VEGETATION ECOLOGY OF SOETDORING NATURE RESERVE: PAN, GRASSLAND AND KARROID COMMUNITIES.

by

BEANéLRI BENèNE JANECKE

Submitted in fulfilment of the requirements
for the degree

MAGISTER SCIENTIAE

in the Faculty of Natural and Agricultural Sciences
(Department of Plant Sciences)
University of the Free State
Bloemfontein

Supervisor: Dr P.J. du Preez
Co-supervisor: Prof H.J.T. Venter

September 2002

I dedicate this MSc. thesis to everyone who has made a contribution in any way during the completion of this study.

BB Janecke

GRASS

I have written of dawn, of the moon, and the trees;
Of people, and flowers, and the song of the bees.
But over these things my mind would pass,
and come to rest among the grass.

Grass so humble, that all things tread
It's tender blades. Grass - the bread,
The staff of life; a constant need
Of man and beast - a power indeed.

Grass so vagrant - does anything stray
With such gallant courage? The hardest way
Is coaxed and beguiled by the wayward grace
Of the constant friend of every space.

God in his wisdom gave many friends
To grace our way, as along it wends
But the grandeur of many, my mind would pass
And come to rest among the grass.

Mabel Duggan in Meredith (1959).

Meredith, D. (ed.) 1959. The grasses and pastures of South Africa. Central News Agency, Parow.

CONTENTS

CHAPTER 7: THE IMPACT OF ANIMALS AND HUMANS ON GRASSLANDS

CHAPTER 8: THE GRASSLAND OF SOETDORING NATURE RESERVE

CHAPTER 9: KARROID GRASSLAND OF SOETDORING NATURE RESERVE

LIST OF FIGURES AND TABLES

CHAPTER 1:

INTRODUCTORY BACKGROUND

Janecke BB. 2002. Vegetation ecology of Soetdoring Nature Reserve: Pan, grassland and karroid communities. Unpublished MSc thesis, University of the Free State, Bloemfontein, South Africa

CHAPTER 1: INTRODUCTORY BACKGROUND

1.1 INTRODUCTION

Ecology is the study of living organisms in relation to their environment, according to Beeby and Brennan (1997). Thus, it is essential to consider all aspects of the environment to obtain a better perspective of the vegetation. Environment is defined as an organism's habitat including all biotic (living) and abiotic (non-living) factors that surround and potentially influence an organism (Barbour *et al.* 1987).

Vegetation is an integral part of an ecosystem and individual plant species are excellent indicators of environmental conditions (Billings 1972; Bredenkamp & Theron 1976; Bredenkamp & Brown 2001). Vegetation consists of all the plant species in a region (the flora) and the ways in which those species are spatially or temporally distributed (Barbour *et al*. 1987). Every plant community is a result of a unique combination of certain environmental conditions. Every meaningful plant community therefore represents a certain ecosystem (Bredenkamp & Theron 1976; Bredenkamp *et al.* 1994). According to Bredenkamp and Theron (1976), plant communities are the fundamental units of ecosystems, and their study is basic for the compilation of management programmes.

According to Bredenkamp and Brown (2001), natural vegetation is modified by man's activities and vegetation cover is destroyed or altered over large areas of the world. As a result natural components of the flora disappear and the free space becomes occupied by aliens, mostly encroachers which are dangerous competitors to the local flora and / or troublesome weeds.

One of the general aims of nature conservation, according to Bredenkamp and Theron (1976), is the formulation and implementation of effective management programmes, which will ultimately result in optimal land use, combined with effective land conservation. Neither land use, nor conservation objectives can be attained without a thorough knowledge of the ecology of a particular area (Edwards 1972; Bredenkamp & Brown 2001). It is obvious that different ecosystems will react differently to certain management practices, like grazing or burning. It is therefore clear that a management programme should be based on the recognition of the various ecosystems as meaningful ecological entities within the area (Bredenkamp & Theron 1976). Vegetation and general ecological surveys of conservation areas are therefore considered to have high priority (Nakor 1979; Bredenkamp & Brown 2001).

1.2 PRESENT STUDY

A study of the vegetation of specifically the pans, grassland and karroid grassland, was done in Soetdoring Nature Reserve. The possibility of karroid grassland being the product of degraded grassland, was looked into. An attempt was also made to incorporate the fauna associated with these vegetation units, thus creating an ecological perspective. The impact, both positive and negative, that animals and humans exert on the different vegetation units was included where possible. This was done to indicate the delicate relationship that exists between the vegetation and the fauna.

1.3 PREVIOUS AND POSSIBLE FUTURE RESEARCH

Since the large scale classification of vegetation by Acocks (1988), much progress has been made towards more detailed classifications. A great deal of research on **grasslands** has been done within the phytosociological research programme under the auspices of the Grassland Biome Project (Mentis & Huntley 1982). This is probably due to the fact that the grasslands of South Africa cover approximately 29% of the total land surface area of the country, predominantly on the Highveld and interior region of the Eastern Cape and Kwazulu-Natal. The Grassland Biome supports a major proportion of the country’s maize, dairy, beef and timber industry and is agriculturally the most productive biome in South Africa (Mentis & Huntley 1982). Regrettably, mostly because of the above mentioned activities, the Grassland Biome is subjected to large scale veld degradation. This degradation has focused the attention of many authors, world wide, on the grassland. The Grassland Biome Project is a long-term project which aims are to monitor the status and degradation of South Africa’s grasslands (Mentis & Huntley 1982).

The **pan** vegetation, however, has received very little attention in the past. Much of the available information on pans focused on the distribution, origin, classification, etc., while the vegetation and inhabitants of the pans have been largely neglected. The only specific description of vegetation that could be found for the pans in the Free State, is that of Geldenhuys (1982). He described six pan types based on the presence of emergent vegetation, as recorded in late summer (about March or April), about two months after the annual inundation (Allan *et al.* 1995). Existing research on pan vegetation in the Free State, mainly seems to be incorporated in unpublished MSc theses or PhD dissertations dealing with Nature Reserves or large areas of the province. No reference to vegetation of the different phases of ephemerally inundated pans, i.e. the dry and wet phases and the transitional phase in between, could be found. Thus, research on the vegetation and different inhabitants of the different phases of ephemeral pans still needs attention in future.

The most recent work that has been done on the overall vegetation of Soetdoring Nature Reserve, is summarised in the reserve's management plan by Watson (1993). He made a general survey of all the vegetation units, but lacks a detailed description of the mentioned important grazing areas, especially the pans.

1.4 THESIS EXPOSITION

The first part of the thesis focuses on pans. The general information on pans, i.e. the origin, classification, importance, conservation, etc., was discussed in the first chapter on pans (Chapter 4) This information was applied to the pans in Soetdoring Nature Reserve in Chapter 5. The subject of pans is concluded in Chapter 6 with the vegetation of the pans in Soetdoring Nature Reserve.

The second part of the thesis deals with the grassland and overgrazed, karroid grassland communities in the reserve. The same approach as above was followed in giving a general overview of grasslands first, before discussing the vegetation. In this case the degradation of grasslands and the role of animals and humans in this process were accentuated (Chapter 7). This is followed by a chapter on the vegetation of each of the grassland and karroid grassland communities (Chapters 8 & 9).

The pans have received a bit more attention, than the grassland or karroid grassland, since very little literature is available on this subject, especially on the vegetation. The grassland and karroid grassland, however, have been dealt with *ad nauseam* in the past. It is included again in this thesis in order to show the state of degradation of specifically the grassland in Soetdoring Nature Reserve. This could also act as a warning for conservation of grasslands in other reserves, so as not to fall in the same trap of mismanagement.

The vegetation of the pans, the grassland and karroid grassland is summarised on a synoptic table and discussed in Chapter 10. A floristic analysis of all the species data concludes the thesis in Chapter 11. **The author names of the species mentioned in the text, that do not occur in the reserve, are included where the species are mentioned. Only the author names of species collected in Soetdoring Nature Reserve are included in Chapter 11.** Where possible, the older names of species, that were changed recently, were also indicated in brackets in the species lists to aid in the comparison with other data sets.

The ordination results, by means of DECORANA (Hill 1979b), were only included for the complete data set, since the results of each vegetation unit proved to be too fragmented to indicate patterns in the vegetation. Photographs of the vegetation of the pans, grassland and karroid grassland are included in Appendix 1. The phytosociological tables (Tables 6.1, 8.1 & 9.1), as well as the synoptic table (Table 10.1), can be found in Appendix 2 (or in the envelope at the back of the hard copy of the thesis).

1.5 AIMS OF THIS STUDY

The aims of this study were:

- To respectively identify, classify, describe and ecologically interpret the plant communities of the following vegetation units in Soetdoring Nature Reserve:
- the pans,
- the moderately grazed areas of the grassland that are in a rather good condition and
    - the overgrazed and retrogressed areas in the grassland.

    - To compile a phytosociological synthesis of the vegetation in the pans, grassland and karroid grassland of Soetdoring Nature Reserve and to compare these different vegetation units with existing data where possible.

- To provide the reserve management / Department of Environmental Affairs and Tourism with a general view of the status of the grassland and pan vegetation since it also serve as important grazing areas.

- To provide a baseline vegetation study which could serve as an ecological basis for future management, conservation and research in this area.

CHAPTER 2: STUDY AREA

2.1 LOCATION AND SURFACE AREA

The study was conducted in Soetdoring Nature Reserve, Free State Province, situated about 38 km north-west of Bloemfontein, between latitudes 28° 48' S & 28° 53' S and longitudes 25° 56' E & 26° 07' E (Figure 2.1). The Bloemfontein-Dealesville road in the west and the Bloemfontein-Bultfontein road in the east bound the reserve. The average altitude of the reserve is 1 450 m.

Soetdoring Nature Reserve covers a total surface area of 6 173 ha. The reserve is situated around the Krugersdrift Dam, which, along with the Modder River, takes up 2 056 ha of the reserve. This leaves about 4 288 ha, of which 587 ha surrounding the Krugersdrift Dam is used for recreational facilities, such as water sport, angling, etc. (Watson 1993).

There are several springs on the reserve, including a hot water spring on the farm Vlakkraal 23. Fossil remains can be found in and around this spring. The south-western part of Soetdoring Nature Reserve, including the Krugersdrift Dam, is fenced off from the rest of the reserve. No large game occur in this area. A gate links the Krugersdrift Dam area to the rest of the reserve (Figure 2.1), but it is off limits to the public. The game viewing area can then only be accessed through the main gate on the Bloemfontein-Bultfontein road.

2.2 HISTORICAL BACKGROUND

Before December 1977, Soetdoring Nature Reserve was known as Krugersdrift Roofdierpark (predator park). It was proclaimed as a provincial nature reserve on the 28th of June 1978. The reserve is made up of land that was previously farmland, comprising about 21 farms or parts thereof. Small family graveyards and ruins of farmsteads serve as reminders of the previous era. Ruins that are still recognisable in the reserve include dams (nine cement and three earth dams), a few stone walls and kraals that were not completely demolished, etc. There are no definite indications of former farming activities, but it would probably have been stock farming, with limited crop farming (Watson 1993).

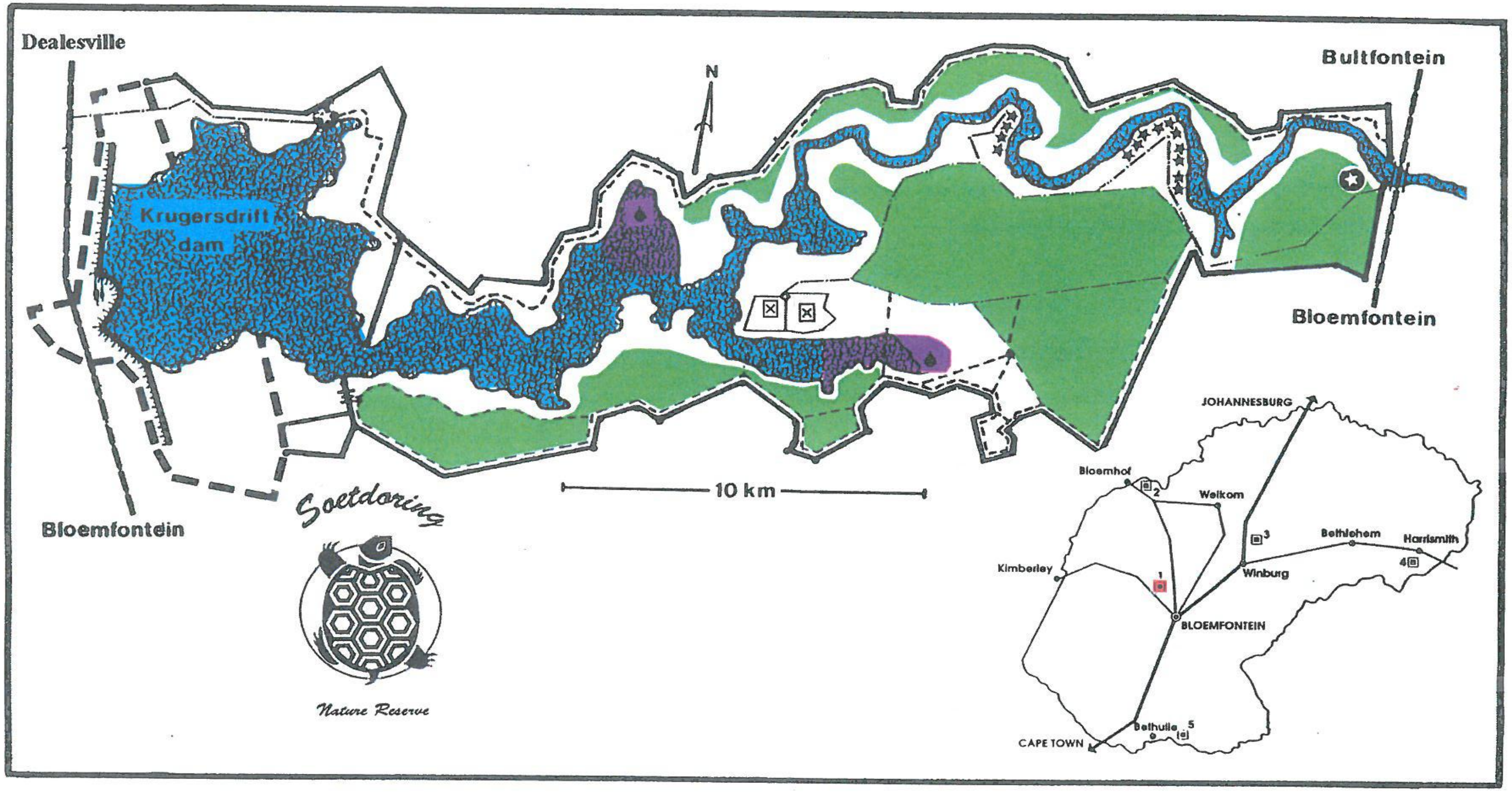


Figure 2.1: Map of Soetdoring Nature Reserve and the location in the Free State Province in relation to towns and other nature reserves. The grassland, including the karroid grassland, is indicated in green and the pans are indicated in purple. Dotted lines indicate roads. Explanation of the symbols used: ★ = picnic spots alongside the Modder River; ✪ = entrance gates; ☒ = lion and wild dog camps; ♦ = position of the pans. 1 = Soetdoring Nature Reserve; 2 = Sandveld Nature Reserve; 3 = Willem Pretorius Nature Resrve; 4 = Sterkfontein Nature Reserve; 5 = Tussen-die-riviere Nature Reserve.

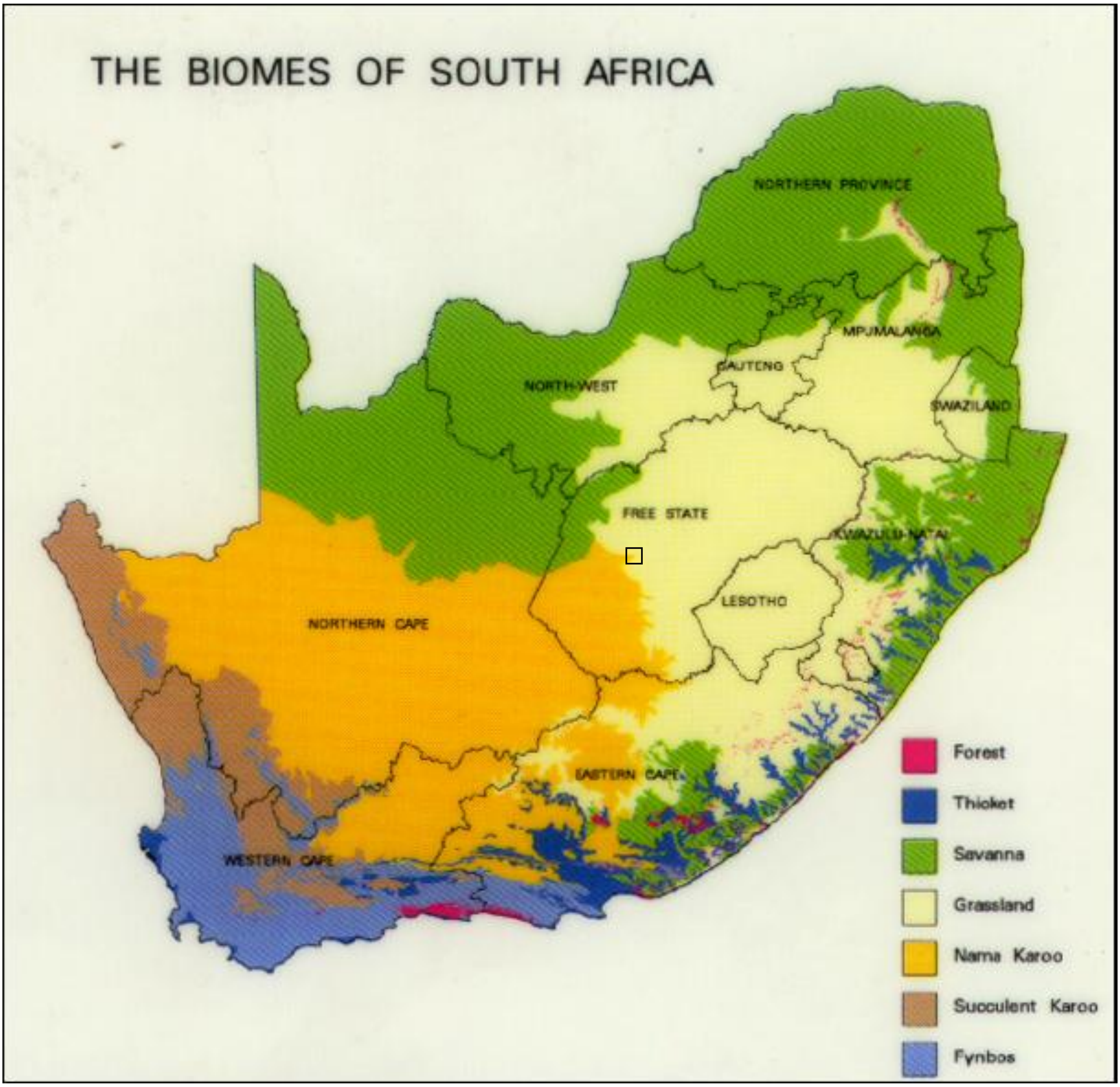


Figure 2.2: The biomes of South Africa, ☐ roughly indicates the position of Soetdoring Nature Reserve.

(*After Low and Rebello 1996).*

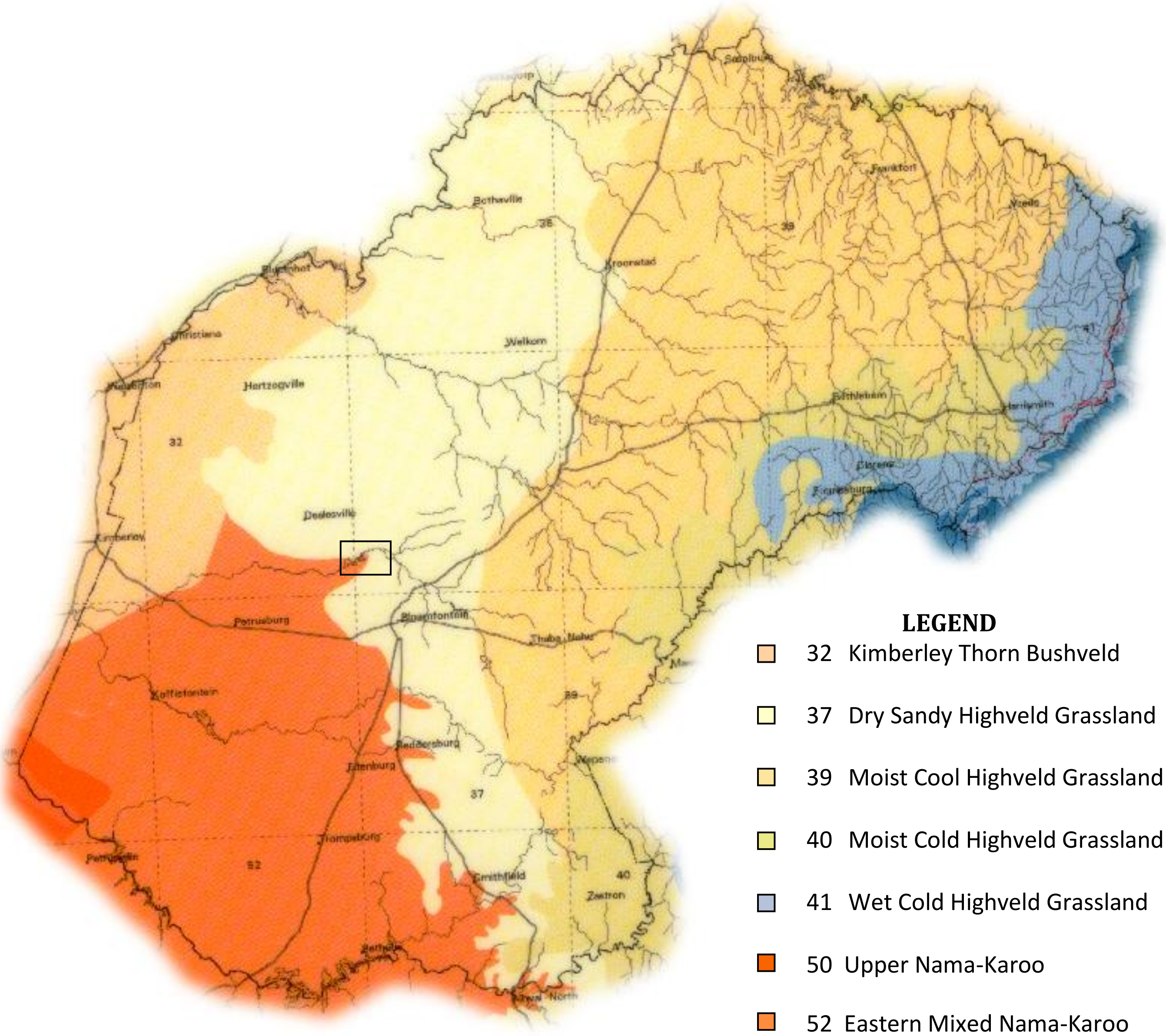


Figure 2.3: The vegetation types of the Free State Province, ☐ roughly indicates the position of Soetdoring Nature Reserve. (*After Low and Rebello 1996*)

2.3 BIOTIC FACTORS

2.3.1 Environment

According to Rutherford and Westfall (1994), two biomes occur in the reserve, namely the Grassland Biome and the Nama-Karoo Biome (Figure 2.2). Acocks (1988) divided the area in which Soetdoring Nature Reserve falls into two different veld types, namely the *Cymbopogon* – *Themeda* veld (A50) and the False Upper Karoo (A36). The *Cymbopogon–Themeda* Veld Type is now a synonym for the Dry Sandy Highveld Grassland (Bredenkamp & Van Rooyen 1996), while the False Upper Karoo is a synonym for the Eastern Mixed Nama-Karoo (Hoffman 1996) (Figure 2.3). Soetdoring Nature Reserve shows much habitat diversity in having grassland, karroid shrubland, *Acacia* thornveld, pan, vlei (marsh), rocky ridge and riparian vegetation. The grassland, including the karroid shrubland, is indicated in green on the map of the reserve (Figure 2.1), while the purple coloured areas represent the two pans.

2.3.2 Animals

The following animals were present on the reserve during the time of study. Common and scientific names conform to Smithers (1983).

<u>Game</u>:

Black wildebeest	*Connochaetes gnou* Zimmerman, 1780
Blesbok	*Damaliscus dorcas phillipsi* Harper, 1939
Common Duiker	*Sylvicapra grimmia* Linnaeus, 1758
Eland	*Taurotragus oryx* Pallas, 1766
Gemsbok	*Oryx gazella* Linnaeus, 1758
Impala	*Aepyceros melampus* Lichtenstein, 1812
Kudu	*Tragelaphus strepsiceros* Pallas, 1766
Red hartebeest	*Alcelaphus buselaphus* Pallas, 1766
Springbok	*Antidorcas marsupialis* Zimmerman, 1780
Steenbok	*Raphicerus campestris* Thunberg, 1811
Waterbuck	*Kobus ellipsiprymnus* Ogilby, 1833
White rhino	*Ceratotherium simum* Burchell, 1817
Zebra	*Equus burchellii* Gray, 1824

Large carnivores:

Lions and Wild Dogs are kept in neighbouring camps separated from the other animals of the Reserve (Figure 2.1). The Brown Hyaena was previously known to occur in the reserve, but it is uncertain whether it is still present.

The following carnivores are present in the reserve:

African wild dog	*Lycaon pictus* Temminck, 1820
Black backed jackal	*Canis mesomelas* Screber, 1778
Brown hyaena	*Hyaena brunnea* Thunberg, 1820
Cape clawless otter	*Aonix capensis* Schinz, 1821
Cape fox	*Vulpes chama* A.Smith, 1833
Lion	*Panthera leo* Linnaeus, 1758

Small mammals: The following species were previously spotted on the reserve, but a detailed survey is still needed (Watson 1993):

Antbear	*Orycteropus afer* Pallas, 1766
Cape Hare	*Lepus capensis* Linnaeus, 1758
Ground Squirrel	*Xerus inauris* Zimmermann, 1780
Hedgehog	*Erinaceus frontalis* A. Smith, 1831
Porcupine	*Hystrix africae-australis* Peters, 1852
Rock Elephant-shrew	*Elephantulus myurus* Thomas & Schwann, 1906
Scrub Hare	*Lepus saxatilis* F. Cuvier, 1823
Slender Mongoose	*Galerella sanguinea* Rüppel, 1836
Small grey mongoose	*Galerella pulverulenta* Wagner, 1839
Smith's Rock Rabbit	*Pronolagus rupestris* A. Smith, 1834
Springhare	*Pedetes capensis* Forster, 1778
Striped Mouse	*Rhabdomys pumilio* Sparrman, 1784
Suricate	*Suricata suricatta* Erxleben, 1777
Vervet monkey	*Cercopithecus pygerythrus* F. Cuvier, 1821
Water mongoose	*Atilax paludinosus* G. Cuvier, 1829
Yellow mongoose	*Cynictis penicillata* G. Cuvier, 1829

Birds:

Ostriches (*Struthio camelus* Linnaeus, 1758) are abundant on the reserve. The reserve, with it's various vegetation types, offers different habitats for a high number of different bird species. A total of 268 birds have already been spotted in the reserve, including some of the rare species, like Blue Crane (*Anthropoides paradisea* Lichtenstein, 1793), Kori Bustard (*Ardeotus kori* Burchell, 1822), and Lesser Flamingo (*Phoeniconaias minor* Geoffroy, 1798) (De Swardt 2001). The common and scientific names of the birds conform to Brown *et al.* (1992) and Urban *et al.* (1993).

2.4 ABIOTIC FACTORS

2.4.1 Geology

Geology can be described as the complex structure of rock formations which occurs in specific locations and sequences (Van Riet *et al.* 1997). Geology has a major influence on most other features of the landscape such as topography, land form, soil and thus also influences the climate and the vegetation (Scheepers 1975; Van Riet *et al*. 1997).

For the greater part, the Grassland Biome is underlain by the Karoo Supergroup. This supergroup consists mostly of sedimentary rock formations with dolerite intrusions and extrusive basalt and rhyolites, or of Precambrian sedimentary and intrusive rock (Huntley 1984). Weathering of the dolerite sheets gives rise to an undulating surface on which Karoo vegetation replaced the grass types, according to Nolte (1995).

The whole study area is underlain by the Tierberg Formation of the Ecca Group from the Karoo Supergroup (Van Riet *et al.* 1997). The Ecca Group consists principally of dark-grey shale together with interbedded sandstone units (Visser 1989; Nolte 1995). The Tierberg Formation consists of shale, siltstone and sandstone (Nolte 1995).

An extensive layer of sand, of aeolian origin, obscures the Ecca Group (Figures 2.4 & 2.5) over a part of the study area (Nolte 1995). Dolerite, an intrusive rock, is also present in the nature reserve in the form of dykes and sills (Figure 2.4), while alluvium and scree can be found next to the river. In a small area of the reserve, the Tierberg formation is covered by calcrete and surface limestone.

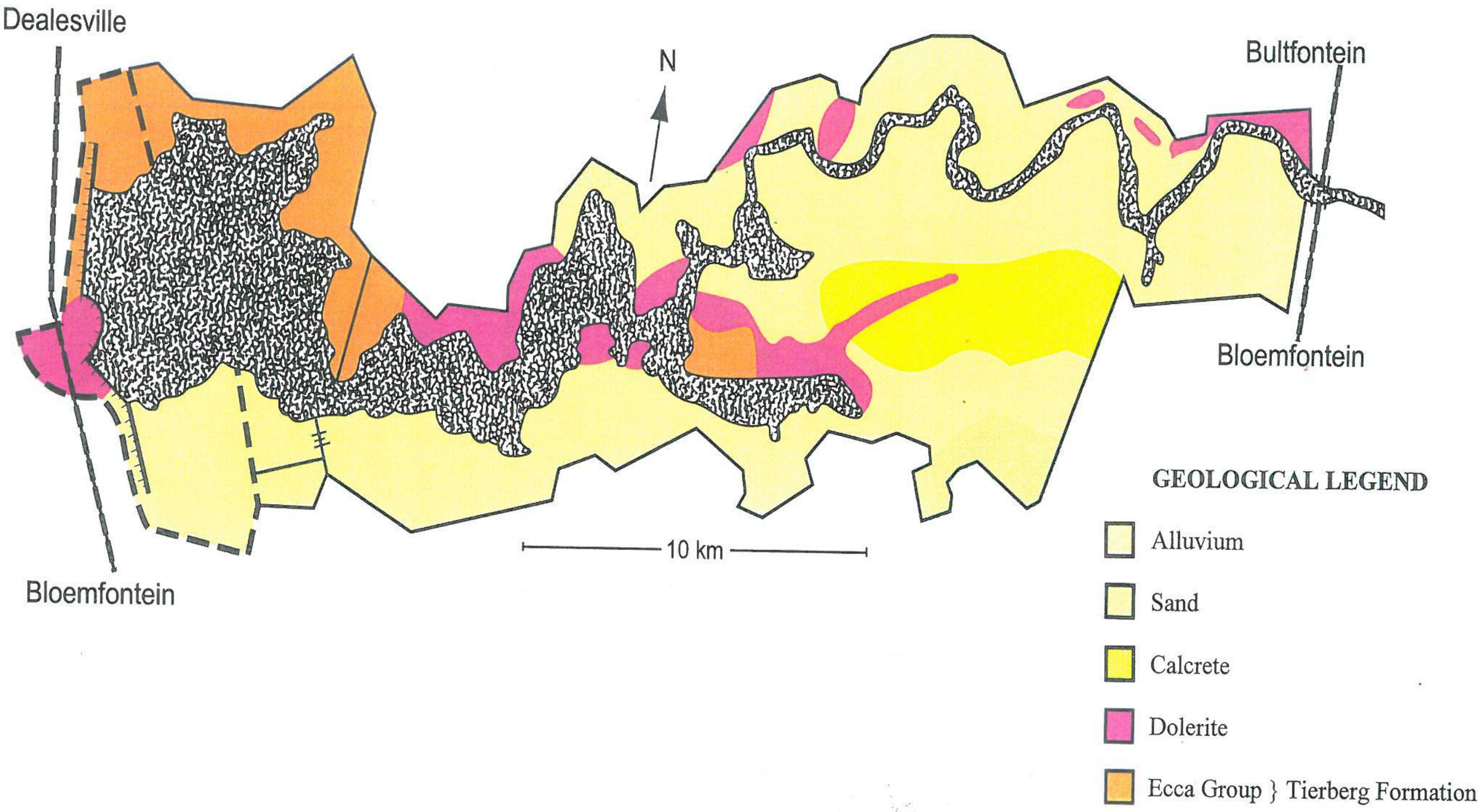


Figure 2.4: Geology of Soetdoring Nature Reserve (After the Geological series (1:250 000) of 2826 Winburg (1998) and 2824 Kimberley (1986). Council for Geoscience, Pretoria).

2.4.2 Land types

A land type denotes an area that can be shown at 1:250 000 scale and that displays a marked degree of uniformity with respect to terrain form, soil pattern and climate (Land Type Survey Staff 1986). Two different land types are distinguished in the study area, namely the Ae and Dc land types. The Dc land type follows the river valley in a broad band, while the Ae land type is situated on the higher ground bordering the Dc land type. The different soil types associated with each land type is presented in Figure 2.5.

The underlying geology of the Ae land type is shale and mudstone of the Ecca Group covered by windblown sand and surface limestone. Dolerite intrusions occur (Land Type Survey Staff 1992). The underlying rock formations of the Dc land type are mudstone, shale and sandstone of the Beaufort and Ecca Groups with a few dolerite intrusions (Land Type Survey Staff 1992).

Simplified terrain form sketches of each of the land types, compiled from Land Type Survey Staff (1992), is presented in Figure 2.6 a & b. Terrain unit 1 represents a crest, unit 2 a scarp, unit 3 a midslope, unit 4 a footslope and unit 5 a valley bottom. The grassland occurs on terrain unit 4 of the Ae and Dc land types, while the pans are represented by terrain unit 5.

2.4.3 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). Soils of the southern Free State are highly dissected and drained by the Orange, Modder, Riet and Caledon rivers. Alluvium brought down by these rivers is deposited (*vid.* Figure 2.4) along the lower reaches and serves as arable soils (Malan 1998). 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 (Malan 1998).

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. Dundee soils are deposited along river banks (Van Der Merwe 1973).

