper Orange River Valley (Werger 1973 a); and
* additional relevés compiled in the southern Free State by the present author.

According to Werger (1973 a) the grasslands of the Upper Orange River Valley are classified into three distinct plant communities, without any syntaxonomical rank. Towards the drier west and south the grasslands merge into False Upper Karoo vegetation (Acocks 1988). Here the grasslands degrade due to anthropogenic influences, particularly overgrazing by sheep, resulting in the floristically poor *Hermannio coccocarpae-Nestleretum confertae* (Werger 1973 a), typical of the False Upper Karoo. The vegetation of this class is characterized by species groups 49 and 50, all with low constancies (Table 11.1). Species exclusive to this class are listed in species group 49 and include the exotic tree *Prosopis velutina*. Associated diagnostic dwarf shrubs and forbs include *Amaranthus thunbergii, Deverra denudata, Galenia africana, Geigeria ornativa, Hertia ciliata, Psilocaulon junceum, Pteronia incana, Ruschia rigida, Stachys hyssopoides, Suaeda fruticosa, Zygophyllum macrocarpon* and *Z. microphyllum*. *Eragrostis bergiana* is the only diagnostic grass (species group 49, Table 11.1).

Shrubs and dwarf shrubs with constancies of 40% and higher include *Hertia pallens* (species group 48), *Eriocephalus ericoides* (species group 50), *Felicia muricata* (species group 55), *Melolobium candicans* (species group 62), *Salsola glabrescens* (species group 75), *Chrysocoma ciliata* (species group 76), *Protasparagus suaveolens, Walafrida saxatilis* (species group 77), *Eriocephalus spinescens* (species group 82), *Lycium cinereum, Pentzia globosa, P. incana* and *Lycium horridum* (species group 83).

Grasses present include *Aristida congesta, A. diffusa* (species group 61), *Eragrostis lehmanniana* (species group 77), *E. curvula* (species group 80) and *Fingerhuthia africana* (species group 83, Table 11.1).

Digitaria eriantha (species group 59) and *Themeda triandra* (species group 65) have much lower constancies here as in the *Themeda triandra-Cymbopogon plurinodis* grassland of the western plains. This is probably due to habitat disturbance accompanied with lower rainfall in the western part of the study area.

CLASS 11: *OROPETIUM CAPENSE-ANACAMPSEROS FILAMENTOSA* COMMUNITIES ON VERY SHALLOW SOILS ON DOLERITE OUTCROPS

The vegetation of this class was encountered on exposed sheets of rock and sandstone of a dolerite sill in the Bloemfontein-area. These very restricted communities occur on dolerite and sandstone rock sheets on the high-lying areas as well as shallow depressions of dolerite rock sheets on the plateaux. This class is in accordance with the *Oropetium capense* Community on rocky sheets along the slopes and on the plateaux of dolerite hills and ridges in the Willem Pretorius Game Reserve described by Müller (1986). Seven communities were included.

This class is distinguished by the species listed in species groups 56 and 57 (Table 11.1). Species with frequencies of 60% and higher are the grasses *Oropetium capense, Eragrostis nindensis*, the succulents *Eberlanzia spinosa, Euphorbia mauritanica, Senecio radicans, Anacampseros truncata, Chasmatophyllum musculinum, Crassula nudicaulis* and *Sarcostemma viminale* (species group 56).

Species exclusive to this class are *Anacampseros filamentosa, Stomatium mustellinum, Crassula corallina, Anacampseros ustulata, Trachyandra saltii, Otholobium prodiens* and *Neohenricia sibbettii* (species group 57, Table 11.1).

Other species of importance include the sedges *Mariscus capensis* (species group 58), *Cyperus rupestris* (species group 66), the grass *Aristida diffusa* (species group 61), the thorny shrub *Eriocephalus spinescens* (species group 82) and the small fern *Cheilanthes eckloniana* (species group 14, Table 11.1).

CLASS 12: *PHRAGMITES AUSTRALIS-SALIX BABYLONICA* RIPARIAN VEGETATION

The vegetation of this class is restricted to the poorly-drained floodplains and dry watercourses of the southern Free State. The habitat is fairly unstable, due to seasonal flooding and drying which, together with frequent overgrazing, have caused the advanced state of degradation of the vegetation. In some cases this vegetation is dominated by *Acacia karroo* on calcareous-sandy soil and also occurs away from river banks on clayey soils in drainage channels. The soils of the lowlands generally have a higher clay content than those of the upland areas.

This vegetation unit includes communities derived from:

* relevés in the Bloemfontein area (Malan 1992);

* *Acacia* communities in the Bloemfontein area (Rossouw 1983); and
* additional relevés encountered in the southern Free State by the present author.

Bezuidenhout (1993) described associated syntaxa with virtually the same habitat conditions in the western Transvaal grasslands under the *Eragrostido planae-Hyparrhenietea hirtae*, while Fuls (1993) described the *Cyperus fastigiatus-Hemarthria altissima* wetland with similar habitat conditions. Du Preez (1991) refers to it as the *Hemarthria altissima* marsh and stream bank community.

This class is distinguished by the presence of species occurring in species groups 62 and 63 (Table 11.1). The differentiating species are listed in species group 62. The reed *Phragmites australis*, the tree *Salix mucronata*, the forbs *Rumex lanceolatus* and *Verbena bonariensis* and the sedge *Cyperus longus* (species group 62) all have high constancies.

Species exclusive to this class are the naturalized exotic tree *Salix babylonica*, the perennial rhizomatous grass *Hemarthria altissima* and the forbs *Conium chaerophylloides, Datura ferox, Mentha longifolia* and *Polygonum kitaibelianum* (species group 63, Table 11.1).

Also prominent are the trees *Acacia karroo* (species group 64), *Diospyros lycioides* (species group 71), the shrub *Protasparagus laricinus* and the forbs *Tagetes minuta* and *Tribulus terrestris* (species group 76).

Typha capensis, normally associated with wetlands (Eckhardt *et al.* 1993), *Juncus exsertus* (species group 68), *Xanthium strumarium* and *Rumex crispus* (species group 78) are among the other species normally associated with wetlands.

A comprehensive formal syntaxonomical review of these syntaxa including the communities from outside the study area, is needed.

CLASS 13: *MARISCUS CONGESTUS-PERSICARIA SERRULATA* STREAM RIPARIAN VEGETATION

Plant communities included in this vegetation unit are:

* wetland communities derived from relevés in the Bloemfontein area (Malan 1992); and
* communities derived from relevés in the southern Free State and Soetdoring Nature Reserve.

This vegetation unit occurs on the banks of perennial rivers and streams characterized by relatively strongly flowing water.

Mariscus congestus, Cyperus rupestris, Medicago sativa, Agrostis lachnantha and *Juncus rigidus* are the most important among the differentiating species (species group 66, Table 11.1).

The diagnostic species are listed in species group 67. *Persicaria serrulata* and *Cichorium intybus* the most abundant.

Cyperus longus (species group 62), *Typha capensis* (species group 68), *Nidorella resedifolia* (species group 69) are also abundant. *Diospyros lycioides* (species group 71) is the only prominent tree present. *Asclepias fruticosa* (species group 76) is especially abundant along drainage channels with clayish soil.

Grass species are scarce and only *Cynodon incompletus, Miscanthus capensis* (species group 62), *Agrostis lachnantha,* (species group 66), *Panicum maximum* (species group 70), *Hyparrhenia hirta* (species group 71) are present.

Related vegetation types outside the study area were described by Kooij *et al.* (1991), Bezuidenhout (1993), Fuls (1993) and Eckhardt *et al.* (1993).

CLASS 14: *JUNCUS KRAUSSII-PHRAGMITES MAURITIANUS* WETLAND AND PAN VEGETATION

This is a transitional vegetation unit, representing the peripheral zone of the pans where the vegetation of the drier surrounding communities and those find within the pans coincide (Eckhardt *et al.* 1993). Similar habitat conditions as in the *Senecio inaequidens-Cynodon transvaalensis* Pan Community (Eckhardt *et al.* 1993) were encountered. 10 Communities encountered in the dry western Free State are included.

The vegetation is characterized by species groups 72 and 73 (Table 11.1). Species exclusive in this class are aquatic plants such as *Phragmites mauritianus, Scirpus dioicus, Cyperus laevigatus, Cyperus* sp. and the small perennial grass *Sporobolus tenellus* (species group 73).

Lobelia thermalis, Cirsium vulgare, Wahlenbergia androsacea and *Scirpus dioecus* (species group 72) are the most important species differentiating this vegetation unit.

This class is dominated by *Lobelia thermalis, Cirsium vulgare* (species group 72), *Juncus kraussii* (species group 74) and *Cyperus marginatus* (species group 75).

Grasses are scarce and only *Sporobolus tenellus* (species group 73), *Eragrostis obtusa, Tragus berteronianus* (species group 76), *E. lehmanniana* (species group 77) and *Fingerhuthia africana* (species group 83) are important.

CLASS 15: *DIPLACHNE FUSCA - SETARIA INCRASSATA* PAN VEGETATION

This class is associated with the central zones of pans and agrees with the *Chloris virgata-Eragrostis bicolor* tall closed grassland associated with poorly drained, moderately deep, clayey soils (> 25% clay content, A - & B-horizons), described by Bezuidenhout (1995). Similar communities were described by Eckhardt *et al.* (1993) under the *Diplachne fusca-Cynodon transvaalensis* Pan Community and Fuls (1993) under the *Sporobolus ioclados-Diplachne fusca* Pan Vegetation.

The only diagnostic species is the perennial, stoloniferous, mat-forming swamp grass *Diplachne fusca* (species group 79). *D. fusca* appears to be annual, "disappearing" during the dry season or prelonged dry spells, only to reappear within a week or so after substantial rain (Fuls 1993).

Woody and semi-woody species are absent and only a few grasses and forbs occur. The most important grasses are *Setaria incrassata* (species group 78), *Eragrostis curvula* and *Chloris virgata* (species group 80). *Sutera albiflora* (species group 13) is the most important forb (Table 11.1).

Xanthium strumarium, Rumex crispus, Hibiscus trionum, Salvia verbenaca and *Schkuhria pinnata* (species group 78), also associated with overgrazed areas (Fuls 1993), are the most important differentiating species present (Table 11.1).

CLASS 16: *FINGERHUTHIA AFRICANA-HELICHRYSUM PENTZIOIDES* PAN GRASSLAND

This class is encountered in dried out pans in the central parts of the study area and includes only two communities.

No exclusive character species occur, but the vegetation is differentiated by the species listed in species group 81, all of which have constancies of 60% and higher.

Forbs are scarce with *Helichrysum pentzioides* (species group 81) the most abundant. The only abundant grasses are *Enneapogon scoparius* (species group 55), *Aristida canescens, Sporobolus ioclados* (species group 81), *Fingerhuthia africana, Stipagrostis ciliata* and *S. obtusa* (species group 83).

Lycium pilifolium (species group 81), *L. cinereum* and *L. horridum* (species group 83) are the most important shrubs. Karoo bushes like the thorny *Eriocephalus spinescens* (species group 82), *Pentzia incana, P. globosa* and *Thesium hystrix* (species group 83) also occur (Table 11.1).

ORDINATION

Three hundred ninety-four synrelevés were used in an ordination algorithm, namely Detrended Correspondence Analysis (DECORANA, Hill 1979 b). This was done in order to determine possible vegetation and associated environmental gradients, as well as floristic relationships among the transitions between the communities. In the scatter diagrams (Figures 11.1-11.3) the distribution of the major syntaxa along the first and second axes of the ordinations are given.

Figure 11.1 shows the scatter diagram of the whole data set. The distribution of the major syntaxa along the first and second axes of the ordination is given.

Along the first axis the plant communities associated with deep soils are to the left of the diagram, while the syntaxa primarily associated with rock sheets are to the right. Pan vegetation is situated to the top with wetland vegetation to the bottom of the diagram (Axis 2, Figure 11.1).

Figure 11.2 shows a DECORANA ordination of all the major syntaxa included in figure 11.1, except the communities associated with very shallow soils on rock slabs (indicated by k in Figure 11.1). In the scatter diagram the distribution of the syntaxa along the first and second axes of the DECORANA ordination is given (Figure 11.2). Although no distinct discontinuity can be observed, the plant communities are restricted to specific spatial areas in the diagram. Along the first axis the syntaxa associated with deep sandy soils are situated to the left of the diagram, the plant communities in rocky habitat to the middle and the syntaxa associated with clayish soils to the right of the diagram. The second axis illustrates a habitat gradient. Pan vegetation of the western Free State are to the top of the diagram with the wetland communities to the bottom (Figure 11.2).