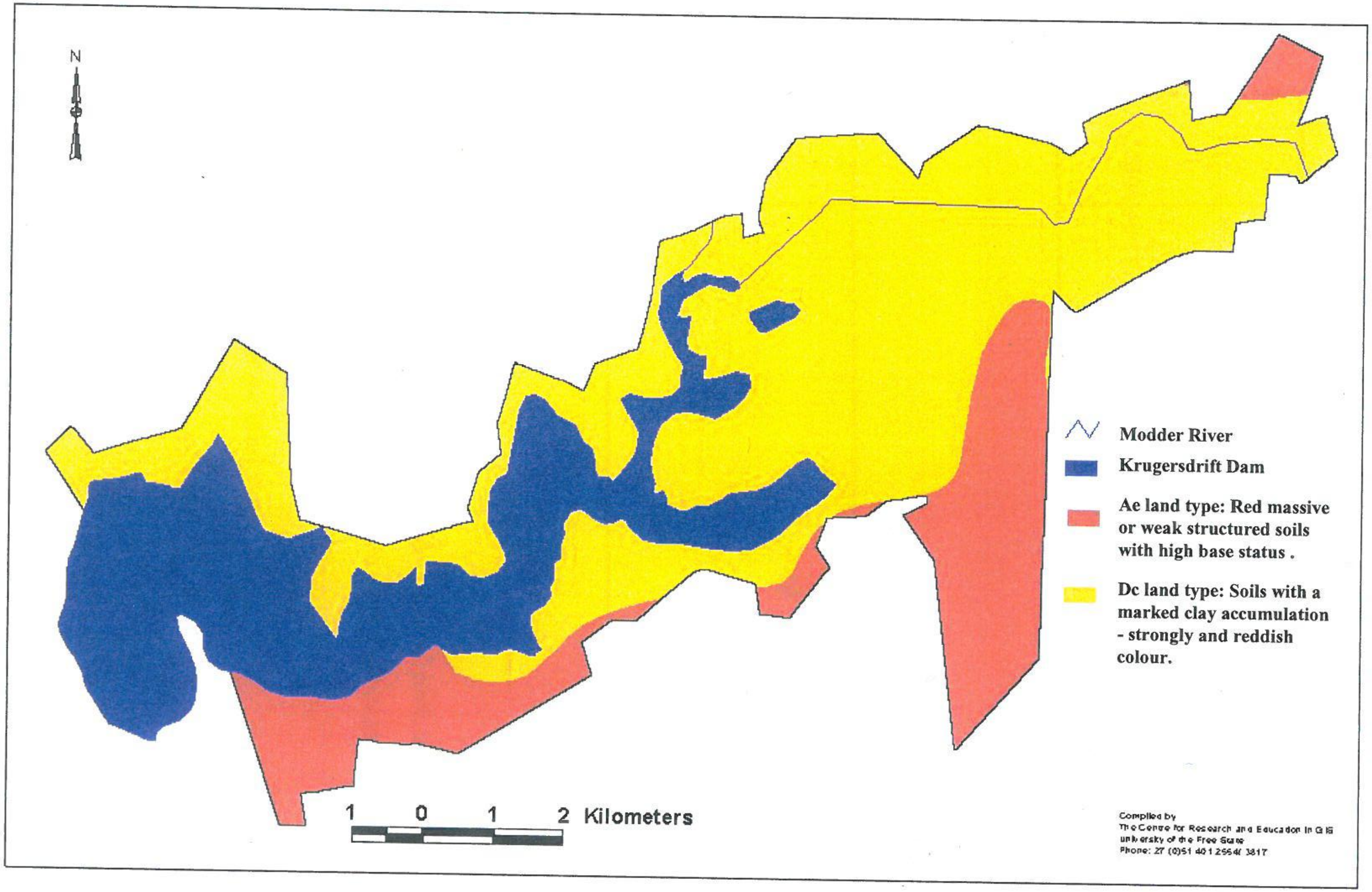
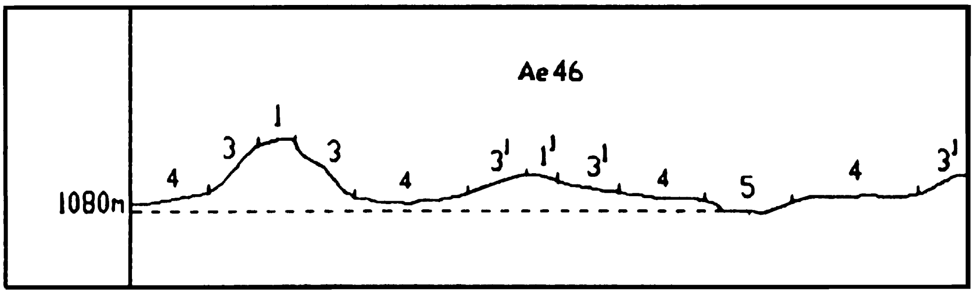


Figure 2.5: Land types and soil types of Soetdoring Nature Reserve.

a



b

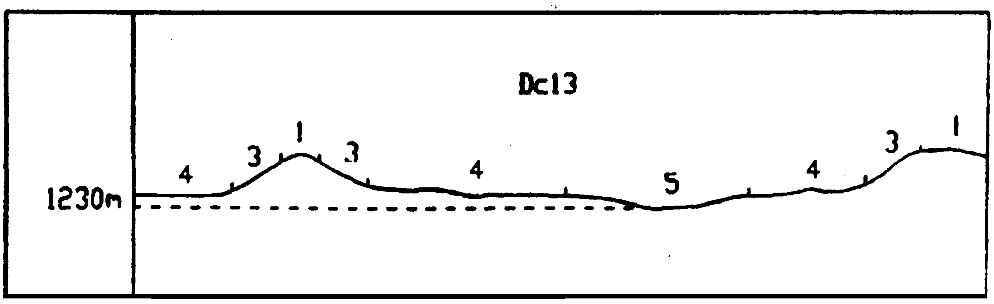


Figure 2.6: Simplified terrain form sketches of each of the land types in Soetdoring Nature Reserve. Terrain unit 1 represents a crest, 3 a midslope, 4 a footslope and 5 a valley bottom.

a) Topography of the Ae land type.

b) Topography of the Dc land type.

(*After Land Type Survey Staff 1992*)

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 susceptible to erosion and all have horizons of high clay content. The A-horizon is easily washed away, exposing the erodable clayey B-horizon (Van Der Merwe 1973).

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. The clay content of these soils is relatively low and increases with depth. The deeper the soil profile, the easier the drainage of excess water away from the roots (Russel 1997). The soils are usually well drained (Eloff 1984).

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

Terrain unit 5 of the Dc land type (Figure 2.6) consists of the following soil series or land classes: Limpopo Oa (40%), Dundee Du (43%), Stream beds (15%), etc. The Limpopo soil series consists of 15 – 30% clay in the A horizon and 30 – 50% in the B horizon. The Dundee soil series differs in clay content from 10 – 15% in the A horizon to 20 – 30%, with no clay in the B horizon (Land Type Survey Staff 1992). The soil has a marked clay accumulation and is reddish in colour.

Terrain unit 4 of the Ae land type (Figure 2.6) consists of the following soil series: Zwartfontein Hu (70%), Shorrocks Hu (20%), Gaudam Hu (5%), etc. The Zwartfontein soil series consists of 4 – 12% clay in the A horizon and 6 – 15% in the B horizon. The Shorrocks soil series consists of 8 – 15% clay in the A horizon and 15 – 30% in the B horizon (Land Type Survey Staff 1992). These are mostly massive or weakly structured soils with a high base status.

2.4.4 Climate

Precipitation:

The normal annual rainfall of the central Free State, in which Soetdoring Nature Reserve falls, is 400 - 600 mm. The rainfall specifically for the Soetdoring Nature Reserve area for December 1999 to April 2001 (the period this study was conducted), is summarised in Figure 2.7 (Information supplied by the South African Weather Bureau, pers. com.)

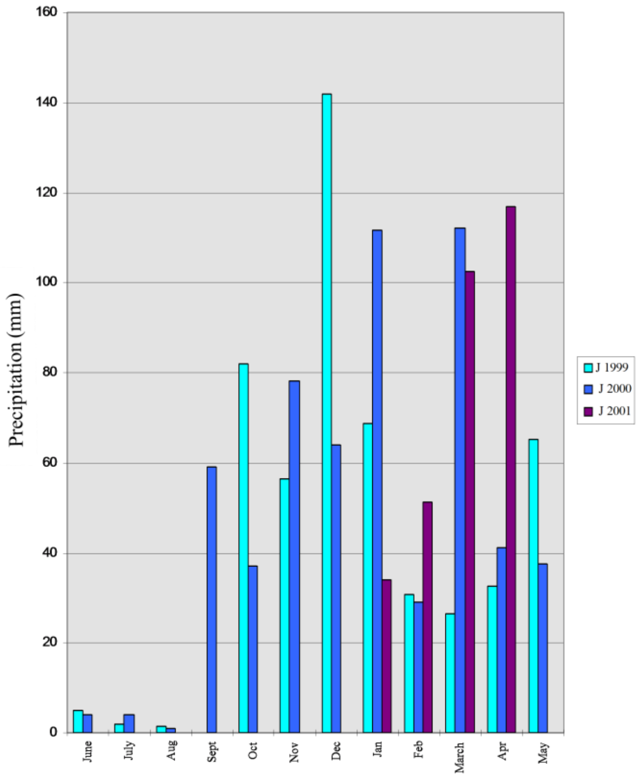


Figure 2.7: Monthly precipitation totals for the Bloemfontein area (January 1999 - April 2001). Information supplied by the South African Weather Bureau, pers. comm.

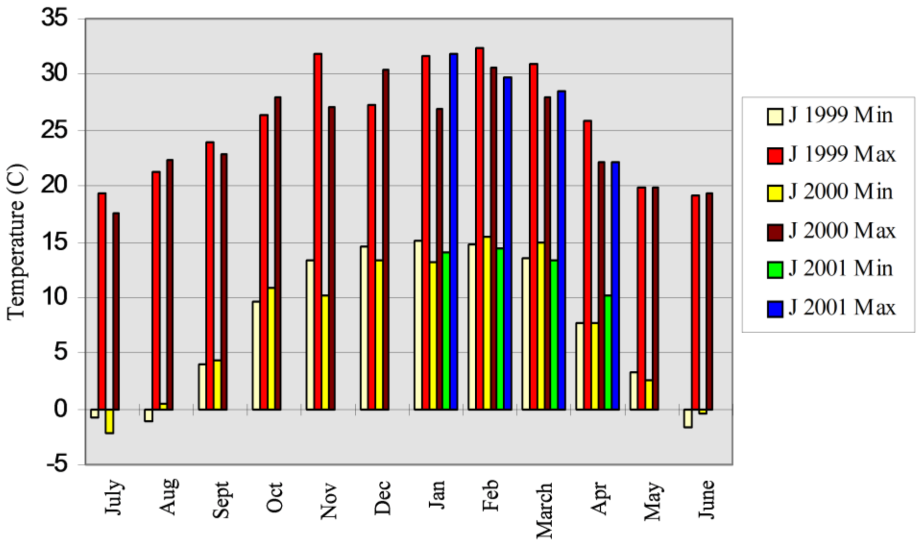


Figure 2.8: Average minimum and maximum temperatures for the Bloemfontein area (January 1999 - April 2001). Information supplied by the South African Weather Bureau, pers. comm.

According to these statistics, the study area falls in the summer rainfall region of South Africa, because the amount of rain during the winter months is very low compared to the summer rainfall values (Figures 2.7 & 2.9). Normally the highest amount of rainfall for the Bloemfontein area can be expected from January to March, with moderate rainfall occurring in April and from October to December (Figure 2.9). However, a rather high amount of rainfall was experienced in April 2001, namely 116.9 mm in 13 days (Figure 2.7). Very high downpour also occurred during February / March 1988, which resulted in a flood that made the Krugersdrift Dam overflow, while the season of 1990/1992 was the driest in the previous century (Watson 1993).

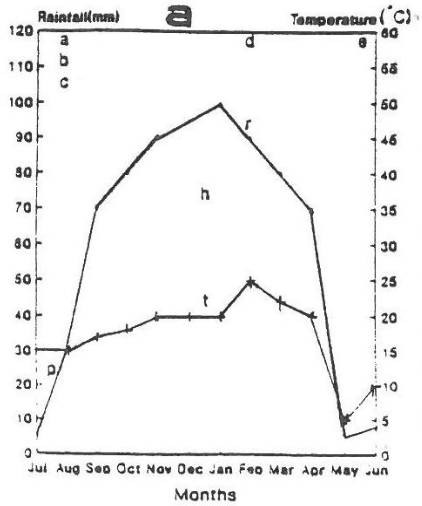
Fog is a rather common phenomenon in this area. Hail-storms occur in the Bloemfontein area from time to time, mostly from October to January. Frost is common in cold winter months when night temperatures drop below 0ºC. Isolated snowfalls were experienced for example on: 10 and 11 June 1993; 29 June 1994; 7 July 1996 and 16 July 2000 (South African Weather Bureau, pers. com. *via* e-mail).

Temperatures:

The average monthly minimum and maximum temperatures for the Bloemfontein area, December 1999 - April 2001 (the period this study was conducted), are summarised in Figure 2.8. The maximum temperatures of the summer months are known to reach 30ºC and more, but in the winter months it gradually drops to anywhere between 15º and 20ºC (Figure 2.8). The average minimum temperatures of the summer months range between 10º - 15ºC, but in winter it tend to drop to 0ºC and below (Figure 2.9). The summer of 1999 appeared to be very hot, compared to the summer of the years 2000 and 2001.

Climate diagram

The climate diagram, created by Walter and Leith (1960), is based upon the most essential weather data used in ecology, namely rainfall and temperature (Walter 1973). The climate diagram of Bloemfontein is presented in Figure 2.9. The humid period (where rainfall exceeds temperature) stretches from middle September to the end of April. The period of drought (where temperature exceeds rainfall) stretches from June to the beginning of September.



a - Name of station

b - period of recording in years - temperature and precipitation

c - altitude (m)

d - mean annual temperature (°C)

e - mean annual precipitation (mm)

h - humid period (where rainfall exceeds temperature)

r - curve of mean monthly precipitation

t - curve of mean monthly temperature

p - period of drought (where temperature exceeds rainfall).

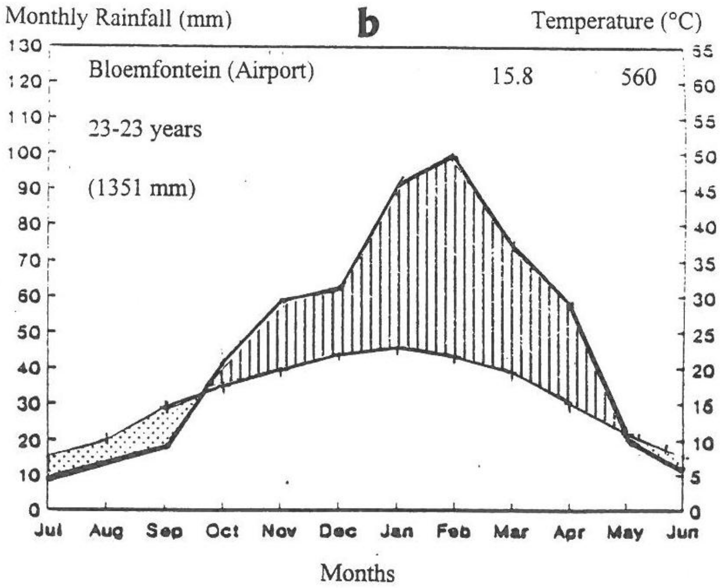


Figure 2.9: Climate diagram for Bloemfontein Airport, compiled from long term data from the South African Weather Bureau (1954, 1965 & 1986).

a) An example of the climate diagram indicating how to read the data from it.

b) The climate diagram for Bloemfontein.

(*Redrawn from Malan 1998*)

Wind direction:

Table 2.1: Percentage frequency of occurrence and resulting average amount of days per year for each wind direction. Analysis based on hourly readings for the period September 1993 - October 1997. (Information supplied by the South African Weather Bureau, pers. com.)

Wind direction	**Percentage frequency**	**Amount of days per year**	**Wind direction**	**Percentage frequency**	**Amount of days per year**
N	8	29.2	WSW	4	14.6
W	8	29.2	ESE	3	10.95
NW	7	25.55	S	3	10.95
E	7	25.55	SW	3	10.95
NNW	6	21.9	SE	2	7.3
WNW	6	21.9	SSE	2	7.3
NE	6	21.9	SSW	2	7.3
NNE	5	18.25			
ENE	5	18.25	Calm	22	80.3

As indicated in Table 2.1, for the highest number of days (80,3 days of the year) calm conditions with no wind can be expected for this area. The wind directions with the highest frequency of occurrence are north and west (8/100 x 365 days = 29,2 days each), followed by north-west and east. The directions in the quadrant between north and west, i.e. NNW and WNW, occur for the third highest amount of days per year (21,9 days per year), while the directions in the quadrant between north and east, i.e. NNE and ENE, have the fourth highest frequency of occurrence. Wind from the other directions do occur, but with a much lower frequency. Thus, the general direction of the wind in this area lies in the quadrant between north and west, both included, and with a lower possibility in the north to east quadrant. The average speed of the wind, as determined by the Weather Bureau, is 3 $m.s^{-1}$ (Information supplied by the South African Weather Bureau, pers. com. *via* e-mail).

CHAPTER 3: METHODS

3.1 INTRODUCTION

In this study the classification of the vegetation is done on the basis of the floristic-sociological (Zurich-Montpellier) approach or Braun-Blanquet method, with the essential viewpoint that plant communities are units of classification, based primarily on species composition (Coetzee 1993). The method is described by Braun-Blanquet (1932, 1964); Poore (1955 a, b, c, 1956); Becking (1957); Pawlowski (1966); Shimwell (1971); Werger (1974); Mueller-Dombois and Ellenberg (1974); Whittaker (1978); Kent and Coker (1996) and others.

The purpose of the methodology of the Braun-Blanquet method, is to construct a global classification of plant communities. The method is based on several fundamental concepts and assumptions (Kent & Coker 1996), but it is unfortunately not without its problems. However, Werger (1973a) stated that the method satisfies the three basic essential requirements of an ecological vegetation study, namely (i) being scientifically sound, (ii) fulfilling the necessity of classification at an appropriate level and (iii) being the most efficient and versatile amongst comparable approaches.

Since the introduction of this method to South African phytososiologists, it has been successfully applied in numerous vegetation classification studies. Some examples from 1973 to 2001 include: Werger (1973a), Coetzee (1974), Bredenkamp (1975), Scheepers (1975), Bredenkamp and Theron (1976), Jarman (1977), Du Preez (1979), Bredenkamp and Theron (1980), Potgieter (1982), Rossouw (1983), Bosch, *et al.* (1986), Du Preez (1986), Müller (1986), Van Wyk and Bredenkamp (1986), Behr and Bredenkamp (1988), Bredenkamp, *et al.* (1989), Turner (1989), Bezuidenhout and Bredenkamp (1990), Bredenkamp and Bezuidenhout (1990), Du Preez and Venter (1990), Kooij *et al.* (1990 a, b, c), Bezuidenhout and Bredenkamp (1991 a, b), Breytenbach (1991), Du Preez and Bredenkamp (1991), Matthews (1991), Du Preez and Venter (1992), Fuls, *et al.* (1992), Kooij *et al.* (1992), Malan (1992), Myburg (1993), Bezuidenhout *et al.* (1994), Coetzee *et al.* (1994), Schulze *et al.* (1994), Smit *et al*. (1995), Eckhardt, *et al.* (1996), Malan *et al.* (1999), Bonyongo *et al.* (2000), Van Wyk *et al.* (2000), Hoare and Bredenkamp (2001), Matthews *et al.* (2001), Morgenthal, *et al.* (2001), and many others.

The Braun-Blanquet method has the following key ideas, as described by Coetzee (1993):
The study of plant communities should be based on a fundamental **vegetation unit**. This vegetation unit should be the association, and associations should be defined by the presence of character species (Kent & Coker 1996). The following definition of an association was presented to the Third International Botanical Congress in Brussels: "An association is a plant community of a definite floristic composition, presenting a uniform physiognomy, and growing in uniform habitat conditions. The association is the fundamental unit of synecology" (Whittaker 1978). Each association consists of stands, and the association can be described from samples of these stands. Each sample plot chosen, should be representative of such a stand, and it should include an analysis of the total species composition. Associations should be grouped together into higher units based on floristic composition (Westhoff & Van Der Maarel 1978; Kent & Coker 1996).

According to Bredenkamp and Brown (2001), **vegetation** is composed of the local flora, that is the plant species of the area organised into populations and communities, which are the result of very long processes of evolution. Vegetation composition is mainly dependant on climate and substrate (Best 1988). A group of associated plant species with it's particular habitat, according to Bredenkamp and Brown (2001), forms a **plant community** and this interrelationship between plants and the physical environment represents an ecosystem at the community level of organisation (Best 1988). In other words a community simply consists of all the plants occupying an area which an ecologist has circumscribed for the purposes of study (Crawley 1991). Plant communities can be distinct, easily separable vegetation units associated with particular sets of environmental conditions including historical land-use; or vegetation can be in gradients (one plant community grades into another without sharp boundaries), as a result of continuity in certain environmental factors (Bredenkamp & Brown 2001).

The execution of the Braun-Blanquet method has been divided into two phases, namely the **analytical** phase, in which the data on species composition and the environmental variables were collected, and the **synthetical** phase in which relevés are synthesised in table form to represent vegetation units that result in the phytosociological table.

3.2 ANALYTICAL PHASE

3.2.1 Distribution, number and size of sample plots.

The sample plots were randomly distributed within the grassland and the pans. The exact position of each sample plot within the relevant vegetation unit was chosen in order to avoid obvious heterogeneity in the physical environment and floristic composition (Coetzee 1993). In each sample plot, the Braun-Blanquet cover abundance scale (Mueller-Dombois & Ellenberg 1974) was used in noting the floristic composition.

According to the methodology of the Braun-Blanquet method, the homogeneity of the sample plot is essential (Whittaker 1978; Kent & Coker 1996). However, according to Daubenmire (1974), there is no natural plant community that is completely homogeneous with regard to floristic composition and environmental factors. Consequently, a homogeneous vegetation stand is defined as one where the variation can be attributed to coincidence rather than environmental factors.

Plot sizes where fixed on $16m^2$ for grassland and pan vegetation. That is in accordance with Müller (1986), Du Preez and Venter (1990, 1992), Bezuidenhout and Bredenkamp (1991a, b), Fuls *et al.*(1992), Malan *et al.* (1994, 1999) and Van Wyk *et al.* (2000). As far as possible, square shaped plots were used. In some cases it was necessary to adapt the shape to ensure a homogenous vegetation sample. Stratification was done according to different habitats in the grassland and pan vegetation. In order to accommodate the growing season, sampling was carried out from January to April 2000 and again from November 2000 to April 2001. Consequently there was the possibility of compiling a more complete species list as well as a more representative sample of the vegetation unit. The total data set consists of 229 relevés and 171 species.

3.2.2 Floristic analysis

The floristic survey includes 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):

r - one or a few individuals (rare) with less than 1% cover of the total sample plot area;

+ - infrequent with less than 1% cover of total sample plot area;

1 - frequent with low cover, or infrequent with higher cover, 1% - 5% of total sample plot area;

2a - abundant with > 5% - 12% cover of total sample plot area, irrespective of the number of individuals.

2b - abundant with > 12% - 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% - 100% cover of total sample plot area, irrespective of the number of individuals.

Taxon names conform to Arnold and De Wet (1993) and the PRECIS species list of the NBI (August 2001), as incorporated in the TURBOVEG database of southern African flora.

3.3 SYNTHETICAL PHASE

3.3.1 Converting the raw data into plant communities.

The synthetical phase involves the objective arranging of relevés and species in such a way that in a phytosociological table, the relevés with a similar floristic composition and the species with the same distribution are grouped together (Schulze 1992). Each group of species, known as diagnostic species, will then be representative of the vegetation unit associated with a specific habitat.

Relevé (French for 'abstract') is the European equivalent for sample plot or vegetation sample (Mueller-Dombois & Ellenberg 1974). The set of floristic and environmental data for a sample plot is then collectively known as a relevé (Schulze 1992). Phytosociology is the study of the composition, development, geographic distribution and environmental relationships of plant communities. Synonyms for phytosociology are: Vegetation science, synecology and community ecology (Mueller-Dombois & Ellenberg 1974). The phytosociological table provides a summary of all, or most of, the above relationships of plant communities.

The computer programmes TURBOVEG (Hennekens 1996a) and MEGATAB (Hennekens 1996b) were used to convert the raw field data into table form. In order to derive a first approximation of the possible communities, a Two-Way Indicator Species Analysis (TWINSPAN, Hill 1979a) was applied to the basic floristic data set. TWINSPAN is a computer programme with a divisive-polythetic algorithm. Refinement of this classification was done by the application of the Braun-Blanquet procedures (Behr & Bredenkamp 1988; Coetzee 1993; Fuls *et al.* 1993; Kent & Coker 1996).

3.3.2 Higher order classification and description of the phytosociological table.

In the Braun-Blanquet method, the level of the association is fundamental and represents the basic unit of vegetation description, equivalent to the plant community. Higher and lower orders can be recognised within an overall floristic association system. For instance, a grouping of two or more associations which have their major species in common can be combined to give an alliance (Kent & Coker 1996). However, formal names were not assigned to the vegetation units due to the small scale of this study.

The following guidelines, as suggested by Pauw (1988), were used during the binomial naming of plant communities in the table:

- The first species name is preferably that of a diagnostic species that occurs in the community.
- The second species name is that of a visually prominent species or a dominant species with a high constancy in the community.

The major vegetation units, the grassland, karroid shrubland and pans, were treated separately in analysis and derivation of plant communities. The plant communities distinguished were described and ecologically interpreted. The diagnostic species of each community, the floristic relatedness to other communities and the structure of each community were also included.

The individual classifications of the data resulted in the identification of 17 plant communities. A synoptic table was constructed for the entire data set, using constancy classes. The constancy of all species within each class was rated on the following scale: I = < 20%; II = 21 - 40% ; III = 41 - 60%; IV = 61 - 80% and V = > 80%. In this way each community was summarised as a single column (synrelevé) in the synoptic table (Du Preez & Bredenkamp 1991).

Ordination methods can also be applied to floristic data to illustrate the floristic relationships between plant communities (Malan 1998). Ordination is a type of classification which involves the grouping of data on a scattergram by using numerical methods. Ordination does not have to be limited to plant relevés only, it can also be used to relate plant groups to environmental or other factors (Best 1988). In this case, the vegetation units and the associated habitat gradients, as well as the floristic relationships among the plant communities were explained by subjecting the floristic data set to Detrended Correspondence Analysis (Matthews *et al.* 2001), by making use of the computer programme DECORANA (both devised by Hill 1979b; Hill & Gauch 1980). Kent and Coker (1996) give a detailed description of the ordination method.

3.4 SOME DISADVANTAGES OF THE BRAUN-BLANQUET METHOD

Much valuable work has been completed by making use of the Braun-Blanquet method. Nevertheless, valid criticism of the method exists and centres around the following points as described by Kent and Coker (1996):

- The subjectivity of the whole methodology, particularly the methods of field sampling. The selection of ‘typical’ or ‘representative’ relevés is often highly biased and does assume a substantial knowledge of the vegetation prior to any attempt at description.
- Non-homogeneous and ecotone (transitional) areas between typical and representative samples are not normally recorded under this method, yet are still clearly plant assemblages.
- The concept of ‘abstract’ communities. Species and relevés are grouped into a community according to the presence or absence of the species in relation to other communities (pers. obs.). This has proved a confusing concept particularly for students and inexperienced researchers.
- The process of tabular rearrangement. The exact methodology of carrying this out varies from one worker to another. The development of computerised methods has helped with the practical aspects of relevé sorting.
- The discarding of relevés which do not fit any of the associations which have been defined from a set of associations. The reason for doing this lies under the first described disadvantage, in that such a relevé must have been badly chosen at the stage of field description.

3.4 ADVANTAGES OF THE METHOD FOR NATURE CONSERVATION PRACTICE.

According to Bredenkamp and Theron (1976), the results of this and other studies (Werger 1973b; Coetzee 1974) indicate that the Braun-Blanquet method may be highly advantageous for management practices. The following advantages of the Braun-Blanquet method are described by Bredenkamp and Theron (1976).

- The method is based on total floristic composition, and therefore also includes species with narrow ecological amplitude which are often not the dominants but which indicate certain ecological factors. Classification of vegetation, particularly on groups of associated species which are restricted to certain sets of environmental conditions, should be ecologically significant.
- The processing of the data leads to the compilation of phytosociological tables, which summarise many of the characteristics of the communities in a single table which can be viewed in it's entirety. The matrix of the table comprises quantitative data which indicate abundance, cover, constancy and fidelity of the individual species in the community. This valuable quantitative data is of great importance for the determination of the grazing potential of the communities involved.
- Any environmental factor of each community can be summarised at the top of the table. The environmental conditions to which each community is restricted as well as the degree of variation in habitat in the different stands of the community are readily available.
- Effects of mismanagement are often brought out by the tables. Werger (1974) stated: "when field observations established that relevés summarised in a particular community always represent overgrazed stands, whereas closely related but less overgrazed stands are summarised in another community, that table would clearly show that the first community is just a degenerated version of the second. The table would show which floristic differences correspond to a particular degree of overgrazing and thus to the degeneration status of the community".
- Results from additional stands can easily be incorporated into existing phytosociological tables, and results obtained from other vegetation surveys, can be compared with the existing tables.
- One of the most important advantages of the method is that it enables a hierarchical classification of vegetation. A phytosociological table indicates that some species are restricted to one community, or a smaller number of related communities. This demonstrates the relationship between the communities and also provides the basis for the hierarchical classification. Floristically and environmentally related communities can be grouped. In this way numerous small vegetation units, or communities are grouped successively into larger, more practical units. This is of considerable importance for management planners, for a management programme can be adapted to and applied at different levels in the hierarchical system.

CHAPTER 4: A GENERAL DISCUSSION ON PANS

4.1 INTRODUCTION

To the casual traveller in 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 are surprisingly common (Seaman 1987). In fact, according to Seaman (1987), in pioneer days, transport routes in the western Free State followed lines of pan abundance because of the water which they provided. In the past many pans were also frequented by wandering herds of antelope and elephants seeking water and fresh pasture (Mepham & Mepham 1987). Pans are important components of the terrestrial ecosystems of the region and, when holding water, they contain a unique and fascinating biota (Seaman 1987).

Unfortunately, this is often not the way in which people see wetlands, including pans. Wetlands are wastelands, at least, that is the traditional view. Words like pan, vlei, floodplain, marsh, swamp, etc. usually imply little more than dampness, disease, difficulty and danger (Maltby 1986). Wetlands cover 6% of the world's land surface and are found everywhere, in all climates and countries, from the tundra to the tropics. Yet few people really know what they are. The word *wetland* does not even appear in most dictionaries (Maltby 1986).

The aim of this chapter is to supply information on pans in general, in order to apply this general information to the pans in Soetdoring Nature Reserve (**Chapter 5**).

4.2 DEFINITIONS

There exists some controversy around the definition of wetlands (e.g. Morant 1983, Walmsley & Botten 1987). Wetlands occupy an intermediate position (ecotone) on the continuum between aquatic and terrestrial environments (Morant 1983; Breen & Begg 1991; Odum 1997). Since the continuum is variable in space and time, it is not surprising that 'there is no single, correct, indisputable, ecologically sound definition for wetlands' (Cowardin *et al.* 1979). The word wetland therefore is a generic term used to group those features of the landscape the formation of which has been dominated by water, which processes and characteristics are largely controlled by water (Maltby 1986), and which are commonly referred to as pans, vleis, floodplains, marshes, swamps and bogs, as a single type of ecosystem (Breen & Begg 1991).

Definitions of wetlands vary in accordance with individual interests (Breen 1991). The 1971 RAMSAR convention on wetlands of international importance, defined wetlands as: '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' (Maltby 1986, Breen 1991). This definition, however, caters for the interest of conservationists in general and of those concerned with waterbirds in particular. As such it sets them apart from other interest groups e.g. hydrologists and agriculturalists (Breen 1991).

What is required, however, is an all embracing definition which is based on the determinants of wetland structure and functioning, rather than on those properties of sectoral interest (Breen 1988). Such a definition has been developed by the United States Fish and Wildlife Service and states that a wetland is: 'Land where an excess of water is the dominant factor determining the nature of soil development and the types of animals and plant communities living at the soil surface. It spans a continuum of environments where terrestrial and aquatic systems intergrade' (Breen 1991; Davies & Day 1998).

Perhaps the most useful definition for southern Africa, which includes so much arid land, is that used by the Directorate of Environmental Affairs in Namibia. It states that wetlands are 'the interfaces between aquatic and terrestrial ecosystems, whether permanent or ephemerally inundated, with fresh or salt water' (Davies & Day 1998).

There may well be some controversy surrounding the definition of wetlands, but endorheic pans (pans with an inlet but no outlet) are relatively easily defined ecosystems. 'Pan' is a South African vernacular term for any large, flat, sediment-filled depression that collects water after rain (Mepham & Mepham 1987; Shaw 1988; Seaman *et al.* 1991; Davies & Day 1998). They usually dry up seasonally, mainly through loss of water due to evaporation (Geldenhuys 1982; Meintjies 1992). Typically their shape is circular to oval (Allan 1987a). They are shallow, even when fully inundated, and usually less than about three metres deep (Allan *et al.* 1995; Malan 1998).

Lancaster (1979) used a locally more applicable definition for describing the southern Kalahari pans. He described them 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 5 - 20 m deep with areas of 2 - 16 km^2.' Inundation is characteristically ephemeral. In most arid regions pans can stand dry for years between temporary flooding (Davies & Day 1986). Goudie and Thomas (1985) and Meintjies (1992) refer to pans as ‘closed basins’. The most common name for a pan used in world geomorphological literature, is “playa” (Neal 1975; Davies & Day 1998), which is Spanish for shore (Waisel 1972).

4.3 DISTRIBUTION

Pans are widespread in South Africa, but not ubiquitous. Most of them occur on the arid side of both the 500 mm mean annual isohyet and the 1000 mm free surface evaporation loss isoline (Le Roux 1978; Goudie & Thomas 1985). Pans are distributed throughout various biomes, being especially common in the Grassland, Nama Karoo and Kalahari Biomes (Allan, *et al*. 1995). Within the arid area there are some major concentrations of pans. Pans are concentrated in, but not restricted to, a pan ‘belt’ that stretches from the North-west Province through the Northern Cape Province, and the western Free State to south of the Orange River (Meintjies 1992). In the western Free State the belt runs southwards from Kroonstad, through Wesselsbron, Boshof and Dealesville to the south of Kimberley in the Northern Cape Province (Goudie & Thomas 1985; Seaman 1987; Shaw 1988).

The pan density is particularly high in the Dealesville-Bultfontein area, according to Goudie and Thomas (1985), and this is the area in which Soetdoring Nature Reserve falls. Thus, it is not surprising that in the ± 3700 ha reserve, excluding the Modder River and Krugersdrift Dam (**Chapter 2**), there are two fairly large pans - over and above the floodplains. Geldenhuys (1981) determined the numbers and densities of pans per sixteenth degree square in the western Free State, and found that in the 2826 CC square, in which a part of Soetdoring Nature Reserve falls, a total of 69 pans can be found, with a density of 10,2 pans per 100 km^2.

4.4 THE ORIGIN OF PANS

Factors influencing pan formation (Figure 4.1) are a complex mixture of climate, availability of geologically susceptible surfaces, disturbance of the surface by animals and salt weathering, the lack of integrated drainage systems (streams and rivers) and deflational processes including wind (Le Roux 1978; Goudie & Thomas 1985).

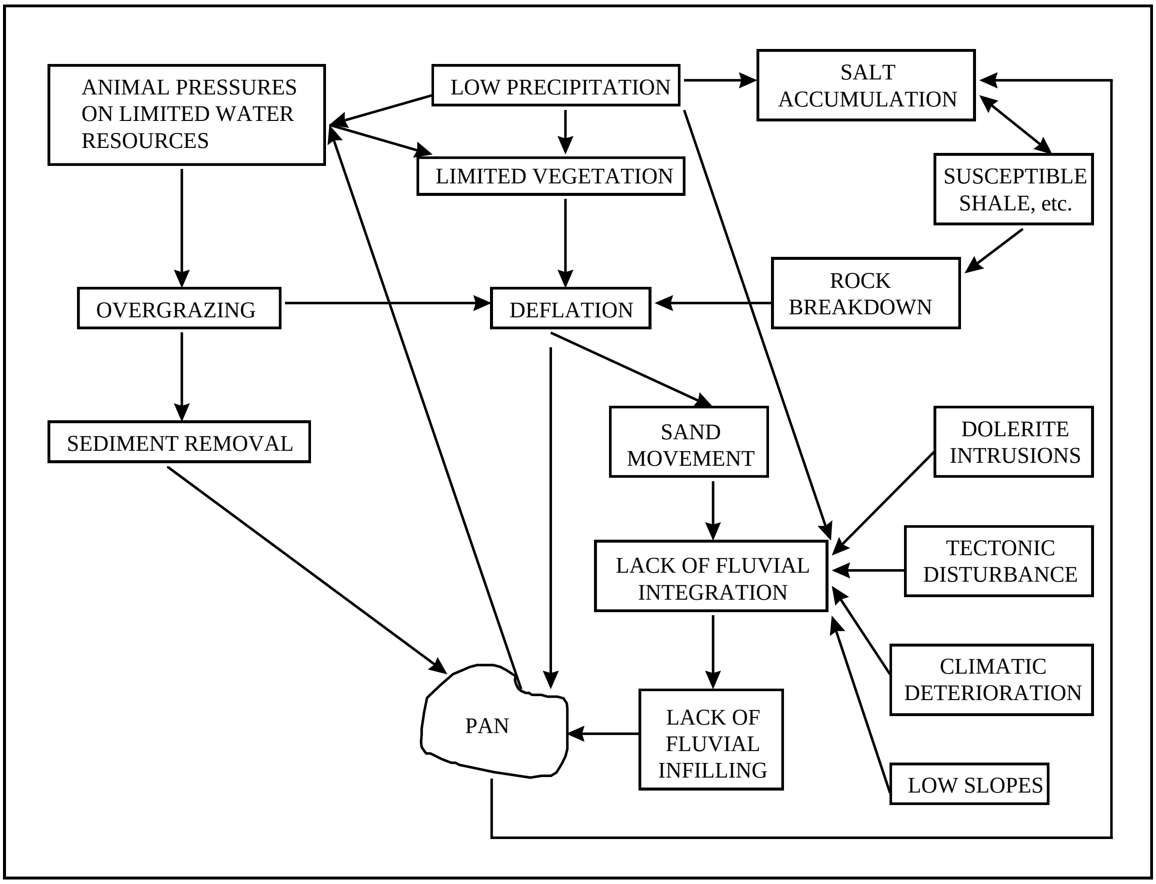


Figure 4.1: A model of pan development. (*Redrawn from Goudie & Thomas 1985*).

Of prime importance in the formation of pans, according to De Bruiyn (1971), is the presence of dolerite basin structures, which, due to the resistance of dolerite to weathering, lead to the development of local inward draining patterns. The most obvious association is with areas of poor drainage. Precipitation in such areas tend to form static pools and these provide the genesis of typical pans (Allan 1987a ; Allan *et al.* 1995). As the water evaporates, salts become concentrated and this results in the death of plants (De Bruiyn 1971; Allan 1987a; Grobler *et al.* 1988). Thus, the drying up of these pools in the drier areas, leave exposed soil not bound by protective vegetation (Allan 1987a ; Allan *et al.* 1995). This allows the wind to scour out a basin.

The circular shape of pans results from them being shaped by swirling winds (Allan *et al.* 1995). Many pans have characteristic low mounds beyond their shorelines on the downward side where soil lifted by wind action have been deposited over aeons (Grobler *et al.* 1988; Allan *et al.* 1995). The orientation of pans along prevailing wind directions and the presence of the lunette dunes on the leeward sides of many pans, emphasise the contribution of wind action (Shaw 1988; Seaman *et al.* 1991; Allan *et al.* 1995). Wind erosion is of particular significance during the dry season when soil in the basin is dry and marginal vegetation is short and sparse (Parris 1984).

Lancaster (1978) proposed deflation (i.e. erosion by wind) as a mode of formation, on the basis of pan orientation and the presence of lunette dunes. Le Roux (1978) stated that wind is the only agent which could have been responsible for the origin of most pans, although some pans probably originated as a result of disturbed drainage. Goudie and Thomas (1985) have observed that deflation would be more effective in areas where salt weathering is an active process.

The Karoo shales have a low resistance to chemical weathering and weather quickly on exposure (Le Roux 1978). An investigation of a large number of pans all over the Free State, according to Le Roux (1978), indicates that pans are located on all formations but that a great majority occur on the shales of the Karoo Supergroup (Ecca, Beaufort and Stormberg Series). As these formations are mostly, and in the western part of the Free State Province (Ecca) almost exclusively, built of shale it may be concluded that the shales of the Karoo Supergroup favour pan formation (Le Roux 1978). Soetdoring Nature Reserve is also underlain by the Ecca Group of the Karoo Supergroup (*vid.* **Chapter 2**)

The role of weathering, both at the surface and at depth, is becoming increasingly recognised (Shaw 1988). The differences between saline, clay and grass pans have also been attributed (Butterworth 1982) to the delicate balance between fluctuations in shallow saline groundwater and deflational activity in controlling the marginal environment of vegetation growth (Shaw 1988).

The role played by mammals in the formation of pans is emphasised by Parris (1984). In the Kalahari, where annual rainfall is low, seasonal waterholes formed during intensive thundershowers are particularly important to game. Excessive grazing and trampling of vegetation around the edges of pans by large mammals inhibits the growth of vegetation and expose pans to destructive wind action (De Bruiyn 1971; Allan 1987a; Grobler *et al.* 1988; Shaw 1988). In addition, soil from the pan substratum adheres to the grazing and drinking animals and is carried away. The removal of soil gradually deepens the pans and helps to maintain their basins (Parris 1984).

In the case of pans associated with fossil riverbeds, the changes in drainage patterns were caused by climatic desiccation, the headwaters of the original river systems being captured by other rivers through erosion, or by tectonic shifts (Allan 1987a). Frequently the old watercourses became blocked by shifting sand and pans formed in areas where these blockages occurred (Parris 1984). Grobler *et al.* (1988) gave a detailed description of the development of pans in palaeodrainage areas.

4.5 THE ORIGIN OF SALTS IN PANS.

In the pan on the southern side of the Modder River, inside Soetdoring Nature Reserve, salts accumulate in the dry phase of the pan as a white crust. Salts usually encountered in pans are sodium and calcium sulphates, sodium chloride and sodium carbonate, and magnesium, mostly as efflorescence at the pan surface, or as a saline clay layer (Seaman 1987; Shaw 1988). Nitrates are less common (Shaw 1988).

The water of wetlands may contain appreciable amounts of salt (Davies & Day 1998). Geldenhuys (1982) has drawn attention to the very large numbers of salt pans in the western parts of the Free State; on the basis that four out of six types of pan he distinguished, contain saline water. The term 'brackish' is a useful, if imprecise, term for 'somewhat salty water' with salt concentrations between about 3 000 and 12 000 $mg.l^{-1}$ (up to about a third of the salt content of sea water). Water containing less than 3 000 mg.l^{-1} of salt (or total dissolved solids, TDS) can be considered as fresh, while all waters with TDS values higher than 12 000 mg.l^{-1} are classified as saline (Davies & Day 1998).

According to Russel (1961) evaporation of water from saline soils eventually results in a saturated solution and on further evaporation in a crust of salt on the surface of the soil. The vapour pressure of a concentrated solution is lower than one with a lower salinity and the soils at such localities remain wet for a longer period. Eventually dissolved salts collect there in greater quantities and the salty patches tend to grow in size (Russel 1961).

With regard to the origins of the ions, those in South Africa mostly seem to be of connate origin (Seaman *et al.* 1991), or in other words the salt originates from the underlying rock formation (De Bruiyn 1971). The majority of the salt pans overlie Ecca and Dwyka shales, the characteristic salts of which are chlorides and sulphates of sodium, calcium and magnesium (Bond 1946). The composition of underground brines clearly reflects this, as does that of water in the pans, and it seems reasonable to conclude that most of the salts in pans are from geological sources (Seaman *et al.* 1991). The large scale erosion of rocks is probably due to thermic distension because sodium chloride present in the underlying rock formations, erodes faster than most other rock components (Geldenhuys 1982).

In arid inland situations, the predominance of evaporation over precipitation, and rising capillary groundwater which carries solutes and salts to the surface, results in salt enriched wetlands (De Bruiyn 1971; Breen 1991). Mazor and Verhagen (1983) mentioned that many thermal springs issue in marine sedimentary rocks and that at least part of the dissolved ions is attributed to flushing from these rocks. The flatpan floors which are covered by a thin layer of calcareous clay, may then be explained by the in depth groundwater having a high sodium chloride content (Loock & Grobler 1988). Modern hydrological views concerning endorheic pans, are that they are far less hydrologically isolated from underlying aquifers, than has been assumed until recently (Seaman *et al.* 1991). Aquifers are defined as layers of rock sufficiently porous to store water and permeable enough to allow water to flow through them in economic quantities (Price 1985).

It is also possible that there can be salt influx into the pan through rain water. In 1914, Dr Juritz determined the salt content of rainwater, according to De Bruiyn (1971), and his results for Bloemfontein was 9 kg sodium chloride (NaCl) in rainwater / ha / year. It is interesting to notice that the amount of salts determined in Durban’s rainwater, because of its proximity to the sea, is

120 kg NaCl / ha / year. If a simple mathematical calculation is made on say 3,37 kg NaCl in rainwater / ha / year, it equals 337 kg NaCl / km^2 / year. The following deduction can then be made, according to De Bruiyn (1971): The area between the Orange and Vaal River covers a surface of 1 036 000 km^2. Thus, with above mentioned information, there would be an annual deposit of 349 200 metric tonnes of NaCl in the province. However, Borchers (1949) calculated that the two rivers remove about 174 600 metric tonnes of salt annually, which is about half that of the total salt deposit. If it is kept in mind that pans accumulate run-off rainwater from the adjacent veld, this could well be a possible source of at least some of the salts in pans.

4.6 THE CLASSIFICATION OF PANS

A universal classification system for the wetlands of southern Africa has remained an elusive, though urgent, goal (Morant 1983). Pan ecosystems are particularly difficult to classify owing to their dynamic nature (Allan *et al*. 1995). There are also theoretical problems in deciding on what parameters the classification should be based. A classification of wetland types drawn up by soil scientists, botanists, ornithologists and invertebrate biologists could all be expected to differ widely (Allan *et al*. 1995).

An early attempt to classify pans was based simply on their distance from the coast, as Du Toit (1927) classified pans as coastal or inland. Since then a number of classification systems were developed, making use of different parameters. Allan *et al*. (1995) give a historical overview of these different classification systems. Only the most recent ones will be discussed.

1. Noble and Hemens (1978) gave a general overview of several pan types in South Africa on the basis of <u>physical characteristics</u> and <u>faunal and floral composition</u>. Noble and Hemens divided the endorheic pans into the following categories, as described by Mepham and Mepham (1987):

1.1 **Salt pans** are dry most of the time, but may contain perennial pools filled by springs. Their soils are highly saline and devoid of any higher vegetation. The fauna includes typical temporary water forms like phyllopod crustaceans, the eggs of which need to dry out before further development can take place. Salt pans are found especially in the Karoo, Kalahari, western Free State and Transvaal.

1.2 **Temporary pans** are shallow and dry out for long periods although they may retain a few perennial pools. Their soils are alkaline and moderately saline. Higher vegetation is restricted to a few salt tolerant grasses and the fauna includes phyllopods. Pans of this type are found throughout the northern Cape Province, the western Free State, the North-west Province and parts of Namibia of which the most famous one is Etosha Pan.

1.3 **Grass pans** are seasonal and dry up in winter except for the usual perennial pools. A thick growth of hygrophilous grasses cover these pans along with other low terrestrial vegetation, some of which are salt tolerant. The vegetation is usually inundated in summer, and a diverse flora of submerged hydrophytes, filamentous and macrophytic algae may develop. The water is rich in nutrients, usually fresh in summer and slightly brackish in winter. Grass pans are mainly found in Gauteng and Mpumalanga Provinces where the annual rainfall is 650-800 mm.

1.4 **Sedge pans** are also seasonal, but do not dry up in the centre sufficiently for terrestrial vegetation to become established. A thick growth of marsh vegetation, about 1m high, is present around the margins, comprising mainly members of the Cyperaceae, but no emergent vegetation can be found in the centre of the pan. The water tends to be rich in nutrients, fresh in summer and slightly brackish in winter.

1.5 **Reed pans** are temporary or semi-permanent pans with a dense stand of *Phragmites* in the middle, and an outer narrow ring of open water. The water is clear and may be fresh to slightly brackish, and the sediments are rich in organic matter. Dense beds of algae may develop in the peripheral ring of water during the summer months.

1.6 **Semi-permanent pans** and lakes are generally deeper than the other types. Some may be fresh, at times at least, but most are somewhat brackish. Some may develop fairly permanent beds of *Potamogeton* species L. and other aquatic flora. Most have sparse grassland around the margins - the best known example is Baberspan in the North-west Province.

2. A more comprehensive classification of pans was devised by Geldenhuys (1982) and summarised in a diagram (Figure 4.2). Six pan types were distinguished in the Free State on the basis of <u>emergent vegetation</u> and in relation to <u>utilisation of pans by water birds</u>, both of which are dependent on the average duration of inundation (Allan *et al*. 1995).

Geldenhuys (1981, 1982) consequently divided pans into the following types:

2.1 **Bare pans** have a distinct high water line and less than one percent is covered with emergent vegetation. Submerged plants such as Characeae and *Zannichellia* species L. may occur at the pan bottoms. The littoral zone may be devoid of vegetation; consist of similar vegetation to the adjacent veld or may include hydrophytic components such as clumps of Cyperaceae. Bare pans are frequently used for salt exploitation.

2.2 **Sedge pans** have high water lines that are frequently difficult to identify. The emergent vegetation, predominantly Cyperaceae, covers the entire water surface and intermingles with the vegetation of the adjacent veld. Sedge pans are relatively small (< 2 ha) and the water is at most moderately brackish.

2.3 **Scrub pans** usually have unclear water lines. They are rarely flooded and are covered, even when dry, with halophytic dwarf shrubs such as *Salsola aphylla* L.f. and *Sueda fruticosa* (L.) Forssk. Hydrophytes are absent around the perimeter. When the pans are flooded, the water reaches hypersaline conditions and crystallised salt is sometimes deposited on the pan floors. Salt works frequently occur at these pans to exploit the salt deposits.

2.4 **Mixed grass pans** have distinct high water lines. Emergents, consisting of various moisture loving grasses (mainly *Eragrostis* species) cover the entire pan, occur on the littoral zone and intermingle with adjacent pan vegetation. Depending on water depth the grasses may be sparsely distributed or form a dense cover. Salt exploitation does not occur.

2.5 **Closed** *Diplachne* **pans** have clearly defined high water lines and emergent grass, particularly *Diplachne fusca* which may cover more than 90% of the water covered surface of the pan. This grass species forms homogeneous stands of sparse to fairly dense cover. Unlike the tuft structure of mixed grass pans, *D. fusca* is a creeping grass. Salt exploitation was not recorded.

2.6 **Open** *Diplachne* **pans** are similar to closed *Diplachne* pans, except that the emergent grass covers only certain areas of the water covered surface. Crystallised salt has been found.

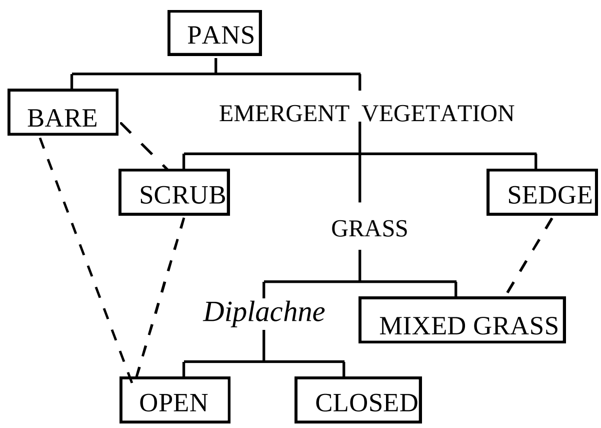


Figure 4.2: Diagram for the classification of pans in the western Free State. Broken lines connect the pan types where characteristics of both types were found. (*Redrawn from Geldenhuys 1982).*

Geldenhuys (1981, 1982) gave a summary of the following results of the waterbird survey, used to classify the pans: "A total of 43 waterbird species were recorded at the pans. Fourteen species were recorded at sedge and scrub pans; 17 at mixed grass pans; 21 at bare pans; 28 at closed *Diplachne* pans and 32 at open *Diplachne* pans. Mixed grass pans had a characteristic waterfowl composition, mainly because of the absence of Shelduck (*Tadorna cana* Gmelin, 1789), Cape Shoveller (*Anas smithii* Hartert, 1891) and Cape Teal (*Anas capensis* Gmelin, 1789) in combination with an abundance of the Egyptian Goose (*Alopochen aegyptiacus* Linnaeus, 1766) and the Spurwinged Goose (*Plectopterus gambensis* Linnaeus, 1766). Similarly sedge pans were the only pans where the Yellowbilled Duck (*Anas undulata* Dubois, 1839) predominated, while Shelduck and the two goose species were absent. Bare and scrub pans had no difference in waterfowl composition - at both types about 80 % of the waterfowl were Shelduck. Except for the rare Maccoa Duck (*Oxyura maccoa* Eyton, 1838) and the Whitefaced Duck (*Dendrocygna viduata* Linnaeus, 1766) , the same waterfowl species were found at closed and open *Diplachne* pans. Apart from the fact that Shelduck were relatively more common at open pans and Redbilled Teal (*Anas erythrorhyncha* Gmelin, 1789) more common at closed *Diplachne* pans, the waterfowl composition of the two pan types closely resembled each other". All species names conform to Brown *et al.* (1992) or Urban *et al.* (1993).

However, Geldenhuys (1981, 1982) stated that from a botanical point of view two pan types, namely closed and open *Diplachne* pans, are similar and can be considered as one type. Yet the avifaunal communities of the two pan types differ to some extent. On the other hand, the bird composition, especially waterfowl, is closely related at scrub and bare pans, which suggests that these two pans may be considered as one type from an ornithological point of view. Thus, for a general classification of pans as habitat for birds, distinguished on the basis of emergent vegetation, Geldenhuys (1982) suggested four types: a) Bare and scrub pans; b) Sedge pans; c) Mixed grass pans and d) *Diplachne* pans.

3. More recently Allan (1987b) has used vegetation physiognomy and species composition to classify different types of pans. Allan (1987a) also stressed the correlation between the type of pan and its avifauna, a synergistic effect which reinforces between-pan differences (Breen & Begg 1991). Allan (1987b) separated pans into the following:

3.1 **Open pans**: Larger pans that tend to be devoid of vegetation except around the shorelines. Their substrate is shallow soil or exposed bedrock. The shore vegetation comprises mainly the grass, *Cynodon dactylon*, sedges (*Scirpoides dioecus* and several *Cyperus* species), various *Juncus* species and the small dicot *Limosella* L. The only grass capable of regularly colonising the actual basins is *Diplachne fusca*. In the North-west Province, two plant species *Crassula tuberella* Tolken and *Frankenia pulverulenta*, have each been recorded only once, in both cases associated with open pans.

3.2 **Sedge pans**: These are small to moderately sized pans. Their substrate is thick black turf and they usually retain water throughout the year, only drying up during droughts. The vegetation is particularly profuse as well as diverse, both along the shoreline and along the basin itself. The two dominant sedges are *Schoenoplectus corymbosus* (Roth. ex Roem. & Schult.) J. Raynal, that forms tall dense stands, and *Eleocharis palustris* R.Br. A particularly interesting discovery in these pans was the aquatic grass, *Odontelytrum abyssinicum* Hack. This grass had only once been recorded in South Africa.

3.3 **Grass pans**: The majority of these pans are smaller than five hectares and covered with grasses and sedges.

3.4 **Salt pans**: This is a class of open pan characterised by extremely saline substrata and these pans are virtually restricted to the dry western areas of South Africa. They are dazzlingly white in the sun when they dry up, due to the exposed salt crystals in their basins. The sedge *Schoenoplectus triqueter* (L.) Palla, is typical of the shorelines and must be particularly well adapted to the saline conditions.

3.5 **Reed pans**: These unique wetlands are characterised by a central *Phragmites* reedbed surrounded by a narrow ring of open water heavily underlain by the submergents *Lagarosiphon* Harv. and *Potamogeton*. They are the most permanent of all pan types usually retaining water throughout droughts.

4. Williams (1987) admitted to the difficulties involved in classifying the temporary waters and suggested that length and intensity of the dry phases are the best criteria to use as they relate directly to biology. Williams (1985) used these two criteria to propose six types of temporary waters according to predictability of inundation and salinity of the water. These types were: predictably filled **discrete fresh water** basins; predictably filled **fresh water** basins associated with rivers; predictably filled **saline water** basins, and the same categories but **un**predictably filled. These six types have the advantage of being applied to both semi-tropical and semi-arid temporary water bodies.

Classification is primarily an information technique that brings order to our thinking and communication by systematically naming the objects being classified and showing the relationship among them (Morant 1983). There is clearly still room for a universal classification system that fulfils all the needs. As for now, pans are distinguished by using the classification system of Geldenhuys (1982) and / or Allan (1987b). The latter being about the same as that suggested by Noble and Hemens (1978). However, **Chapter 5** emphasises the differences between, and difficulties which can arise from using, the current classification systems.

4.7 IMPORTANCE OF PANS

- The quantitative data on the pans of the western Free State underline the importance of pans in this area as a major part of South Africa's natural wetlands. Their value as wetland habitat lies primarily in providing wintering grounds for palaearctic waders as well as breeding habitat for certain duck species, like the Redbilled Teal, Cape Shoveller, Cape Teal and to a lesser extent the Spurwinged Goose and Yellowbilled Duck (Zaloumis & Milstein 1975; Geldenhuys 1981; Maltby 1986; Allan 1987a; Seaman 1987). However, the pans have to be inundated for a total of 110 days or longer, because the waterfowl species that breed in pans need at least 110 days for territorial spacing, nesting, egglaying, incubation and rearing of the young (Geldenhuys 1981, 1982).

- Pans are, however, crucial not only to these specialist birds. Vast numbers of other waterbirds characteristic of wetlands generally exploit pans for at least part of their life cycles, for example snipes, avocets, stilts, ibises, spoonbills, coots, terns and plovers (Allan 1987a). The pans are also widely used by the two flamingo species (Geldenhuys 1981, 1982; Allan 1987a; Seaman *et al.* 1991), both of which are listed in the South African Red Data Book, Aves (Siegfried *et al.* 1976). The flamingos can appear in their thousands at a single pan - the major attraction of the pans to the general public (Geldenhuys 1981, 1982; Allan 1987a).

- It was the importance of wetlands as habitat for waterfowl which spurred the first diplomatic efforts towards their preservation and the resulting RAMSAR convention (Maltby 1986). Wetlands are the only ecosystem type that has their own international convention - the RAMSAR Convention of 1971, under which signatories agree to include wetland conservation in their national planning and to promote their sound utilisation (Maltby 1986). The primary aim of the RAMSAR Convention, of which South Africa is a contracting party, is the conservation of wetlands of international importance, especially as waterfowl habitat (Geldenhuys 1981).

- Not only are pans important as a resting site for migratory birds and for feeding, breeding, drinking, roosting and moulting purposes (Zaloumis & Milstein 1975; Meintjies 1992; Allan *et* *al*. 1995), but also as a factor which may probably help to regulate the population sizes of these birds. Birds able to exploit pans for reproduction presumably increase their population sizes during successive good rainfall years. Lack of habitat during dry years, with less than 110 days inundation per pan, would presumably restrict breeding and regulate the population size back to normal (Geldenhuys 1981, 1982).

- It is, however, difficult to evaluate the quality of wetlands, because all components of the biotic and abiotic compositions of the ecosystem should ideally be considered, yet the problem can be solved to some extent by studying members at the top of the food chain. In these ecosystems birds usually occupy this position, which identify them as possible indicators of aquatic ecosystem functioning (Geldenhuys 1981, 1982). However, care must be taken not to apply too much weight to certain groups, for example some species of birds (Maitland & Morgan 1997).

- Pans are not only important to birds, it also provides an important habitat for other organisms. Wetlands in general are typically very productive systems which are extensively used by invertebrate as well as vertebrate groups.

⇒ **Invertebrates** are a major component of the temporary water inhabitants (Kok 1987). Many of the unique invertebrate fauna which inhabit temporary waters, never occur in water of more permanent nature (Kok 1987; Meintjies 1992). Three groups of eubranchiopod crustaceans are, according to Kok (1987), truly characteristic of temporary waters, namely the anostracans (fairy "shrimps"), notostracans (tadpole "shrimps") and conchostracans (clam "shrimps").

⇒ **Fish** are normally absent because of the temporary nature of the pans. However, Breen and Begg (1991) gave the number of fish species that occur in Free State pans as 10 and indicated that all ten are rare or endangered in South Africa. Milstein (1975) also listed 10 species of fish found in Baberspan. These species presumably reached Baberspan by means of its link to the Orange River System through the fossil river bed of the Harts River. Such pans associated with watercourses therefore can be expected to, at least temporarily, be colonised by fish during periods of flooding (Allan *et al.* 1995). The wetlands are mostly used for breeding and feeding purposes and to provide shelter for the young (Bruton *et al.* 1987).

⇒ **Frogs and toads** feature prominently in the varied assemblage of plant and animal life which inhabit wetlands (De Villiers 1987; Davies & Day 1998). Channing and Van Dijk (1995) listed 17 genera of frog that inhabit temporary pools. Frogs include a wide variety of insects in their diet, and in the process help to control insect populations (De Villiers 1987), especially mosquitoes that breed in these standing waterbodies (Channing & Van Dijk 1995). Grass pans, in particular, are crucial breeding grounds for the near threatened bullfrog (Allan 1987a, b).

⇒ **Reptiles** that make use of pans include tortoises, terrapins, snakes, etc. Jacobsen (1995) listed 11 species of wetland reptiles that can be found in wooded savanna or grassland areas. Relatively little is known, however, about the reptiles of endorheic pans (Allan *et al.* 1995).

⇒ Small **mammals**, like the ground squirrel, bat-eared fox and suricate, concentrate in and around pans (Parris 1984; Allan *et al*. 1995). Large mammals, for example the springbok, red hartebeest, black wildebeest, gemsbok, etc., concentrate at these sites to graze and drink (Parris 1984; Allan *et al*. 1995; Davies & Day 1998). Otters are present in the more permanent pans and the water mongoose probably also inhabits pan ecosystems within its range (Allan *et al*. 1995).

Each group of animals is linked into an inconceivably complex web of interactions which, together, create an ecological balance. If one group is removed, the delicate balance is broken, sometimes with disastrous results (De Villiers 1987).

- Wetlands are also important in protecting inland areas from floods, by absorbing floodwater and acting as barrages against surges of storm water, thereby reducing the risks to people and agriculture (Maltby 1986; Maitland & Morgan 1997; Davies & Day 1998; Chapman & Kreutzwiser 1999). Much of our rainfall in southern Africa occurs as high intensity, short-duration storm events. Floods are therefore not uncommon (Breen & Begg 1987). The ability of wetlands to provide short-term, temporary storage of water is important for reducing flood peaks (Chapman & Kreutzwiser 1999). This is applicable to pans that are close to rivers, floodplains, vleis, etc.

- Wetlands in general sift dissolved and suspended materials from floodwaters, thereby encouraging plant growth and preventing the water of becoming over-rich in nutrients and poor in oxygen (Parris 1984; Maltby 1986; Davies & Day 1998). The wetland acts as a 'sediment trap', because the water is static particular material (including bacteria, both pathogenic and free living) tends to settle out as sediments (Davies & Day 1998).

- Salt pans are especially important resources for the production of salt. Their fauna has been cultivated for useful purposes too, e.g. the salt-tolerant brine shrimp (*Artemia* species) which is used for the production of fish food. Its freshwater relative (*Streptocephalus* species) can be used for the production of protein rich animal feed (Meintjies 1992).

This clearly indicates the importance of wetlands, including pans, in providing habitat and/or food for all the groups of the animal kingdom, and even helping man in producing salt and other products, and in controlling floods. There are certainly more advantages that are not mentioned here, but which will further underline the tremendous importance of pans and other wetlands.

4.8 CONSERVATION

From the above mentioned, the importance of wetlands become clear and this also highlights the importance of the conservation thereof. The word ‘wetland’ is an emotive term for many of us because we fear that the relentless advance of development will ultimately destroy these unique habitats (Breen & Begg 1987). Temporary waters, especially the smaller ones are hardly considered by the public, or by developers, to be wetlands at all. As a result, in much of the world, and certainly in southern Africa, they are probably the most neglected and threatened of all ecosystems, terrestrial or aquatic (Davies & Day 1998).

Ironically, temporary wetlands are threatened even by well-meaning but ill-informed planners and managers who consider that permanent waters are somehow ‘better’ than temporary ones (Davies & Day 1998). Not far north from Cape Town, for instance, a thick deposit of gypsum underlying a seasonal salt pan is presently being mined. The mining company, which is relatively ‘green’, commissioned an environmental impact assessment. Its executives were surprised that wetland ecologists resisted the suggestion that the pan be deepened to form a permanent, rather than seasonal, pan. They were quite unaware that an entirely different suite of organisms would become established there, or that the endangered temporary-pool fauna would have one less place in which to live (Davies & Day 1998). Compare in this regard the differences between the permanent earth dams inside the pan of Soetdoring Nature Reserve, with the temporary pan itself (**Chapter 6**).

The natural functions of wetlands provide various services for mankind (e.g. they regulate water flow, assimilate wastes and trap sediment) and so, activities that disrupt these functions, such as agricultural encroachment, undoubtedly deprive us of the benefits accruing from these services (Breen & Begg 1987). On the other hand, the agricultural development of wetlands can also bring benefits, such as increased crop yields and stock production through pasture development (Breen & Begg 1987). However, because the wetland soils are highly susceptible to erosion, these benefits will be short-lived. Thus instead of surface run-off and erosion being buffered by wetlands, it is being aggravated by their destruction (Breen & Begg 1987).

For centuries, noted David Baldock, director of Britain's Earth Resources Research Ltd, "the drainage of wetlands has been seen as a progressive, public-spirited endeavour, the very antithesis of vandalism" (Maltby 1986). A former U.S.A. President, Jimmy Carter, said in an environment message in 1977: "*The lasting benefits that society derives from wetlands often exceeds the immediate advantages it might get from draining or filling them. Their destruction shifts economic and environmental costs to other citizens…who have no voice in the decision to alter them*" (Breen & Begg 1987).

Physical damage such as boreholes and ploughing; as well as dumping and industrial effluent are all factors which threaten the survival of pans (Geldenhuys 1982; Seaman 1987). Pans are also frequently seen as 'lines of least resistance' by road planners. Over 40 % of pans in Gauteng are affected by the practice of road building (Allan *et al*. 1995). Drainage from ploughed fields situated in pan catchments can introduce pesticides and fertilisers resulting in contamination and eutrophication, which is exacerbated by the endorheic nature of these wetlands (Geldenhuys 1982; Allan 1987a; Seaman 1987). Such drainage, coupled with overgrazing, increases siltation of the basins. Overstocking also leads to excessive trampling of shore vegetation - the habitat of fauna such as breeding waterfowl (Allan 1987a).

A particularly topical issue at present is the problem of aerial spraying of problem seedeater flocks with avicides. Large flocks of these species frequently roost in pan reedbeds and the potential exists for a major ecological disaster to non-target birds should any of these sites be sprayed. Such operations should be banned at pans and indeed at any wetland site (Allan *et al*. 1995).

The pan ecosystem is actively maintained by the combination of biotic and abiotic components, thus its conservation requires the conservation of its components and the perpetuation of these interactions (Parris 1984). One of the major interactions essential for maintaining the system is the undisturbed use of pans by herds of antelope, and since these herds are highly mobile, the protected area must remain large enough to enable this natural antelope-soil-plant interaction to continue (Parris 1984).