Figure 11.3 shows a scatter diagram of the distribution of the major syntaxa along the first and second axes of the DECORANA ordination. In this diagram all the wetland communities and the communities associated with rock slabs are excluded (indicated by m, n, j and k in Figures 11.1 & 11.2). The distribution of the major syntaxa indicates a distinct discontinuity among some of the plant units. The first axis illustrates a gradient of rainfall. Plant communities to the left of the diagram are mainly karroid vegetation associated with low rainfall regions (300 mm per annum and less), especially in the dry western parts of the study area. Shrubland communities to the right are associated with a moist to wet habitat where the rainfall often exceeds 600 mm/a. Axis two illustrates a soil moisture and soil structure gradient. Plant communities to the top are associated with moist habitats, especially in drainage channels and other areas associated with clayish soil. To the bottom of the diagram dry plant communities, primarily associated with sandy soil, occur (Figure 11.3).

DISCUSSION

The Grassland Biome of South Africa, encompassing the grasslands of the southern Free State, was identified by Greyling & Huntley (1984) as one of the most critically threatened southern African ecosystems, with only 0.19% of the grassland area conserved. This confirms the necessity of compiling a phytosociological synthesis as has been proposed by Scheepers (1986).

This is the first comprehensive synecological account of the vegetation of the southern Free State. The analysis of the large floristic data set of the study area by means of the two-step technique (Bredenkamp & Bezuidenhout 1995) has proven to be successful. The next step, a reduction of the comprehensive synoptic class table to a synoptic table, where the classes are represented by single columns, makes it possible to compare the classes with ease (Du Preez 1991).

Sixteen phytosociological classes have been identified, all of which are strongly related to a specific habitat. Species from species groups 14, 19, 26, 27, 38, 41, 47, 54, 55, 59, 60, 61, 64, 65, 69, 70, 71, 75, 76, 77, 80, 82, 83 and 84 (Table 11.1) are the most abundant in the southern Free State. All the other species indicate minor floristic relations among the different classes (Table 11.1).

Although the classes are easily correlated with the habitat, there are similarities and differences among the different vegetation units. A combination of biotic and abiotic factors play an important role in the distribution of the different vegetation units. The main contributing biotic factors, which influence the distribution of the classes and degradation of natural vegetation, have been identified as mismanagement of natural pasture (eg. the uncontrolled ploughing of land) and overgrazing practices. Abiotic factors such as soil depth, rockiness of the soil surface and rainfall also play an important role in the distribution of vegetation (Figure 11.3).

The most important woody and semi-woody species encountered in the southern Free State are *Acacia karroo, A. mellifera, A. tortilis, Celtis africana, Chrysocoma ciliata, Diospyros austro-africana, D. lycioides, Ehretia rigida, Euclea crispa* subsp. *crispa, Felicia filifolia, F. muricata, Grewia occidentalis, Lycium cinereum, Maytenus polyacantha, Olea europaea, Osyris lanceolata, Pentzia globosa, P. incana, Protasparagus suaveolens, Rhus burchellii, R. ciliata, R. erosa, R. lancea, R. pyroides, Rhamnus prinoides, Rhigozum obovatum, R. trichotomum, Solanum incanum, Tarchonanthus camphoratus* and *Ziziphus mucronata*.

Grasses of importance include *Aristida adscensionis, A. congesta, A. diffusa, Chloris virgata, Cenchrus ciliaris, Cymbopogon excavatus, C. plurinodis, Cynodon incompletus, Digitaria eriantha, Enneapogon desvauxii, Eustachys paspaloides, Elionurus muticus, Enneapogon scoparius, Eragrostis capensis, E. chloromelas, E. curvula, E. gummiflua, E. lehmanniana, E. nindensis, E. obtusa, E. plana, E. superba, Fingerhuthia africana, Heteropogon contortus, Microchloa caffra, Panicum coloratum, Setaria sphacelata, Sporobolus fimbriatus, Stipagrostis ciliata, S. obtusa, Themeda* *triandra, Tragus berteronianus, T. koelerioides, Trichoneura grandiglumis* and *Triraphis andropogonoides*.

The most abundant ferns are *Cheilanthes eckloniana* and *Pellaea calomelanos*.

According to Potgieter *et al.* (1995) veld degradation may be ascribed to unfavourable climatic conditions accompanied by too high stock numbers. The ecotone between the Grassland- and Nama-Karoo Biomes is best illustrated in the differences between classes 9 and 10 (Table 11.1). *Cymbopogon plurinodis* (species group 47), *Digitaria eriantha* (species group 59) and *Themeda triandra* (species group 65) have much higher constancies in the *Themeda triandra-Cymbopogon plurinodis* grasslands of the western plains than in the *Hertia pallens-Prosopis velutina* karroid vegetation of the dry western Free State. Karroid shrub communities extend west along a rainfall gradient (Rutherford & Westfall 1994). This supports Acocks's (1979) hypothesis for an increase in shrub cover at the expense of grasses across a wide expanse from the central and eastern Karoo through to the grasslands of the southern Free State. This is illustrated in the higher constancies of *Hertia pallens* (species group 48), *Melolobium candicans* (species group 62), *Salsola glabrescens* (species group 75), *Protasparagus suaveolens* (species group 77), *Eriocephalus spinescens* (species group 82), *Lycium cinereum, Pentzia globosa, P. incana, Thesium hystrix* and *Lycium horridum* (species group 83) in the *Hertia pallens-Prosopis velutina* karroid vegetation of the dry western Free State.

Other species frequently associated with habitat disturbance include *Asclepias fruticosa, Berkheya onopordifolia,* the Karoo encroacher, *Chrysocoma ciliata, Protasparagus laricinus, Tribulus terrestris* (species group 76), *Berkheya pinnatifida, Chenopodium album, Protasparagus suaveolens, Talinum caffrum, Walafrida saxatilis* (species group 77), *Salvia verbenaca* (species group 80), as well as the grasses *Aristida congesta, A. diffusa* (species group 61), *Eragrostis obtusa, Tragus berteronianus* (species group 76), *Eragrostis lehmanniana* (species group 77), *Chloris virgata* and *Eragrostis curvula* (species group 80).

According to Rutherford & Westfall (1994) the usual progression, given a significant reduction in grazing pressure and a suitable distribution of rainfall (Vorster & Roux (1983); is a steady increase in cryptophyte cover and a more variable decrease in chamaephyte cover. The soils of the moist grasslands, however, are usually more leached by the higher rainfall and tend to be dystrophic in comparison with generally eutrophic soils of the drier areas (Rutherford & Westfall 1994). The southern Free State, however, seems to have a broad transition zone of shrub-grass mixtures and thus emphasize the necessity for future management programmes to be implemented in this region.

Although veld degradation occurs in all the Broad Homogeneous Zones of the Free State (Fuls 1993), each area has an own identity and characteristic pattern of veld degradation and must be approached individually. In the southern parts, early stages of degradation can be observed in deterioration of the plant cover, followed by a change in the plant species composition. In the northern and eastern parts of the Free State, the pattern is reversed - composition changes first, followed by deterioration in plant cover (Potgieter *et al.* 1995).

Table 11.1: A synoptic table of the synrelevés of the vegetation classes of the southern Free State.

CLASS NUMBER	1	2.1	2.2	2.3	3.1	3.2	4	5	6.1	6.2	7	8	9	10	11	12	13	14	15	16
SPECIES GROUP 1																				
Leucosidea sericea	4			1												2				
Rhus dentata	3		1	1																
Cussonia paniculata	3		1	1																
Helichrysum rugulosum	3			1								2	1							
Rosa eglanteria	3			1																
Myrsine africana	2	1		1																
Buddleja salviifolia	2			1				1												
Salvia namaensis	2		1	1						1										
Senecio isatideus	2											2								
Tristachya leucothrix	2											2								
Helichrysum pilosellum	2											2					2			
Cliffortia nitidula	2			1																
Rhus dregeana	1			1																
SPECIES GROUP 2																				
Stoebe plumosa	4																			
Euclea crispa subsp. crispa	3																			
Passerina montana	3																			
Cliffortia paucistaminea	2																			
Peucedanum capense	2																			
Aristea cognata	1																			
Helichrysum appendiculatum	1																			
Pelargonium alchemilloides	1																			
SPECIES GROUP 3																				
Aloe ferox		2		1																
Helichrysum pilosellum		1		1																
SPECIES GROUP 4																				
Euclea crispa subsp. ovata		2	4	4		2			1	1				1						
Buddleja saligna	1		3	1																
Delosperma pottsii	1		1																	
Eragrostis echinochloidea			1				1		1					1				1		
Homeria pallida			1		1			1												
Pelargonium abrotanifolium			1							1										
Crotalaria eremicola			1							1										
Protasparagus capensis			1				1													
Urtica dioica			1					1												
Garuleum pinnatifidum			1					1												
Vicia sativa			1					1												
Commelina eckloniana			1						1				1	1						

CLASS NUMBER	1	2.1	2.2	2.3	3.1	3.2	4	5	6.1	6.2	7	8	9	10	11	12	13	14	15	16
Opuntia species			1							1			1							
Scilla nervosa			1							1										
Moraea spathulata			1							1										
Sutherlandia microphylla	1		1					1									1			
Lithospermum cinereum			1		1															
SPECIES GROUP 5																				
Kleinia longiflora			1																	
Sisymbrium capense			1																	
Sisymbrium thellungii			1																	
Trachyandra aspera			1																	
SPECIES GROUP 6																				
Zinnia peruviana		2	1					1												
Opuntia ficus-indica		1	1							1				1						
Tragus racemosus		1	1		1								1							
Populus canescens		1	1										1							
Hermannia amoena		1	1						1											
Prunus persica		1	1																	
Achyranthes aquatica		1	1																	
SPECIES GROUP 7																				
Sesamum capense	1	1	1						1	1				1						
Cotoneaster species	1	1	1																	
Sutera filicaulis	1	1	1																	
SPECIES GROUP 8																				
Argyrolobium lanceolatum				4		3														
Lotononis laxa				3	1			1												
Brachiaria serrata				3	1						3	2								
Hermannia linearifolia				3	1		1						1	1						
Phyllanthus maderaspatensis				3	1		1							1						
Helichrysum lucilioides				3	1		1													
Sutera halimifolia				3	1	1														
Blepharis villosa				2	1		1													
Hermannia pulverata				2	1		1													
Helichrysum niveum				2	1							2								
Polygala uncinata		1		2	1					1										
Sutera atropurpurea	1	1		2	1		1				1			1						
Pteronia glauca			1	2			1			1				1						
Crassula capitella		1		2	1															
Phymaspermum aciculare				2		1														
Rhus divaricata				1							1									
Withania somnifera	1			1				1												

CLASS NUMBER	1	2.1	2.2	2.3	3.1	3.2	4	5	6.1	6.2	7	8	9	10	11	12	13	14	15	16
SPECIES GROUP 9																				
Anacampseros lanceolata				2																
Pelargonium aridum				2																
Athrixia angustissima				1																
Bidens pilosa				1																
Chamarea capensis				1																
Crassula exilis				1																
Gerbera viridifolia				1																
Haworthia tessellata				1																
Helichrysum rosum				1																
Heliophila suavissima				1																
Hermannia species				1																
Hypoxis hemerocallidea				1																
Hypoxis iridifolia				1																
Kalanchoe rotundifolia				1																
Kalanchoe thyrsiflora				1																
Koeleria capensis				1																
Polygala ephedroides				1																
Sanseviera aethiopica				1																
Schistostephium crataegifolium				1																
Schizoglossum linifolium				1																
Senecio hieracioides				1																
Senecio inornatus				1																
Senecio latifolius				1																
Senecio retorsus				1																
Setaria lindenbergiana				1																
SPECIES GROUP 10																				
Solanum coccineum	1		2	3													2			
Viscum rotundifolium	1		2	3				1							1					
Senecio burchellii	1		1	1		1								1						
Argyrolobium pauciflorum	1		1	1						1										
Kalanchoe paniculata	1		1	1												1				
Rhynchosia nervosa	1		1	1																
Haemanthus humilis	1		1	1																
Hermannia cuneifolia			1	4						1										
Cotyledon orbiculata			1	3												2				
Pachypodium succulentum			1	1					1							1				
Stapelia grandiflora			1	1												1				
Lightfootia nodosa			1	1			1								1					
Pseudognaphalium luteo-album			1	1		1				1										
Pupalia lappacea			1	1					1	1										
Elephantorrhiza elephantina			1	1						1										
Coccinia sessilifolia			1	1				1												
Protasparagus denudatus			1	1				1												
Heteromorpha trifoliata			1	1				1									2			
Maytenus heterophylla			1	1				1												
Ehrharta erecta			1	1				1												