Much remains to be done concerning the conservation of pans. Management strategies aimed at land in private ownership, as suggested by Geldenhuys (1982), are as important as land acquisition for 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 (Malan 1998). On the other hand, "panveld" as it is colloquially called, deserves to be conserved as part of a larger terrestrial-aquatic unit (Malan 1998). This latter course has to an extent been followed inadvertently in the private conservation areas like Rooipoort near Kimberley and on the Defence Force Property, De Brug, west of Bloemfontein (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 educational potential (Allan *et al.* 1995).

These protected pans could also provide baseline information against which status of pans in unprotected areas could be compared (Allan *et al.* 1995). Therefore consideration should be given to including the more important pans in the nature reserve system. Many pans and pan systems would also qualify for inclusion in the RAMSAR Convention (Allan *et al.* 1995).

In the words of Breen and Begg (1987): "It's not that we are asking too much, because even a three-metre-wide wetland alongside a river can significantly reduce erosion, increase sedimentation and purify water passing through it". Whatever the reason for conserving it, wetlands are valuable as ecological laboratories because of their diversity (Davies & Day 1998). There is no longer time simply to talk about wetland conservation. Civilisation began around wetlands; today's civilisation has every reason to leave them wet and wild (Maltby 1986).

CHAPTER 5: THE PANS OF SOETDORING NATURE RESERVE.

5.1 INTRODUCTION AND EXPOSITION OF THE CHAPTER

A discussion on pans in general, is given in **Chapter 4**. This chapter roughly follows the order of Chapter 4 and aims to indicate how this general information can be applied to specific pans, in this case the pans of Soetdoring Nature Reserve. There were some doubts at first whether the two pans are in fact pans or not, because of the presence of the drainage canals (Afrikaans: sloep) in each pan. Thus, the first step of applying the information was to determine if the water body is in actual fact a pan, or if it is another kind of wetland, because this would drastically influence the functioning of the water body and the habitat it creates.

The morphology and classification of the two pans are also included in this chapter because these aspects are necessary for the discussion on the vegetation of the pans that follows in Chapter 6. The chapter further focuses on the importance of these pans and the conservation thereof. This chapter is an important contribution to the existing information on pans in general.

5.2 DETERMINING THE KIND OF WETLAND FOR THE RESERVE

The arrow represents a definition of a specific water body followed by the application of the definition to the wetlands of Soetdoring Nature Reserve in order to determine the kind of wetland that is present in the reserve.

⇒ The word **wetland** is a collective term that is used to group those features of the landscape that are commonly referred to as pans, vleis, floodplains, marshes, swamps, etc. as a single type of ecosystem (Breen & Begg 1991). For a detailed discussion on the definitions of wetlands and pans, refer to **Chapter 4**.

Two panlike wetlands occur in the reserve - one each on the southern and northern side of the Modder River (*vid.* Figure 2.1 & **Chapter 2**). It was rather difficult to distinguish what kind of wetland is represented in these two areas, because both have characteristics corresponding to many of the specific types of wetland.

⇒ There is no definitive distinction in the literature between the local names **pan** and **vlei**, (Seaman *et al.* 1991), but according to Burgis and Symoens (1987), pans lie in endorheic systems, and vleis include waters associated with river drainage systems. The terms **lake** and **pan** usually refer to permanent and temporary water bodies respectively, although there are many exceptions to this rule, and the words are to a certain extent interchangeable (Shaw 1988).

The term vlei is not applicable to these areas, because they rather seem to resemble pans. A pan being a depression usually filled by rainwater; the wind playing a major role in creating and maintaining it (**Chapter 4**) and the vegetation also differing from that which is normally viewed as a vlei. The term lake is definitely not applicable to Soetdoring Nature Reserve, because these are not permanent wetlands, they are only ephemerally inundated and the water dries up after a while.

⇒ '**Pan**' is a South African vernacular term for any large, flat, sediment-filled depression that collects water after rain (Mepham & Mepham 1987; Shaw 1988; Seaman *et al.* 1991; Davies & Day 1998). These temporary waters characteristically occur in closed basins without outlet, which are named endorheic basins, as opposed to exorheic basins which have one or more outlets (Meintjies 1992). Pans usually dry up seasonally, mainly through loss of water due to evaporation (Geldenhuys, 1982; Meintjies 1992). Typically their shape is circular to oval (Allan 1987a). They are shallow, even when fully inundated, and usually less than about three metres deep (Allan *et al.* 1995; Malan 1998).

⇒ Two major types of pan are recognised in southern Africa (Davies & Day 1998). The first, being the **terminal water bodies of endorheic systems** in arid areas, for example the grass-bottomed pans of the Free State. They may accumulate salts, because they are inwardly draining and occur in arid areas, in which case the lakes that develop in them are highly saline. The second kind of pan are **floodplain pans**, which are depressions along river banks that retain part of the flood waters, sometimes for long periods (Davies & Day 1998).

⇒ There further seems to be a difference between a **floodplain** and a **floodplain pan**. Floodplains are areas of low-lying flat ground over which rivers flood during high water (Breen & Begg 1991), or in other words, areas where rivers periodically overflow their banks (Noble & Hemens 1978; Davies & Day 1998). In regions with distinct wet and dry seasons, as in Africa, flooding is confined to the wet season and is predictable (Maitland & Morgan 1997).

Floodplains are the most hydrologically dynamic freshwater wetland systems because of their location in middle and lower reaches of river catchments. Whenever a river attains grade and flow is dispersed horizontally, particularly during floods, sediment deposition, levee formation, channel switching and other fluvial processes can create a mosaic of varied land-forms and wetland habitats (Breen & Begg 1991). On the Pongolo floodplain, for example, there is a mosaic of seasonally and permanently inundated habitats, and considerable standing water remains in pans after floods subside (Breen *et al.* 1978; Furness & Breen 1980). Noble and Hemens (1978) referred to these as storage floodplains, which are probably the same as floodplain pans. Other floodplains are homogeneous, the diversity of wetland habitats is narrow, and little or no water standing water remains after floods have subsided (Breen & Begg 1991). The above mentioned true floodplain ecosystems, although fairly common throughout the world, are rare in southern Africa (Davies & Day 1998).

In a way, both of the reserve's wetlands are rather close to the river and in times of very high precipitation, the river does flood these areas. The term floodplain was, however, rejected because of the fact that these wetlands are not situated right next to the river, where the river could fill the wetland when overflowing it's banks. The wetlands are also not completely "flat, low-lying ground" as the definition suggests, but it is rather a hole or a depression in the ground.

Each of the two wetlands is connected to the river by a drainage canal, which is a small branch of the river with slow flowing to standing water, but not part of the riverbed itself. Thus, when the river is in flood it backs up through each drainage canal and the water finally ends up in the two pans. The term, floodplain pan may appear to be more appropriate, but since the area is not considered to be a floodplain, this also does not seem to be quite correct. From aerial photographs, it is evident that the southern pan is part of a low lying drainage line of the river. This area may even have been a branch of the Modder River that has been cut off from the river long ago through the deposition of silt, while the damming of the river could also have contributed to this process. According to Parris (1984) and Grobler *et al* (1988), these old water courses would easily become blocked by shifting sand and pans would then develop in such areas (**Chapter 4**).

In summation: the term 'pan' was eventually chosen to describe these specific types of wetland in Soetdoring Nature Reserve, because they are large, flat depressions which collects water (i) after rain (as stated in the definition of a pan), (ii) through run-off from the adjacent veld and (iii) also through an inlet from the river. Once the river has receded, it retracts the water from the drainage canal, but the water in the pans is retained. The pans are not closed basins, however. They have an inlet, but no outlet, and are therefore endorheic. They have specific pan-like vegetation; lunette dunes are present possibly as a result of wind action during the formation of pans (**Chapter 4**); they dry up seasonally - mainly through loss of water due to evaporation; their shapes are more or less oval and they are shallow (about 15 - 30 cm deep) when fully inundated. This description of the pans in Soetdoring Nature Reserve, thus fits the definition of pans perfectly.

5.3 MORPHOLOGY OF THE PANS IN THE RESERVE.

The two pans differ remarkably - the one on the southern side of the Modder River (which will be referred to as ‘Southern Pan’) is not completely covered by vegetation (Figure II, Appendix 1). Quite a number of bare patches, where salts accumulate, are visible on the pan floor. The vegetation of the pan on the northern side (which will be referred to as ‘Northern Pan’), on the other hand, covers the whole pan with no bare patches and no visible salt precipitate.

The soil on the **Southern Pan** floor is mostly compacted clay, which forms cracks when it dries out. The soil is generally more compact than that of the surrounding grassland, but ranges from hard and almost impenetrable on the pan floor to loose and well-drained on the pan dune. The pan floor is not completely flat - there are areas that are a step higher than the rest of the pan floor and contain more sand than clay (Figure VI, Appendix 1). The vegetation of these elevations differs from the rest of the pan vegetation and resembles the surrounding grassland instead (**Chapter 6**).

A dirt road that runs through the Southern Pan (Figure 5.1) forms an important link to the south-western side of the reserve. The only other road leading to this part of the reserve runs alongside the southern border fence (Figure 2.1). This fence road, however, is not often used and is not well maintained. Being much shorter, the road through the pan has become the preferred route.

The pans are surrounded by higher plains or ridges. These ridges form an ecotone between the pan vegetation and the surrounding grassland. The edges of the Southern Pan differ in height, with the south-eastern shore forming a high dune which slopes fairly steeply from the grassy banks. However, on the south-western shore, a high, steep dune is absent. This region is being encroached by herbaceous and karroid vegetation from the surrounding veld.

The high lunette dune on the south-eastern side of the Southern Pan can easily be explained. The prevalent wind direction, in which the wind blows for an average of 25.5 days per year, is north-west, as indicated in **Chapter 2**. Also, a dolerite bank is present on the south-eastern side of the pan (Figure 2.4) that would probably not erode away as easily and provide an area where the windblown sand can accumulate. The formation of pans (*vid.* **Chapter 4**) in the Free State is mainly attributed to deflation of sediments by the north-western wind (Grobler *et al.* 1988). The unconsolidated materials deflated from the hollows would accumulate as crescentic lunettes (dunes) on the down-wind side (Parris 1984; Grobler *et al.* 1988; Loock & Grobler 1988), which in this case would be south-east. During the rainy season, the soil is moist and firm and the wind blowing across the pan has little effect on the pan soil. However, towards the end of the dry season, the soil dries out and becomes trampled. Parris (1976) shows that under these conditions, the wind erodes a fair amount of pan soil. The dunes on the leeward side of most pans illustrate the effect of wind action on pans in course of time (Parris 1984).

A hot water spring is present inside the Southern Pan. Two manmade earth dams (Afrikaans: gronddamme) can also be found in the pan (Figure 5.1). The first earth dam wall (Earth Dam A) was bulldozed from the existing pan soil. The earth wall itself is completely covered with vegetation (Figure IV, Appendix 1). The earth wall of the second dam (Earth Dam B) was built partly with rocks. Both earth dams are permanent water bodies, and their vegetation (**Chapter 6**) and fauna differ from that of the surrounding temporary pan.

Contrary to the Southern Pan, the **Northern Pan** has no earth dams, or hot spring, or road running through it. Neither are there sandy elevations inside the pan. However, a small stone wall is present in the pan that creates a water filled depression with a diameter of about 3 m. The Northern Pan is smaller than the Southern Pan, and it is more circular than oval shaped. It further differs from the Southern Pan in having dense stands of *Phragmites australis* along the outer edge of the pan. The pan floor consists of a dense grass cover, with no clay or salt crusts visible anywhere. The soil of the pan floor is composed of a mixture of sand and clay. There are also lunette dunes present on the north-eastern and southern side of the pan. The dunes act as an ecotone between the grassland and the pan, while the herbaceous and karroid vegetation from the adjacent veld encroach on this region.

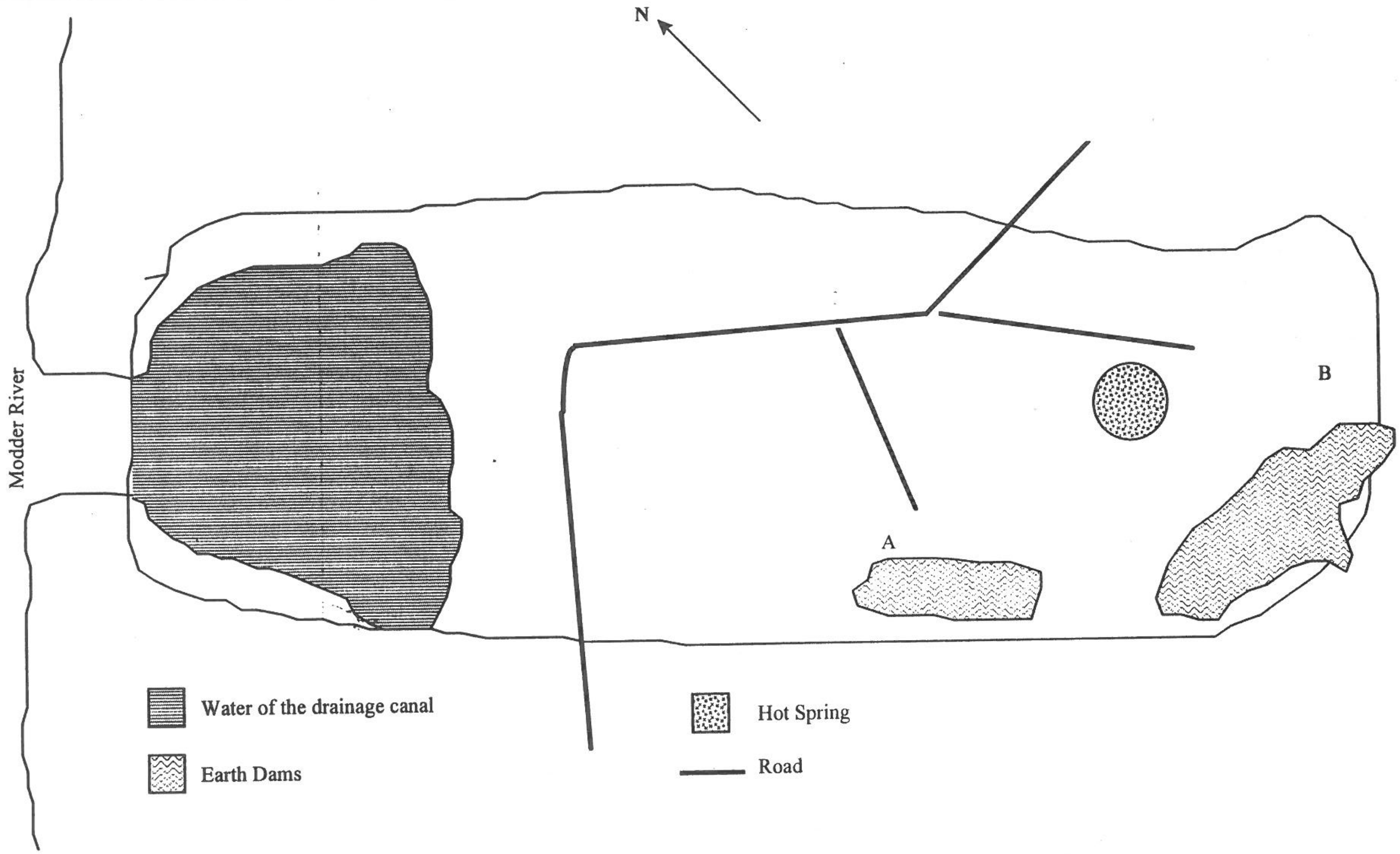


Figure 5.1: Morphology of the Southern Pan, indicating the position of the hot spring, Earth dams A and B, the road as well as the drainage canal (Not drawn to scale).

5.4 THE HOT SPRING INSIDE THE SOUTHERN PAN.

Location

The spring at Vlakkraal 23 (a farm now incorporated in the reserve) is one of three mineral springs within a relatively small area near the Modder River. The others are respectively at Florisbad and Lombards Drift 832 - immediately east of the bridge on the Soutpan tarred road (Grobler & Loock 1988). According to Kent (1949), all three springs are classified as warm springs.

Water temperature

No specific literature could be found on the Vlakkraal spring. Grobler and Loock (1988), however, gave a detailed description of the factors contributing to the high temperatures of the Florisbad spring. From the findings of Grobler and Loock (1988), it can be assumed that the high temperature of all three springs can be attributed to the same process. The temperature of the spring water at Florisbad is only about 10°C above normal borehole temperatures in the area and issues at 29°C (Grobler & Loock 1988).

Salt

Down-stream at Soutpan and Skoppan, the groundwater is NaCl-rich (Grobler & Loock 1988). The fact that the groundwater is NaCl rich in the area, can possibly account for some of the salt that precipitates on the Southern Pan’s floor (**Chapter 4**).

Standing water

Inside the Etosha Pan there are also fountains or springs which give rise to more or less permanent water holes. These are heavily utilised by animals in the dry season (Mepham & Mepham 1987). It is difficult to say whether the spring inside Soetdoring Nature Reserve also could have provided permanent water in the past, but there is no visible, permanent, standing water at present.

Where springs occur

Water will flow from an aquifer (layers of rock sufficiently porous to store water and permeable enough to allow water to flow through them in economic quantities) wherever the water table intersects the ground surface (Figure 5.2) (Price 1985). Where the flow from an aquifer is diffuse, a seepage occurs; where it is localised, as for example along a fault or fissure (Figure 5.2a), a spring opens (Price 1985). According to Price (1985), it is common to find lines of springs or seepages where permeable sandstones or limestones form high ground and rest on less permeable rocks such as shales or clays (Figure 5.2b).

According to Grobler & Loock (1988), Basberg forms part of an approximately E-W high, or watershed, for a system of palaeodrainage delineated for the north-western Free State. Outcrops of Beaufort sandstone, which is more permeable than the Ecca shales, occur along this watershed and
constitute relatively favourable beds for infiltration of meteoric water. These would probably be the places where springs occur.

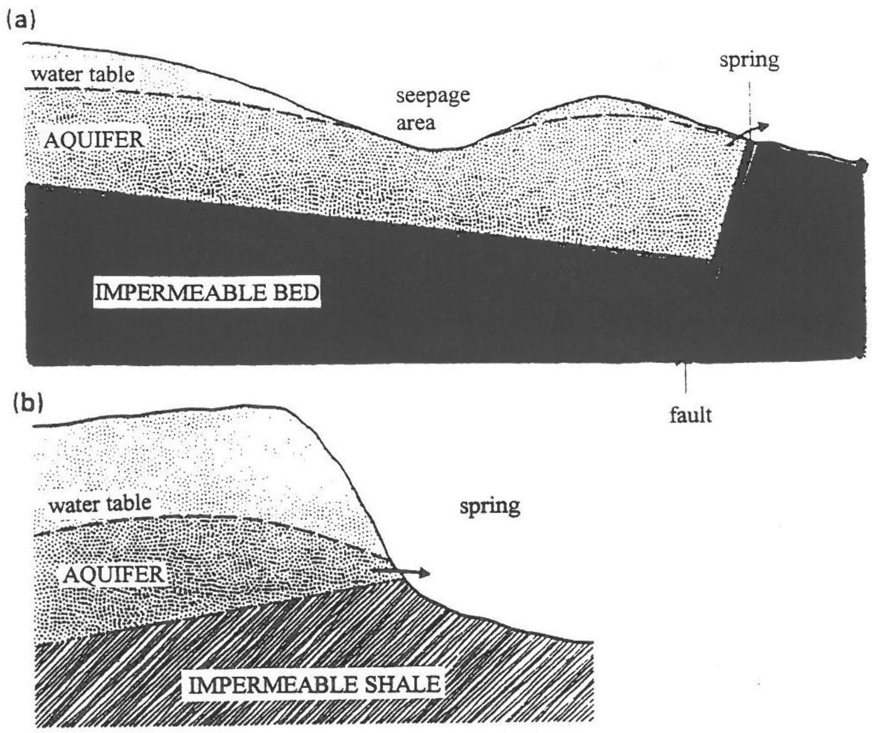


Figure 5.2: Common occurrences of springs and seepage areas.

(a) The difference between a seepage area and a spring.

(b) Lines of springs or seepages are common where permeable sandstones or limestones rest on less permeable rocks.

(Reprinted from Price 1985)

5.5 CLASSIFICATION OF THE RESERVE'S PANS.

The classification systems of Noble and Hemens (1978); Geldenhuys (1982) and Allan (1987b), as described in **Chapter 4**, will be used.

The Northern Pan can be classified according to the following three definitions.

- Noble and Hemens (1978): **Grass Pan**. Seasonal pans that dry up in winter except for the usual perennial pools. They are covered with a thick growth of hygrophilous grasses and other low terrestrial species, some of which are salt tolerant. This vegetation is usually inundated in summer. However, the Northern Pan does not fall in the 650-800 mm annual rainfall zone.
- Geldenhuys (1982): **Mixed Grass Pan**. Emergents, consisting of various moisture loving grasses (mainly *Eragrostis* species) cover the entire pan, occur on the littoral zone and intermingle with vegetation adjacent to the pan. Depending on water depth the grass may either form a sparse or a dense cover. Salt exploitation does not occur.
- Allan (1987b): **Grass Pan**. The majority of these pans are smaller than five hectares and are covered with grass and sedges.

According to the classification of all three above mentioned authors, it is evident that the Northern Pan, with its thick carpet of different grasses, can be classified as a Grass Pan (Figure I, Appendix 1).

The Southern Pan can be classified according to the following three definitions.

- Noble and Hemens (1978): **Temporary Pan**. Shallow pans that dry out for long periods although they may retain a few perennial pools. Their soils are alkaline and moderately saline.
- Geldenhuys (1982): **Open** *Diplachne* **Pan**. Open Pans are similar to Closed *Diplachne* Pans, except that the emergent grass covers only certain areas of the water surface. Crystallised salt may be found occasionally. The emergent grass, particularly *Diplachne fusca*, of Closed *Diplachne* Pans, on the other hand, covers more than 90% of the water surface. This grass species forms homogeneous stands of sparse to fairly dense cover.
- Allan (1987b): **Open Pan**. Larger pans tend to be devoid of vegetation except around their shorelines. The shore vegetation comprises mainly the grass *Cynodon dactylon*, sedges (*Scirpoides dioecus*), various *Juncus* species, etc. The only grass really capable of regularly colonising the actual basin is *Diplachne fusca*.

The Southern Pan is clearly not as easily classified as the Northern Pan. The only characteristics that are agreed upon by two of the three mentioned authors at a time, are that these pans are moderately saline, or that the grass *Diplachne fusca* grows in the basin of the pan. The presence of the spring complicates the classification, as it is probably an additional source of salt (**Chapter 4**) which can contribute to it being classified as a salt pan.

Noble and Hemens (1978) described **salt pans** as being dry most of the time, but may contain perennial pools filled by springs. Their soils are highly saline and devoid of any higher vegetation. Allan (1987b) describes salt pans as a type of open pan characterised by extremely saline substrata which are virtually restricted to the dry western areas of South Africa. Due to the exposed salts in their basins, they have a dazzling white colour in the sun when they dry up. The sedge *Schoenoplectus triqueter* is typical of the shorelines of these pans.

Thus, it seems that the only characteristic of the Southern Pan that fits the description of a salt pan is the presence of salt. The salt, however, does not give the pan a dazzling white colour. *Schoenoplectus triqueter* was not found in the pan, and the pan is not devoid of higher vegetation. The classification that fits all the characteristics of the Southern Pan best, is that of Geldenhuys (1982), describing the pan as a *Diplachne* pan (Figure II, Appendix 1).

5.6 USERS OF THE TWO PANS.

There are several different kinds of animal that make use of pans (**Chapter 4**), but only those who have been observed in and around the two pans during the time of study, will be discussed. As this study concentrates on the vegetation of the pans, a detailed survey is still required for a complete description of the animals, especially the invertebrates, fish and reptiles that make use of these pans as habitat. Only the scientific names of the animals that were not listed in Chapter 2 are included.

The following **large mammals** were spotted in the pans: herds of black wildebeest, red hartebeest, springbok, blesbok, gemsbok, zebra and occasionally the two white rhino's. Only small herds of these animals are present in the Southern Pan. The animals will only remain in the pan as long as new growth is present. The Northern Pan is characterised by large herds of the above mentioned animals occupying the pan on a semi-permanent basis. They are only absent when the pan becomes inundated.

The Southern Pan may even be used by some of the animals as a salt-lick. The animals will mostly visit these pans to graze or to drink. When the pan is inundated, it is closer to the territories of these animals than the water of the river or that of the drainage canal. According to farmers, the value of Mixed Grass Pans and *Diplachne* Pans as pasture for cattle and sheep during the dry seasons following wet periods, is considerable (Geldenhuys 1982). Kreulen (1980) showed that grasses growing on pans and river banks have significantly better nutritional quality than grasses growing in the sandveld, for example. This could provide an explanation for the great numbers of grazers that frequent the Northern Pan in particular. Luckily there is no visible damage due to overgrazing on the pan, yet. The ephemeral nature of the dry phase of the pan, which restricts overgrazing and trampling, probably explains this. Trampling itself is not really considered to be detrimental to these specific pans, as it is a action that possibly helps to create and maintain the basin of pans (**Chapter 4**).

The animals that appear to be damaging the pans are the **diggers**. Many of the smaller mammals dig into the soil of the pans in search of food. Smithers (1971) describes some of the smaller carnivores, such as the bat-eared fox and the suricate, as avid diggers, digging even in the hardest soil. Their role in affecting the ecology of ecosystems was studied in the Kalahari (Smithers 1971; Parris 1984). Ground squirrels are particularly associated with pans and live in colonies of up to 30 individuals on the hard soils of the pan floor or pan edge (Smithers 1971; Parris 1984). They feed up to 200 m from their burrows and have a considerable impact on the pan vegetation. This is evident in the Southern Pan, where the diggers really damaged large areas of the pan by digging holes everywhere and destroying all the vegetation around the burrows.

There are a number of small rodent species normally found on pans and they mostly feed in all parts of the pan and on all types of pan vegetation (Parris 1984). They are often responsible for extremely heavy local use of pan vegetation and may completely destroy the perennial vegetation in the immediate vicinity of their burrow (Parris 1984).

These diggers, however, are characteristic of pans and they thus have a contribution to make to the pans. In the Kalahari, this extensive digging and burrowing activities on pans result in a continuous turning of the pan soils and is particularly important in breaking up the underlying calcrete and mixing it with the overlying sand. This mixing and consequent exposure to other soil-forming agents lead to the development of the characteristic pan soils (Parris 1984). The diggers that are commonly seen in the pans of the reserve are ground squirrel, suricate and yellow mongoose, while tracks of hare and springhare are also commonly found in the pan.

In the summer, a number of **frogs** were observed in the Southern Pan, especially near the two earth dams. No frogs were observed in the Northern Pan, however. The two species identified, are: the Common Caco (*Cacosternum boettgeri* Boulenger, 1882) and the juveniles of the Giant Bullfrog (*Pyxicephalus adspersus* Tschudi, 1838). However, these species were the only ones present in the daytime and it is quite possible that, when a survey is done at night - by identifying the sounds of the frogs, a few other species, like the Tremolo Sand Frog (*Tomopterna cryptotis* Boulenger, 1907), the Snoring Puddle Frog (*Phrynobatrachus natalense* Smith, 1849), or the Bubbling Kassina (*Kassina senegalensis* Duméril & Bibron, 1841) could also be found (Passmore & Carruthers 1995).

The **bird** species spotted on the pans during the time of study, differed between the permanent water bodies and the ephemeral pan. A lot of birds were seen on the pans, but only the most common birds will be listed here. Coots, ducks and grebes are of the more permanent inhabitants of the earth dams, while mostly the African Spoonbill (*Platalea alba* Scopoli, 1786), Whiskered Tern (*Chlidonias hybridus* Pallas, 1811), Greyheaded Gull (*Larus cirrocephalus* Vieillot, 1818), etc. frequent the drainage canal, with the African Fish Eagle (*Haliaeetus vocifer* Daudin, 1800) often visiting as well. A few unlikely visitors, like five Blue Cranes (*Anthropoides paradisea* Lichtenstein, 1793 - an endangered species), also show up once in a while. The dry phase of the pan is characterised by the presence of mostly Blacksmith Plovers (*Vanellus armatus* Burchell, 1822), Crowned Plovers (*Vanellus coronatus* Boddaert, 1783), Three-banded Plovers (*Charadrius tricollaris* Vieillot, 1818), etc. The wet phase is characterised by great flocks of Egyptian Geese (*Alopochen aegyptiacus* Linnaeus, 1766), Spurwinged Geese (*Plectopterus gambensis* Linnaeus, 1766), various ducks, African Spoonbills and a few Lesser Flamingos (*Phoeniconaias minor* Geoffroy, 1798), among others.

Several **tortoises** were spotted on the two pans, while grazing the vegetation. **Terrapins** are present in the drainage canal, but not in the inundated pan itself - the water is probably not deep enough. **Catfish** (cf. *Clarias gariepinus* Burchell, 1882) are also abundant in the drainage canal and were found in small holes inside the pans that hold water for a longer time than the pan itself. In the Northern Pan, in a depression that had dried up completely before the rain could replenish it, quite a number of old fish skeletons were found. These fish probably gained access to the pans through the drainage canal which connects it to the Modder River. Further study, however, is needed to classify the specific species of reptile and fish that usually use the pans as habitat.

5.7 CONSERVATION

The pans, although already included in a nature reserve, are not completely safe from the impact of humans. Even the impact of the previous owners of the land is still recognisable (*vid*. 5.3 Morphology of the pans). In the Southern Pan, two earth dams have been created to hold water permanently. The natural pan vegetation in the area of the earth dams has been drastically changed from plants that are adapted to occupy ephemeral areas to plants normally associated with permanent water bodies (*vid*. **Chapter 6**).

Furthermore, the dirt road that runs through the Southern Pan also plays a major part in the degradation of the pan vegetation. The road is off limits to the public and only supposed to be used by wardens and workers, in order to reach the other side of the reserve. However, many of the visitors ignore the "No Entry' sign in their eagerness to view the animals and birds present in the pan and earth dams. They drive through the pan, many of the times not even following the road. This leads to the increase of bare areas, where clay is compacted by numerous vehicles. Should the use of the dirt road be restricted to wardens and workers only, as it is supposed to, the impact would most probably be almost negligible.

Malan (1998) stated that, in order to conserve pans, 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. The farmers of the area are nevertheless still influencing the pans of the reserve. They demand that action should be taken against large flocks of queleas which cause extensive damage to their crops. These queleas sleep mostly in the reedbeds of the reserve. Presently, preventative measures entail burning or spraying the reedbeds with avicide in order to exterminate the queleas. This does not only affect the reedbeds of the river, but also those on the edge of the Northern Pan. It poses a great danger to other non-target birds that also sleep and breed in the reeds. A further source of danger to the pans, because they are fed by the Modder River, is that drainage from ploughed fields into the river can introduce pesticides and fertilisers into the standing water of the pans.

According to Parris (1984), 'the pan ecosystem is actively maintained by the combination of biotic and abiotic components, thus its conservation requires the conservation of its components and the perpetuation of these interactions. One of the major interactions essential for maintaining the system is the undisturbed use of pans by herds of antelope. Since these herds are highly mobile, the protected area must remain large enough to enable this natural antelope-soil-plant interaction to continue' (*vid.* **Chapter 4**).

The number of animals, however, needs to be regulated in the reserve, in order to avoid overgrazing, especially of the pans. The two pans contain grasses with a high grazing value that can easily be reduced by overgrazing, especially in the new growth season when the pans are drying up.

5.8 CONCLUSIONS

The general information given in **Chapter 4** could successfully be applied to the pans of Soetdoring Nature Reserve in this chapter. The pans of Soetdoring Nature Reserve are very important and justify conservation, not only as habitat for animals and birds, but also by helping to reduce floods further downstream of the Modder River. Water from the overflowing river fills the pans, by means of drainage canals connecting them to the river, and they serve as storage areas for water - hence reducing the possibility of a flood.

The pans inside the reserve are still in danger of disturbance coming from outside of the reserve. Large areas of the Southern Pan are not even in its natural state any more, due to man's previous actions. Care should be taken that the pans are indeed conserved inside the nature reserve. If a complete wetland bird list, especially for the two pans, can be supplied, it may even result in the pans being incorporated in the RAMSAR Convention (*vid*. **Chapter 4**), which would lead to more controlled protection of these wetlands, specifically as avifaunal habitats.

CHAPTER 6: THE VEGETATION OF THE PANS.

6.1 INTRODUCTION

Compared with other major natural forms of landscape, wetlands are young and dynamic. Many are physically unstable, changing in a season or even in a single storm (Maltby 1986). The vegetation is not fixed and changes every time the pan is inundated or dries up. Plant and animal species change according to the depth, duration and volume of flooding, lay of the land and soil types (Maltby 1986). The climate of southern Africa has changed considerably during the Quarternary, suggesting that many pans are fossil landforms, no longer in equilibrium with their environment (Shaw 1988).

Wetlands provide classic examples of ecological succession, where a plant community alters environmental conditions in a way that makes the habitat less favourable for its own survival but more favourable for the development of a different community. Wetland ecosystems can pass through many such stages, emphasising their dynamic yet ephemeral nature (Maltby 1986). **Thus, it is important to note that the communities presented here may not be representative of all the successional stages, but only of that final stage the succession of the vegetation will reach in the dry phase of the pan, before it becomes inundated again.**

The definition of climax communities (the community in the final stage of succession) in halophytic habitats is a matter of dispute, according to Waisel (1972). Oosting (1956) favoured the use of the concepts of “polyclimax” or “prevailing climax”. Climax in this sense means a self-perpetuating plant community, which comprises the highest developmental stage of a succession. Such a state would be reached only under constant environmental conditions (Waisel 1972). Most wetlands, including pans, exhibit changes in water level, salinity, soil, etc. In such habitats, a strict definition of climax cannot be given. The vegetation does not reach the climax stages as a result of the ephemeral nature of pans. However, a community that shows minor changes in structure and composition for a period of time may be regarded as a sere climax (Waisel 1972).

6.2 RESULTS

Five plant communities are recognisable (**Table 6.1 – Appendix 2**) between the two pans of the reserve. The one pan is situated on the northern side of the Modder River (referred to as Northern Pan), and the other on the southern side (referred to as Southern Pan). The hierarchical classification is as follows:

In the Northern Pan:

1. *Cynodon transvaalensis - Gnaphalium declinatum* community
1.1 *Hemarthria altissima – Cyperus denudatus* subcommunity
1.2 *Selago dinteri – Cynodon transvaalensis* subcommunity
1.3 *Panicum schinzii – Cynodon transvaalensis* subcommunity
1.4 *Portulaca oleracea – Cynodon dactylon* subcommunity
1.5 *Eleusine coracana – Cynodon dactylon* subcommunity

In the brackish Southern Pan:

2. *Diplachne fusca* community
2.1 *Sporobolus ioclados – Eragrostis bicolor* subcommunity
2.2 *Eragrostis bicolor – Diplachne fusca* subcommunity
3. *Helictotrichon turgidulum – Phyla nodiflora* community
4. *Juncus rigidus* community
4.1 *Cyperus bellus – Eragrostis biflora* subcommunity
4.2 *Cynodon transvaalensis – Juncus rigidus* subcommunity
4.3 *Digitaria eriantha – Selago dinteri* subcommunity
4.4 *Phragmites australis – Juncus rigidus* subcommunity
5. *Sporobolus virginicus* community

Species of Minor Occurrence

6.3 DISCUSSION

Two characteristic features of the vegetation of pans, according to Leistner (1967) and Parris and Child (1973), are (i) the concentric zonation of the vegetation around a pan, caused by physical and chemical gradients in the soil and (ii) its karroid nature. The karroid nature seems to be more specific of the Kalahari regions and does not apply to the reserve's pans. However, the characteristic feature of concentric zonation can be seen around the Northern Pan. On the outer edge, just on the inside of the pan, a grey coloured concentric zone was observed, consisting mostly of *Gnaphalium declinatum*, *Phyla nodiflora*, etc. Inside this ring, a zone dominated by *Cynodon transvaalensis* is found, while the pan basin is covered by grasses, like *Panicum schinzii* and *Echinochloa holubii*. No concentric zonation was, however, discernible in the Southern Pan at the time of study.

The physical differences between the two pans of the reserve have already been discussed (*vid*. **Chapter 5**). These differences are also clearly visible in the vegetation (Table 6.1). The vegetation of the Northern Pan is represented by community 1 and it's subcommunities, and the vegetation of the Southern Pan in communities 2 - 5 (Table 6.1). The species composition of the two pans differs to a great extent. The vegetation of the Northern Pan consists of a *Cynodon transvaalensis – Gnaphalium declinatum* community (Species Group E, Table 6.1), while that of the Southern Pan comprises three communities, namely a *Diplachne fusca* community (Species Group H), a *Helictotrichon turgidulum – Phyla nodiflora* community (Species Groups I) and a *Sporobolus virginicus* community (Species Group N). Many of the species that occur in the Northern Pan, are not present in the Southern Pan, and *vice versa*. The species common to both pans are mostly represented by Species Groups E & O (Table 6.1).

In the description of the communities, existing information on pan vegetation was included. The only references, concerning the vegetation of pans that could be located at the time were those of Fuls (1993); Allan *et al.* (1995) and Malan (1998). The study areas of these specific authors included the pans of the southern Free State, northern Free State, Mpumalanga and North-west Provinces (Transvaal highveld), respectively. Specific references were also made to Müller's (1986) results of the more permanent water bodies of the Willem Pretorius Nature Reserve.

6.3.1 <u>The pan communities</u>

1. *Cynodon transvaalensis – Gnaphalium declinatum* community

This community (Species Group E, Table 6.1) characterises the vegetation of the Northern Pan and also forms part of the concentric zonation of pan vegetation. *Cynodon transvaalensis* is dominant in the community and occurs in high densities in the pan, forming a thick carpet. *Cynodon transvaalensis* forms part of the vegetation in the basin of the pan, but is not confined to this zone, as it also occurs in the outer concentric zone on the edge of the pan. This zone is occupied mostly by the greyish herb *Gnaphalium declinatum*, with *Alternanthera sessilis* and *Agrostis lachnantha* (Species Group E) also present.

Malan (1998) found *Alternanthera sessilis* in the pans of the southern Free State, but did not seem to come across *Cynodon transvaalensis*. Fuls (1993), however, found *Cynodon transvaalensis* in the pans of the northern Free State, being dominant in a zone similar to that of the Northern Pan in Soetdoring Nature Reserve - the zone between the pan's edge and the water's edge. It often forms a dense, near monotypic 'belt' around the water, according to Fuls (1993). Müller (1986) found *Alternanthera sessilis* associated with *Agrostis lachnantha* on the banks of the Allemanskraal Dam in Willem Pretorius Nature Reserve. Mosterd (1958) listed *Agrostis lachnantha* as one of the characteristic species to be found on dam edges and wet vleis. Allan *et al*. (1995) also listed *Agrostis lachnantha* to occur in the endorheic pans of Mpumalanga, but *Cynodon transvaalensis* is not mentioned. It can thus be assumed that the association between *Agrostis lachnantha* and *Alternanthera sessilis* can be found on the semi-dry edges of pans and dams.

Five distinct subcommunities characterise the *Cynodon transvaalensis – Gnaphalium declinatum* community.

1.1 *Hemarthria altissima – Cyperus denudatus* subcommunity

This subcommunity is restricted to the Northern Pan and is not part of the vegetation of the pan itself. It occurs in a zone on the edge of the pan, between the pan and Modder River. The river forms a sort of **s**-shape, with the last curve of the **s** ending as a drainage canal in the pan. This community extends into the curl of the **s**-shaped river.

The diagnostic species of the *Hemarthria altissima – Cyperus denudatus* subcommunity are given in Species Group A. *Hemarthria altissima* is the dominant species and is a highly palatable, creeping, mat-forming grass (Van Oudtshoorn 1999). The common name of this grass, Swamp Couch, is rather descriptive of the habitat in which it usually grows. *Hemarthria altissima* prefers wet areas like vleis (or swamps) and river banks, always growing in or near water (Mosterd 1958; Van Oudtshoorn 1999). *Cyperus denudatus*, a sedge, is usually also associated with water and occurs in dense stands between *Hemarthria altissima* in this area. *Xanthium strumarium*, or Cocklebur, is an invader weed that is present in high densities. The National Department of Agriculture has divided the invader plants into three categories and has given stipulations on how the plants in each category should be dealt with (*vid*. **Chapter 11**). *Xanthium strumarium* is accordingly classified as a Category 1 plant, being an invader plant that has to be removed and destroyed immediately on site (Bromilow 2001).

Malan (1998) also found *Xanthium strumarium* forming part of the pan vegetation of the southern Free State. He classified this species as part of a community that occupies disturbed areas on the edge of pans. Fuls (1993) and Müller (1986) found *Xanthium strumarium* in varying densities on disturbed stream and river banks in the northern Free State and Willem Pretorius Nature Reserve respectively. Both authors grouped *Xanthium strumarium* into a subcommunity of the major community in which *Hemarthria altissima* and a *Cyperus* species, among others, fell. Allan *et al*. (1995) listed *Hemarthia altissima* and *Cyperus denudatus* to occur in reed, sedge and open pans in the Mpumalanga and North-west Provinces (Transvaal highveld).

1.2 *Selago dinteri – Cynodon transvaalensis* subcommunity

This subcommunity was mostly present on the edge of the Northern Pan, between the pan and *Acacia* thornveld on the river's side. Species Groups E and K characterise this subcommunity. *Cynodon transvaalensis* (Species Group E) is the dominant species, but *Selago dinteri* (Species Group K) is diagnostic. The grass *Eragrostis bicolor* (Species Group G) and the herb *Gnaphalium declinatum* (Species Group E) are scattered throughout the subcommunity. This subcommunity, or rather its constituents, was not noted by any of the above mentioned authors, except for *Cynodon transvaalensis*.

1.3 *Panicum schinzii – Cynodon transvaalensis* subcommunity

The vegetation of this subcommunity covers the basin of the Northern Pan, excluding the edges and the two circular zones on the outside. It is the presence of this subcommunity that contributed largely to the classification of the pan as a Mixed Grass Pan (**Chapter 5**).

The species of Species Groups B and E are characteristic of the pan vegetation. The grasses *Panicum schinzii*, *Echinochloa holubii* (Species Group B) and *Cynodon transvaalensis* (Species Group E) are the dominant plants of the subcommunity that jointly cover the whole basin of the pan – leaving no bare patches. These grasses are moisture loving grasses, growing in pans or vleis (Van Oudtshoorn 1999). *Panicum schinzii* is a highly palatable grass. *Echinochloa holubii* on the other hand has an average grazing value. *Verbena brasiliensis* (Species Group B) also occurs frequently between the grasses, while *Frankenia pulverulenta* (Species Group B), *Polygonum aviculare* and *Phyla nodiflora* (Species Group O) are occasionally found in the pan basin.

Malan (1998) did not mention any of these species present in the Grass Pan, to occur in the pans of the southern Free State. However, *Panicum schinzii* was listed as part of the riparian vegetation. Fuls (1993) found all three grass species (*Panicum schinzii*, *Echinochloa holubii* and *Cynodon transvaalensis*) in rather high densities in the pans of the northern Free State. Allan et al. (1995) also came across *Panicum schinzii* and *Echinochloa holubii* in the grass pans of the North-west Province, contrary to the other types of pan.

1.4 *Portulaca oleracea – Cynodon dactylon* subcommunity

This subcommunity occurs between the edge of the Northern Pan and the water of the drainage canal on damp ground. This subcommunity is characterised by mostly pioneers of which the diagnostic species are given in Species Group C. *Cotula microglossa* (Species Group C) and *Alternanthera sessilis* (Species Group E) are the dominant species, with *Portulaca oleracea* (Species Group C) also being very prominent. The grasses *Cynodon transvaalensis* (Species Group E) and *Cynodon dactylon* (Species Group O) are also present in varying densities. *Cynodon dactylon* is a pioneer grass often found in damp places, but not restricted to it. It provides average to good pasture with high grazing value and remains green until late in the winter (Van Oudtshoorn 1999). *Phyla nodiflora* and *Polygonum aviculare* (Species Group O) were also encountered but in low quantities.

Malan (1998) listed *Portulaca oleracea* to occur on the edge of permanently waterlogged pans in the southern Free State. Fuls (1993) found *Cynodon dactylon* in high densities in the northern Free State, in pans that contain small patches or pools with standing water after substantial rainfall. Müller (1986) came across *Alternanthera sessilis* in association with *Polygonum aviculare* on the damp edges of the Allemanskraal Dam in Willem Pretorius Nature Reserve. According to Müller (1986), the community is non-permanent, can cover large areas or, depending on the level of the dam, can be totally absent. Allan *et al*. (1995) lists *Cynodon dactylon*, a *Polygonum* species, and a *Cotula* species to occur in the pans of the Mpumalanga and North-west Provinces (Transvaal Highveld). It seems as if all the above mentioned authors also found some kind of *Chenopodium* species to be associated with pans, which verifies the presence of *Chenopodium murale* in the Northern Pan. *Chenopodium murale* is, however an intruder plant (Bromilow 2001).

1.5 *Eleusine coracana – Cynodon dactylon* subcommunity

This subcommunity occurs in the Southern Pan on the banks of Earth Dam A (*vid*. Figure 5.2). This earth dam holds water permanently, thus its vegetation differs from that of the surrounding ephemeral pan, as well as from the vegetation of the drainage canal, which fills and retreats as the water level of the river rises and falls.

Species Group D contains the diagnostic species of the subcommunity. *Eleusine coracana* (Species Group D) is dominant, along with *Cynodon dactylon* (Species Group O). *Bulbostylis burchellii* (Species Group D), *Cynodon transvaalensis*, *Gnaphalium declinatum*, *Alternanthera sessilis* (Species Group E) and *Phyla nodiflora* (Species Group O) occur in rather high densities in some of the relevés. *Agrostis lachnantha* (Species Group E) has a high frequency, and is regarded as a valuable grass to stabilise damp soil (Van Oudtshoorn 1999). The presence of *Cyperus denudatus* (Species Group A) and *Panicum schinzii* (Species Group B) are interesting, seeing that they have been previously proven to also occur in more permanent water areas.

It is therefore not surprising that neither Fuls (1993), nor Malan (1998) encountered any of the conspicuous species of this subcommunity in the pans of the Free State, since these species seem to be associated with permanent water bodies, rather than ephemeral pans.

2. *Diplachne fusca* community

This community characterises the vegetation of the Southern Pan basin. It does not, however, cover the whole basin (Figure III, Appendix 1). There are still bare patches, not covered by any vegetation, where salt crystallises (Figure II).

Species Group H is the diagnostic species of the community. *Diplachne fusca* is the dominant plant species in the pan and occurs in varying densities. It is the presence of this grass and the accumulation of salt that resulted in the Southern Pan being classified as a *Diplachne* pan (**Chapter 5**).

Diplachne fusca is a highly palatable, rhizomatous swamp grass, with different growth forms. The form in Soetdoring Nature Reserve is a small plant - the culms are only about 0.1 m tall and the inflorescences about 50 mm long. Van Oudtshoorn (1999) described it as a perennial, tufted grass with culms 0.3 – 1. 5 m tall and the inflorescences 0.2 – 0.35 m long. It is one of very few grass species that grow successfully in brackish soil. It always grows in or near water, like in seasonal pans. Fuls (1993) found the mat-forming stoloniferous form to be annual, “disappearing” during the dry season and only re-appearing within a week or so after substantial rain.

Malan (1998) and Fuls (1993) both classified *Diplachne fusca* as a separate community in the pans of the southern and northern Free State, respectively. Allan *et al*. (1995), as well, found *Dipachne fusca* in the pans of the Mpumalanga and North-west Provinces (Transvaal Highveld). Malan (1998) described the habitat, where *Diplachne fusca* grows, as fairly unstable owing to seasonal flooding and drying, which, together with the frequent overgrazing cause an advanced state of degradation. This advanced state of degradation is luckily not yet visible in the Southern Pan in Soetdoring Nature Reserve, except if the bare patches in the pan were to be regarded as degradation.

The two distinct subcommunities associated with the *Diplachne fusca* community, represent the vegetation of the Southern Pan basin.

2.1 *Sporobolus ioclados – Eragrostis bicolor* subcommunity

This subcommunity occurs on the edge of the pan and contains a mixture of vegetation from the pan basin and from that of the adjacent grassland. Species Groups F and K contain the diagnostic species of this subcommunity. *Sporobolus ioclados* (that also occurs inside the pan basin, not only on the edges) is the dominant species, along with *Salsola glabrescens* (Species Group F) and *Eragrostis bicolor* (Species Group G). *Sporobolus ioclados* (Species Group F), particularly, grows in and around seasonal pans and is a relatively palatable grass. It has an excellent resistance to brackish and other saline soils, and has been observed in soil with a salt crust (Van Oudtshoorn 1999). *Diplachne fusca* (Species Group H), as well as the grassland species *Digitaria eriantha* and *Selago dinteri* (Species Group K) have equally high cover values in the subcommunity.

Malan (1998) also described a *Salsola glabrescens - Sporobolus ioclados* subcommunity on the edges of pans in the southern Free State, as well as in disturbed, overgrazed areas. *Salsola glabrescens*, *Sporobolus ioclados* and *Eragrostis bicolor* are also present in Malan's (1998) subcommunity of the *Salsola glabrescens* community. Fuls (1993) classified *Sporobolus ioclados* as a subcommunity of the *Diplachne fusca* community that occurs on the pan edges of the northern Free State pans. Allan (1995), however, did not find *Salsola glabrescens* or *Sporobolus ioclados* in the pans of the Transvaal Highveld (Mpumalanga and North-west Provinces).

2.2 *Eragrostis bicolor – Diplachne fusca* subcommunity

This subcommunity (Species Groups G & H) mainly represents the vegetation of the Southern Pan basin. *Diplachne fusca* (Species Group H) is dominant in the pan basin with *Eragrostis bicolor* (Species Group G) in high densities in between. *Eragrostis bicolor* often grows in moist soil or dry pans, mostly in brackish soil (Van Oudtshoorn 1999). *Lycium horridum* (Species Group G) occurs in a low density throughout the pan basin. *Polygonum aviculare* (Species Group O) occurs frequently between the grasses. The absence of all the species groups, except for Species Groups G, H and O, are noteworthy. Bare patches, not covered by any vegetation occur in the basin.

Malan (1998) found high densities of *Diplachne fusca* and *Eragrostis bicolor* in the pans of the southern Free State. Fuls (1993) and Allan *et al*. (1995) came across *Diplachne fusca* in the pans of the northern Free State, Mpumalanga and North-west Provinces respectively, but not *Eragrostis bicolor*.

3. *Helictotrichon turgidulum – Phyla nodiflora* community.

This community occurs in a disturbed area of the pan basin that holds water for a longer period than the rest of the basin. It is next to the dirt road that runs through the pan, in an area where a storm-water drainage pipe had been installed.

The diagnostic species of this community are given in Species Group I, while Species Groups B, F and J also contain characteristic species. *Helictotrichon turgidulum* (Species Group I) is dominant, along with *Cynodon dactylon* and *Phyla nodiflora* (Species Group O). *Panicum coloratum*, *Eragrostis plana* (Species Group I), *Eragrostis biflora* (Species Group J), *Verbena brasiliensis* (Species Group B), *Sporobolus ioclados* (Species Group F) and *Eragrostis obtusa* (Species Group I) also occur in the community in varying densities. Except for the forb *Verbena brasiliensis*, the others are all grass species that remind of grassland, or disturbed areas. Some of the grass species are adapted to grow in damp places, even growing in grassland where rainwater collects, like *Eragrostis plana* and *Helictotrichon turgidulum* (Mosterd 1958; Van Oudtshoorn 1999).

Neither Malan (1998), nor Fuls (1993) found the above mentioned species in the pans of the southern or northern Free State. Müller (1986) did, however, find *Helictotrichon turgudulum*, *Cynodon dactylon*, *Eragrostis plana* and *Panicum coloratum*, among others, associated with each other in the vleis and swampy areas of Willem Pretorius Nature Reserve.

4. *Juncus rigidus* community

This community, characterised by Species Group M, surrounds the hot spring and Earth Dam B of the Southern Pan (*vid*. Figure 5.2) and also connects these two areas. The rush, *Juncus rigidus* (Species Group M), forms an almost homogeneous, dominant community, with the few open spaces between the *Juncus* tussocks occupied by species like *Cynodon transvaalensis* (Species Group E), *Polygonum aviculare* (Species Group O), *Frankenia pulverulenta* (Species Group B), a *Scirpus* species and *Atriplex semibaccata* (Species of Minor Occurrence).

According to Waisel (1972), the various species of *Juncus* play an important part in the succession of saline habitats, and under certain conditions form a long prevailing community (sere climax), which will remain as long as the water table and salt levels are constant. The *Juncus* plants are tall perennials forming thick tussocks with leaves usually tapering to a sharp fine point

(Thompson *et al.* 1985). Fresh seeds are highly salt tolerant, but tolerance decreases with age (Waisel 1972).

Chapman (1974) called the principle association of thermal saline areas in central Africa, a *Juncus rigidus – Sporobolus virginicus* community. Malan (1998) did not find any *Juncus* species in the pans, but he located two other *Juncus* species in the riparian areas of the southern Free State. Malan (1998) did, however, find *Atriplex semibaccata*, along with other halophytic species, in the salt pans of the southern Free State. According to Fuls (1993), *Juncus inflexus* L. occurs in the pans of the northern Free State. Allan *et al*. (1995) lists *Atriplex semibaccata* along with six species of *Juncus*, including *Juncus rigidus*, to occur in the pans of the North-west and Mpumalanga Provinces.

The *Juncus rigidus* community comprises four subcommunities. The first two subcommunities were found at Earth Dam B, and the rest are associated with the hot spring of the Southern Pan.

4.1 *Cyperus bellus – Eragrostis biflora* subcommunity

This subcommunity and the following one (4.2) represent the vegetation of Earth Dam B. Earth Dam B is surrounded by two connecting manmade walls, the first being a pile of rocks and the other a mound of soil. Thus, the earth dam is a permanent water body, the vegetation of which completely differs from that of the pan (note the absence of the *Diplachne fusca* community (2).

The *Cyperus bellus – Eragrostis biflora* subcommunity is characterised by Species Group J. *Cynodon dactylon* (Species Group O) is dominant, while *Cyperus bellus*, *Eragrostis biflora* (Species Group J), *Phyla nodiflora*, *Polygonum aviculare* (Species Group O) and *Cynodon transvaalensis* (Species Group E) are rather prominent as well. *Cyperus bellus* grows on the soil mound wall of the earth dam and *Eragrostis biflora* was mostly found on the stone wall. *Eragrostis biflora*, or Shade Eragrostis, normally grows under trees or in other shady places (Van Oudtshoorn 1999). The wall of the earth dam provides some shade for the vegetation growing on the wall itself and at the water's edge.

Malan (1998) found none of the above mentioned species in the pans, but listed five *Cyperus* species for permanent wetlands of the southern Free State. Fuls (1993) listed five *Cyperus* species in the wetlands of the northern Free State, but *Cyperus bellus* and *Eragrostis biflora* were absent. Müller (1986) found three *Cyperus* species in the wetlands of Willem Pretorius, but no *Eragrostis* *biflora*. Allan *et al*. (1995) listed eight *Cyperus* species for the pans of the Mpumalanga and North-west Provinces, but *Cyperus bellus* and *Eragrostis biflora* were also absent.

4.2 *Cynodon transvaalensis* - *Juncus rigidus* subcommunity

This subcommunity is present at Earth Dam B, along with the previous one (4.1), but also represents the dense stand of *Juncus rigidus* that links the earth dam and hot spring. Species Groups E and M are diagnostic. *Juncus rigidus* (Species Group M) is the dominant species, while *Cynodon transvaalensis* (Species Group E), *Cynodon dactylon*, *Phyla nodiflora* and *Polygonum aviculare* (Species Group O) also form a prominent part of the vegetation in the vicinity of the earth dam. The species of Species Group O have a rather high density in this subcommunity. *Cynodon dactylon* was mostly found growing between the rocks of the stone wall of the earth dam, while *Phyla nodiflora* mostly occupied the zone next to the water's edge. The other species inhabited the soil wall of the earth dam, which was completely overgrown with vegetation.

Juncus species, as discussed earlier, were mostly found in more permanent water bodies by the above mentioned authors. *Cynodon dactylon* is mostly present in disturbed places, where it acts as a pioneer (Van Oudtshoorn 1999). This explains it's presence on the stone wall of the earth dam. Malan (1998) did not come across any of the above mentioned species in the pans of the southern Free State. *Phyla nodiflora* was, however, found on the river banks and in moist soil areas. According to Fuls (1993), *Cynodon dactylon* occurs in high densities in pans of the northern Free State that contain small pools with standing water after substantial rainfall. Müller (1986) found *Polygonum aviculare* and *Cynodon dactylon* on the damp edges of the Allemanskraal Dam in Willem Pretorius Nature Reserve. According to Müller (1986), the community is non-permanent, can cover large areas or, depending on the level of the dam, be totally absent. Allan *et al*. (1995) listed *Cynodon dactylon* and a *Polygonum* species to also occur in the pans of the Mpumalanga and North-west Provinces.

4.3 *Digitaria eriantha – Selago dinteri* subcommunity

This subcommunity is associated with the vegetation of the hot spring in the Southern Pan. It occurs on 'islands', isolated from the rest of the pan floor and from the grassland, that are a step higher than the pan basin (Figure VI, Appendix 1). The soil of these 'island' areas contains somewhat more sand than clay, as opposed to the clay on the pan floor itself. No salt precipitate is visible in these patches. The *Digitaria eriantha – Selago dinteri* subcommunity can also be found in between the dense stand of *Phragmites australis*, covering the spring head, and the dominant stand of *Juncus rigidus* on the outside (Subcommunity 4.4).

This subcommunity is characterised by Species Group K. *Digitaria eriantha* is the dominant species, with *Selago dinteri* also present in high densities (Species Group K). *Chrysocoma ciliata, Eragrostis chloromelas* (Species of Minor Occurrence) and *Cynodon dactylon* (Species Group O) occur in small patches on the 'islands'. All other pan species, Species Groups A-J, L and N, are absent and the 'islands' resemble the grassland instead. *Juncus rigidus* is also present in this subcommunity, but in a lower density than in the zone just outside the island community.

The grasses and karroid shrubs mentioned are mostly associated with grassland communities and can thus well be considered as a grassland island inside the pan and not as part of normal pan vegetation. Malan (1998) grouped *Chrysocoma ciliata* and a *Juncus* species together in a subcommunity of the streambed vegetation of the southern Free State, but did not observe it in the pans. Fuls (1993) listed *Digitaria eriantha* and *Eragrostis curvula* as streambed vegetation in the northern Free State, but not in the pans. Müller (1986) found *Digitaria eriantha* and *Eragrostis chloromelas* on the slopes of dry river courses in the Willem Pretorius Nature Reserve as well as on the banks of the Allemanskraal Dam, where they formed part of an ecotone to the grassland. Allan *et al*. (1995) listed none of these species for the pans of the Mpumalanga and North-west Provinces.

4.4 *Phragmites australis – Juncus rigidus* subcommunity

This subcommunity represents the vegetation of the hot spring. *Phragmites australis* forms a dense stand that covers the spring head, or core area of the spring, while a stand of *Juncus rigidus* (Subcommunity 4.2) surrounds the *Phragmites* stand (Figure V, Appendix 1), with a small zone of mostly *Digitaria eriantha* (Subcommunity 4.3) in between, as already mentioned.

Species Group L characterises the subcommunity, along with Species Group M. *Phragmites australis* (Species Group L) is the dominant species, with *Juncus rigidus* (Species Group M) forming a prominent part of the vegetation. *Setaria verticillata* and *Cirsium vulgare* (Species of Minor Occurrence) also form part of this subcommunity. *Cirsium vulgare* is, however, a Category 1 invader plant (*vid*. **Chapter 11**), that has to be removed and destroyed immediately. (Bromilow 2001). *Juncus rigidus,* along with *Digitaria eriantha* (Species Group K) and *Cynodon dactylon*

(Species Group O) are probably part of the ecotone between the two dominant *Juncus* and *Phragmites* stands.

Phragmites australis is a perennial grass which grows mostly in fresh but also in saline water (Waisel 1972). It is normally associated with damp, wet, swampy areas (Mosterd 1958; Thompson *et al*. 1985; Van Oudtshoorn 1999). The leaves cannot tolerate continuous flooding and will die off should this happen. Thus the reed can possibly be a useful indicator of the water level (Thompson, *et al*. 1985) of the spring, as it is rather difficult to reach the spring head itself to determine the water level. From a slightly elevated level on the pan dune it is possible to see that the reedbed covers the whole area, concealing the spring.

Phragmites australis is mostly associated with rivers, streams and lakes and not really with ephemeral pans. Fuls (1993) and Malan (1998) did not list any *Phragmites australis* for the pans of the Free State, but rather found it to be associated with streambed and riparian areas, along with *Cirsium vulgare* and *Setaria verticillata*. Müller (1986) also found *Phragmites australis* in riparian areas as well as in vleis and on the banks of the Allemanskraal Dam in the Willem Pretorius Nature Reserve. However, according to Allan *et al*. (1995) *Phragmites australis* is present in reed and sedge pans (**Chapter 4**) of the Mpumalanga and North-west Provinces (Transvaal Highveld). In the Northern Pan, *Phragmites australis* occurs on the edge of the pan, but not inside the pan itself. The above indicates that *Phragmites australis*, although not normally associated with pans, may be present in the pan habitat.

5. *Sporobolus virginicus* community

This homogeneous community occurs in a small patch inside the Southern Pan, located in the area between the hot spring and the lunette dune. The species of Species Group N are diagnostic of this community and occur nowhere else on the table. The dominant species, *Sporobolus virginicus*, is a halophytic, mat-forming, perennial grass with salt glands on its leaves (Naidoo & Naidoo 1998). Salt secretion in halophytes is regarded as an adaptive mechanism to cope with high substrate salinity (Waisel 1972; Naidoo & Naidoo 1998). Although this grass is common along the South African coastal areas, the species may also occur inland around saline water bodies (Naidoo & Naidoo 1998).

Diplachne fusca (Species Group H) and *Polygonum aviculare* (Species Group O) only occurred in one relevé (37065), in an ecotone between this *Sporobolus virginicus* dominated patch and the pan basin on the other side of the hot spring. All other species groups are absent.

Neither Malan (1998), Fuls (1993) nor Allan *et al*. (1995) found *Sporobolus virginicus* in the pans of the Free State, Mpulanga and North-west Provinces. Malan (1998), however, noted *Sporobolus virginicus* to be part of disturbed riparian vegetation trampled by cattle.

Species of Minor Occurrence

The following species were considered to be of too low frequency in the pans, less or equal to 5 occurrences in the 55 relevés on Table 6.1, to make a considerable contribution to the communities and have subsequently been omitted. The species are however listed here in the different localities or areas inside the pans where they were found. The relevé number is indicated in brackets followed by the cover value of the species.

Only two species of minor occurrence were listed for the Northern Pan, namely *Chascanum pinnatifidum* (25: 2b) and *Hibiscus pusillus* (25: 1, 24: +).

The following species that occur in the different localities of the Southern Pan were found to be of low frequency:
Hibiscus trionum (42: +) and *Sporobolus fimbriatus* (43: 1, 15: 2b) on the pan basin;
Atriplex semibaccata (5: 2b), *Bulbine frutescens* (15: +), *Chrysocoma ciliata* (8: 1, 53: 2b, 14: 2b, 15: 1), *Cirsium vulgare* (52: 2b, 10: 2b), *Dipcadi viride* (11: +), *Eragrostis chloromelas* (11:2b), *E. lehmanniana* (48: 1, 53: 3), *E. trichophora* (6: 1, 49: 1), *Oxalis depressa* (50: r), *Pentzia incana* (15: 1), *Scirpus* species (30: 1) and *Setaria verticillata* (49: 1) at the hot spring, mostly on the elevated steps of the pan basin;
Aristida adscensionis (39: 3), *Berkheya pinnatifida* (1: +), *Chloris virgata* (48: 2b), *Chrysocoma ciliata* (48: 2b), *Commelina africana* (14: +), *Eragrostis trichophora* (48: 2b), *Gnidia polycephala* (48: 2b), *Mestoklema arboriforme* (14: 1), *Ophioglossum polyphyllum* (48: 1), *Pogonarthria squarrosa* (48: 2b), *Rosenia humilis* (39: 1), *Themeda triandra* (48: 3), *Thesium hystrix* (48: 2b) and *Tragus koelerioides* (14: 1, 48: 2b) on the edges of the pan and the lunette dune, creating an ecotone between the pan and grassland vegetation. Relevé 48 was, however, deleted from Table 6.1 because of the complete ecotonal nature of this relevé (*vid.* Disadvantages of the Braun-Blanquet method, **Chapter 3**). The presence of grassland grasses (*Digitaria eriantha* and

Themeda triandra) and pan grasses (*Eragrostis bicolor*, *Diplachne fusca* and *Sporobolus ioclados*), along with dwarf karroid shrubs (*Chrysocoma ciliata*, *Rosenia humilis* and *Salsola glabrescens*) and grasses of disturbed areas (*Aristida adscensionis*, *Chloris virgata*, *Tragus koeleroides* and *Pogonarthria squarrosa*) emphasise the ecotonal nature of the area.

6.4 CONCLUSIONS

A characteristic feature of pans containing relatively fresh water seems to be the concentric zones present in the vegetation. This is evident in the Northern Pan. A greyish zone of mostly *Gnaphalium declinatum* on the edge of the pan merges into an inner zone of mostly *Cynodon transvaalensis*, while the pan basin is covered by *Panicum schinzii* and *Echinochloa holubii*. The concentric zones may indicate a sere of hydrophytic communities. Concentric vegetation zones are, however, not a feature of the Southern Pan.

Pans become ephemerally inundated and the vegetation change accordingly, by means of succession. Thus, the vegetation and communities that were presented here may not be representative of all the successional stages, but only of the stage the vegetation reached during the dry phase of the pan, before it was inundated again.

The **Northern Pan** is characterised by a *Cynodon transvaalensis – Gnaphalium declinatum* community, associated with the following subcommunities: *Selago dinteri – Cynodon transvaalensis*, *Panicum schinzii – Cynodon transvaalensis* and *Portulaca oleracea – Cynodon dactylon* subcommunity. The *Hemarthria altissima – Cyperus denudatus* subcommunity is not really part of the pan vegetation, but rather represents riparian vegetation, as it occurs between the pan and the river.

The **Southern Pan** itself, on the other hand, is characterised by a *Diplachne fusca* community with an *Eragrostis bicolor – Diplachne fusca* subcommunity associated with it. The other subcommunity associated with the *Diplachne fusca* community, the *Sporobolus ioclados – Eragrostis bicolor* subcommunity, represents the ecotone between pan vegetation and grassland vegetation. The *Helictotrichon turgidulum – Phyla nodiflora* community indicates a disturbed area inside the Southern Pan, while the *Sporobolus virginicus* community represents only a small area between the hot spring and the lunette dune, but is absent from the rest of the pan basin.

The two earth dams inside the Southern Pan are respectively characterised by the *Eleusine coracana – Cynodon dactylon* subcommunity of the *Cynodon transvaalensis – Gnaphalium declinatum* community (Earth Dam A), and a *Juncus rigidus* community along with its *Cyperus bellus – Eragrostis biflora* and *Cynodon transvaalensis – Juncus rigidus* subcommunities (Earth Dam B). This differs from the normal pan vegetation and rather represents vegetation of more permanent water bodies. The hot spring is also characterised by the *Juncus rigidus* community, but along with the *Digitaria eriantha – Selago dinteri* and *Phragmites australis – Juncus rigidus* subcommunities.

It is evident from the high concentration of grass in the communities, that the Northern Pan can be classified as a Grass Pan. The Southern Pan is dominated by communities associated with brackish conditions. The high presence of *Diplachne fusca*, together with the presence of salt in the Southern Pan, resulted in the classification of this pan as a *Diplachne* pan.

Most of the species encountered in the reserve's *Diplachne* Pan (Southern Pan) correspond to those listed by Malan (1998) for the pans of the southern Free State. However, Malan (1998) listed no species that were present in the Grass Pan (Northern Pan), except for those which are also associated with *Diplachne* Pans. The results of Fuls (1993) and Allan *et al*. (1995) are mostly in agreement with the results for the two kinds of pan in Soetdoring Nature Reserve. The vegetation associated with the permanent water bodies that occur inside the pans of the reserve, where, however absent from all the above mentioned author's results for pan vegetation, because it is not normally associated with ephemeral pans. Müller (1986) did not include any specific detail of pan vegetation for Willem Pretorius Nature Reserve, but the results could successfully be applied in a comparison with the vegetation of the permanent water bodies inside the pans of Soetdoring Nature Reserve.