CLASS NUMBER	1	2.1	2.2	2.3	3.1	3.2	4	5	6.1	6.2	7	8	9	10	11	12	13	14	15	16
Rhynchosia totta			1	1							1									
SPECIES GROUP 11																				
Cheilanthes hirta			1	3																
Adromischus triflorus			1	2																
Aloe broomii			1	2																
Mohria caffrorum			1	2																
Boophane disticha			1	1																
Ceterach cordatum			1	1																
Cheilanthes viridis			1	1																
Commelina benghalensis			1	1																
Dimorphotheca cuneata			1	1																
Gerbera piloselloides			1	1																
Pelargonium myrrhifolium			1	1																
Schoenoxiphium sparteum			1	1																
SPECIES GROUP 12																				
Gnidia microcephala	1			1	1															
Vernonia capensis	1			1																
Linum thunbergii	1			1																
SPECIES GROUP 13																				
Sutera albiflora	1	1	4	1		1			1										3	
Pollichia campestris	1	1	4		1		1													
Melinis repens	2	1	2						1				1							
SPECIES GROUP 14																				
Rhus erosa	5	4	3	4								2								
Olea europaea subsp. africana	3	4	4	4		1		1												
Pavonia burchellii	1	2	2	1				2	1											
Celtis africana	1	3	1	2				2												
Diospyros austro-africana	4	4	3	4		1			1				1							
Rhigozum obovatum	1	3	2	2		1			2	2				1						
Cheilanthes eckloniana	3	2	3	3					1	1				1	3					
Maytenus polyacantha	1	1	2	2					1	1			1	1				1		
Pellaea calomelanos	3	2	2	4		2			1	1										
Cymbopogon excavatus	1	2	1	2					1											
Lantana rugosa	1	1	2	3						2						2				
Pentzia sphaerocephala	2	1	1	2						1			1							
Rhamnus prinoides	2	3	1	1																
Osyris lanceolata	4	1	2	2																
Grewia occidentalis	1	4	1	1																
Rhus pyroides subsp. gracilis	1	2	1	1																
Clutia pulchella	2	1	1	1																

CLASS NUMBER	1	2.1	2.2	2.3	3.1	3.2	4	5	6.1	6.2	7	8	9	10	11	12	13	14	15	16
SPECIES GROUP 15																				
Rosenia humilis				1	5	3		3						1						
Conyza bonariensis			1	1	4	1		3				2	1	1			1			
Cyperus usitatus				1	4		1	1				3								
Sporobolus ludwigii					4			1												
Digitaria argyrograpta			1	1	3						2	2								
Eriochloa parvispiculata			1	1	3															
Barleria macrostegia				1	3			1			1						1			
Chamaesyce inaequilatera				1	3			1												
Dimorphotheca zeyheri				1	3				1											
Pentzia viridis				1	3			2												
Mestoklema arboriforme				1	3			1												
Ornithogalum prasinum				1	3			1												
Ledebouria luteola				1	3			2							1					
Pentzia spinescens				1	2	1	2													
Bulbine abyssinica				1	2			2							1					
Medicago polymorpha				1	2												1			
Arctotis venusta			1		2			1		1			1							
Kyllinga alba					2			1				2	1	1						
Salsola rabieana					2		1	2												
Eragrostis bicolor					2		2	1			2							1		
Tulbaghia acutiloba					1			1							1					
Bulbine narcissifolia			1		1			1						1				1		
Commicarpus pentandrus				1	1				1											
Dipcadi viride				1	1			1												
Massonia jasminiflora				1	1			1												
Felicia flanaganii				1	1		1													
Sutera pinnatifida		1		1	1									1						
Senna italica				1	1					1				1						
Crassula setulosa			1	1	1															
SPECIES GROUP 16																				
Duthiastrum linifolium					2															
Kyllinga alata					2															
Menodora africana					2															
Brachiaria eruciformis					1															
Gethyllis undulata					1															
Moraea polystachya					1															
Oenothera tetraptera					1															
SPECIES GROUP 17																				
Dianthus basuticus				4	2			1												
Trichodiadema pomeridianum				2	2			1												
Blepharis integrifolia				3	4							2								
Hibiscus marlothianus				3	3		1					2								
Cynodon hirtellus				2	3			2			1	3								
Aptosimum procumbens				2	2		1				1									

CLASS NUMBER	1	2.1	2.2	2.3	3.1	3.2	4	5	6.1	6.2	7	8	9	10	11	12	13	14	15	16
SPECIES GROUP 18																				
Thesium spartioides				3	2															
Euphorbia clavarioides				2	2															
Euclea coriacea				2	1															
Nananthus vittatus				2	1															
Osteospermum leptolobum				2	1															
Stachys burchelliana				2	1															
Crassula muscosa				1	2															
Galenia pubescens				1	2															
Raphionacme hirsuta				1	2															
Albuca shawii				1	1															
Andropogon appendiculatus				1	1															
Aristida junciformis				1	1															
Helichrysum caespititium				1	1															
Melolobium calycinum				1	1															
Nolletia ciliaris				1	1															
Sutera argentea				1	1															
Wahlenbergia denticulata				1	1															
SPECIES GROUP 19																				
Helichrysum dregeanum			1	4	2			1			1	3	1							
Solanum supinum			1	4	3		2	2		1		2								
Plexipus pinnatifidus			1	4	2				1	1			1							
Cineraria lyrata			1	1	2			1				2				2				
Sutera caerulea			1	1	1			1	1				1							
Indigofera sessilifolia	1		1	2	1		1		1					1						
Helichrysum zeyheri			1	4	1	1				1										
Corbichonia decumbens			1	2	1		1		1	1										
Lightfootia albens	1		1	4	1						1			1						
Turbina oenotheroides			1	1	1					1			1							
SPECIES GROUP 20																				
Turbina oblongata		1	1	1	1						1									
SPECIES GROUP 21																				
Hermannia erodioides				1	2	4														
Salvia disermas	1			1		4							1	1						
Stipagrostis uniplumis				1		3	1													
Salsola calluna				1	1	3								1						
Aptosimum indivisum			1	1		2								1						
Argemone ochroleuca			1		1	2		2					1							
Indigofera nigromontana	1			2		2														
Barleria irritans				1		2														
Cotula anthemoides				1		2														
Medicago laciniata				1		2														

CLASS NUMBER	1	2.1	2.2	2.3	3.1	3.2	4	5	6.1	6.2	7	8	9	10	11	12	13	14	15	16
Monechma divaricatum				1		2														
Phyllanthus burchellii				1		2														
Sanseviera species				1		2														
Sutherlandia frutescens				1		2														
Hibiscus lunarifolius				1		1														
Veronica anagilis-aquatica				1		1														
SPECIES GROUP 22																				
Syncarpha argyropsis						2														
SPECIES GROUP 23																				
Phaeoptilum spinosum				1			5													
Dicoma macrocephala				2	1		4													
Plinthus karooicus				1			4							1						
Schizoglossum capitatum					1		4													
Eragrostis porosa				1			4	1												
Pentzia calcarea							4	1												
Peliostomum leucorrhizum			1	1			3													
Aptosimum spinescens				1			3							1						
Plinthus cryptocarpus				1			3													
Hermannia spinosa				1			3													
Monechma incanum				1			3													
Psilocaulon absimile				1		1	2	1												
Senecio longifolia			1	1			2							1						
Phymaspermum parvifolium				1	1		2													
Eragrostis truncata				1		2	2							1						
Boscia albitrunca			1	1		1	2	1												
Gnidia capitata				1			2													
Aloe claviflora				1			2													
Pteronia sordida				1			2													
Tetragonia arbuscula					1		2													
Kohautia amatymbica				1	1		1													
Drosanthemum species							1							1						
Sarcocaulon salmoniflorum							1							1						
SPECIES GROUP 24																				
Nolletia arenosa							3													
Zygophyllum gilfillanii							3													
Aptosimum albomarginatum							2													
Euphorbia aequoris							2													
Coelachyrum yemenicum							1													
Hoodia gordonii							1													
Rhynchopsidium pumilum							1													
SPECIES GROUP 25																				
Abutilon austro-africanum				1			1													

CLASS NUMBER	1	2.1	2.2	2.3	3.1	3.2	4	5	6	6.1	6.2	7	8	9	10	11	12	13	14	15	16
Cadaba aphylla				1			1														
Microloma armatum				1			1														
Polygala asbestina				1			1														
Psammotropha mucronata				1			1														
Walafrida geniculata				1			1														
SPECIES GROUP 26																					
Gnidia polycephala				3	2	4	5					2									
Helichrysum asperum				2	2	4	2					2									
Osteospermum scariosum				2	2	2	1					2									
Aptosimum marlothii				2	1	2	5							1							
Melolobium microphyllum		1		4	3	2	1			1											
Enneapogon desvauxii				2	3	3	5	1													
Pegolettia retrofracta				4	1	1	2														
Aristida adscensionis				3	1	1	3														
Aptosimum decumbens				2	1	1	1														
Lessertia pauciflora				2	2		3					2									
Kyphocarpa angustifolia				2		1	3			1											
Eriocephalus pubescens				3	1		5														
Polygala leptophylla				2	1		5														
SPECIES GROUP 27																					
Indigofera alternans			1	4	4		5	1		1			1								
Limeum aethiopicus			1	3	2		4							1				1			
SPECIES GROUP 28																					
Melica decumbens	1	1	1	2				5													
Achyranthes aspera			1	1				5													
Clematis brachiata		3	1	1				4													
Setaria verticillata		1	1	1			1	4													
Bromus catharicus			1	1				4													
Rhus pyroides subsp. pyroides	1			1				4													
Cineraria lobata			1	1	1			3													
Protasparagus cooperi			1	1				3													
Antizoma angustifolia			1	1			1	3													
Lepidium africanum			1	1		2		3													
Bidens bipinnata			1					3					1								
Pentarrhinum insipidum			1					3													
Urochloa panicoides			1					2			1		1	1							
Solanum retroflexum			1	1				2		1							1				
Sonchus oleraceus		1	1					2	1												
Delosperma cooperi	1				1			2					1								
Silene undulata			1					2													
Opuntia vulgaris			1					2													
Rubia petiolaris				1				2													

CLASS NUMBER	1	2.1	2.2	2.3	3.1	3.2	4	5	6.1	6.2	7	8	9	10	11	12	13	14	15	16
Protasparagus setaceus				1				2												
Alternanthera pungens								2	1											
Ammocharis coranica								1					1							
Papaver aculeatum								1		1										
Sphaeralcea bonariensis			1					1		1										
Salvia repens			1					1												
SPECIES GROUP 29																				
Chenopodium murale								2												
Hebenstretia integrifolia								2												
Rubia horrida								2												
Verbena officinalis								2												
SPECIES GROUP 30																				
Delosperma mahonii					1			1												
Lappula squarrosa					1			1												
Limeum sulcatum					1			1												
Protasparagus glaucus					1			1												
Trichodiadema barbatum					1			1												
SPECIES GROUP 31																				
Crassula lanceolata		1	1	1	1			2												
Teucrium trifidum		1	1	1	1			2						1						
SPECIES GROUP 32																				
Oxalis corniculata	3	1	1					3		1			1							
Melianthus comosus	1	1	1	1				2					1	1						
SPECIES GROUP 33																				
Acacia tortilis			1	1			2		5	1				1						
Grewia flava				1					2	1										
Hermannia bryoniifolia		1	1						2	1			1	1						
Schmidtia pappophoroides							1		1	1				1						
Enneapogon cenchroides				1					1	1				1						
Prosopis chilensis									1	1				1						
Acacia erioloba							1		1											
Mestoklema tuberosum							1		1				1	1						
Kedrostis africana				1	1				1											
Schmidtia kalahariensis									1					1						
Blepharis diversispina									1					1						

CLASS NUMBER	1	2.1	2.2	2.3	3.1	3.2	4	5	6.1	6.2	7	8	9	10	11	12	13	14	15	16
SPECIES GROUP 34																				
Acacia hebeclada									1											
Heliophila carnosa									1											
Hermannia modesta									1											
SPECIES GROUP 35																				
Polygala hottentotta		1	1	1			2		1											
Solanum panduriforme		1	1	1					1	1	1									
Melinis nerviglume		1	1	1					1	1										
SPECIES GROUP 36																				
Phyllanthus parvulus		1	1							2			1		2					
Enneapogon scaber	1			1			1			1										
Melhania rehmannii				1			1			1										
Justicia cuneata										1				1						
SPECIES GROUP 37																				
Abutilon pycnodon										1										
Cullen obtusifolia										1										
Justicia protracta										1										
SPECIES GROUP 38																				
Acacia mellifera			1	1		1	3		3	3			1							
Cenchrus ciliaris			1	1			2		3	1			1	1						
Tarchonanthus camphoratus			2	4		2			3	4				1						
SPECIES GROUP 39																				
Aristida bipartita				1		1					4									
Crabbea acaulis				1							3									
Monsonia angustifolia			1	1	1						3		1		2					
Conyza podocephala				1				1			3				1					
Scabiosa columbaria	1	1		1	1						2		1							
Sporobolus discoporus			1								2		1		2					
Pogonarthria squarrosa					1					1	1									
Ruschia species				1							1									
Oenothera stricta								1			1									
SPECIES GROUP 40																				
Lactuca serriola											2									
SPECIES GROUP 41																				
Eragrostis chloromelas			1	3	3	2		1			5	2	1							