CHAPTER 7: IMPACT OF ANIMALS AND HUMANS ON GRASSLANDS

7.1 INTRODUCTION

It is generally accepted that conservation areas are managed to attain specific goals and that monitoring is necessary to determine the extent to which these goals are realised (Mentis & Collinson 1979; Bell 1982; Joubert 1982; Macdonald & Brooks 1982; Millar 1982). In this context the impact of herbivores on the vegetation is of general concern, particularly in small reserves (Macdonald & Brooks 1982).

In order to understand the composition of the grassland communities in the following two chapters, it is essential, first of all, to discuss the negative and positive impact of animals and humans on grasslands. The negative, as well as positive, impact can influence the composition and vigour of grasslands. Degradation and the resultant retrogression, as well as the possible secondary succession, will explain the high concentration of certain species and the absence of other species, which will eventually result in the grassland resembling a mosaic pattern. Consequently, this chapter **aims** to give a general overview on the grassland habitat and the degradation thereof, as is also applicable to Soetdoring Nature Reserve.

7.2 OVERGRAZING *VERSUS* OTHER FACTORS

When the degradation of the veld, especially grasslands, comes to mind overgrazing usually carries all the blame. The climate, however, may have the same effects as overgrazing (Mosterd *et al.* 1971; Novellie & Strydom 1987). Plant species composition and productivity are, according to Archer (1996), largely a function of the prevailing climate. O'Connor (1995) compared the effects of **drought** and overgrazing and attributed the following changes to drought: a decrease in total basal cover, drastic decrease in the basal cover of the perennial grasses like *Themeda triandra*, an increase in annual grasses and in short lived forbs, and an increase in the magnitude of compositional change. According to O'Connor (1995) it would seem that drought is the primary agent responsible for the initial restructuring of these communities, but the extent of restructuring still depends on the previous history of grazing.

Drought conditions following grazing treatments in Kenia, produced soil and vegetation changes similar to that of overgrazing. For instance, high soil bulk density, low soil moisture and low herbage biomass were caused by intensive grazing in the absence of drought, and were also caused by drought in the absence of grazing (Mworia *et al.* 1997). Post-drought vegetation in the semi-arid grasslands near Bloemfontein also resembles overgrazed areas in being initially dominated by "weedy species" and in the decrease of *Themeda triandra* (Danckwerts & Stuart-Hill 1988; Snyman & Van Rensburg 1990; O'Connor & Bredenkamp 1997). Grass species that normally increase in overgrazed grassland (*Aristida congesta, Eragrostis obtusa*, etc.) proved to be drought sensitive, but generally more resilient than relatively drought tolerant grasses, like *Themeda triandra* (Milton *et al.* 1995).

Resilience is defined as the ability of grassland to recover to its former soil and vegetation condition after drought and grazing (Mworia *et al*. 1997). In a recent definition of rangeland degradation by Abel and Blaike (1990), an area is considered degraded if the loss of production is beyond the bounds of resilience. This differs from the conventional approach where a change in composition from palatable to less palatable species and an increase in bare ground, constitute degradation (Mworia *et al*. 1997). Thus the resilience of a range site to climatic and grazing effects could be used to characterise degradation. The ability of an area to recuperate from shifts toward degradation depends mainly on two factors, the level of grazing intensity and the variation in rainfall (Mworia *et al*. 1997).

The grassland of Soetdoring Nature Reserve, in general, restored itself after experiencing above normal amounts of rainfall during the rainy season of 2001 - 2002, after the study was conducted (**Chapter 12**). Thus, according to the above mentioned definition of degradation, Soetdoring Nature Reserve is not degraded, because the loss of production is not beyond the bounds of resilience. However, the question that remains to be answered is whether the reserve's grassland could have recovered if it did not experience the above normal amount of rainfall. The normal amount of rainfall did not seem to have the same effect of sprouting grasses everywhere and dominating the dwarf karroid shrubs and the bare patches.

Not only the climate but also **soils** and **topography** have a strong influence on patterns of plant distribution. According to Archer (1996), grazing influences are superimposed on this background of topo-edaphic heterogeneity and climatic variability to further influence vegetation structure and ecosystem processes. Snyman (1999a) stated that the interaction between soil, the climate and the vegetation is so intertwined that it becomes difficult to study it as separate units. For the purpose of this study, however, it will be more appropriate to concentrate on the general effects of overgrazing which is better known, because no long term vegetation data is available for

Soetdoring Nature Reserve. Furthermore, the broad-scale climatic factors alone cannot account for the spatial patterns of vegetation that exists at a local scale (Archer 1996).

7.3 THE NEGATIVE EFFECT OF OVERGRAZING

Roberts *et al.* (1975) summarised the normal events that can lead to the deterioration of grasslands in a figure (Figure 7.1), in order to avoid a lengthy discussion thereof. However, in order to illustrate important aspects of overgrazing of grasslands, a detailed discussion, following the order of processes in Figure 7.1, will be necessary in this chapter.

The main theme of Figure 7.1 is the progressive path of the secondary succession of plant communities. Van Oudtshoorn's (1999) description of succession is used. When an area is disturbed, it is colonised by a new, better adapted plant community. This new community is dominated by pioneers, or annual species that can grow in very unfavourable conditions. The pioneers improve growing conditions and are then replaced by a plant community better adapted to the new conditions. This plant succession continues until the climax community has been established. The climax grasses are perennial and adapted to normal, optimal growth conditions. As soon as the succession process is interrupted through disturbance, it will again return to the pioneer stage. Plant succession also goes hand in hand with soil changes. The development from the pioneer to the climax condition is accompanied by the general building up and improvement of the soil (higher moisture and nutrient status), while changes in the opposite direction, from the climax to the pioneer condition (retrogression), are accompanied by general deterioration and loss of soil (Malan 1998).

According to Figure 7.1, the first step of grassland deterioration due to overgrazing is a reduction of vigour, through the removal of biomass and photosynthetic tissue which affects growth. Herbivores (grazing mammals and insects) can consume about 30 - 60% of the aboveground grassland vegetation (Ricklefs 1990). Grazing herbivores thus also affect seed production, and fecundity, by reducing the vegetative growth that is required to support reproduction. Flowering probability, seed number and the number of vegetative offspring may be decreased by reduced growth through grazing, or by the removal of seed heads (Bullock 1996).

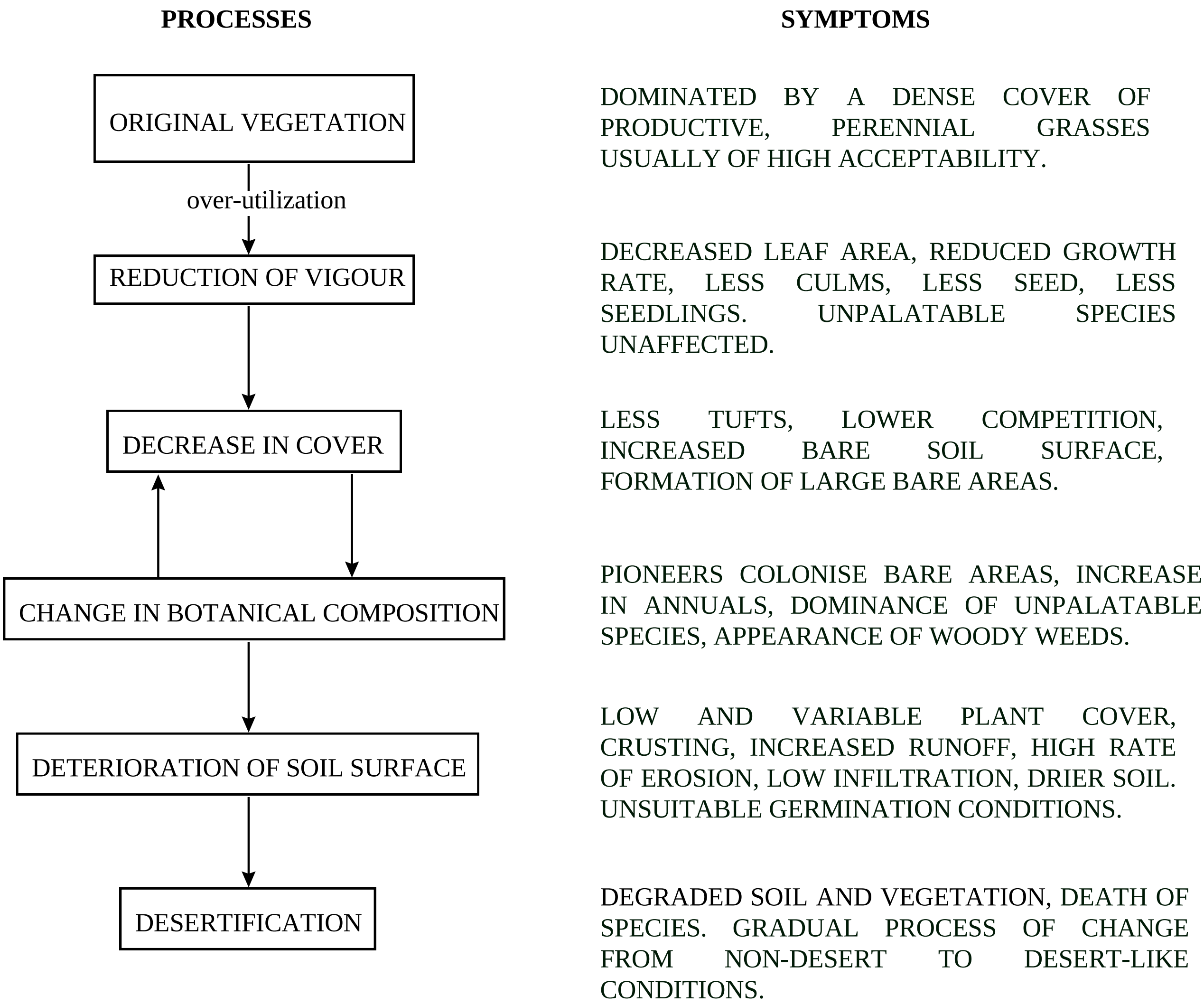


Figure 7.1: Theoretical sequence of processes in grassland deterioration.

(*Redrawn from Roberts et al. 1975*)

It has been proposed that the palatable, longer-lived, obligate seed reproducing species that produce smaller amounts of large, poorly dispersed seeds (e.g. *Themeda triandra*, *Heteropogon contortus*, etc.) are extinction prone and would be eliminated under sustained grazing (O'Connor 1991a). In contrast, the shorter-lived, unpalatable, obligate seed-reproducing species, that produce larger amounts of small, better-dispersed seeds (e.g. many *Aristida* species) may have an opposite response, and will increase under the same conditions (O'Connor & Picket 1992; O'Connor 1994).

The grass plants removed through overgrazing can normally be replaced by available seeds from the seed bank. However, seeds of *Themeda triandra* for example, do not survive in the seed bank for longer than a year (O'Connor 1995) and heavy grazing prevents the input of fresh seed (O'Connor & Picket 1992). Re-establishment of *T. triandra* may be very slow, because it possesses relatively heavy seeds (Capon & O'Connor 1990) and is usually self-dispersed unless dispersal is facilitated by animal vectors (e.g. hares - Agnew & Flux 1970).

Through severe continuous grazing, the animals may thus cause local extinction of the palatable, seed-reproducing perennials. Local extinction is defined by O'Connor (1994) as the disappearance of the existing population and the seed bank for the time required for a complete turnover of all individuals. Palatable climax species capable of vegetative reproduction by stoloniferous growth, like *Digitaria eriantha*, may colonise the newly formed space, but such colonisation is restricted to the area around already existing patches (Vallentine 1990; O'Connor 1991b, 1994).

A reduction of vigour thus usually leads to a decrease in cover (Figure 7.1). Once the vegetative cover is damaged in semi-arid ecosystems, the percentage of bare soil surface increases and a downward spiral begins, which is very difficult to stop (Walker 1979a). Almost simultaneously a change in botanical composition occurs. The density of vegetation cover, represented by the biomass (the amount of organic matter) per unit area and the proportion of land covered by vegetation, is reduced through overgrazing (Grainger 1992).

A change to a less productive type of vegetation cover, involving a modification in species composition and also in the general types of plants growing in an area, is common in overgrazed grasslands. Perennial grasses are replaced by less palatable annual grasses and dwarf shrubs, both of which are characteristic of less productive ecosystems of the drier climates (Grainger 1992). The degradation of the grassland and the resulting encroachment of dwarf karroid shrubs, for instance: *Chrysocoma*, *Pentzia* and *Felicia*, have been dealt with in detail in almost every part of southern Africa, to name just a few more recent publications: Bredenkamp and Bezuidenhout (1990); Ricklefs (1990); Skarpe (1990); Du Preez and Venter (1992); Bond *et al.* (1994); O'Connor and Bredenkamp (1997); Du Plessis *et al.* (1998); Malan (1998); Wiegand *et al.* (1998); Tainton (1999a); etc.

This type of transformation can also occur at biome scale where the Grassland Biome becomes invaded by the Nama-Karoo Biome (Rutherford & Westfall 1994). Soetdoring Nature Reserve, as a matter of fact, lies on the boundary (Figure 2.2) of the sweet Grassland Biome and the Nama-Karoo Biomes (referring to the vegetation maps of Acocks 1988 and Low & Rebelo 1996). It may thus be very easy for the Nama-Karoo Biome to replace parts of the Grassland Biome inside the reserve, if it is not managed correctly.

The next step in the grassland deterioration process (Figure 7.1), after a decrease in cover and a change in botanical composition, is the deterioration of the soil. Most scientists often refer to the soil-plant-animal complex, or interrelations, to underline the fact that the proper functioning of all three are inextricably linked (Costin 1964; Frame 1992). Grass is one of the most conspicuous factors in creating and maintaining many of the more fertile soils. Since grasses are short lived compared with trees, a larger amount of organic matter is added to the soil (Roberts *et al*. 1975; Odum 1997). Grasses cover the soil and bind it with their roots, reducing erosion and generally improving the physical condition of the soil. Further, bacteria in the root nodules of legumes help improve soil fertility by taking nitrogen from the air and depositing it in the soil (Semple 1972).

Most grasses are also remarkably efficient in their ability to increase the water-absorbing and water-holding capacity of soil (Semple 1972; Williams 1980). According to Semple (1972), this property is principally due to the fineness of the leaves, stems and roots; the density of the vegetative cover on the surface of the soil; the innumerable channels made by grass roots; the granulating effect of grass roots on the soil particles, and to the amount of organic matter added to the soil by grass roots. The importance of a high basal cover is also emphasised by the high rate of infiltration by means of bunch grasses that funnel rainwater through their crowns (Walker 1979b).

Overgrazing converts continuous grass cover into patches of grass and this exposes soil to the elements (Miller 1996). The grass roots are not available any more to bind the soil and this allows erosion to remove the topsoil. This has serious implications for soil productivity. Goudie (1993) lists a few implications:

- A reduction in soil thickness reduces available water capacity as well as the depth through which root development can occur.
- The water-holding properties of the soil may be lessened as a result of the removal of the organic material and fine sediment.
- Erosion removes nutrients from the soil.
- Splash erosion may cause soil compacting and crusting which may be unfavourable to germination and seedling establishment (Figure 7.1).

The vegetation cover usually protects the soil surface from raindrop impact, which causes surface sealing and splash erosion, by reducing the kinetic energy of falling raindrops (Snyman 1999b). For example, a rainfall event with an intensity of 25 mm/hr will deliver a pounding to the soil surface with a mass of 200 t/ha at an average speed of 20 km/hr (Matthee & Van Schalkwyk 1984). Basal cover also has an influence on the rate at which water infiltrates into the soil and by promoting infiltration it reduces erosion (Snyman 1999b). While the crowns of grasses and karoo bushes appear to be equally effective in dampening raindrop impact, the protection which grass plants give the soil is usually much greater than that of non-grasses, because the grasses have a much greater basal cover and a thick network of roots below the soil surface (Roux 1981; Snyman 1999a, b). Even within grass communities the level of protection varies. Stands of perennials provide a much more stable cover than stands of annual grasses - which are mostly pioneers colonising bare patches due to overgrazing (Snyman 1999b).

As a general rule, the higher the basal cover, the greater the potential carrying capacity of the veld, the lower the percentage run-off and the more stable the soil (Costin 1964; Roberts *et al*. 1975). Also, in a given situation, the higher the cover, the more likely are useful (desirable) grass species to be present (Roberts *et al*. 1975). Snyman and Fouche (1991) as well as Snyman (1993a, b) have established that runoff from veld in good condition is only about half that of veld in poor condition. Other workers (Kelly & Walker 1976; Van Den Berg *et al.* 1976) have also shown a direct relation between veld condition and infiltration rates in grassland.

The last theoretical step in the deterioration of the grassland (Figure 7.1), is the process of desertification. It may seem strange to mention desertification occurring in grasslands, but Grainger (1992) and Miller (1996) view the degradation of semi-arid grasslands mainly through overgrazing, as part of the wider problem of desertification. The relationship between drought and desertification has led to debate, but drought is best thought of as a short term event which acts as a catalyst to speed up the long term desertification process. Desertification also has to be viewed in the context of possible changes in global climate caused by the 'greenhouse effect' (Grainger 1992).

Desertification has various dimensions. Bond *et al*. (1994) define desertification as a shift from more productive to less productive states, which is manifested in South Africa as the spread of semi-arid karroid shrublands into more mesic grasslands by means of overgrazing. Roux and Vorster (1983) and Bosch (1989) concur. The Karoo gives the impression of being bare soil dotted with karoo bushes (Acocks 1988) or "of karoo bushes each in its own little desert" (Acocks 1988 quoting a Mr H.V. Morton) and this is becoming a more common sight in grasslands.

In the temporal sense, desertification involves long term changes in the physical properties of the land principally due to soil and vegetation degradation. But desertification is not a linear trend, according to Grainger (1992), being influenced by dynamic relationships between vegetation degradation and soil degradation, or by the incidence of drought. Vegetation cover is regarded here as degraded when it experiences a temporary or permanent change in density, structure or species composition relative to what might be expected on the basis of climate, site conditions and historical experience. Soil is degraded in the following main ways: wind and water erosion; compacting, salinisation, etc. (Grainger 1992).

Miller (1996) included a world map in his book, indicating the state of desertification of arid and semi-arid grasslands, with data obtained from the UN Environment Programme. Shockingly, the state of degradation is indicated as being very severe over most of the Free State. Degradation and desertification are two of the most serious threats to arid and semi-arid plant communities where rainfall is low and unpredictable (Wiegand *et al*. 1998). An overgrazed grassland is surely an inherently unstable ecosystem (Miller 1996).

7.4 OTHER NEGATIVE EFFECTS OF ANIMALS

According to Bullock (1996), research on the responses of the grassland communities to grazing in general, is concerned with the changes in species relative abundance caused by direct or indirect responses to grazing. Direct effects on demography (survival, fecundity, etc.) are caused by biomass removal, trampling, etc. by grazers.

Grazing animals trampling or treading the sward is part and parcel of the grazing process (Vallentine 1990; Frame 1992) and also amplifies some of the mentioned effects of overgrazing.

Excessive trampling modifies soil structure by altering the equilibrium between soil particles, air and water. This results in the compaction of the upper soil layers which in it's turn impedes grass root development and reduces root mass. Uptake of soil nutrients become restricted, thus again limiting grass growth rate and production (Frame 1992). Other signs of trampling are poor water infiltration, puddling of the soil surface, reduced soil porosity (Frame 1992), splash erosion and removal of protective plant cover (Van den Berg *et al*. 1975). In extreme cases there may be run-off of surface water and soil erosion may be enhanced (Frame 1992). Soil treading generally has a much greater impact on wet, heavy soils than on dry, sandy soils. Grazing animals also affect the soil by creating animal trails through treading (Valentine 1992).

Indirect effects of grazing can arise through alterations in plant-plant interactions. Competition is probably the major plant-plant interaction in most communities, and has been detected consistently in grasslands. The outcome of competition is determined by species characteristics and the environment (Bullock 1996). Although competitive exclusion is a common prediction of theoretical and empirical studies, grazing has been shown to increase the number of species co-existing (Bullock 1996). The extent to which a plant is under competitive pressure from other plants will largely determine its tolerance of defoliation and trampling by grazing animals (Caldwell 1984). Intense competition by surrounding plants may be more suppressive of foliage yield than severe defoliation by grazing, but the two in combination are additive in their negative effects on yield and survivability (Vallentine 1990).

7.5 POSITIVE EFFECTS OF ANIMALS IN GRASSLANDS

Animals are mostly known for the negative effects they have on grasslands, while their positive effects are often overlooked. Grasses are renewable resources if not overgrazed, because the grass blades grow from the base, not the tip. The stems can thus regrow again and again after being nibbled off by grazers (Goudie 1993; Miller 1996). Grasses have co-evolved with animals and are able to thrive while being grazed (Macdonald 2000) if grazing occurs moderately.

Reardon *et al.* (1972) reported that the grazing bovine animal causes plant growth stimulation by deposition of saliva during grazing; they showed that animal saliva contained thiamine (Vitamin B1) at concentrations previously reported to stimulate a growth response in plants. Vallentine (1990) also refers to the animal inoculating plant parts with saliva, which may stimulate plant growth. If this is also true regarding the grazing of wild animals, then light or moderate grazing may have a very pronounced positive effect on grasses.

Grazing may even improve the nutrient status of regrowing plant tissue, as indicated by nitrogen content (McNaughton 1985). The recycling of nutrients may be an important component of stimulation of productivity by grazing (McNaughton 1979, 1985; Goudie 1993). McNaughton (1984) did an exclosure experiment in the Serengeti and found that grazing stimulated net above ground productivity and reduced biomass concentration. Also, the removal of coarse, dead stems of *Themeda triandra* for example, permits succulent sprouts to shoot (Young 1984; Goudie 1993).

Vallentine (1990) also lists some positive influences that grazing can have on forage and soil resources:

- Accelerate nutrient recycling in the ecosystem and make some nutrients more available.
- Stimulate growth or regrowth by a pruning effect, i.e. tillering of grasses.
- Enhance nutritive value of available herbage by increasing the new growth: old growth ratio.
- Reduce excess accumulations of standing dead vegetation that may chemically and physically inhibit new growth.
- Trample seeds into the soil.

Soil treading may thus have a positive effect in that the grazing animal can plant naturally broadcasted seed. Benefits may be derived from the effect of hoof impact working the seed into the soil surface and compacting the soil around the seed (Vallentine 1990). Soil damaging by hooves becomes positive when it breaks the crust that forms in trampled veld (Young 1984) and thus allowing seeds to become settled. Herbivores may even help in the dispersal of seeds (Janzen 1984).

Domestic animals exert a few other positive effects on forage, because of their prescribed grazing, for example the manipulation of botanical plant composition through selective grazing for biological control (Vallentine 1990). Many studies have been conducted on domestic animals, but further study is needed to illustrate the specific effect that wild grazers have on the veld.

One effect of wild grazers on the veld that is mostly seen in a negative light is the maintaining of grazing lawns by the short grass grazers. Decreaser grasses, (grasses that are abundant in good veld but decrease when overgrazed) are poorly adapted to frequent heavy defoliation and do not persist in grazing lawns (Danckwerts & Stuart-Hill 1987). Thus the short grass grazers effectively promote increaser grasses and communities dominated by increasers (mostly unpalatable grasses that increase in under- or overused veld) (Van Oudshoorn 1999).

According to Novellie (1990): **The prejudice against the short grass grazers appears to stem largely from the unfounded assumption that veld dominated by decreaser species is universally 'superior' to veld dominated by increasers.** In fact, as pointed out by McNaughton (1983), patch-selecting is an important agent of **plant community diversity**. Novellie (1990) states further: **For conservation areas where the objective is to maintain a variety of wild ungulate species it would be appropriate to encourage a wide range of plant communities differing in height structure and species composition. One way of achieving this is to allow short grass grazers to establish grazing lawns.**

The patch selecting of short grass grazers can thus also be seen in a positive light, in the creation of different communities, such as tall and short grass areas. This is important as the height distribution of the sward is evidently one of the main factors determining niche separation among African grazers (Owen-Smith 1985). Further, the aim of game viewers driving through a reserve, is to see animals. The grazing lawns of the short grass grazers are thus also positive in that it clears the veld and allows for game viewers to see the animals that would otherwise be hidden in tall grass. Furthermore, the different plant communities make the reserve more interesting to drive through, by means of creating variation in the grassland. However, an important question that needs to be resolved, is whether the heavily grazed lawns can be maintained in a productive condition under continuous grazing, or whether they will eventually be reduced to a state, either through soil loss or invasion of unpalatable species, where they will no longer provide adequate grazing (Novellie 1990).

Grizmek and Grizmek (1960) were the first to recognise that not all areas were being equally grazed by herbivores. At the same time Vesey-Fitzgerald (1960) also put forward his suggestion of "interspecific facilitation", whereby one herbivore creates a feeding opportunity for another by grazing of the vegetation.

Interspecific facilitation, or ecological separation, between species is an indirect positive effect of the animals on grasslands, in that they create different habitats which can maintain different species of animal. Bell (1970) describes the grazing succession in terms of feeding preferences. Zebra eat a high proportion of stem and significant quantities of grass seed (McNaughton 1985) This enables it to move into longer grass areas earlier in the dry season than the others. Bell suggested that zebra open up the tall coarse grasses by removing stems, thus exposing the green leaves at the base of the plant and allowing greater access for wildebeest (Young 1984), which need a higher proportion of leaf in their diet. Wildebeest then remove the majority of the tall grass, leaving a short sward, favoured by some antelope.

This interaction between herbivores and vegetation is dynamic at two levels, as is described by Jarman and Sinclair (1984). First, if grazing pressure would be lighter or more selective, grasses would grow longer and zebra would benefit. If zebra numbers increase, wildebeest would benefit, and their grazing would lead to invasion by herbs and an increase in, for instance springbok or blesbok. Selective grazing on the part of the short grass grazers might allow longer grass to grow which will again favour the zebra and the whole cycle is set off again.
Second, different phases of the cycle may occur simultaneously in different areas or even in the same large area which will favour the wildebeest and zebra parts of the cycle. Thus, a healthy grassland can play host to a complex mix of co-existing plant and animal species (Macdonald 2000).

7.6 THE IMPACT OF HUMANS ON SOETDORING NATURE RESERVE

The impact that humans have on grasslands in general is a wide topic. It includes overgrazing and trampling by domestic stock, replacing the grasses with crops and every other conceivable kind of destruction, for example the creation of rubbish dumps, the construction of buildings, roads, railways, etc. In order to enable optimal resource utilisation and conservation of the grasslands, a vegetation classification programme has been implemented in the Grassland Biome (Mentis & Huntley 1982; Scheepers 1987). The long-term aim of the Grassland Biome Project is to compile a synecological and syntaxonomical synthesis of the Grassland Biome of southern Africa (Scheepers 1987). Although humans have a destructive impact on grasslands in different ways, this study will only concentrate on the impact that humans have directly or indirectly on the grassland of Soetdoring Nature Reserve, specifically.
Humans are indirectly responsible for the overgrazing of the reserve when the **carrying capacity** levels are exceeded and when parts of the reserve were previously farmland where domestic animals could have been allowed to overgraze the area. Carrying capacity is expressed in the stocking rate (Snyman 1989), which can be defined as the number of animals of a particular class that are allocated to a unit area of land for a specified period of time, usually the growing period of the veld type in question (Bartholomew 1991). The stocking rate in turn can be expressed either in terms of animal numbers per unit land area (ha) or as land area available for each animal (Morris *et al.* 1999). A possible reason for exceeding the carrying capacity in the reserve will be to meet the visitors' complaints of not seeing enough animals. This, however, is detrimental for

the vegetation by promoting overgrazing and not helping to conserve vegetation, which are also entitled to conservation inside a reserve.

Unfortunately, **roads** are indispensable if people and nature are to be brought together (Paynter & Nussey 1986) but they do not have positive effects on the reserve. All roads present in nature reserves contribute to the disturbance of the natural environment (Paynter & Nussey 1986; Du Toit & Van Rooyen 1996). There are different kinds of road in Soetdoring Nature Reserve, for example visitor roads, which aim to provide visitors with the opportunity of viewing the plant, animal, bird species and other natural resources of the reserve.

According to Du Toit and Van Rooyen (1996), visitor roads should never be long straight stretches of road but should preferably twist through the reserve along a vegetation border (ecotone) or a contour line. In Soetdoring Nature Reserve, however, the visitor roads are made up of a few long, straight stretches, but also of twists and turns (Figure 2.1). Meanders have a few advantages over long, straight roads, especially in an aesthetic point of view (Schulze 1992). The most important advantage of meandering roads, however, is that it forces the road user to drive slowly and thus reduces animal mortalities, road accidents, dust pollution, etc. (Schulze 1992). Dust pollution should be minimised, because the dust forms a layer on the roadside vegetation, which results in this vegetation becoming unpalatable (Paynter & Nussey 1986).

Roads that are used for hunting and game counting are also present in Soetdoring Nature Reserve and are mostly twisting two-track roads, where the public is not allowed. Other two-track roads run all along the border fence, and are used to repair and monitor the condition of the fences. According to Schulze (1992), the long straight roads that ran along the fences of the Imberbe Game Lodge have been changed to a system of meanders, which follow the borders of the different plant communities. However, this would be difficult to achieve in Soetdoring Nature Reserve, because most of the grassland is heavily overgrazed and small plant communities are scattered through the reserve - thus, they provide no clear border. Also, the bigger plant communities, like riparian communities, grassland communities, etc. are already divided by the border fence, thus it would be of little value to redo the whole reserve’s border fence roads into meanders. Easy access to the fences should not be compromised, because the reserve’s fences are constantly damaged by animals and poachers.

The human presence is also clearly visible in the leftovers of **previous farming activities**, for example 9 old cement dams are present; corroded parts of implements and other articles are strewn all over the reserve; parts of stone walls remained; etc. (*vid.* **Chapter 2**). All of the above mentioned farming leftovers contribute to the visible impact of human activity in the reserve and spoil the reserve's natural image.

7.7 THE EFFECT OF FIRE ON THE DRY SANDY HIGHVELD GRASSLAND

Themeda triandra is very important for grazing in the reserve and in order to improve the quality of the veld, a part of the reserve may be burned in order to stimulate the growth of this grass. In the areas that have been burned in the past, *Themeda triandra* has a very high density, while the other grasses are almost absent and the dwarf karroid shrubs have a low concentration.

Different grasses react differently to burning. In a semi-arid grassland for example, differences between *Themeda triandra* and *Sporobolus fimbriatus* suggest that *Themeda triandra* is primarily adapted to defoliation by fire, while *Sporobolus fimbriatus* is mainly adapted to year-long defoliation by herbivores (Danckwerts & Stuart-Hill 1987).

The reason for burning the veld in Soetdoring Nature Reserve, was primarily to lure the Black Wildebeest to the nutritious flush of the burnt veld and away from their territories, in order to allow the veld to rest a while from the continuous grazing. The system of continuous grazing will result in uneven use, leading to a patchwork effect. If this is not corrected, the patches will increase in size, the vigour of the plants will decline and soil may begin to erode. According to Edwards (1984), burning may relieve previously heavily used areas, although some game is very habitat specific and cannot be moved in this way. This is exactly what happened in Soetdoring Nature Reserve - all the other grazers where lured to the green sprouts that appeared after the burning, except for the territorial bound Black Wildebeest. Other than that, Edwards (1984) feels that burning in the wild herbivore system is almost essential, even in sweetveld.

There is still room for further research, but it seems that burning of the sweetveld, or better known as the *Cymbopogon-Themeda* veld, is not recommended, especially in the semi-arid regions of the Free State (Mosterd *et al*. 1971; Tainton & Mentis 1984; Everson 1999). According to Everson (1999), there should be no real need to remove accumulated ungrazed material by means other than grazing in these sweetveld areas. Since they are climatic climax grassland they are not subject to rapid degeneration if under-utilised, although individual plants may become moribund if they are left unutilised for long periods. If burned regularly in late autumn or winter, the density of the cover of the grassland will decline and susceptibility of the soil to erosion will increase (Mentis & Tainton 1984).

Fire may be used in game parks to create habitats suited to certain game species and to induce game to graze otherwise non-preferred areas (Edwards 1984). Another reason for burning, is to remove the woody components invading the grassland (Mosterd *et al* 1971; Clapham 1973; Barnes 1979; Odum 1997; Everson 1999). Since woody components usually begin growth in early spring before grasses are active, late dry season burns, according to Kruger (1984), usually maintain grass at the expense of karroid shrubs and trees, like *Acacia karroo*. This could be a solution to the problem of invading karroid shrubs in Soetdoring Nature Reserve, but further study in the reserve is definitely needed to confirm this, because it is possible that if used incorrectly, fire may promote the increase of karroid shrubs rather than stopping it.

Various hypotheses based on experiment and on general experience have already been presented to explain the role of fire in the dynamic relations between the grass sward, shrub and tree strata. Kruger (1984) reduced this to the following: the competitive ability of species of the grass sward seems to be crucial and any factor which acts against this, including deferred burning, too frequent burning, and aseasonal burning, will favour development of woody components.

Although it seems that burning should largely be discounted as a regular management tool in this vegetation type, it may be used occasionally after a series of wet seasons to remove dead grass (Everson 1999), to stop invasion by woody components, or to create habitat for grazers. After burning, such veld however needs to be rested (Everson 1999) and care must be taken that overgrazing of the newly formed grass do not occur.

CHAPTER 8: THE GRASSLAND OF SOETDORING NATURE RESERVE

8.1 INTRODUCTION

A high percentage of the land surface of the earth is covered in natural grassland. The Grassland Biome occupies 349 174 km^2 and is centrally located in southern Africa. It adjoins all, except the desert, fynbos and succulent karoo biomes (O'Connor & Bredenkamp 1997). It spans a rainfall gradient from ca. 400 to >1 200 mm yr^{-1}, a temperature gradient from frost-free to snow-bound in winter, ranges in altitude from sea level to >3 300 m, and occurs on a spectrum of soil types from humic clays to poorly structured sands (O'Connor & Bredenkamp 1997). Little wonder then that the grasses are considered the most important plant family on earth and grasslands one of the most important life-support systems on earth (Macdonald 2000). They are important in terms of numbers of species, land area covered and diversity of habitats, which is why, according to Macdonald (2000), the World Wide Fund for Nature (WWF-SA) has made the conservation of South Africa's grassland eco-region one of its highest priorities.

The grasslands also host many of South Africa's threatened animals, including endangered **birds** such as the blue crane, the large bustards, numerous larks; endangered **lizards** such as the sungazer lizard, etc. (Huntley 1984; Macdonald 2000). In fact, nearly three-quarters of the most threatened bird species listed in the Red Data Book of South Africa's Endangered Birds occur in dry or wet grassland habitats (Tarboton 1997b). This, unfortunately, indicates that the grasslands and wetlands have been subjected to great ecological stress and remain the most poorly managed and heavily transformed of the country's vegetation types (Macdonald 2000). The ongoing threats to grasslands include overgrazing, excessive burning, transformation to monoculture and the expansion of towns, cities, roads and railway networks.

The semi-arid region in which Soetdoring Nature Reserve falls, was classified by Bredenkamp and Van Rooyen (1996) as Dry Sandy Highveld Grassland. This vegetation type includes the Western Bankenveld (A61) and Dry *Cymbopogon-Themeda* Veld (A50) of the Acocks classification system, Dry Cold Temperate Grassland, etc. The Dry Sandy Highveld Grassland covers approximately 30 976 km^2 of the Free State Province, of which only 0.01% is conserved (Low & Rebelo 1996). The conservation status is evidently very poor, the reasons being that it is an excellent cattle and sheep farming area and many areas have been ploughed for the cultivation of maize, thus the natural vegetation is only represented by small remnants, which are further degraded by means of overgrazing (Bredenkamp & Van Rooyen 1996).

The vegetation of the Grassland Biome follows a rainfall gradient, which generally corresponds to the relative contributions by ‘sweet’ and ‘sour’ grass plants to the plant cover (Rutherford & Westfall 1994). Sweet grasses have lower fibre content, maintain their nutrients in the leaves in winter and are therefore palatable to grazers (Low & Rebelo 1996). Sour grasses have higher fibre content and tend to withdraw their nutrients from the leaves during winter so that they are unpalatable to grazers. Sour grass prevails in colder areas at higher altitudes that also have higher rainfall, with the 625 mm isohyet as the boundary between the sweet and sour grassland zones (Low & Rebelo 1996). Soetdoring Nature Reserve should thus be dominated by sweet grasses, because of the lower rainfall (*vid*. **Chapter 2**). Malan (1998) described the sweet grassland of the southern Free State as being very disturbed, as indicated by the numerous karroid species present.

According to Bredenkamp and Van Rooyen (1996) the Dry Sandy Highveld Grassland can be characterised by the presence of some *Acacia karroo* trees, occurring occasionally along water courses (Odum 1997), with diagnostic grasses such as *Eragrostis lehmanniana*, *E. obtusa* and *Panicum coloratum*, as well as the common dwarf karroid shrub *Pentzia globosa*. Other prominent grass species include *Aristida congesta*, *Cynodon dactylon*, *Digitaria eriantha*, *Eragrostis curvula*, *E. trichophora* and *Themeda triandra*. West of Bloemfontein, affinity to Karoo vegetation can be seen in plant communities dominated by the dwarf shrubs *Chrysocoma ciliata*, *Felicia muricata*, *Nenax microphylla*, *Pentzia incana*, *Salsola kali* and *Selago dinteri* (Bredenkamp & Van Rooyen 1996). Mosterd *et al.* (1971) and Acocks (1988) gave a more or less similar description of the *Cymbopogon-Themeda* Veld.

8.2 RESULTS

Five plant communities have been identified in the moderately grazed grassland of Soetdoring Nature Reserve (**Table 8.1 – Appendix 2**). The hierarchical classification is as follows:

1. *Salsola glabrescens* - *Aristida congesta* community

2. *Eragrostis chloromelas* - *Themeda triandra* community
2.1 *Brachiaria eruciformis* - *Themeda triandra* subcommunity
2.2 *Digitaria eriantha* - *Schkuhria pinnata* subcommunity

3. *Aristida adscensionis - Eragrostis trichophora* community
3.1 *Chloris virgata - Eragrostis trichophora* subcommunity
3.2 *Hypertelis salsoloides - Eragrostis trichophora* subcommunity

4. *Sporobolus fimbriatus - Themeda triandra* community

5. *Cymbopogon plurinodis - Nenax microphylla* community

5.1 *Hertia pallens - Themeda triandra* subcommunity
5.1.1 *Melolobium candicans - Nenax microphylla* variant
5.1.2 *Lycium horridum - Rosenia humilis* variant
5.2 *Eragrostis lehmanniana - Eragrostis superba* subcommunity
5.2.1 *Heteropogon contortus - Eragrostis lehmanniana* variant
5.2.2 *Sporobolus fimbriatus - Eragrostis superba* variant
5.3 *Aristida adscensionis - Themeda triandra* subcommunity

Species of Minor Occurrence

8.3 DISCUSSION

Soetdoring Nature Reserve's grassland (*vid.* Figure 2.1) gives the impression of a mosaic pattern, where patches of grass alternate with patches of karroid shrubs and bare patches (Figure VIII, Appendix 1). The grassland patches themselves are comprised of alternating stands of *Themeda triandra*, together with other climax grasses, as well as stands of mostly pioneer grasses of *Aristida* and *Eragrostis* species. Consequently, the classification proved to be very difficult due to this mosaic pattern of the grassland and the fact that there are no significant differences in habitat between communities. Causes for this mosaic pattern are most probably overgrazing and trampling with the consequent erosion of the topsoil, which leaves the clayey horizon underneath, exposed. This creates bare patches not sufficient to sustain grasses, and these areas are taken over by, mostly, dwarf karroid shrubs. All of these factors contribute to the character of the grassland, which is also reflected in the vegetation on Tables 8.1 and 9.1.

The boundary between the Grassland and Nama-Karoo Biomes cuts, according to Low and Rebello (1996), through the central Free State (Figure 2.2). The grassland communities that were found in Soetdoring Nature Reserve, were thus compared to the grassland communities of the southern Free State, the northern Free State and to the Willem Pretorius Nature Reserve in the northern Free State.

8.3.1 The grassland communities

1. *Salsola glabrescens* - *Aristida congesta* community

Species Groups A and N (Table 8.1) characterise the community, while Species Groups C, E, H, I, K and L contain all the species that were found in these three relevés. The pioneer grass, *Aristida congesta* (Species Group N), is dominant and attains its highest cover values in this community. The dwarf karroid shrub, *Salsola glabrescens* (Species Group A), has varying constancies in the community, from low to relatively high cover (Figure X, Appendix 1).

Besides the two dominant species that characterise this community, only a few species are found namely the climax grasses *Digitaria eriantha* (Species Group L), *Panicum coloratum* (Species Group N) and *Sporobolus fimbriatus* (Species Group E); the pioneer grasses *Eragrostis lehmanniana* (Species Group I) and *E. obtusa* (Species Group N); the dwarf karroid shrubs *Pentzia globosa* (Species Group K) and *Selago dinteri* (Species Group N); the forb *Nidorella resedifolia* (Species Group N); and the succulent member of the Mesembryanthemaceae (mesemb) *Mestoklema arboriforme* (Species Group C). The cover abundance values of all these species are relatively low, with less than 12% canopy cover noted in a plot. *Themeda triandra* (Species Group M) is completely absent. The community is further characterised by numerous bare spaces where no vegetation covers the soil. Most of the above mentioned species are known to occur in overgrazed areas (**Chapter 9**). Thus, the *Salsola glabrescens* - *Aristida congesta* community represents disturbed, impoverished grassland.

2. *Eragrostis chlormelas* - *Themeda triandra* community

Species Groups B, L and M characterise the community where *Themeda triandra* (Species Group M) is dominant. *Digitaria eriantha* (Species Group L), *Panicum coloratum* and *Nidorella resedifolia* (Species Group N) are prominent, while *Eragrostis chloromelas* and *Brachiaria eruciformis* (Species Group B) are present with a lower constancy. All of the above mentioned species of the community, except for the forb *Nidorella resedifolia*, are grasses that can frequently be found in grasslands. However, there are also dwarf karroid shrubs present with a low frequency, like *Pentzia globosa*, *Nenax microphylla* (Species Group K) and *Rosenia humilis* (Species Group H). Species Groups A, C - G, I and J are absent. The *Eragrostis chlormelas – Themeda triandra* community represents a relatively small part of the *Themeda triandra – Digitaria eriantha* grassland unit, comprised of the more widespread *Sporobolus fimbriatus – Themeda triandra* and *Cymbopogon plurinodus – Nenax microphylla* communities.

The community has the following two subcommunities associated with it.

2.1 *Brachiaria eruciformis - Themeda triandra* subcommunity

The subcommunity is comprised of mainly Species Groups B, M and N. *Themeda triandra* (Species Group M) is dominant and occurs in very high densities, with *Panicum coloratum* and *Nidorella resedifolia* (Species Group N) also occurring frequently. This subcommunity is distinguished from the *Digitaria eriantha - Schkuhria pinnata* subcommunity (2.2) by the presence of *Selago dinteri* and *Aristida congesta* (Species Group N), as well as the absence of the climax grass *Digitaria eriantha* (Species Group L) and the exotic forb *Schkuhria pinnata* (Species Group N). *Digitaria eriantha* has a higher acceptability for grazers than *Themeda triandra* and is consequently selected and removed in certain areas of the grassland.

2.2 *Digitaria eriantha - Schkuhria pinnata* subcommunity

The species of the subcommunity are presented in Species Groups B, H, and K - N. *Digitaria eriantha* (Species Group L) and *Themeda triandra* (Species Group M) are dominant, while *Schkuhria pinnata* (Species Group N) is prominent in the subcommunity. *Panicum coloratum* and *Nidorella resedifolia* (Species Group N) occur in lower densities, if compared to the *Brachiaria eruciformis - Themeda triandra* subcommunity (2.1). It can be also differentiated from the previous subcommunity in that *Selago dinteri* and *Aristida congesta* (Species Group N) are completely absent.

3. *Aristida adscensionis - Eragrostis trichophora* community

All of the species groups, except Species Groups F, G and K, have some species with varying constancies present in the community, but Species Group D is characteristic. *Eragrostis* *trichophora* (Species Group D) is the dominant species, while *Chloris virgata* and *Aristida adscensionis* (Species Group D) are present with lower constancies and canopy covers. *Sporobolus ludwigii* and *Salsola kali* (Species Group D) are restricted to this community, but are present with low constancies and low cover values of less than 12%. The community is characterised in having only pioneer species as diagnostic entities.

The following two subcommunities are associated with the *Aristida adscensionis - Eragrostis trichophora* community.

3.1 *Chloris virgata - Eragrostis trichophora* subcommunity

Species Groups A, B, D, H – J and L - N contain all the species present in the subcommunity. The diagnostic species are *Chloris virgata* (Species Group D) and *Nidorella resedifolia* (Species Group N). *Nidorella resedifolia* is also the dominant species, while other species with high constancies, are: *Eragrostis trichophora*, *E. lehmanniana* (Species Group I), *Digitaria eriantha* (Species Group L) and *Themeda triandra* (Species Group M). Some of these species have rather high cover abundance values with up to 75% canopy cover in a sample plot. Other species present, with less than 12% canopy cover per sample plot, are the dwarf karroid shrubs *Salsola glabrescens* (Species Group A), *S. kali* (Species Group D), *Felicia muricata* (Species Group C), *Lycium horridum*, *Rosenia humilis* (Species Group H), *Selago dinteri*, *Chrysocoma ciliata* (Species Group N); the pioneer grasses *Sporobolus ludwigii* (Species Group D), *Eragrostis obtusa*, *Urochloa panicoides* (Species Group N); the forbs *Cyperus rupestris*, *Conyza podocephala* (Species Group H), *Berkheya pinnatifida*, *Schkuhria pinnata*, *Ledebouria luteola* and *Pterodiscus speciosus* (Species Group N). *Chenopodium album* (Species Group J) has a cover abundance value of 3 (25% - 50% cover) in one single relevé.

The high number of karroid species and pioneer grasses, as well as the relatively low cover values indicate that this subcommunity represents a moderately overgrazed grassland. The species with the highest percentage canopy cover and constancy, are mostly climax or subclimax grasses, like *Eragrostis trichophora* (Species Group D), *E. lehmanniana* (Species Group I), *Digitaria eriantha* (Species Group L) and *Themeda triandra* (Species Group M) and their collective canopy cover is so high that barely any bare soil is visible. It thus seems as if this subcommunity have not been subjected to the same degradation or overgrazing, as the *Salsola glabrescens - Aristida congesta* community (1) in which the climax and pioneer grasses, as well as the karroid species, exhibit low canopy cover values.

This *Chloris virgata - Eragrostis trichophora* subcommunity differs from the *Hypertelis salsoloides - Eragrostis trichophora* subcommunity (3.2) in the absence of Species Groups C and E and in the presence of Species Groups I and J.

3.2 *Hypertelis salsoloides - Eragrostis trichophora* subcommunity

This subcommunity is characterised by Species Group C. *Eragrostis trichophora* (Species Group D) is the dominant, diagnostic species of the subcommunity, with a canopy cover of between 50% and 100% (Figure IX, Appendix 1). All the other species have canopy covers of less than 12%.

Species Group C is a rather unique group, with species that only occur in five other relevés on the table. It contains the following species: the dwarf karroid shrubs *Asparagus glaucus* and *Felicia muricata*; the succulent mesembs *Mestoklema arboriforme* and *Trichodiadema barbatum*, as well as the forb *Hypertelis salsoloides*. Other species present, but absent from subcommunity 3.1, are: *Sporobolus fimbriatus* (Species Group E), *Commelina africana*, *Tragus koelerioides* and *Agrostis lachnantha* (Species Group N).

This *Hypertelis salsoloides - Eragrostis trichophora* subcommunity thus differs from the *Chloris virgata - Eragrostis trichophora* subcommunity (3.1) by the absence of Species Groups B, I and J, the presence of Species Groups C and E as well as the presence or absence of a few species from Species Group N. The species in Species Group H have a higher constancy in this subcommunity than in the previous one. Otherwise, except for *Brachiaria eruciformis* (Species Group B), *Conyza podocephala* (Species Group H), *Eragrostis lehmanniana* (Species Group I), *Chenopodium album* (Species Group J) and *Pterodiscus speciosus* (Species Group N), this subcommunity contains the same species as the previous one.

4. *Sporobolus fimbriatus - Themeda triandra* community

This community is characterised by Species Group E. All the species groups, except for Species Groups C and I, contain species present in the community. *Digitaria eriantha* (Species Group L) and *Themeda triandra* (Species Group M) are dominant. *Sporobolus fimbriatus* (Species Group E) is subdominant with high constancy and cover abundance values. All three of these grass species are perennial, climax grasses, with rather high acceptability for grazers, and indicate a well developed seral stage (Figure VII, Appendix 1). *Nidorella resedifolia* (Species Group N) has a high constancy in the community, but its canopy cover is less than 5% of a sample plot. All other species present in the community cover only between 1% and 12% of a sample plot.

5. *Cymbopogon plurinodis* - *Nenax microphylla* community

All the species groups on the table are represented by one or more species in this community, but Species Group K is characteristic. *Themeda triandra* (Species Group M) is the dominant species, followed by *Cymbopogon plurinodis* (Species Group K) and *Digitaria eriantha* (Species Group L). *Nenax microphylla* (Species Group K) has a rather high constancy and a canopy cover of between 1% and 50%.

The abundance of *Cymbopogon plurinodis* and *Themeda triandra* indicate why one of the names given to this grassland unit in the central Free State, is the Dry *Cymbopogon*-*Themeda* Veld. However, *Cymbopogon plurinodis* (Species Group K) is not very common in Soetdoring Nature Reserve, it occurs in small patches lumped together or just one or two plants in a sample plot, as is evident on the table. This *Cymbopogon plurinodis* - *Nenax microphylla* community, along with its subcommunities and their variants, is representative of the larger mosaic patches of the grassland of Soetdoring Nature Reserve and represents, along with community 4, the best grassland that the reserve has to offer. This community has three subcommunities.

5.1 *Hertia pallens* - *Themeda triandra* subcommunity

The diagnostic species of this subcommunity are given in Species Group F. Only Species Group A is absent, all other species groups are represented. *Themeda triandra* (Species Group M) is the dominant species, *Cymbopogon plurinodis* (Species Group K) is subdominant and *Hertia pallens* (Species Group F), *Digitaria eriantha* (Species Group L) and *D. argyrograpta* (Species Group F) are a prominent part of the subcommunity. *Hibiscus pusillus* (Species Group F) is scarce in the subcommunity with very low cover values of less than 1% of a sample plot. The species of Species Group F, *Hertia pallens*, *Digitaria argyrograpta* and *Hibiscus pusillus*, are almost restricted to this *Hertia pallens* - *Themeda triandra* subcommunity and except for three other relevés, were found nowhere else.

The *Hertia pallens* - *Themeda triandra* subcommunity has the following two variants.

5.1.1 *Melolobium candicans - Nenax microphylla* variant

Species Groups F and G are characteristic of the variant. The species of Species Group G, *Melolobium candicans, Helichrysum herbaceum* and *Eragrostis curvula,* are restricted to this variant of the *Hertia pallens - Themeda triandra* subcommunity (5.1), except for three other relevés on the table.

This *Melolobium candicans - Nenax microphylla* variant differs from the *Lycium horridum - Rosenia humilis* variant (5.1.2) by the absence of Species Groups B - D, H and I and by the presence of Species Group G as well as *Sporobolus fimbriatus* (Species Group E). Except for the presence of *Heteropogon contortus* in one relevé, Species Group J is also absent. The species present in Species Group N for this variant, are *Nidorella resedifolia*, *Commelina africana*, *Selago dinteri*, *Berkheya pinnatifida*, *Tragus koelerioides*, *Ledebouria luteola*, *Chrysocoma ciliata* and *Pterodiscus speciosus*.

The canopy cover of all the above mentioned species, however, is low with a cover value of less than 12%, only *Helichrysum herbaceum* (Species Group G) has one cover abundance value of 2b (12 - 25% cover). The very high constancy and cover abundance values of *Themeda triandra* (Species Group M) and to a lesser extent that of *Digitaria eriantha* (Species Group L) in this variant, explains the lower cover values of the other species.

5.1.2 *Lycium horridum - Rosenia humilis* variant

Species Group H is characteristic of this second variant of the *Hertia pallens - Themeda triandra* subcommunity (5.1). It differs from the *Melolobium candicans - Nenax microphylla* variant (5.1.1) by the absence of Species Group G and the presence of Species Groups H and I. *Commelina africana*, *Schkuhria pinnata*, *Eragrostis obtusa*, *Aristida congesta*, *Oxalis depressa*, *Monsonia angustifolia* and *Hibiscus trionum* (Species Group N) are present in this variant, but absent from variant 5.1.1. *Nidorella resedifolia* (Species Group N) is about absent in this variant, whereas it has a high constancy in the previous variant (5.1.1). *Themeda triandra* (Species Group M) is present with a high constancy and cover abundance values of up to 5 (up to 100% canopy cover). The majority of other species in this variant have canopy cover values of less than 5%.

5.2 *Eragrostis lehmanniana - Eragrostis superba* subcommunity

All the species groups are represented by one or more species in this subcommunity. Species Group I is characteristic. *Eragrostis lehmanniana* (Species Group I) and *Themeda triandra* (Species Group M) are dominant, with high constancies and cover values of 12% - 75% of a sample plot. *Digitaria eriantha* (Species Group L) and *Eragrostis superba* (Species Group I) are subdominant.

The *Eragrostis lehmanniana - Eragrostis superba* subcommunity has the following two variants.

5.2.1 *Heteropogon contortus - Eragrostis lehmanniana* variant

Species Group J is characteristic, while Species Groups A, H, I and K - N contain species associated with the variant. *Heteropogon contortus* and the exotic *Chenopodium album* (Species Group J) grow mostly in disturbed areas, although *Heteropogon contortus* can also be found on slopes (Van Oudtshoorn 1999). This variant differs from the *Sporobolus fimbriatus - Eragrostis superba* variant (5.2.2) by the presence of Species Groups A, D, H and the absence of Species Group E. In Species Group N, the only significant differences between the two variants, are the presence of *Selago dinteri* and the higher constancy of *Oxalis depressa*. *Cymbopogon plurinodus* (Species Group K) becomes very scarce in this variant, but has a high constancy in the *Sporobolus fimbriatus - Eragrostis superba* variant (5.2.2).

5.2.2 *Sporobolus fimbriatus - Eragrostis superba* variant

Sporobolus fimbriatus is the diagnostic species of this variant. *Sporobolus fimbriatus* (Species Group E), *Cymbopogon plurinodis* (Species Group K), *Digitaria eriantha* (Species Group L) and *Themeda triandra* (Species Group M) are all rather dominant in this variant. The above mentioned four species are all climax grasses considered to be characteristic of grassland that is not overgrazed, especially when present in a high concentration. This variant lacks *Chenopodium album* and *Heteropogon contortus* (Species Group J) that are mostly present in disturbed grassland. It further differs from the previous variant by the presence of Species Group E and the absence of *Selago dinteri* (Species Group N).

5.3 *Aristida adscensionis* - *Themeda triandra* subcommunity

Species Groups D, K and M are characteristic of this subcommunity. The dominant, diagnostic species is *Aristida adscensionis* (Species Group D), with cover abundance values of 4 (50% - 75% canopy cover) for the whole subcommunity. *Cymbopogon pluronodis* (Species Group K) is the only other species present with a 12% - 25% canopy cover. The other species, namely *Themeda triandra* (Species Group M), *Nidorella resedifolia*, *Panicum coloratum*, *Tragus koelerioides*, *Eragrostis obtusa*, *Aristida congesta* (Species Group N), *Brachiaria eruciformis* (Species Group B) and *Hibiscus pusillus* (Species Group F), all have canopy covers of less than 5%. No other species are present, except the species of minor occurrence, *Fingerhuthia africana* and *Elionorus muticus*, that also have a canopy cover of less than 5%.

This is clearly a disturbed subcommunity, where the majority of species are pioneer grasses (*Aristida adscensionis*, *A. congesta*, *Brachiaria eruciformis*, *Eragrostis obtusa* and *Tragus koelerioides*) that occur in overgrazed and trampled grassland (Van Oudtshoorn 1999). The climax grasses *Cymbopogon plurinodis*, *Themeda triandra* and *Panicum coloratum* are the only remnants of the true grassland in this area. There are also bare patches present.

<u>Species of Minor Occurrence</u>

The following species were considered to be of too low frequency in the grassland, less or equal to 3 occurrences in the 78 relevés on Table 8.1, to make a significant contribution to the communities or subcommunities and have subsequently been omitted. They are, in alphabetical order (indicating the relevé numbers and Braun-Blanquet cover abundance values): *Aptosimum indivisum* (227: 1, 67: +, 54: 1), *Asparagus suaveolens* (123: 1), *Atriplex semibaccata* (127: 1, 186: +), *Barleria macrostegia* (18: r, 131: r), *Bidens pilosa* (37: 1), *Blepharis integrifolia* (44: r, 61: r, 77: r), *Bulbine frutescens* (64: r), *Commicarpus pentandrus* (18: r, 177: 1, 137: 1), *Crabbea acaulis* (53: +, 77: 1, 54: r), *Crassula setulosa* (134: +), *Cynodon dactylon* (116: 2b, 95: 3, 63: +, 123: 1), *C. transvaalensis* (2: r), *Dicoma macrocephala* (192: 1), *Elionurus muticus* (192: 1), *Enneapogon scoparius* (193: 2a, 123: 1), *Eragrostis biflora* (25: 1, 53: 1), *E. gummiflua* (156: 1, 166: 2a, 175: 1), *E. plana* (2: 5), *Eriospermum cooperi* (228: +, 229: +), *Fingerhuthia africana* (175: +, 139: 2a), *Geigeria filifolia* (211: +, 67: r), *Gnidia polycephala* (190: 1, 210: 1), *Haemanthus montanus* (207: +), *Helichrysum zeyheri* (163: 2a, 79: 3), *Hermannia comosa* (175: +), *Indigofera alternans* (189: +, 123: +, 192: +), *I. rhytidiocarpa* (145: +) , *Koeleria capensis* (177: 1), *Laggera decurrens* (64: 1), *Limeum aethiopicum* (14: 1, 205: 1, 147: +), *Lycium* *cinereum* (190: +), *Papaver aculeatum* (37: 1), *Pseudognaphalium oligandrum* (116: 2a, 63: +), *Ruschia hamata* (205: +), *R. spinosa* (154: 1, 131: 1), *Salvia verbenaca* (190: 1, 191: 1, 79: +), *Senna italica* (190: +), *Setaria sphacelata* (63: 1, 225: 1), *Solanum supinum* (142: r), *Sphaeralcea bonariensis* (186: 1), *Talinum caffrum* (37: +, 130: +), *Taraxacum officinale* (37: +), *Tephrosia capensis* (95: +), *Teucrium trifidum* (117: 1), *Thesium hystrix* (156: 1, 79: 1, 123: 2b), *Tribulus terrestris* (193: +) and *Vahlia capensis* (53: 1).

8.4 COMPARISON BETWEEN THE GRASSLAND VEGETATION OF SOETDORING NATURE RESERVE AND OTHER AREAS

8.4.1 The grassland of the southern Free State, the Ae land type

Since the grassland of Soetdoring Nature Reserve is in such a degraded state (Table 8.1), resulting in a mosaic character, it is difficult to make a comparison with other grasslands, even when it is in the same area and on the same land type. However, Malan *et al.* (1994) listed some species that concur with those noted in Soetdoring Nature Reserve's grassland, but no communities resemble those of the reserve. Malan *et al.* (1994) found the major community on the plains of the Ae land type to be a *Themeda triandra* - *Lactuca dregeana* major community. All the grasses of the grassland of the Ae land type, except *Themeda triandra* and *Digitaria eriantha*, were listed by Malan *et al.* (1994) in one species group, namely *Eragrostis curvula*, *E. lehmanniana*, *E. superba*, *E. obtusa*, *Aristida diffusa* and *Heteropogon contortus* and were present throughout the phytosociological table, thus not falling into specific communities. *Nidorella resedifolia*, among other species, was also found where the pasture was overgrazed.

All of the above mentioned species, except for *Aristida diffusa* and *Lactuca dregeana* DC., were encountered in the grassland of Soetdoring Nature Reserve, but sorted into different communities. A further difference from the classification of the Ae land type (Malan *et al.* 1994) is that the grassland unit of Soetdoring Nature Reserve is classified as a *Themeda triandra* - *Digitaria eriantha* major community, with a *Cymbopogon plurinodis* - *Nenax microphylla* community associated with it. It seems as though Malan *et al.* (1994) gave a general overview of all the vegetation units occurring on the Ae land type, including the rocky ridges, riparian vegetation and overgrazed grassland, rather than providing detail of each specific vegetation unit, like the grassland in particular.

8.4.2 The grassland of the northern Free State

Fuls *et al.* (1993) named the vegetation type on the plains of the northern Free State, an *Eragrostis curvula - Themeda triandra* grassland. The most dominant grasses are *Themeda triandra*, *Cymbopogon plurinodis* and *Eragrostis curvula*. Others, such as *Eragrostis plana*, *Elionurus muticus* and *Aristida junciformes* Trin. & Rupr. are occasionally dominant or co-dominant depending on specific environmental conditions. Pristine grassland vegetation in the study area, according to Fuls *et al.* (1993), is characterised by the total dominance of a few perennial grass species, with very few forbs and other species. Fuls (1992) also found the grassland to have a "patchy appearance, which is primarily ascribed to the wide range of grazing regimes, on a macro-scale, and the micro-scale patch-overgrazing within grazing units in the area".

The grasses that are dominant in the pristine grassland described by Fuls *et al.* (1993), are also present in Soetdoring Nature Reserve, but along with forbs, dwarf karroid shrubs and pioneer grasses that lend the reserve it's mosaic appearance. The grassland of Soetdoring can also be described as having a patchy appearance due to the different grazing patterns of herbivores.

8.4.3 Willem Pretorius Nature Reserve

It was decided to compare the data of Soetdoring Nature Reserve with another nature reserve in the Free State Province as well, in order to take the impact of game into account in the classification of vegetation. The grass communities proved to have a lot in common with those of Soetdoring Nature Reserve.

Müller (1986) classified the grassland vegetation of Willem Pretorius Nature Reserve, located in the northern Free State, as being a *Cymbopogon - Themeda* grassland. This grassland is further characterised by grass species that normally occur in grasslands, like *Themeda triandra*, *Cymbopogon plurinodis*, *Eragrostis chloromelas*, *Aristida congesta*, *Setaria sphacelata*, *Heteropogon contortus* and *Eragrostis curvula*. Müller (1986) divided this grassland unit into a *Felicia muricata - Themeda triandra* community with two subcommunities, namely an *Aristida bipartita - Brachiaria eruciformis* subcommunity, further divided into a climax phase and a pioneer phase, and a *Salsola glabrescens - Felicia muricata* subcommunity.

Müller (1986) indicated that the characteristic species of the *Felicia muricata - Themeda triandra* community, are *Felicia muricata* (89% presence), *Pentzia globosa* (79%), *Eragrostis* *lehmanniana* (69%), *Panicum coloratum* (69%), *Hibiscus pusillus* (51%), *Berkheya pinnatifida* (41%), *Eragrostis obtusa* (38%), *Blepharis integrifolia* (17%), and *Cynodon hirsutus* (13%).

According to Müller (1986), the characteristic species of the **climax phase**, of the *Aristida bipartita* - *Brachiaria eruciformis* subcommunity, are *Themeda triandra* (92% presence), *Cymbopogon plurinodis* (84%), *Panicum coloratum* (69%), *Eragrostis chloromelas* (69%) and *Pentzia globosa* (69%). The **pioneer phase** of the *Aristida bipartita* - *Brachiaria eruciformis* subcommunity is dominated by the following species: *Felicia muricata* (100% presence), *Aristida congesta* (100%), *Aristida bipartita* (87%), *Panicum coloratum* (87%), *Pentzia globosa* (87%), *Berkheya pinnatifida* (62%), *Brachiaria eruciformis* (62%), *Eragrostis chloromelas* (62%), *Cynodon dactylon* (62%) and *Eragrostis lehmanniana* (50%). This pioneer phase, with the dominance of pioneer species and dwarf karroid shrubs, was described as an ecotone to the *Cymbopogon* - *Themeda* veld.

All of the above mentioned species, except for *Aristida bipartita*, *Setaria sphacelata* and *Cynodon hirsutus*, occur in the grassland communities of Soetdoring Nature Reserve, with varying constancies and cover values. There are a lot of pioneer species and dwarf karroid shrubs present in Soetdoring Nature Reserve, as seems to be the case in Willem Pretorius Nature Reserve. The grassland of Soetdoring Nature Reserve can also be divided in a pioneer stage and a climax stage. The first part of Table 8.1 (communities 1 - 3) indicates the pioneer phase and the last part, especially the *Cymbopogon plurinodis* - *Nenax microphylla* community (5) and subcommunities, represents the climax phase. The same species are present in the climax phase for both the reserves. The pioneer phase of Willem Pretorius Nature Reserve thus also indicates disturbance in the grassland, caused by overgrazing.

8.5 CONCLUSIONS

- The grassland was classified, according to the two dominant species, as a *Themeda triandra* – *Digitaria eriantha* grassland incorporating a mosaic of pioneer species, dwarf karroid shrubs, forbs and bulbous plants, along with bare patches not covered by any vegetation at all (Figures VII & VIII, Appendix 1). The grassland unit in the central Free State was classified by Acocks (1988) as a Dry *Cymbopogon* - *Themeda* Veld. However, *Cymbopogon plurinodis* was found to be less dominant in the grassland of Soetdoring Nature Reserve. *Digitaria eriantha* is more dominant. This may be one of the reasons why Bredenkamp and Van Rooyen (1996) classified this grassland in the central Free State as Dry Sandy Highveld Grassland, not using the specific species names, since these can vary a lot between different areas.

- The grassland of the reserve ranges from heavily degraded grass communities, with a high concentration of annual, pioneer grasses (Table 8.1), through to grassland communities of a much better species composition consisting of perennial climax grasses. However, when moving through the veld, this pattern is not visible as a gradient. The grassland rather depicts a mosaic pattern, with patches of grass alternating with patches of dwarf karroid shrubs. The grass patches also show alternation between climax grass patches, reddish in appearance, and pioneer grass species that are usually whitish when in flower.

- The high number of pioneer grass species present seems to support the supposition of secondary succession taking place in the reserve (*vid.* **Chapter 7**). The *Aristida adscensionis* - *Eragrostis trichophora* community (3) and subcommunities may represent a kind of pioneer stage of secondary succession. The number of pioneer grasses exceeds the climax grasses in this community. However, the presence of other kinds of pioneer species in the entire grassland of Soetdoring Nature Reserve (Table 8.1), like *Tragus koelerioides*, *Eragrostis obtusa* and *Aristida congesta* (Species Group N), indicate that the grassland unit is in poor condition and seems to be undergoing retrogression rather than secondary succession. The grassland unit of Soetdoring Nature Reserve can thus be considered as a mosaic of different seral stages - from degraded to fairly good. Due to the state of degradation of the grassland and the high amount of karroid shrubs, the unit was divided into grassland communities and karroid grassland communities (**Chapter 9**).

- There are no significant habitat differences inside the nature reserve - the macro climate is constant; the grassland occurs on the same type of clay soil along the Modder River (*vid.* **Chapter 2**), covered by a red, sandy topsoil; etc. The only difference in soil composition is found where overgrazing has occurred, which resulted in erosion of the topsoil, leaving the clayey B horizon exposed. The clay soil does not sustain the same high grass cover of the sandy soil and karroid shrubs have become more prominent in these areas.

- Although various grassland communities, as discussed in this chapter, occur in the same micro habitat, the differences in species composition seem to relate to the feeding preferences and the different concentrations of game in certain areas.

- The grasslands of the **southern** and **northern Free State** are, to a large extend, similar to those of Soetdoring Nature Reserve. These grasslands all seem to have patchy appearances, or a mosaic character, in common. It proved to be difficult to make a thorough comparison between the different grasslands because of the different stages of degradation that occur.

- Soetdoring Nature Reserve and **Willem Pretorius Nature Reserve** have a lot in common. Overgrazing also seems to be a part of the grassland ecology of Willem Pretorius Nature Reserve, because of the high number of pioneer species present. The grassland of the latter has been divided into a pioneer phase, a climax phase and also into a dwarf karroid phase (*vid.* **Chapter 9**). The grassland of Soetdoring Nature Reserve can also be divided into pioneer and climax phases. These two phases have more or less similar species for both the nature reserves and concur largely.