CLASS NUMBER	1	2.1	2.2	2.3	3.1	3.2	4	5	6.1	6.2	7	8	9	10	11	12	13	14	15	16
Cynodon dactylon			1	1	2	3		2		1	3						1	1		
SPECIES GROUP 42																				
Oenothera indecora				1						1		4	1							
Sutera aurantiaca			1	1	2			1				4	1				1			
Berkheya discolor				1	1							4								
Eragrostis racemosus	1		1	1								3								
Euryops annae				1								3								
Panicum stapfianum	1			1								3		1						
Stoebe vulgaris				1							1	2								
Helichrysum nudifolium	1			1							1	2								
Dicoma anomala	1			1							1	2								
Euphorbia striata				1							1	2								
Lactuca capensis				1	1						1	2								
Lotononis tenella				1	1		1					2								
Ajuga ophrydis				1								2								
Haplocarpa scaposa				1								2								
Harpochloa falx				1								2								
Helichrysum longifolium				1								2								
Hermannia quartiniana				1								2								
Hibiscus aethiopicum				1								2								
Pentaschistis setifolia				1								2								
Polygala amatymbica				1								2								
Senecio coronatus				1								2								
Sutera kraussiana				1								2								
Trachypogon spicatus				1								2								
Stenostelma capense				2								2								
Aloina species					1							2								
Brunsvigia radulosa			1		1							2	1							
Lotononis listii				1								2	1							
Senecio erubescens				1								2	1							
Wahlenbergia undulata												2	1							
SPECIES GROUP 43																				
Cymbopogon dieterlenii												2								
Ficinia species												2								
Hermannia geniculata												2								
Selago galpinii												2								
SPECIES GROUP 44																				
Eragrostis plana				1		1					5	5	1				1			
Trichoneura grandiglumis				1	1	1					4	4								
Eragrostis gummiflua			1	1		1					3	4	2							
Microchloa caffra				1	1						3	3	1		3					
Eragrostis capensis	1			1							2	5	1							

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                               12223345667891111111
CLASS NUMBER                     .....  ..   0123456
                                 12312  12

Hermannia depressa                 111    24
Pennisetum sphacelatum            11      22
Lightfootia denticulata            111    22
Walafrida densiflora               12  2  14    1

SPECIES GROUP 45
Salsola kali                      1    111  21   1

SPECIES GROUP 46
Arctotis arctotoides                          1
Dipcadi glaucum                               1
Hypoxis filiformis                            1
Tragopogon dubius                             1

SPECIES GROUP 47
Cymbopogon plurinodis           323531 111553   1
Salvia stenophylla              1 11   1 13 1
Elionurus muticus               2 132     351
Helichrysum callicomum         1 11    1 1211
Hibiscus pusillus               1 1552 2  221
Hermannia comosa                  113 21 1  1

SPECIES GROUP 48
Hertia pallens                    1 1 1  1  12   1
Panicum schinzii                   1   1    11  1
Helichrysum lineare                     1   11   1
Zygophyllum incrustatum                      1      1   1
Stipagrostis namaquensis                1    1 1   1

SPECIES GROUP 49
Amaranthus thunbergii                         1
Deverra denudata                              1
Eragrostis bergiana                           1
Galenia africana                              1
Geigeria ornativa                             1
Hertia ciliata                                1
Prosopis velutina                             1
Psilocaulon junceum                           1
Pteronia incana                               1
Ruschia rigida                                1
Stachys hyssopoides                           1
Suaeda fruticosa                              1
Zygophyllum macrocarpon                       1
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CLASS NUMBER	1	2.1	2.2	2.3	3.1	3.2	4	5	6.1	6.2	7	8	9	10	11	12	13	14	15	16
Zygophyllum microphyllum														1						
SPECIES GROUP 50																				
Eriocephalus ericoides												2	2	2						
SPECIES GROUP 51																				
Becium angustifolium										1				1						
Flaveria bidentis										1				1						
Thesium strictum										1				1						
SPECIES GROUP 52																				
Eriocephalus aspalathoides									1					1						
Saltera sarcocolla									1					1						
SPECIES GROUP 53																				
Pterothrix spinescens				3	3		1					2		1						
Convolvulus boedeckerianus				2	3		1	1				2		1						
SPECIES GROUP 54																				
Gazania krebsiana		1	1	4	4	2	4	1			2	4	1	1			1			
Solanum incanum		1	1	2		1		2	2	2	1			1						
Ziziphus mucronata		2	2	3		2		4	2	2				1						
Ehretia rigida		1	2	4		1	2	1	3	3			1	1		2				
Selago albida		1	2	3	1		1	1					1	1						
Osteospermum muricatum		1	1						1	1	1		1	1						
Protasparagus striatus		1	2	2					1	2				1						
Aloe grandidentata		1	1	1				1	1	1					1					
SPECIES GROUP 55																				
Felicia muricata	1	1	2	5	5	2	2	4	1	2	3	2	2	2			1			
Sporobolus fimbriatus	1	2	2	5	2	2	1	4	2	4		4	2	1			1	1		
Setaria sphacelata	1	1	1	2	2	1		2			5	5	2	1						
Eragrostis superba	1	1	1	2	3	1		1	1	1	2		1	1						
Rhus ciliata	1	2	4	4	1	2	1		1	1			1	1	1					
Enneapogon scoparius	1	1	2	4	3			1	3	2				1						3
Felicia filifolia	5	2	3	3					1	1	1	3	1	1						
Triraphis andropogonoides	1		1	1	1					1	1	2	1	1						
Hermannia vestita	1		1	2	1	3			1	2			1	1						
Pseudognaphalium luteo-album	1		1	1	2			2		1			1	1			1	1		
Stachys rugosa	1		2	2		2			1	1				1						

CLASS NUMBER	1	2.1	2.2	2.3	3.1	3.2	4	5	6.1	6.2	7	8	9	10	11	12	13	14	15	16
SPECIES GROUP 56																				
Oropetium capense				1	3		2	1							5					
Eragrostis nindensis	1		1	1	1	2	1			1				1	4					
Eberlanzia spinosa			1	1	1		3		1					1	4					
Euphorbia mauritanica			1	1					1					1	3					
Senecio radicans			1												3					
Anacampseros truncata			1					1							3					
Chasmatophyllum musculinum				1	1					1					3					
Crassula nudicaulis			1	1											3					
Sarcostemma viminale			1	1											3					
Bonatea speciosa			1	1											2					
Euphorbia rectirama			1	1						1					2					
Crassula dependens				1											2					
Pteronia species					1										2					
Orbeopsis lutea				1	1		1								1					
Albuca setosa			1												1					
Gladiolus permeabilis				1											1					
Adromischus trigynus				1											1					
Helichrysum species													1		1					
SPECIES GROUP 57																				
Anacampseros filamentosa															4					
Stomatium mustellinum															4					
Anacampseros ustulata															3					
Crassula corallina															3					
Neohenricia sibbettii															2					
Otholobium prodiens															2					
Trachyandra saltii															2					
SPECIES GROUP 58																				
Anthospermum rigidum				3	2						2	3			2					
Mariscus capensis				3	2									1	3					
SPECIES GROUP 59																				
Tragus koelerioides			1	5	5	3	5	1			5	2	1	1	2					
Digitaria eriantha			3	5	3	2		2	2	3		5	4	1	1					
Commelina africana			1	2	3		1	1		1			1		2					
SPECIES GROUP 60																				
Hermannia coccocarpa		1	1	3	4	4	1	1		1	1	3	1	1	1					
Geigeria filifolia		1	1	2	3	2	4	1		1	1	2	1		2					
Eustachys paspaloides		1	2	5	1				1	1		2	1		1					
Nenax microphylla		1	1	3	3			1		2		2	1	1	1					

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CLASS NUMBER                      12223345667891111111
                                   .....   ..  0123456
                                   12312   12

SPECIES GROUP 61
Heteropogon contortus             3345331145351111
Aristida congesta                 1235555223343222
Aristida diffusa                  2235312 3212223

SPECIES GROUP 62
Phragmites australis               1     1       52
Salix mucronata                          1       51
Verbena bonariensis                  1    2 11 11 4
Rumex lanceolatatus                          1  1  42
Cyperus longus                     2     1       432
Lactuca dregeana                             1  1  212
Paspalum dilatatum                1 1       1 11 21
Oenothera rosea                     11   2       21
Cynodon incompletus                 11   2 1  11 221
Melolobium candicans               11   1 12  12 2 1
Euryops multifidus                1 1     1    112
Thesium species                   1 11     1     2
Sida dregei                         11     1     2
Phyla nodiflora                     1 1  1       2
Convolvulus arvensis                1    1    1  2
Schinus molle                       1          1 2
Leucas martinicensis                 1   1       2
Equisetum ramosissimum                   1       2
Scirpus inanis                           1       2
Gomphostigma virgatum                    1       2
Tetrachne dregei                            11   2
Nicotiana glauca                         1       21
Miscanthus capensis                  1           211
Ranunculus multifidus                            2 1

SPECIES GROUP 63
Salix babylonica                                 5
Conium chaerophylloides                          2
Datura ferox                                     2
Hemarthria altissima                             2
Mentha longifolia                                2
Polygonum kitaibelianum                          2

SPECIES GROUP 64
Acacia karroo                     213211511   1 41
Tagetes minuta                    31    3 1  21 411
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CLASS NUMBER	1	2.1	2.2	2.3	3.1	3.2	4	5	6.1	6.2	7	8	9	10	11	12	13	14	15	16
SPECIES GROUP 65																				
Themeda triandra	5	5	5	5	5	3		2	2	4	5	5	5	1	1	2		1		
Rhus burchellii	3	3	4	4		3	1	1	1	2		2		1		2				
Oxalis depressa	1	1	2	1	4			3			1	2	1	1	1	2				
Rhus lancea	1	3	2	1		1		1		1				1		2				
Artemisia afra	1	2	1	1				2		1			1			2				
SPECIES GROUP 66																				
Mariscus congestus			1							1			1	1			4	1		
Cyperus rupestris				1							1		1		3		3	1		
Medicago sativa										1			1	1			3			
Agrostis lachnantha				1				1					1				2	1		
Juncus rigidus													1				2			
Pulicaria scabra				1													1			
SPECIES GROUP 67																				
Persicaria serrulata																	4			
Cichorium intybus																	2			
Alternanthera nodiflora																	1			
Convolvulus sagittatus																	1			
Cyperus eragrostis																	1			
Schoenoplectus paludicola																	1			
SPECIES GROUP 68																				
Typha capensis																2	3			
Juncus exsertus																2	2			
SPECIES GROUP 69																				
Nidorella resedifolia			1	1	3			3		1	1		2	1	1		3			
Atriplex semibaccata			1	1	2			5		1			1	1			2			
SPECIES GROUP 70																				
Lycium hirsutum		2	1	1	1	3		5					1	1			1			
Panicum maximum		2	1	1				2		1			1	1			2			
SPECIES GROUP 71																				
Diospyros lycioides	3	5	2	5		1		5	1		1		1			4	3			
Hyparrhenia hirta	2	2	1	2		1						3					1			
Vahlia capensis	1		1		2							2	1				2			
Salvia runcinata	1		1	1	1			1		1			1				1			
Euryops empetrifolius	1	1	1	1									1	1	1		2			
Hyparrhenia dregeana	1	1	1							1			1				2			

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CLASS NUMBER                  12223345667891111111
                                           0123456
                               .....  ..
                               12312  12
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SPECIES GROUP 72
Lobelia thermalis                1 2      11   4
Cirsium vulgare                 1      1  1  213
Wahlenbergia androsacea        111 1            2
Scirpus nodosus                           1     2
Fuirena hirsuta                           1     1
Sporobolus virginicus                     1     1
Atriplex nummularia                        1    1
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SPECIES GROUP 73
Phragmites mauritianus                          2
Scirpus dioecus                                 2
Sporobolus tenellus                             2
Cyperus laevigatus                              1
Cyperus species                                 1
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SPECIES GROUP 74
Juncus kraussii                                24
Portulaca oleracea                             22
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SPECIES GROUP 75
Salsola glabrescens            1233521   13   2
Xanthium spinosum              1 1  11   1    1
Cyperus marginatus             11 2 1    11 223
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SPECIES GROUP 76
Eragrostis obtusa              11555322253331  2
Chrysocoma ciliata             235455333 333 2 1
Tragus berteronianus           1111251 13 211  2
Protasparagus laricinus        3231 4421  11 421
Asclepias fruticosa            111   2 1 211 242
Berkheya onopordifolia         1111  1 13221   1
Tribulus terrestris            11    121  11 4 1
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SPECIES GROUP 77
Eragrostis lehmanniana         123555531323431  2
Protasparagus suaveolens       1335245534  121 11
Berkheya pinnatifida           21114213 15 21 2 1
Chenopodium album              11121 2331  21  12
Walafrida saxatilis            13245 13 2 322   1
Talinum caffrum                1 134 22211  1   1
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CLASS NUMBER	1	2.1	2.2	2.3	3.1	3.2	4	5	6.1	6.2	7	8	9	10	11	12	13	14	15	16
SPECIES GROUP 78																				
Hibiscus trionum	1	2	1	1	2			1			1		1						5	
Schkuhria pinnata			1					1	1	1			2		1				5	
Setaria incrassata	2	2	1					1					1						5	
Xanthium strumarium		1	1					1								2	2		5	
Rumex crispus								1		1				1		2	2		5	
SPECIES GROUP 79																				
Diplachne fusca																			5	
SPECIES GROUP 80																				
Salvia verbenaca	1	1	1	1	2	1		1		1			2	1		2	1		5	
Eragrostis curvula	2	4	2	5	3	3		4	3	2	2	5	3	2		2		1	5	
Chloris virgata			1	1	2	3	1	3	1	1	3		2	1				1	5	
SPECIES GROUP 81																				
Helichrysum pentzioides			1					1		1				1				1		5
Aristida canescens				1	1						3			1						3
Lycium pilifolium							3							1		2				3
Sporobolus ioclados								1						1				2		3
Osteospermum spinescens							1							1						3
Protasparagus mucronatus			1						2					1						3
SPECIES GROUP 82																				
Eriocephalus spinescens				3	2	1	3		2	1				2	3					3
SPECIES GROUP 83																				
Lycium cinereum		2	1	1		2	1	5	1	1	3		1	3			1	1		3
Pentzia globosa			2	4	3	5	2	3	4	2	4	3	3	4		2		2		3
Fingerhuthia africana			1	3	2	4	3	1	3	3				2						5
Pentzia incana			1	1	3		5	2	1	1			1	2				1		3
Stipagrostis obtusa			1	1			5		1	1				1						5
Barleria rigida			1	2		1	5		2	2				1						3
Rhigozum trichotomum			1	1			4		1	1				1						3
Thesium hystrix			1	2	2	4	3	1	1					2						3
Stipagrostis ciliata			1	1			4							1						3
Lycium horridum			1						2	1				2				1		3
SPECIES GROUP 84																				
Ruschia hamata	2	1	1	1	1			1		1	2		1	1						3
Panicum coloratum	1		1	1	4	1			1		5		2	1				2		3

11.4 REFERENCES

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CHAPTER 12

Vegetation ecology of the southern Free State

Vegetation ecology of the southern Free State: A floristic analysis.

CHAPTER 12

VEGETATION ECOLOGY OF THE SOUTHERN FREE STATE: A FLORISTIC ANALYSIS.

A checklist of all the species collected and recorded during the survey is presented. The families and species are arranged alphabetically (Bryophyta, Pteridophyta, Gymnospermae, Monocotyledonae and Dicotyledonae separately), thus making quick reference easier. Taxon and author names confirm to those of Arnold & De Wet (1993). Naturalized exotic taxa are marked with an asterisk (*).

The relationship between the number of families, genera and species of Bryophyta, Pteridophyta, Gymnospermae, Monocotyledonae and Dicotyledonae is given in Table 1. The most prominent families and genera are given in Tables 2 and 3 respectively. A list of all the naturalized exotic species is presented in Table 4.

BRYOPHYTA

Pottiaceae

Aloina sp. (Malan 1122, BFLU)

PTERIDOPHYTA

Adiantaceae

Cheilanthes eckloniana (Kuntze) Mett.
C. hirta Swartz var. hirta
C. quadripinnata (Forssk.) Kuhn
C. viridis (Forssk.) Swartz

Pellaea calomelanos (Swartz) Link

Aspleniaceae

Ceterach cordatum (Thunb.) Desv.

Azollaceae

Azolla filiculoides Lam *

Equisetaceae

Equisetum ramosissimum Desf.

Schizaeaceae

Mohria caffrorum (L.) Desv.

GYMNOSPERMAE

Cupressaceae

Cupressus torulosa D. Don *

ANGIOSPERMAE

MONOCOTYLEDONAE

Alliaceae

Tulbaghia acutiloba Harv.

Amaryllidaceae

Ammocharis coranica (Ker-Gawl.) Herb.
Boophane disticha (L. f.) Herb.
Brunsvigia radulosa Herb.
Crinum bulbispermum (Burm. F.) Milne-Redh. & Schweick.
Gethyllis undulata
Haemanthus humilis Jacq.
Nerine laticoma (Ker-Gawl.) Dur & Schinz

Asparagaceae

Protasparagus capensis (L.) Oberm.
P. cooperi (Bak.) Oberm.
P. denudatus (Kunth) Oberm.
P. glaucus (Kies) Oberm.
P. laricinus (Burch.) Oberm.
P. mucronatus
P. setaceus (Kunth) Oberm.
P. striatus (L.F.) Oberm.
P. suaveolens (Burch.) Oberm.
Protasparagus sp. (Malan 227, BFLU)

Asphodelaceae

Aloe broomii Schonl.
A. claviflora Burch.
A. ferox Mill.
A. grandidentata Salm-Dyck
A. hereroensis Engl.
Bulbine abyssinica A. Rich.
B. narcissifolia Salm-Dyck
Haworthia tessellata (Salm-Dyck) Bak.
Trachyandra asperata Kunth

T. saltii (Bak.) Oberm.

Commelinaceae

Commelina africana L.
C. benghalensis L.
C. eckloniana Kunth

Cyperaceae

Carex schlechteri Nelmes
Cyperus bellus Kunth
C. difformis L.
C. eragrostis Lam. *
C. laevigatus L.
C. longus L.
C. margaritaceus Vahl
C. marginatus Thunb.
C. obtusifloris Vahl.
C. rupestris Kunth var. rupestris
C. usitatus Burch.
Cyperus sp. (Malan 861, BFLU)
Ficinia sp. (Malan 480, BFLU)
Fuirena hirsuta (Berg.) P.L. Forbes
Kyllinga alba Nees
Mariscus capensis (Steud.) Schrad.
M. congestus (Vahl) C.B. CL.
M. indecorus (Kunth) Podlech
Pycreus macranthus (Boeck.) C.B. Cl.
Schoenoplectus paludicola (Kunth) Palla ex J. Raynal
Schoenoxiphium sparteum (Wahlenb.) C.B. Cl.
Scirpus dioecus (Kunth) Boeck.
S. inanis (Thunb.) Steud.
S. nodosus Rottb.

Dracaenaceae

Sansevieria aethiopica Thunb.

Hyacinthaceae

Albuca setosa Jacq.
A. shawii Bak.
Dipcadi glaucum (Ker-Gawl.) Bak.
D. viride (L.) Moench
Eucomis autumnalis (Mill.) Chitt.
Massonia jasminiflora Burch. ex Bak.
Ornithogalum cf. dubium Houtt.
O. prasinum Lindl.
Polyxena cf. odorata (Hook. f.) Bak.
Scilla nervosa (Burch.) Jessop
Ledebouria luteola Jessop
L. ovatifolia (Bak.) Jessop

Hypoxidaceae

Hypoxis filiformis Bak.
H. hemerocallidea Fisch. & Mey.
H. iridifolia Bak.

Iridaceae

Duthiastrum linifolium (Phill.) De Vos
Gladiolus permeabilis Delaroche
Homeria pallida Bak.
Moraea polystachya (Thunb.) Ker-Gawl.
M. spathulata (L.f.) Klatt

Juncaceae

Juncus exsertus Buchen.
J. kraussii Hochst.
J. rigidus Desf.

Orchidaceae

Bonatea speciosa (L.f.) Willd.

Poaceae

Agrostis lachnantha Nees
Andropogon appendiculatus Nees
Anthephora pubescens Nees
Aristida adscensionis L.
A. bipartita (Nees) Trin. & Rupr.
A. canescens Henr.
A. congesta Roem. & Schuldt
A. diffusa Trin.
A. junciformis Trin. Rupr.
Arundo donax L. *
Brachiaria eruciformis (J.E. Sm.) Griseb.
B. serrata (Thunb.) Stapf
Bromus catharticus Vahl *
B. unioloides H.B.K.
Bromus sp. (Malan 82, BFLU)
Cenchrus ciliaris L.
Chloris virgata Swartz
Coelachyrum yemenicum (Schweinf.) S.M. Phillips
Cymbopogon dieterlenii Stapf ex Phill.
C. excavatus Hochst.
C. plurinodis Stapf
Cynodon dactylon (L.) Pers.

C. hirsutus Stent
C. incompletus Nees
Diheteropogon filifolius Nees
Digitaria argyrograpta (Nees) Stapf
D. eriantha Steud.
Diplachne fusca (L.) Beauv. ex Roem. & Schult.
Ehrharta erecta Lam.
Elionurus muticus (Spreng.) Kunth
Enneapogon cenchroides (Roem. & Schult.) C.E. Hubb.
E. desvauxii Beauv.
E. scaber Lehm.
E. scoparius Stapf
Eragrostis bergiana (Kunth) Trin.
E. bicolor Nees
E. capensis (Thunb.) Trin.
E. chloromelas Steud.
E. curvula (Schad.) Nees
E. echinochloidea Stapf
E. gummiflua Nees
E. lehmanniana Nees
E. micrantha Hack.
E. nindensis Fical. & Hiern
E. obtusa Munro ex Fical. & Hiern
E. plana Nees
E. porifolius Nees
E. racemosa (Thunb.) Steud.
E. superba Peyr.
E. trichophora Coss. & Dur.
E. truncata Hack.
Eriochloa parvispiculata C.E. Hubb.
Eustachys paspaloides (Vahl) Lanza & Matthei
Fingerhuthia africana Lehm.
Harpochloa falx (L.f.) Kuntze
Helictotrichon turgidulum (Stapf) Schweick.
Hemarthria altissima (Poir.) Stapf & C.E. Hubb.
Heteropogon contortus (L.) Roem. & Schult.

Hyparrhenia dregeana (Nees) Stapf
H. hirta (L.) Stapf
Koeléria capensis (Steud.) Nees
Melica decumbens Thunb.
Melinis nerviglume (Franch.) Zizka
M. repens (Willd.) C.E. Hubb.
Microchloa caffra Nees
Miscanthus capensis (Nees) Anderss.
Oropetium capense Stapf
Panicum coloratum L.
P. deustum Thunb.
P. maximum Jacq.
P. schinzii Hack.
P. stapfianum Fourc.
Paspalum dilatatum Poir. *
P. distichum L.
Pennisetum setaceum (Forssk.) Chiov. *
P. sphacelatum (Nees) Dur. & Schinz
Pentaschistis setifolia (Thunb.) McClean
Phragmites australis (Cav.) Steud.
P. mauritianus Kunth
Pogonarthria squarrosa (Licht.) Pilg.
Schmidtia kalahariensis Stent
S. pappophoroides Steud.
Setaria incrassata (Hochst.) Hack.
S. lindenbergiana (Nees) Stapf
S. nigrirostris (Nees) Dur. & Schinz
S. pallide-fusca (Schumach.) Stapf & C.E. Hubb.
S. sphacelata (Schumach.) Moss
S. verticillata (L) Beauv.
Sorghum bicolor (L.) Moench
S. halepense (L.) Pers. *
Sporobolus discoporus Nees
Sporobolus cf. festivus A. Rich.
S. fimbriatus (Trin.) Nees var. fimbriatus
S. ioclados (Trin.) Nees

S. ludwigii Hochst.
S. tenellus (Spreng.) Kunth
S. virginicus (L.) Kunth
Stipagrostis brevifolia (Nees) De Winter
S. ciliata (Desf.) De Winter
S. namaquensis (Nees) De Winter
S. obtusa (Del.) Nees
S. uniplumis (Licht.) De Winter
Tetrachne dregei Nees
Themeda triandra Forssk.
Trachypogon spicatus (L.f.) Kuntze
Tragus berteronianus Schuldt
T. koelerioides Aschers.
T. racemosus (L.) All.
Trichoneura grandiglumis (Nees) Ekman
Triraphis andropogonoides (Steud.) Phill.
Tristachya leucothrix Nees
Urochloa panicoides Beauv.

Potamogetonaceae

Potamogeton pusillus L.

Typhaceae

Typha capensis (Rohrb.) N.E. Br.

DICOTYLEDONAE

Acanthaceae

Barleria irritans Nees

B. macrostegia Nees

B. rigida Nees

Blepharis diversispina (Nees) C.B. Cl.

B. integrifolia (L.f.) E. Mey.

B. villosa (Nees) C.B. Cl.

Crabbea acaulis N.E. Br.

Justicia cuneata Vahl

J. protracta (Nees) T. Anders.

Monechma divaricatum (Nees) C.B. Cl.

M. incanum (Nees) C.B. Cl.

Aizoaceae

Corbichonia decumbens (Forssk.) Exell

Galenia africana L.

G. sarcophylla Fenzl

Hypertelis salsoloides (Burch.) Adamson

Limeum aethiopicum Burm.

L. sulcatum (Klotzsch) Hutch.

Plinthus cryptocarpus Fenzl

P. karooicus Verdoorn

Psammotropha mucronata (Thunb.) Fenzl

Tetragonia arbuscula Fenzl

Amaranthaceae

Achyranthes aspera L.

Alternanthera nodiflora R. Br. *

A. pungens H.B.K. *

A. repens (L.) Kuntze

A. sessilis (L.) DC. *

Amaranthus caudatus L. *

A. hybridus L. *

A. thunbergii Moq.

Centrostachys aquatica (R. Br.) Wall. ex Moq.
Guilleminea densa (Willd.) Moq.
Kyphocarpa angustifolia (Moq.) Lopr.
Pupalia lappacea (L) Juss.
Sericorema remotiflora (Hook.f.) Lopr.

Anacardiaceae

Rhus burchellii Sond. ex Engl.
R. ciliata Licht. ex Schuldt
R. dentata Thunb.
R. divaricata Eckl. & Zeyh.
R. dregeana Sond.
R. erosa Thunb.
R. lancea L.f.
R. pendulina Jacq.
Rhus pyroides Burch. var. gracilis (Engl.) Burtt Davy
Rhus pyroides Burch. var. pyroides
Schinus molle L. *

Apiaceae

Berula erecta (Hudson) Cov. subsp. thunbergii (D.C.) B.L. Burtt
Chamarea capensis (Thunb.) Eckl. & Zeyh.
Conium chaerophylloides (Thunb.) Sond.
Deverra denudata (Viv.) Pfisterer & Podl.
Heteromorpha trifoliata (Wendl.) Eckl. & Zeyh.
Peucedanum capense (Thunb.) Sond.

Apocynaceae

Pachypodium succulentum (L.f.) Sweet

Araliaceae

Cussonia paniculata Eckl. et Zeyh.

Asclepiadaceae

Asclepias crispa Berg
A. fruticosa L.
Hoodia gordonii (Mass.) Sweet ex Decne.
Microloma armatum (Thunb.) Schltr.
Orbeopsis lutea (N.E. Br.) Leach
Pentarrhinum insipidum E. Mey.
Riocreuxia torulosa Decne.
Sarcostemma viminale (L.) R. Br.
Schizoglossum capitatum Schltr.
S. linifolium Schltr.
Stapelia grandiflora Mass.
Stenostelma capense Schltr.

Asteraceae

Arctotis arctotoides (L.f.) O. Hoffm.
A. venusta T. Norl.
Artemisia afra Jacq. ex Willd.
Athrixia angustissima DC.
Berkheya discolor (DC.) O. Hoffm. & Muschl.
B. onopordifolia (DC.) O. Hoffm. ex Burtt Davy
B. pinnatifida (Thunb.) Thell.
B. setifera DC.
Bidens bipinnata L. *
B. formosa L. *
B. pilosa L. *
Chrysocoma ciliata L.
Cichorium intybus L. *

Cineraria aspera Thunb.
C. lobata L 'Hérit.
C. lyrata DC.
Cirsium vulgare (Savi) Ten. *
Conyza bonariensis (L.) Cronq. *
C. podocephala DC.
Cotula anthemoides L.
Denekia capensis Thunb.
Dicoma anomala Sond.
D. macrocephala DC.
Dimorphotheca cuneata (Thunb.) Less.
D. zeyheri Sond.
Epaltes gariepina (DC.) Steets
Eriocephalus aspalathoides DC.
E. ericoides (L.f.) Druce
E. pubescens DC.
E. spinescens Burch.
Euryops annae Phill.
E. empetrifolius DC.
E. laterifloris (L.f.) DC.
E. multifidus (Thunb.) DC.
Felicia filifolia (Vent.) Burtt Davy
F. flanaganii H. Bol.
F. muricata (Thunb.) Nees
Flaveria bidentis (L.) Kuntze *
Garuleum pinnatifidum (Thunb.) DC.
Gazania krebsiana Less.
Geigeria aspera Harv.
G. filifolia Mattf.
G. ornativa O. Hoffm.
Gerbera piloselloides (L.) Cass.
G. viridifolia (DC.) Sch. Bip.
Haplocarpa scaposa Harv.
Helichrysum appendiculatum (L.f.) Less.
H. argyrosphaerum DC.
H. asperum (Thunb.) Hilliard & Burtt

H. caespititium (DC.) Harv.
H. callicomum Harv.
H. cerastioides DC.
H. dregeanum Sond. & Harv.
H. erubescens Hilliard
H. lineare DC.
H. longifolium DC.
H. lucilioides Less.
H. niveum (L.) Less.
H. nudifolium (L.) Less.
H. pentzioides Less.
H. pilosellum (L.f.) Less.
H. rosum (Berg.) Less.
H. rugulosum Less.
H. zeyheri Less.
Helichrysum sp. (Malan 998, BFLU)
Hertia ciliata (Harv.) Kuntze
H. pallens Less.
Ifloga paronychioides (DC.) Fenzl
Kleinia longifolia DC.
Lactuca capensis Thunb.
L. dregeana DC.
L. serriola L.
Nestlera conferta DC.
Nidorella auriculata DC.
N. resedifolia DC.
Nolletia arenosa O. Hoffm.
N. ciliaris (DC.) Steetz
Osteospermum leptolobum (Harv.) T. Norl.
O. muricatum E. Mey. ex DC.
O. scariosum DC.
O. spinescens Thunb.
Pegolettia retrofracta (Thunb.) Kies
Pentzia calcarea Kies
P. globosa Less.
P. incana (Thunb.) Kuntze

P. sphaerocephala DC.
P. spinescens Less.
P. viridis Kies
Phymaspermum aciculare (E. Mey. ex Harv.) Benth. & Hook. ex Jackson
P. parvifolium (DC.) Benth. & Hook. ex Jackson
Pseudognaphalium luteo-album (L.) Hillard & Burtt
P. oligandrum (DC.) Hillard & Burtt
P. undulatum (L.) Hillard & Burtt
Pteronia glauca Thunb.
P. incana (Burm.) DC.
P. sordida N.E. Br.
Pteronia sp. (Malan 587, BFLU)
Pterothrix spinescens DC.
Pulicaria scabra (Thunb.) Druce
Rhynchopsidium pumilum (L.f.) DC.
Rosenia humilis (Less.) Bremner
Schistostephium crataegifolium (DC.) Fenzl ex Harv.
Schkuhria pinnata (Lam.) Cabr. *
Senecio affinis DC.
S. burchellii DC.
S. consanguineus DC.
S. coronatus (Thunb.) Harv.
S. erubescens Ait.
S. hastatus L.
S. hieracioides DC.
S. inaequidens DC.
S. inornatus DC.
S. isatideus DC.
S. latifolius DC.
S. radicans (L.f.) Sch. Bip.
S. retrorsus DC.
Sonchus hypochoeridea L.
S. oleraceus L.
Stoebe plumosa (L.) Thunb.
S. vulgaris Levyns
Syncarpha argyropsis (DC.) B. Nord.

Tagetes minuta L. *
Tarchonanthus camphoratus L.
Tragopogon dubius Scop. *
Vernonia capensis (Houtt.) Druce
Xanthium spinosum L. *
X. strumarium L. *
Zinnia peruviana (L.) L. *

Bignoniaceae

Rhigozum obovatum Burch.
R. trichotomum Burch.

Boraginaceae

Anchusa capensis Thunb.
Ehretia rigida (Thunb.) Druce
Heliotropium curassavicum L.
H. lineare (A. DC.) C.H. WR.
H. zeylanicum (Burm. f.) Lam.
Lappula squarrosa (L.) Dumort.
Lithospermum cinereum DC.

Brassicaceae

Heliophila carnosa Steud.
H. suavissima Burch. ex DC.
Lepidium africanum (Burm. f.) DC.
Sisymbrium capense Thunb.
S. thellungii O.E. Sculz

Cactaceae

Cereus cabrera Mill. *
Opuntia ficus-indica (L.) Mill. *
O. imbricata (Haw.) DC. *
O. vulgaris Mill. *
Opuntia sp. * (Malan 392, BFLU)
Pseudocactus sp. * (Malan 268, BFLU)

Caesalpineaceae

Senna italica Mill. *

Campanulaceae

Lightfootia albens Spreng. ex A. DC.
L. denticulata (Burch.) Sond.
L. nodosa Buek
Lobelia erinus L.
L. thermalis Thunb.
Wahlenbergia androsacea A. DC.
W. denticulata (Burch.) A. DC.
W. undulata (L.f.) A. DC.

Capparaceae

Boscia albitrunca Schinz
Cadaba aphylla (Thunb.) Wild
Cleome angustifolia Forssk.

Caryophyllaceae

Dianthus basuticus Burtt Davy
Polycarpon tetraphyllum L. f.
Silene undulata Ait.

Celastraceae

Maytenus heterophylla (Eckl. & Zeyh.) N.K.B. Robson
M. polyacantha (Sond.) Marais

Chenopodiaceae

Atriplex erosa Brückner & Verdoorn
A. nummularia Lindl. *
A. semibaccata R. Br.
Chenopodium album L. *
C. ambrosioides L. *
C. cristatum F. Müll.
C. murale L. *
Salsola calluna Fenzl ex C.H. Wr.
S. glabrescens Burtt Davy
S. kali L.
S. rabieana Verdoorn
Suaeda fruticosa (L.) Forssk.

Clusiaceae
Hypericum aethiopicum Thunb.

Convolvulaceae

Convolvulus arvensis L. *

C. boedeckerianus Peter
C. sagittatus Thunb.
Ipomoea bathycolpos Hallier f.
Merremia verecunda Rendle
Turbina oblongata (E. Mey. ex Choisy) A. Meeuse
T. oenotheroides (L.f.) A. Meeuse

Crassulaceae

Adromischus triflorus (L.f.) Berger
A. trigynus (Burch) V. Polln.
Cotyledon orbiculata L.
Crassula capitella Thunb.
C. corallina Thunb.
C. dependens H. Bol.
C. exilis Harv.
C. lanceolata (Eck & Zeyh.) Endl. ex Walp.
C. muscosa L. var. muscosa
C. natans Thunb.
C. nudicaulis L.
C. orbicularis L.
C. sarcocaulis Eck. & Zeyh.
C. setulosa Harv. var. setulosa
Kalanchoe paniculata Harv.
K. rotundifolia (Haw.) Haw.
K. thyrsiflora Harv.

Cucurbitaceae

Acanthosicyos naudinianus Welw. ex Hook. f.
Coccinia hirtella Cogn.
C. sessilifolia (Sond.) Cogn.
Cucumis myriocarpus Naud.
Kedrostis africana (L.) Cogn.

Dipsacaceae

Scabiosa columbaria L.

Ebenaceae

Diospyros austro-africana De Winter
D. lycioides Desf.
Euclea coriacea A. DC.
E. crispa (Thunb.) Guerke subsp. crispa
E. crispa (Thunb.) Guerke subsp. ovata (Burch.) F. White

Euphorbiaceae

Clutia pulchella L.
Chamaesyce inaequilatera (Sond.) Sojak
C. prostrata (Ait.) Small *
Euphorbia aequoris N.E. Br.
E. caterviflora N.E. Br.
E. clavarioides Boiss.
E. mauritanica L.
E. rectirama N.E. Br.
E. striata Thunb.
Phyllanthus burchellii Müll
P. maderaspatensis L.
P. parvulus Sond.

Fabaceae

Argyrolobium lanceolatum Eckl. & Zeyh.
A. pauciflorum Eckl. & Zeyh.
Crotalaria distans Benth.
C. eremicola Bak. f.

Cullen obtusifolia (DC.) C. H. Stirton
Dolichos linearis E. Mey.
Elephantorrhiza elephantina (Burch.) Skeels
Gleditsia triacanthos L. *
Indigofera alternans DC.
I. cryptantha Benth. ex Harv.
I. nigromontana Eckl. & Zeyh.
I. rhytidocarpa Benth. ex Harv.
I. sessilifolia DC.
I. setiflora Balk.
Indigofera sp. (Malan 315, BFLU)
Lessertia annularis Harv.
L. cf. depressa Harv.
L. pauciflora Harv.
Lotononis calycina (E. Mey.) Benth.
L. laxa Eckl. & Zeyh.
L. listii Polhill
L. tenella Eckl. & Zeyh.
Medicago laciniata (L.) Mill.
M. polymorpha L.
M. sativa L. *
Melolobium calycinum Benth.
M. candicans (E. Mey) Eck. & Zey.
M. microphyllum (L.F.) Eckl. & Zeyh.
Otholobium prodiens C.H. Stirton
Prosopis chilensis (Mol.) Stuntz *
P. velutina Wooton *
Rhynchosia caribaea (Jacq.) DC.
R. confusa Burtt Davy
R. nervosa Benth. & Harv.
R. totta (Thunb.) DC.
Sutherlandia frutescens (L.) R. Br.
S. microphylla Burch. ex DC.
Tephrosia capensis (Jacq.) Pers.
Vicia sativa L. *

Gentianaceae

Sebaea filiformis Schinz
S. leiostyla Gilg

Geraniaceae

Monsonia angustifolia E. Mey. ex A. Rich.
Pelargonium abrotanifolium (L.f.) Jacq.
P. alchemilloides (L.) L'Hérit.
P. aridum R.A. Dyer
P. myrrhifolium (L.) L'Hérit
P. tragacanthoides Burch.
Sarcocaulon salmoniflorum Moffett

Illecebraceae

Pollichia campestris Ait.

Lamiaceae

Ajuga ophrydis Burch. ex Benth.
Becium angustifolium (Benth.) N.E. Br.
Leonotis ocymifolia (Burm. f.) Iwarsson
Leucas capensis (Benth.) Engl.
L. martinicensis (Jacq.) R. Br.
Mentha longifolia (L) Huds.
Salvia disermas L.
S. namaensis Schinz
S. repens Burch. ex Benth.
S. runcinata L.f.
S. stenophylla Burch.
S. verbenaca L.

Stachys burchelliana Launert
S. hyssopoides Burch. ex Benth.
S. rugosa Ait.
Teucrium trifidum Retz.

Linaceae

Linum thunbergii Eckl. & Zeyh.

Loganiaceae

Gomphostigma virgatum (Lf.) Baill.
Buddleja saligna Willd.
B. salviifolia (L.) Lam.

Malvaceae

Abutilon austro-africanum Hochr.
A. grandifolium (Willd.) Sweet
A. piloso-cinereum A. Meeuse
A. pycnodon Hochr.
Hibiscus aethiopicus L.
H. lunarifolius Willd.
H. malacospermus (Turcz.) E. Mey. ex Harv.
H. marlothianus K. Schum.
H. microcarpus Garcke
H. pusillus Thunb.
H. trionum L.
Pavonia burchellii (DC.) R.A. Dyer
Sphaeralcea bonariensis (Cav.) Griseb. *
Sida dregei Burtt Davy
Radyera urens (L.f.) Bullock

Meliaceae

Melia azederach L. *

Melianthaceae

Melianthus comosus Vahl

Menispermaceae

Antizoma angustifolia (Burch.) Miers ex Harv.

Mesembryanthemaceae

Chasmatophyllum musculinum (Haw.) Dinter & Schwant.
Delosperma cooperi (Hook.f.) L. Bol.
D. mahonii (N.E. Br.) N.E. Br.
D. pottsii (L. Bol) L. Bol.
Delosperma sp. (Malan 119, BFLU)
Drosanthemum sp. (Malan 1123, BFLU)
Eberlanzia spinosa (L.) Schwant.
Mestoklema arboriforme (Burch.) N.E. Br. ex Glen
M. tuberosum (L.) N.E. Br. ex Glen
Nananthus vittatus (N.E. Br.) Schwant.
Neohenricia sibbettii (L. Bol.) L. Bol.
Psilocaulon absimile N.E. Br.
P. junceum (Haw.) Schwant.
Stomatium mustellinum (Salm-Dyck) Schwant.
Ruschia hamata (L. Bol.) Schwant.
R. rigens L. Bol.
R. rigida (Haw.) Schwant.
Ruschia sp. (Malan 766, BFLU)
Trichodiadema barbatum (L.) Schwant.

T. pomeridianum L. Bol.

Mimosaceae

Acacia erioloba E. Mey.
A. hebeclada DC.
A. mellifera (Vahl) Benth.
A. karroo Hayne
A. tortilis (Forssk.) Hayne subsp. heteracantha

Myrsinaceae

Myrsine africana L.

Myrtaceae

Eucalyptus sp. * (Malan 68, BFLU)

Nyctaginaceae

Commicarpus pentandrus (Burch.) Heimerl
Phaeoptilum spinosum Radlk.

Ochnaceae

Ochna serrulata (Hochst.) Walp.

Oleaceae

Menodora africana Hook.
Olea europaea subsp. africana (Mill.) P.S. Green

Onagraceae

Oenothera biennis L. *
O. indecora Cambess. *
O. rosea L'Herit. ex Ait. *
O. stricta Ledeb. ex Link *
O. tetraptera Cav. *
Oenothera sp. * (Malan 221, BFLU)

Oxalidaceae

Oxalis corniculata L. *
O. depressa Eckl. & Zeyh.

Papaveraceae

Argemone mexicana L. *
A. ochroleuca Sweet subsp. ochroleuca *
Papaver aculeatum Thunb.

Pedaliaceae

Harpagophytum procumbens (Burch.) DC. ex Meissn.
Sesamum capense Burm. f.
S. triphyllum Welw.

Penaeaceae

Saltera sarcocolla (L.) Bullock

Periplocaceae

Raphionacme hirsuta (E. Mey.) R.A. Dyer ex Phill.

Phytolacaceae

Gisekia pharnacioides L.

Plantaginaceae

Plantago lanceolata L. *

Polygalaceae

Polygala amatymbica Eckl. & Zeyh.
P. asbestina Burch.
P. ephedroides Burch.
P. hottentotta Presl
P. leptophylla Burch.
P. rehmannii Chod.
P. uncinata E. Mey. ex Meisn.

Polygonaceae

Persicaria attenuata (R. Br.) Sojak
P. serrulata (Lag.) Webb & Moq.
Polygonum aviculare L. *
P. hystriculum Schuster
P. kitaibelianum Sadler *
Rumex acetosella L.
R. crispus L. *
R. lanceolatus Thunb.

Portulacaceae

Anacampseros filamentosa (Haw.) Sims
A. lanceolata (Harv.) Sweet
A. telephiastrum DC.
A. truncata V. Poelln.
A. ustulata E. Mey. ex Sond.
Portulaca oleracea L. *
Talinum caffrum (Thunb.) Eckl. & Zeyh.

Ranunculaceae

Clematis brachiata Thunb.
Ranunculus multifidus Forssk.

Resedaceae

Oligomeris sp. (Malan 148, BFLU)

Rhamnaceae

Rhamnus prinoides L'Hérit.
Ziziphus mucronata Willd.

Rubiaceae

Anthospermum herbaceum L.F.
A. rigidum Eckl. & Zeyh.
A. spathulatum Spreng.
Kohautia amatymbica Eckl. & Zeyh.

Rosaceae

Althaea rosea L. *
Cliffortia nitidula (Enbl.) R.E. & Th. Fries Jr.
C. paucistaminea Weim.
Cotoneaster sp. * (Malan 89, BFLU)
Leucosidea sericea Eckl. & Zeyh.
Prunus persica (L.) Batsch *
Pyracantha crenulata (D. Don) M.J. Roem. *
Rosa eglanteria L. *

Rubiaceae

Nenax microphylla (Sond.) Salter
Rubia horrida (Thunb.) Puff
R. petiolaris DC.

Salicaceae

Populus canescens (Ait.) J. E. Sm. *
P. nigra L. *
Salix babylonica L. *
S. mucronata Thunb.

Santalaceae

Osyris lanceolata Hochst. & Steud.
Thesium hystrix A.W. Hill
T. spartioides A.W. Hill
T. strictum Berg.
Thesium sp. (Malan 280, BFLU)

Scrophulariaceae

Alectra orobanchoides Benth.
Aptosimum albomarginatum Marloth & Engl.
A. indivisum Burch. ex Benth.
A. marlothii (Engl.) Hiern
A. procumbens (Lehm.) Steud.
A. spinescens (Thunb.) Weber
Nemesia albiflora N.E. Br.
N. fruticans (Thunb.) Benth.
Peliostomum leucorrhizum E. Mey.
Striga bilabiata (Thunb.) Kuntze
S. elegans Benth.
Sutera albiflora Verdoorn
S. argentea (L.f.) Hiern
S. atropurpurea (Benth.) Hiern
S. aurantiaca (Burch.) Hiern
S. caurulea (L.f.) Hiern
S. crassicaulis (Benth.) Hiern
S. filicaulis (Benth.) Hiern
S. halimifolia (Benth.) Kuntze
S. kraussiana (Bernh. ex Krauss) Hiern
S. pinnatifida (Benth.) Kuntze
Veronica anagallis-aquatica L.

Selaginaceae

Hebenstretia integrifolia L.
Selago albida Choisy
S. galpinii Schltr.
S. speciosa Rolfe
Walafrida densiflora (Rolfe) Rolfe
W. geniculata (L.f.) Rolfe
W. saxatilis (E. Mey.) Rolfe

Solanaceae

Datura ferox L. *
Lycium cinereum Thunb.
L. hirsutum Dun.
L. horridum Thunb.
L. pilifolium C.H. Wr.
Nicotiana glauca R.C. Grah. *
Nierembergia caerulea Hook. *
Physalis viscosa L. *
Solanum coccineum Jacq.
S. eleagnifolium Cav. *
S. incanum L. *
S. linnaeanum Hepper & Jaeger
S. panduriforme E. Mey. *
S. retroflexum Dun. *
S. rostratum Dun. *
S. supinum Dun. *
Withania somnifera (L.) Dun.

Sterculiaceae

Hermannia amoena Dinter ex M. Holzhammer
H. bryoniifolia Burch.
H. coccocarpa (Eckl. & Zeyh.) Kuntze
H. comosa Burch. ex DC.
H. cuneifolia Jacq.
H. depressa N.E. Br.
H. erodioides (Burch. ex DC.) Kuntze
H. geniculata Eckl. & Zeyh.
H. linearifolia Harv.
H. modesta (Ehrenb.) Mast.
H. parviflora Eckl. & Zeyh.
H. pulverata Andr.
H. quartiniana A. Rich.

H. spinosa E. Mey. ex Harv.
H. tomentosa (Turcz.) Schinz ex Engl.
H. vestita Thunb.
Hermannia sp. (Malan 595, BFLU)
Melhania prostrata DC.
M. rehmannii Szyszyl.

Thymelaeaceae

Gnidia capitata L.f.
G. microcephala Meisn.
G. polycephala (C.A. Mey.) Gilg
Passerina montana Thoday

Tiliaceae

Corchorus asplenifolius Burch.
Grewia flava DC.
G. occidentalis L.

Ulmaceae

Celtis africana Burm. f.

Urticaceae
Forsskaolea viridis Ehrenb. ex Webb
Urtica dioica L. *

Vahliaceae

Vahlia capensis (L.f.) Thunb.

Verbenaceae

Lantana rugosa Thunb.
Phyla nodiflora (L.) Greene
Plexipus pinnatifidus (L.f.) R. Fernandes
Verbena bonariensis L. *
V. officinalis L. *
V. tenuisecta Briq. *

Viscaceae

Viscum rotundifolium L.f.

Vitaceae

Cyphostemma hereroense (Schinz) Descoings ex Wild & Drum.

Zygophyllaceae

Tribulus terrestris L.
Zygophyllum cylindrifolium Schinz
Z. gilfillanii N.E. Br.
Z. incrustatum E. Mey. ex Sond.
Z. macrocarpon Retief
Z. microphyllum L.f.
Z. simplex L.

Table 1: The relationship between the number of families, genera and species.

	Families	Genera	Species
Bryophyta	1	1	1
Pteridophyta	5	6	9
Gymnospermae	1	1	1
Monocotyledonae	16	94	195
Dicotyledonae	75	275	568
TOTAL	98	377	774

Table 2: Most prominent families (represented by 10 and more species).

Family	Genera	Species
Asteraceae	55	128
Poaceae	52	109
Fabaceae	17	39
Cyperaceae	10	24
Scrophulariaceae	7	22
Mesembryenthemaceae	11	20
Sterculiaceae	2	19
Crassulaceae	4	17
Solanaceae	7	17
Lamiaceae	8	16
Malvaceae	6	15
Amaranthaceae	8	13
Asclepiadaceae	10	12
Chenopodiaceae	4	12
Euphorbiaceae	4	12
Hyacinthaceae	8	12
Acanthaceae	5	11
Anacardiaceae	2	11
Aizoaceae	7	10

Table 2: (Continue)

Asparagaceae	1	10
Asphodelaceae	4	10

Table 3: Genera represented by 5 and more species.

Genera	Species
Helichrysum (Asteraceae)	19
Eragrostis (Poaceae)	17
Hermannia (Sterculiaceae)	17
Senecio (Asteraceae)	13
Crassula (Crassulaceae)	11
Cyperus (Cyperaceae)	11
Protasparagus (Asparagaceae)	10
Rhus (Anacardiaceae)	10
Sutera (Scrophulariaceae)	10
Solanum (Solanaceae)	8
Hibiscus (Malvaceae)	7
Indigofera (Fabaceae)	7
Polygala (Polygalaceae)	7
Sporobolus (Poaceae)	7
Aristida (Poaceae)	6
Euphorbia (Euphorbiaceae)	6
Oenothera (Onagraceae)	6
Pentzia (Asteraceae)	6
Salvia (Lamiaceae)	6
Setaria (Poaceae)	6
Zygophyllum (Zygophyllaceae)	6
Acacia (Mimosaceae)	5
Aloe (Asphodelaceae)	5
Anacampseros (Portulacaceae)	5
Aptosimum (Scrophulariaceae)	5
Panicum (Poaceae)	5
Pelargonium (Geraniaceae)	5
Stipagrostis (Poaceae)	5

Table 4: List of naturalized exotic species (Arnold & De Wet 1993).

Alternanthera nodiflora	Nierembergia caerulea
A. pungens	Oenothera biennis
A. sessilis	O. indecora
Althaea rosea	O. rosea
Amaranthus caudatus	O. stricta
A. hybridus	O. tetraptera
Argemone mexicana	Oenothera sp.
A. ochroleuca	Opuntia ficus-indica
Arundo donax	O. imbricata
Atriplex nummularia	O. vulgaris
Azolla filiculoides	Opuntia sp.
Bidens bipinnata	Oxalis corniculata
B. formosa	Paspalum dilatatum
B. pilosa	Pennisetum setaceum
Bromus catharticus	Physalis viscosa
Cereus cabrera	Plantago lanceolata
Chamaesyce prostrata	Polygonum aviculare
Chenopodium album	P. kitaibelianum
C. ambrosioides	Populus canescens
C. murale	P. nigra
Cichorium intybus	Portulaca oleracea
Cirsium vulgare	Prosopis chilensis
Convolvulus arvensis	P. velutina
Conyza bonariensis	Prunus persica
Cotoneaster sp.	Pseudocactus sp.
Cupressus torulosa	Pyracantha crenulata
Cyperus eragrostis	Rosa eglanteria
Datura ferox	Rumex crispus
Eucalyptus sp.	Salix babylonica
Flaveria bidentis	Schinus molle
Gleditsia triacanthos	Schkuhria pinnata
Medicago sativa	Senna italica
Melia azederach	Solanum coccineum
Nicotiana glauca	S. eleagnifolium

Table 4: (Continue)

Solanum incanum	Urtica dioica
S. panduriforme	Verbena bonariensis
S. retroflexum	V. officinalis
S. rostratum	V. tenuisecta
S. supinum	Vicia sativa
Sorghum halepense	Xanthium spinosum
Sphaeralcea bonariensis	X. strumarium
Tagetes minuta	Zinnia peruviana
Tragopogon dubius	

CHAPTER 13

Vegetation ecology of the southern Free State

Vegetation ecology of the southern Free State: General discussion and concluding remarks

CHAPTER 13

GENERAL DISCUSSION AND CONCLUDING REMARKS

13.1 GENERAL DISCUSSION

The presented detailed identification, description, classification and ecological interpretation of the plant communities encountered in the southern Free State contribute substantially towards the knowledge of the vegetation of the study area and the Grassland Biome of southern Africa.

The Braun-Blanquet approach was used to floristically define the plant communities. The subsequent Braun-Blanquet classifications of the different vegetation units and synecological synthesis of the vegetation on the study area provide an important classificatory and managerial reference framework of the major vegetation units and vegetation types in the southern Free State.

The two-step classification method, a new approach to investigate, compare and classify large phytosociological data sets from various sources and from large geographical regions, proved to be successful, not only to effectively bring together all related plant communities from different regions, or different studies, but especially to identify phytosociological classes as the highest syntaxonomical rank.

The relatively low and erratic rainfall of the study area, especially in the western parts, does not favour agronomy, although many farmers have ploughed and planted maize and/or other crops in good rainfall years. Mismanagement of natural pasture (e.g. overgrazing) in many parts of the study area contributed greatly to the degradation of natural pasture.

Grazing during the active growth stages of a plant results in vegetative damage and destruction of plant material. This can lead, in severe cases, to the complete absence of ecologically important species and thus seriously affects the whole environment by the invasion of ecologically less important species. This is clearly illustrated in the presence of species such as

Asclepias fruticosa, Berkheya onopordifolia, B. pinnatifida, Chenopodium album, the Karoo encroacher *Chrysocoma ciliata, Hertia pallens, Lycium cinereum, Pentzia globosa, Protasparagus laricinus, P. suaveolens, Salvia verbenaca, Talinum caffrum, Tribulus terrestris, Walafrida saxatilis,* as well as the grasses *Aristida congesta, Chloris virgata, Eragrostis curvula, E. lehmanniana, E. obtusa* and *Tragus berteronianus* (See Chapter 11). According to Hoffman *et al.* (1990) an increase in grass basal cover may negatively influence shrub basal cover. According to them, a large increase in summer rain, relative to the long-term mean, would result in an associated increase in the percentage change in grass basal cover. It should, however, be kept in mind that various other environmental factors, such as light intensity, temperature etc. are also involved in vegetation changes. A further aspect is to incorporate different stock ratios to attempt to utilize a wider spectrum of plants which could lead to better unit area utilization, favourable grazing capacities, and consequently higher economic returns.

All over the province one finds examples of good, conservation-conscious farmers whose use of the correct number of animals and the healthy rotation of stocks between camps, promote veld recovery. Unfortunately, the contrary has also been widely observed. According to Potgieter *et al.* (1995) the advantage of good veld management lies in the correct number of animals according to the grazing capacity. An increase in stock numbers will have a severe and adverse effect on the veld.

Stratification was based on land type, topographical position (plateau or slope), aspect and geology. The slopes were stratified according to crests, scarps, midslopes, footslopes and valley bottoms or flood plains which is in accordance with the stratification used by Fuls (1993).

Bezuidenhout (1993), Coetzee (1993), Eckhardt (1993) and Kooij (1993) also used land types as a first stratification.

Seven major communities were identified and can easily be recognized in the study area.

The significant plant community variation in an area which is generally regarded as homogeneous, concomitant with an unique set of environmental conditions prevalent with each plant community, have important management implications (Fuls 1993). These results can be used in future ecologically sound research, management and conservation strategies. It should also be used by conservationists and agriculturists for optimal land use planning. It is also possible that the farmer at farm level scale could make use of these results.

Two biomes were identified in the study area, namely the Grassland and Nama-Karoo Biomes. The mean annual rainfall in the Grassland Biome in the study area varies between 500 and 700 mm per annum while the Nama-Karoo Biome mainly falls within the 200-400 and 400-600 mm per annum rainfall intervals.

The vegetation of the Grassland Biome is physiognomically monolithic and is characterized by strong dominance of hemicryptophytes of the Poaceae. Canopy cover is moisture dependent and decreases with mean annual rainfall. Grazing has a decisive influence on canopy structure (Rutherford & Westfall 1994).

The vegetation of the Grassland Biome follows a rainfall gradient which generally corresponds to the relative contributions to the plant cover by "sweet" and "sour" grasses. Probably the most noteworthy species with wide distribution in the Grassland Biome is *Themeda triandra* Forssk.

The number of rare plants in the Grassland Biome is not particularly large, but increases in the wetter areas and mainly includes non-graminoid plants, especially geophytes (Hilton-Taylor 1996).

The vegetation of the Nama-Karoo Biome is dominated by chamaephytes and hemicryptophytes and can be described as a grassy, dwarf shrubland (Edwards 1983). The hemicryptophytes of the biome are mainly C4 graminoids (Vogel *et al.* 1978). Plant species diversity and number of rare and endangered species in the biome are relatively low (Hall *et al.* 1980). Succession of plant composition is usually taken to start after disturbance by overgrazing. The usual progression, given a significant reduction in grazing pressure and a suitable distribution of rainfall (Vorster & Roux 1983), is a steady increase in hemicryptophyte cover and a more variable decrease in chamaephyte cover.

Acocks (1988) identified six veld types in the southern Free State. On a 1: 1 500 000 scale Acocks's veld types are relatively accurate in the southern Free State, but refinement of the boundaries between the different veld types is necessary. These veld types, however, can still be used as a basis for future research.

The final synthesis of the vegetation of the southern Free State resulted in the identification of 16 phytosociological classes. These classes are also easily distinguishable in the veld. Although some floristic relationships do exist between the different classes, each class has its own set of environmental and ecological attributes. The results of the ordinations (DECORANA) (Hill 1979) indicate the floristic relationships amongst the vegetation units. It was possible to relate the vegetation units to certain environmental variables and often clear gradients could be recognized. This could be ascribed to the relatively low to intermediate rainfall of the study area where the importance of terrain and soil types, soil depth, clay content, drainage and rockiness of the soil surface is emphasized (Bezuidenhout 1993). Higher rainfall to the south-eastern parts causes the influence of these environmental factors to be less prominent (Eckhardt 1993 and Fuls 1993). The large impact of habitat disturbance in the study area by means of utilization is evident throughout the whole southern Free State.

13.2 CONCLUDING REMARKS

The aims set forth for this study were satisfactorily achieved.

The aims as put forward in Chapter 1 of this dissertation were threefold:

(1) To identify, classify, describe and ecologically interpret the different plant communities of the southern Free State,

(2) to compile a synecological synthesis of the southern Free State, and
(3) to concur with the goals of the Grassland Biome Project namely to identify, describe and determine the location of major vegetation types within the Grassland Biome (Mentis & Huntley 1982).

The classification, description and ecological interpretations of the vegetation and associated habitats in the southern Free State should form the basis for future conservation and management strategies. A major future research priority which flows from this study is a refinement of the vegetation classes identified in the study area. Such a refinement, followed by a formal syntaxonomical classification of all the syntaxa, should complement the Grassland Biome Project.

In conclusion, natural veld remains the cheapest form of forage for farmers, and everything possible must be done to keep it at its optimum condition by means of the application of the correct number of animals and the correct rest and grazing periods. This should always be the basis of any forage flow programme on any farm (Potgieter *et al.* 1995).

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OPSOMMING

Plantekologie van die suidelike Vrystaat

deur

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Hierdie studie vorm 'n integrale deel van die oorhoofse langtermyn doel om 'n omvattende sinekologiese sintese van die Grasveldbioom van suidelike Afrika daar te stel. Met die aanvang van die projek was daar relatief min inligting oor die plantegroei van die gebied bekend. Die hoofdoel van hierdie studie was:

(1) om die plantgemeenskappe in die studiegebied te identifiseer, te klassifiseer en ekologies te interpreteer,
(2) om 'n omvattende fitososiologiese en sinekologiese sintese van die plantegroei van die studiegebied daar te stel, insluitende alle fitososiologiese data ingesamel deur ander navorsers in die suidelike Vrystaat, en
(3) om 'n bydrae te lewer omtrent die daarstelling van 'n volledige sinekologiese sintese van die Grasveldbioom.

Die studiegebied is in die suidelike Vrystaat geleë, beslaan 'n totale oppervlakte van ongeveer 27 000 km^2 en word begrens deur die

lengtegraad 29°Suid en breedtegraad 27°Oos. Dit word begrens deur die Oranjerivier in die suide en die denkbeeldige grens tussen die Vrystaat- en Noord-Kaap Provinsie in die weste.

Die doelwitte is bereik deur ekstensiewe fitososiologiese opnames in die studiegebied uit te voer. Die studiegebied is gestratifiseer volgens relatiewe homogene eenhede van faktore soos geologie, topografie (terrein vorm), fisionomie en dominante spesies. 'n Fitososiologiese ondersoek, volgens Braun-Blanquet prosedures asook 'n habitat opname is uitgevoer. Die data is deur middel van die TWINSPAN- program geklassifiseer en daarna deur die Braun-Blanquet prosedures verfyn.

Uit die 2 370 relevés wat in die suidelike Vrystaat saamgestel is, is 394 plantgemeenskappe geïdentifiseer, geklassifiseer, beskryf en ekologies geïnterpreteer.

Uit die omvattende fitososiologiese sintese van die 394 beskryfde plantgemeenskappe van die suidelike Vrystaat is 16 hoofplantegroeitipes in die studiegebied beskryf.

'n Ordeningsalgoritme (DECORANA) wat die floristiese verwantskappe tussen die plantegroei-eenhede aandui, is gebruik om die klassifikasies aan te vul.

Die sinekologiese sintese van die suidelike Vrystaat lewer 'n bydra tot die uiteindelike doel, nl. om 'n volledige sinekologiese en sintaksonomiese sintese van die Grasveldbioom in suidelike Afrika daar te stel.

SUMMARY

Vegetation ecology of the southern Free State

by

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This study forms an integral part of the main long-term goal to compile a comprehensive synecological synthesis of the vegetation of the southern Free State.

Relatively little is known about the vegetation of the study area. The main aim of the study was:

(1) to identify, classify and ecologically interpret the plant communities in the study area,
(2) to compile a comprehensive phytosociological and synecological synthesis of the vegetation of the study area, including all the phytosociological data compiled by other researchers in the southern Free State, and
(3) to take part in compiling a comprehensive synecological synthesis of the Grassland Biome.

The study area is situated in the southern Free State, covers approximately 27 000 km^2 and is bounded by latitude 29° South and

longitude 27° East. It is bounded by the Orange River in the south and by the imaginary boundary between the Free State and Northern Cape Province in the west.

The aims were achieved through compiling extensive phytosociological surveys in the study area. The study area was stratified into relative homogeneous units of major attributes such as geology, topography (land form), physiognomy and dominant species. A phytosociological survey according to Braun-Blanquet procedures as well as habitat analysis were being done. Data were being classified through the TWINSPAN program and then refined by Braun-Blanquet procedures.

From the 2 370 relevés compiled in the southern Free State, 394 plant communities were identified, classified and ecologically interpreted.

16 Major vegetation units were described from the 394 described plant communities.

An ordination algorithm (DECORANA) was used to indicate the floristic relationships among the vegetation units and make the classifications more interpretable.

The synecological synthesis of the vegetation of the southern Free State plays an important role in compiling a comprehensive synecological and syntaxonomical synthesis of the vegetation of the Grassland Biome of southern Africa.

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