CHAPTER 9: THE KARROID GRASSLAND OF SOETDORING NATURE RESERVE

9.1 INTRODUCTION

Soetdoring Nature Reserve falls in the Grassland Biome (Figure 2.3), as stated before, but it is also situated on the transition between the Grassland and Nama Karoo Biomes (Rutherford & Westfall 1994; Low & Rebello 1996). The specific vegetation type of the area in which the reserve falls, is the Eastern Mixed Nama Karoo (Hoffman 1996) and itself reflects an extensive ecotone between the Nama Karoo Biome in the west and the Grassland Biome to the east. This vegetation type has the highest rainfall of all the karoo vegetation types and is thus transitional to grassland (Hoffman 1996). As a result, it is relatively sensitive to grazing and, depending on stocking density and rainfall conditions, may resemble either grassland or karoo. The dominant vegetation is a grassy dwarf shrubland. Grasses tend to be more common in depressions and on sandy soils, and less abundant on clayey soils. **Veld mismanagement resulted in the relative abundance of karroid shrubs** (Hoffman 1996). Karroid shrubland is not considered to be the best grazing in most parts of the Free State (Mosterd *et al.* 1971), however, springbok (mixed feeder) are known to increasingly revert to dwarf shrubs in the dry season, while still retaining some grass in their diets.

The Eastern Mixed Nama Karoo covers about 27 194 km^2 of the Free State Province (Low & Rebelo 1996). Synonyms for the Eastern Mixed Nama Karoo are: False Upper Karoo (A36) and False Karroid Broken Veld (A37) (Hoffman 1996). It has the highest cover of herbaceous species of all the Nama Karoo types, including numerous geophytes. *Pentzia incana* is a common dwarf karroid shrub, while grasses such as *Themeda triandra*, the various *Aristida* species and *Eragrostis* species may dominate the landscape after good summer rains (Hoffman 1996).

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). *Chrysocoma ciliata* and *Felicia fillifolia*, two of the most prominent encroaching karroid species, are considered to be important elements of karoo invasion in the Grassland Biome (Tainton 1999b). Malan (1998) found the following species to be characteristic of overgrazed or selectively grazed, degraded vegetation: the karroid species *Pentzia globosa*, *Melolobium candicans*, *Selago dinteri*, and the grasses *Eragrostis lehmanniana*, *E. obtusa* and *Fingerhuthia africana*. Thus, the vegetation of an overgrazed grassland seems to correspond to the vegetation of the Eastern Mixed Nama Karoo Biome, in also being dominated by dwarf karroid shrubs.

9.2 RESULTS

Three major communities (indicated by solid lines on the table) and seven communities represent the karroid grassland of Soetdoring Nature Reserve. The hierarchical classification, as on **Table 9.1 (Appendix 2)**, is as follows:

1. *Themeda triandra – Eragrostis obtusa* major community

1.1 *Commelina africana – Themeda triandra* community
1.1.1 *Eragrostis trichophora – Lycium horridum* subcommunity
1.1.2 *Themeda triandra – Cyperus rupestris* subcommunity
1.1.3 *Panicum coloratum – Commelina africana* subcommunity
1.1.3.1 *Pentzia globosa – Themeda triandra* variant
1.1.3.2 *Tragus koelerioides – Aristida congesta* variant

1.2 *Brachiaria eruciformis – Themeda triandra* community
1.2.1 *Pentzia globosa – Chloris virgata* subcommunity
1.2.2 *Eragrostis chloromelas – Brachiaria eruciformis* subcommunity

2. *Conyza podocephala – Nidorella resedifolia* major community

2.1 *Eragrostis lehmanniana – Chloris virgata* community

2.2 *Pentzia globosa – Nidorella resedifolia* community

2.3 *Selago dinteri – Chloris virgata* community

3. *Felicia muricata – Salsola glabrescens* major community

3.1 *Felicia muricata - Cyperus rupestris* community
3.1.1 *Sporobolus ludwigii – Felicia muricata* subcommunity
3.1.1.1 *Chloris virgata – Nidorella resedifolia* variant
3.1.1.2 *Eragrostis chloromelas – Sporobolus ludwigii* variant

3.1.2 *Salsola glabrescens – Eragrostis obtusa* subcommunity

3.2 *Nidorella resedifolia - Rosenia humilis* community

Species of Minor Occurrence

9.3 DISCUSSION

The karroid grassland forms a part of the grassland unit of the reserve. The karroid grassland is incorporated in the grassland and patches of dwarf karroid shrubs alternate with patches of grass inside the larger grassland unit. The classification of the grassland unit proved to be difficult due to this mosaic character and to simplify it, the grassland unit was divided into grassland communities (as discussed in **Chapter 8**) and karroid communities.

9.3.1 The karroid grassland communities

1. *Themeda triandra – Eragrostis obtusa* **major community**

This major community is comprised of two communities with their subcommunities. It represents the 'best' examples of karroid grassland patches in the reserve, since *Themeda triandra* is present with high cover values along with the dwarf karroid shrubs. Species Groups A – D (Table 9.1) characterise the major community.

1.1 *Commelina africana – Themeda triandra* community

The community is characterised by Species Group B. All the species groups are represented in the community, except for Species Group F (*Sporobolus ludwigii*). *Themeda triandra* (Species Group C) dominates the community. The species of Species Group B, the small forbs *Commelina africana*, *Hibiscus pusillus* and the dwarf karroid shrub *Chrysocoma ciliata*, have low cover values of less than 5%. This community differs from the *Brachiaria eruciformis – Themeda triandra* community (1.2) by the presence of Species Groups A and B and the low presence of species from Species Group H. The *Commelina africana – Themeda triandra* community has the following three subcommunities associated with it.

1.1.1 *Eragrostis trichophora – Lycium horridum* subcommunity

The diagnostic species of the subcommunity are listed in Species Groups A and I. Only Species Groups E and F are completely absent. *Eragrostis trichophora* (Species Group A) is dominant and has up to 100% cover per sample plot. It is also restricted to this subcommunity, except for one other relevé. *Themeda triandra* (Species Group C) was only found in one relevé. It is notable that *Themeda triandra* is absent where *Eragrostis trichophora* has high cover abundance values (Figure IX, Appendix 1) and conversely the low cover abundance values of *Eragrostis trichophora* where *Themeda triandra* is present. This pattern is also evident in the grassland communities (**Table 8.1**, Species Groups C and M).

Felicia muricata (Species Group G) has one cover abundance value of 3 (25% - 50% cover) in the subcommunity. Species with cover values of 5% - 25%, are: the forb *Cyperus rupestris* (Species Group G), the karroid shrub *Salsola glabrescens* and the pioneer grass *Eragrostis obtusa* (Species Group J). All other species present have cover values of less than 5%, namely the forbs *Commelina africana* (Species Group B), *Monsonia angustifolia* (Species Group D), *Nidorella resedifolia*, *Berkheya pinnatifida*, *Ledebouria luteola* and *Pterodiscus speciosus* (Species Group J); the climax grass *Panicum coloratum* (Species Group D); the mesemb *Mestoklema arboriforme* (Species Group H) and the dwarf karroid shrubs *Lycium horridum* (Species Group I) and *Rosenia humilis* (Species Group J).

1.1.2 *Themeda triandra – Cyperus rupestris* subcommunity

This subcommunity is characterised by Species Groups B, C and G. *Themeda triandra* (Species Group C) is present with a high constancy and cover abundance values of 4 and 5 (50% - 100% cover). *Cyperus rupestris* (Species Group G) has a high constancy in this subcommunity, compared to the rest of the major community, but does not have very high cover abundance values. Other species present with low cover abundance values and a high constancy, are: *Commelina africana*, *Hibiscus pusillus* (Species Group B), *Felicia muricata* (Species Group G), *Tragus koelerioides* (Species Group I), *Nidorella resedifolia*, *Salsola glabrescens*, *Rosenia humilis*, *Berkheya pinnatifida* and *Ledebouria luteola* (Species Group J). This subcommunity differs from the *Eragrostis trichophora – Lycium horridum* subcommunity (1.1.1) by the absence of Species Group A and the higher constancy of the species in Species Group G.

1.1.3 *Panicum coloratum – Commelina africana* subcommunity

Species Groups B - D characterise this subcommunity. All the other species groups are represented, except for Species Groups A and F that are absent. The biggest difference between this subcommunity and the previous two subcommunities (1.1.1 & 1.1.2), is the stronger presence of species from Species Groups D and I.

The *Panicum coloratum – Commelina africana* subcommunity has the following two variants.

1.1.3.1 *Pentzia globosa – Themeda triandra* variant

This variant consists in particular of Species Groups B, C, D and J. In almost all of the relevés comprising this variant, *Themeda triandra* (Species Group C) has a cover abundance value of 5 (75% - 100% cover), being the highest cover for this species in the karroid grassland communities. The dwarf karroid shrub, *Pentzia globosa* (Species Group D), has a high constancy, but only reaches a maximum of 5% cover in a plot. None of the species present exceed a cover of 12%, probably due to the very high presence of *Themeda triandra*. The only other grasses present, but with low cover abundance values, are: the climax grass, *Panicum coloratum* (Species Group D) and the pioneer grasses *Chloris virgata* (Species Group I) and *Eragrostis obtusa* (Species Group J). The dwarf karroid shrubs present, are *Chrysocoma ciliata* (Species Group B), *Asparagus glaucus* (Species Group D), *Felicia muricata* (Species Group G), *Lycium horridum* (Species Group I), *Salsola glabrescens* and *Rosenia humilis* (Species Group J). The variant differs from the *Tragus koelerioides – Aristida congesta* variant (1.1.3.2) by having more species of Species Group D present, the presence of *Nidorella resedifolia* (Species Group J) and the absence of *Eragrostis lehmanniana* (Species Group D) and Species Group I, except for one relevé.

This variant represents patches of the grassland that has not been overgrazed so extensively, as to result in the dwarf karroid shrubs gaining dominance over the grass. However, the relevés were far apart and found in larger patches, scattered through the reserve, and not as a continuous unit.

1.1.3.2 *Tragus koelerioides – Aristida congesta* variant

All the Species Groups, except A, E and F, contain species present in this variant, but Species Groups G and I are characteristic. The dwarf karroid shrub, *Felicia muricata* (Species Group G), is the dominant species, present with cover abundance values of a 2a or a 2b (5% - 25% cover). *Aristida congesta* (Species Group I) is more dominant than *Tragus koelerioides* (Species Group I), but both species have low cover values of mostly below 5%. In general, all the species present in this variant have low cover values of less than 12%.

This variant differs from the *Themeda triandra – Pentzia globosa* variant (1.1.3.1) by the absence of *Pentzia globosa* (Species Group D) and *Nidorella resedifolia* (Species Group J) and by the presence of *Eragrostis lehmanniana* (Species Group D) and Species Group I. *Felicia muricata* (Species Group G) is also present with a higher cover (5%- 25%) in this variant than the previous one (1% - 5% cover).

The variant may be an overgrazed version of the *Pentzia globosa – Themeda triandra* variant (1.1.3.1). There are more pioneer grasses (Species Group I) present in this variant than in the previous one and *Themeda triandra* has lower cover values.

1.2 *Brachiaria eruciformis – Themeda triandra* community

The community is characterised by Species Group H, with the diagnostic species *Eragrostis chloromelas* and *Brachiaria eruciformis*. It differs from the *Commelina africana – Themeda triandra* community (1.1) by the absence of Species Group A, the low presence of Species Group B and the presence of Species Group F. Also, *Themeda triandra* does not have high cover abundance values throughout the community. The pioneer grass, *Brachiaria eruciformis* (Species Group H), can be found in this community (while being absent from the previous community, 1.1) with a 1% – 12% cover. *Brachiaria eruciformis* is usually found in disturbed, trampled places, mostly in clay soil (Van Oudtshoorn 1999).

The following two subcommunities are associated with the *Brachiaria eruciformis – Themeda triandra* community.

1.2.1 *Pentzia globosa – Chloris virgata* subcommunity

The prominent species of this subcommunity can be found in Species Groups C, D, H, I and J. *Themeda triandra* remains the dominant species. This subcommunity differs from the *Tragus koelerioides – Aristida congesta* variant (1.1.3.2) by the species of Species Group I being less concentrated and having a lower constancy and the presence of *Brachiaria eruciformis* (Species

Group H). Furthermore, Species Group B is absent from this subcommunity. It differs from the *Eragrostis chloromelas – Brachiaria eruciformis* subcommunity (1.2.2) by the higher constancy and cover abundance values of the species in Species Group I and the absence of *Sporobolus ludwigii* (Species Group F) and *Eragrostis chloromelas* (Species Group H).

1.2.2 *Eragrostis chloromelas – Brachiaria eruciformis* subcommunity

Species Groups C, D, F, H, I and J contain the prominent species of this subcommunity. The subclimax grass, *Eragrostis chloromelas* (Species Group H), is diagnostic and dominant with the highest cover abundance values (12% - 75% cover) and constancy in this subcommunity, than in the rest of the table. This subcommunity differs from the *Pentzia globosa – Chloris virgata* subcommunity (1.2.1) by the presence of *Eragrostis chloromelas* (Species Group H) and *Sporobolus ludwigii* (Species Group F), as well as by the lower cover abundance values of *Themeda triandra* (Species Group C).

2. *Conyza podocephala – Nidorella resedifolia* **major community**

The major community is characterised by the higher constancy of *Conyza podocephala* (Species Group E). *Themeda triandra* (Species Group C) is completely absent, along with Species Groups A, B and F. *Nidorella resedifolia* (Species Group J) is the dominant species of the major community. The grasses *Eragrostis lehmanniana* (Species Group D), *Chloris virgata* and *Aristida adscensionis* (Species Group I) are also present with high cover abundance values. *Panicum coloratum* (Species Group D) is the only climax grass present, along with many forbs, dwarf karroid shrubs and pioneer grasses. This major community seems to be the transition zone between the *Themeda triandra – Eragrostis obtusa* major community (1) and the *Felicia muricata – Salsola glabrescens* major community (3). The first major community (1) represents the best karroid grassland that the reserve has to offer, including climax grasses with high cover values, while the last major community (3) contains the most degraded karroid grassland with the highest amount of dwarf karroid shrubs and very few climax grasses. The *Conyza podocephala – Nidorella resedifolia* major community is comprised of the following three communities.

2.1 *Eragrostis lehmanniana – Chloris virgata* community

The species that comprise the community are included in Species Groups D, E, G, I and J. The dominant species of the community is *Eragrostis lehmanniana* (Species Group D), having high cover abundance values. *Eragrostis lehmanniana* usually grows in places that have been subjected to overgrazing in the past (Van Oudtshoorn 1999). *Chloris virgata* (Species Group I) is also present with up to 25% cover per plot. A few diagnostic species, that are absent from the *Pentzia globosa – Nidorella resedifolia* community (2.2), are *Eragrostis lehmanniana* (Species Group D), *Felicia muricata* (Species Group G), *Chloris virgata* and *Aristida adscensionis* (Species Group I). It further differs from the next community (2.2) by the absence of Species Group H and the lower constancy of the species in Species Group J.

2.2 *Pentzia globosa – Nidorella resedifolia* community

Species Group H is characteristic of the community. *Nidorella resedifolia* (Species Group J) is dominant and has high cover values of 12% - 75%. *Eragrostis chloromelas* and *Brachiaria eruciformis* (Species Group H) also have high cover abundance values in one relevé each, of 5 (75% - 100%) and 4 (50% - 75%) respectively. *Panicum coloratum* (Species Group D) has a higher constancy, but only 1% - 5% cover, in this community if compared to the previous community (2.1). Other characteristics of this community, distinguishing it from the other two (2.1 & 2.3), are the presence of Species Group H and *Cyperus rupestris* (Species Group G), the near absence of *Chloris virgata* and *Aristida adscensionis* (Species Group I), and also the higher constancy of the species in Species Group J.

2.3 *Selago dinteri – Chloris virgata* community

The community is characterised by Species Groups D, E, I and J. *Chloris virgata* (Species Group I) is dominant, but *Aristida adscensionis* (Species Group I) and *Nidorella resedifolia* (Species Group J) are also present with high constancy and cover abundance values. Species Group J is rather sparsely represented if compared to the *Pentzia globosa – Nidorella resedifolia* community (2.2). It differs from the previous community (2.2) by Species Groups G and H being absent and by the presence of *Chloris virgata* and *Aristida adscensionis* (Species Group I).

3. *Felicia muricata – Salsola glabrescens* **major community**

All the species groups (A – J) are represented in this major community, but Species Groups F, G and H are characteristic. *Sporobolus ludwigii* (Species Group F) has a strong presence in the major community, but is about absent from the other major communities (1 & 2). The dwarf karroid shrub, *Felicia muricata* (Species Group G), has a high constancy and high canopy cover.

Species Group D is present, but the species have low constancies and are sparsely distributed through this major community, compared to the other two major communities (1 & 2). *Eragrostis trichophora* (Species Group A) is only present in one relevé with a 1% - 5% cover, otherwise it is also absent from the major community. This last major community represents the most degraded karroid shrubland in the reserve, because of the presence of a high amount of dwarf karroid shrubs and pioneer grasses and the low presence of climax grasses (Figure XII, Appendix 1). The major community is comprised of two communities with their subcommunities.

3.1 *Felicia muricata – Cyperus rupestris* community

Species Group G is characteristic of the community, but all the species groups are represented. *Felicia muricata* (Species Group G) is dominant, along with *Salsola glabrescens* (Species Group J). *Nidorella resedifolia*, *Rosenia humilis* and *Eragrostis obtusa* (Species Group J) have high constancies, while Species Group I is well represented in the community. This community differs from the *Nidorella resedifolia – Rosenia humilis* community (3.2) by the stronger presence of species from Species Groups F, G and I. The following subcommunity, with it's two variants, is associated with this *Felicia muricata – Cyperus rupestris* community.

3.1.1 *Sporobolus ludwigii – Felicia muricata* subcommunity

The subcommunity is characterised by the pioneer grass, *Sporobolus ludwigii* (Species Group F), but the dwarf karroid shrub, *Felicia muricata* (Species Group G), is dominant. *Nidorella resedifolia*, *Salsola glabrescens*, *Rosenia humilis* and *Eragrostis obtusa* (Species Group J) have a high constancy in the subcommunity. The *Sporobolus ludwigii – Felicia muricata* subcommunity differs from the *Salsola glabrescens – Eragrostis obtusa* subcommunity (3.1.2) by the presence of *Sporobolus ludwigii* (Species Group F) and by more species of Species Group D being present.

The *Sporobolus ludwigii – Felicia muricata* subcommunity has the following two variants.

3.1.1.1 *Chloris virgata – Nidorella resedifolia* variant

The prominent species of this variant can be found in Species Groups F, G, I and J, with one or two species in Species Groups A, B, D and H as well. The dominant species is *Felicia muricata* (Species Group G). It differs from the *Eragrostis chloromelas – Sporobolus ludwigii* variant

(3.1.1.2) by the lower presence of Species Groups D and H, the presence of *Chloris virgata* (Species Group I), as well as Species Group A and the absence of Species Groups C and E.

3.1.1.2 *Eragrostis chloromelas – Sporobolus ludwigii* variant

All the species groups are represented in this variant, except for Species Groups A and B. *Felicia muricata* (Species Group G) remains the dominant species. The climax grasses *Themeda triandra* (Species Group C), *Panicum coloratum* (Species Group D) and the subclimax grass *Eragrostis lehmanniana* (Species Group D) are present with low cover values (less than 12% cover), while *Eragrostis chloromelas* (Species Group H) has higher cover values. The following pioneer grasses are present in this variant: *Sporobolus ludwigii* (Species Group F), *Brachiaria eruciformis* (Species Group H), *Aristida adscensionis*, *Tragus koelerioides*, *Aristida congesta* (Species Group I) and *Eragrostis obtusa* (Species Group J). However, the dwarf karroid shrubs *Pentzia globosa*, *Asparagus glauca* (Species Group D), *Felicia muricata* (Species Group G), *Salsola glabrescens* and *Rosenia humilis* (Species Group J), dominate the subcommunity by having higher cover values and constancies. It differs from the *Chloris virgata – Nidorella resedifolia* variant (3.1.1.1) by the high presence of the species of Species Groups D and H, the absence of *Chloris virgata* (Species Group I), as well as Species Groups A and B and the presence of the species of Species Groups C and E with low cover abundance values.

3.1.2 *Salsola glabrescens – Eragrostis obtusa* subcommunity

All the species groups, except A and C, are represented in the subcommunity. *Felicia muricata* (Species Group G) is dominant, because of it's high cover abundance values. *Nidorella resedifolia* (Species Group J) has lower cover abundance values and a low constancy compared to its values in the *Sporobolus ludwigii – Felicia murricata* subcommunity (3.1.1). The dwarf karroid shrubs *Salsola glabrescens*, *Rosenia humilis* and the pioneer grass *Eragrostis obtusa* (Species Group J) also have high constancies, like in the previous subcommunity (3.1.1). It differs from the *Sporobolus ludwigii – Felicia muricata* subcommunity (3.1.1) by the absence of *Eragrostis trichophora* (Species Group A), *Themeda triandra* (Species Group C) and *Sporobolus ludwigii* (Species Group F).

3.2 *Nidorella resedifolia – Rosenia humilis* community

The community is characterised by Species Groups D, H and J. *Nidorella resedifolia* and *Rosenia humilis* (Species Group J) are both dominant. This subcommunity does not have a lot of species, only the climax grass *Panicum coloratum* (Species Group D) and the subclimax grass *Eragrostis chloromelas* (Species Group H), the pioneers *Brachiaria eruciformis* (Species Group H), *Chloris virgata* (Species Group I) and *Eragrostis obtusa* (Species Group J), the dwarf karroid shrubs *Felicia muricata* (Species Group G), *Salsola glabrescens* and *Rosenia humilis* (Species Group J) and a few forbs. The subcommunity represents disturbed veld, with bare patches and very few grass species. It differs from the previous community (3.1) by the absence of Species group I, except for one occurrence of *Chloris virgata*, and the low presence of species in Species Groups F and G.

Species of Minor Occurrence

The following species are considered to be too scarce in the karroid grassland, less or equal to 4 occurrences in the 97 relevés of Table 9.1, to significantly contribute to the major communities, communities or subcommunities and have subsequently been omitted. They are, in alphabetical order (indicating the relevé number and the Braun-Blanquet cover abundance value of the species in that relevé): *Agrostis lachnantha* (169: 1), *Amaranthus* species (204: 2b), *Aptosimum indivisum* (107: +, 176: +, 68: +, 240: +), *Aristida bipartita* (80: 1), *Atriplex semibaccata* (185: +, 199: 1), *Bidens pilosa* (40: +), *Bulbine narcissifolia* (174: +), *Chamaesyce inaequilatera* (34: r), *Chenopodium album* (107: 1, 180: 4, 6: 1), *Chortolirion angolense* (7: r), *Commicarpus pentandrus* (138: 1, 80: 1), *Digitaria argyrograpta* (11: 1, 59: +, 106: 1), *Dipcadi ciliare* (78: r, 72: r), *Enneapogon scoparius* (215: 2b), *Eragrostis biflora* (103: r, 164: 2a), *Eragrostis curvula* (68: 3), *Eragrostis superba* (107: 1), *Eriospermum cooperi* (171: +, 170: +), *Felicia filifolia* (238: 2a, 98: 2b), *Geigeria filifolia* (47: r , 91: r, 80: 1), *Haemanthus montanus* (10: 1, 46: 1), *Helichrysum zeyheri* (80: 1), *Hermannia coccocarpa* (80: r), *Hermannia comosa* (173: r), *Hertia pallens* (181: 1), *Hibiscus trionum* (47: +, 87: r, 83: r), *Hypertelis salsoloides* (74: +, 75: r), *Indigofera alternans* (215: +), *Ipomoea oenotheroides* (10: +), *Koeleria capensis* (178: 1, 185: 1, 179: 1), *Lactuca inermis* (80: r), *Limeum aethiopicum* (136: 1, 235: 1), *Lycium pilifolium* (136: 1), *Nenax microphylla* (138: 2a), *Oxalis depressa* (171: +), *Phyllanthus parvulus* (103: +), *Portulaca oleracea* (125: +), *Pseudognaphalium oligandrum* (62: 1), *Ruschia spinosa* (136: 1, 125: 1), *Salsola kali* (36: r), *Setaria nigrirostris* (29: 3), *Sporobolus fimbriatus* (106: +, 176: 1, 115: 1), *Talinum caffrum* (85: r), *Thesium hystrix* (173: 1, 91: +, 80: 1, 179: 1), *Trachyandra saltii* (99: r), *Tribulus terrestris* (59: r, 85: r, 36: 1), *Trichodiadema barbatum* (9: 1, 180: 1, 126: 1, 161: 2a) and *Urochloa panicoides* (143: 1, 83: 1).

9.4 COMPARISON BETWEEN THE KARROID GRASSLAND OF SOETDORING NATURE RESERVE AND OTHER AREAS IN THE FREE STATE

9.4.1 The southern Free State

On the **Ae land type** in the southern Free State, Malan *et al.* (1994) found the following species to be present in disturbed, overgrazed grassland: *Asclepias fruticosa* L., *Aristida congesta*, *Berkheya pinnatifida*, *Chrysocoma ciliata*, *Digitaria eriantha*, *Eragrostis curvula*, *E. lehmanniana*, *E. obtusa*, *E. superba*, *Felicia filifolia*, *F. muricata*, *Helichrysum pentzioides* Less., *Hertia pallens*, *Melolobium candicans*, *Nenax microphylla*, *Nidorella resedifolia*, *Pentzia incana*, *Pseudognaphalium undulatum* (L.) Hilliard & Burtt, *Rumex lanceolatus* Thunb., *Salsola kali*, *Solanum incanum* L., *Tagetes minuta* L., *Themeda triandra*, *Tribulus terrestris* and *Selago dinteri*. Malan *et al.* (1994) classified all of the above mentioned species into one major community, namely the *Themeda triandra* - *Lactuca dregeana* major community (**Chapter 8**). However, the vegetation of wet areas and hills were also included in the classification of this major community and have been excluded in the comparison. Only the karroid communities that were found on the lowlands will be compared to the karroid grassland of Soetdoring Nature Reserve, including the Species of Minor Occurrence.

Of these above mentioned species, the following were found to have a high constancy on the karroid table (Table 9.1) of Soetdoring Nature Reserve: *Aristida congesta* (Species Group I), *Berkheya pinnatifida* (Species Group J), *Eragrostis lehmanniana* (Species Group D), *E. obtusa* (Species Group J), *Felicia muricata* (Species Group G), *Nidorella resedifolia* (Species Group J) and *Themeda triandra* (Species Group C), while the Species of Minor Occurrence were: *Eragrostis curvula*, *E. superba*, *Felicia filifolia*, *Hertia pallens*, *Nenax microphylla*, *Salsola kali* and *Tribulus terrestris*. *Chrysocoma ciliata* (Species Group B) and *Selago dinteri* (Species Group D) have a low constancy on the karroid table, while the other species listed above were absent from the karroid communities.

Malan *et al.* (1994) listed the following grassland species to have high constancies in the community: *Eragrostis curvula*, *E. lehmanniana*, *Eragrostis superba*, *Chrysocoma ciliata*, *Eragrostis obtusa*, *Aristida diffusa* Trin. and *Themeda triandra*. The species with high constancies in one of the two subcommunities, are *Nidorella resedifolia*, *Digitaria eriantha*, *Helichrysum pentzioides*, *Salsola kali*, *Felicia muricata*, *Cynodon dactylon*, *Nenax microphylla*, *Berkheya pinnatifida* and *Hertia pallens*.

The vegetation of the Ae land type in the southern Free State made a good comparison to that of Soetdoring Nature Reserve. There are also a lot of dwarf karroid shrubs present, along with pioneer grasses and some climax grasses which were all grouped into one major community. However, Soetdoring Nature Reserve's karroid grassland was separated into three major communities, where the first represents the best karroid grassland in the reserve, the last major community represents the most degraded grassland in the reserve and the second major community represents a transition zone between the other two.

9.4.2 The northern Free State

Fuls *et al.* (1993) classified the grassland of a part of the northern Free State as an *Eragrostis curvula - Themeda triandra* grassland including the following species, ranked according to overall abundance: *Themeda triandra*, *Cymbopogon plurinodis*, *Eragrostis curvula*, *Elionurus muticus*, *Heteropogon contortus*, *Setaria sphacelata*, *Aristida junciformes*, *Tristachya leucothrix* Nees, *Brachiaria serrata* (Thunb.) Stapf and *Setaria nigrirostris*. *Aristida congesta* and *Felicia muricata* were also listed on the table, but in another community that is present mostly on hills and ridges.

All of the above mentioned species, except *Aristida junciformes*, *Tristachya leucothrix* and *Brachiaria serrata*, also occur in the grassland of Soetdoring Nature Reserve. However, since the grassland unit was divided into grassland and karroid communities and this chapter specifically deals with the karroid grassland, there are certain species that were not found to occur in the karroid communities but rather in the grassland communities, like *Cymbopogon plurinodis*, *Elionorus muticus*, *Heteropogon contortus* and *Setaria sphacelata* (**Chapter 8**). *Aristida congesta* and *Felicia muricata*, that Fuls *et al.* (1993) mostly found on hills and ridges, occur in Soetdoring Nature Reserve also in the karroid grassland. Some of the other species listed by Fuls *et al*. (1993) to occur in the grassland were found in Soetdoring Nature Reserve to occur mostly on the hills and foothills next to the grassland, like *Elionurus muticus* and *Heteropogon contortus* for example. These species may then probably represent an ecotone between the vegetation of grassland and hills.

Fuls *et al.* (1992) also list the following species on the synoptic table to occur in another part of the grassland of the northern Free State: *Panicum coloratum*, *Eragrostis obtusa*, *Crabbea acaulis*, *Felicia muricata*, *Pentzia globosa*, *Hibiscus trionum*, *Chamaesyce inaquilatera*, *Blepharis integrifolia*, *Aristida bipartita*, *Salvia runcinata* L.f., *Hibiscus pusillus*, *Cyperus rupestris*, *Selago densiflora* Rolfe, *Eragrostis curvula*, *Themeda triandra*, *Cymbopogon plurinodis*, *Setaria sphacelata*, *Eragrostis plana*, *Cynodon dactylon* and *Digitaria eriantha*.

This area contains more dwarf karroid shrubs than the previously discussed area of the northern Free State. The above mentioned species (including the Species of Minor Occurrence) that were absent from the karroid grassland of Soetdoring Nature Reserve, are *Crabbea acaulis*, *Salvia runcinata*, *Selago densiflora*, *Cymbopogon plurinodis*, *Setaria sphacelata*, *Eragrostis plana*, *Cynodon dactylon* and *Digitaria eriantha*.

According to Fuls *et al.* (1993), whenever the vegetation was visibly overutilized, increases in the number and abundance of both forb and grass species were noted. This is ascribed to a greater variation of ecological niches created as the vegetation is 'opened' by overutilization (Fuls 1992). The grassland of the northern Free State has a patchy appearance, which is primarily ascribed to the wide range of grazing regimes, according to Fuls (1992). The grassland unit of Soetdoring Nature Reserve also has a patchy appearance, where grass alternate with dwarf karroid shrubs to create a mosaic pattern. This can also be ascribed to the wide range of grazing regimes of the animals in the reserve.

9.4.3 Willem Pretorius Nature Reserve in the northern Free State

Müller (1986) classified the disturbed grassland of Willem Pretorius Nature Reserve as a *Felicia muricata* - *Themeda triandra* community. The species characterising the community, were, in order of dominance: *Felicia muricata*, *Pentzia globosa*, *Eragrostis lehmanniana*, *Panicum coloratum*, *Berkheya pinnatifida*, *Hibiscus pusillus*, *Eragrostis obtusa*, *Blepharis integrifolia* and *Cynodon hirsutus*. This community was divided into two subcommunities, namely an *Aristida bipartita* - *Brachiaria eruciformis* subcommunity and a *Salsola glabrescens* - *Felicia muricata* subcommunity.

The *Aristida bipartita* - *Brachiaria eruciformis* subcommunity was divided into one variant containing mostly climax grasses and a second variant containing mostly pioneer grasses. The species present in this subcommunity and it's variants, were *Aristida bipartita*, *Brachiaria eruciformis*, *Elionurus muticus*, *Themeda triandra*, *Cymbopogon plurinodis*, *Eragrostis chloromelas*, *Pentzia globosa*, *Panicum coloratum*, *Felicia muricata*, *Aristida congesta*, *Eragrostis lehmanniana* and *Berkheya pinnatifida*. The *Salsola glabrescens - Felicia muricata* subcommunity contained the following species: *Salsola glabrescens*, *Lycium horridum*, *Chloris virgata*, *Felicia muricata*, *Pentzia globosa*, *Eragrostis lehmanniana* and *Aristida congesta*.

All of the species in Müller's (1986) disturbed grassland community were also found in the karroid grassland of Soetdoring Nature Reserve, except for *Cynodon hirsutus*, *Elionurus muticus* and *Cymbopogon plurinodis*. However, the species of Soetdoring Nature Reserve were classified into a **major community** (No 1 on Table 9.1) with two distinct communities (1.1 & 1.2).

Müller (1986) divided the grassland of Willem Pretorius Nature Reserve, excluding the wet areas, into three categories (or communities), namely 1) grassland of the hills, 2) pristine grassland and 3) disturbed grassland, compared to Soetdoring Nature Reserve where the grassland was divided into grassland and karroid communities. The karroid grassland of Soetdoring Nature Reserve shows many similarities to the disturbed grassland of Willem Pretorius Nature Reserve.

9.5 CONCLUSIONS

- The grassland unit of Soetdoring Nature Reserve proved to be disturbed, having a high number of dwarf karroid shrubs present (as is evident in Table 9.1). This disturbance resulted in a mosaic character of the reserve's grassland, where patches of grass alternate with patches of dwarf karroid shrubs. The karroid grassland is not homogeneous, but comprises patches of dwarf karroid shrubs within the larger grassland unit. Consequently grassland communities (*vid*. **Chapter 8**) and karroid communities were recognised.

- According to Le Roux *et al.* (1994): *Atriplex semibaccata*, *Hertia pallens* and *Selago dinteri* are indicative of veld disturbance, while the presence of *Chrysocoma ciliata*, *Felicia filifolia* and *Pentzia globosa* indicate karoo invasion of the grassland. Shearing (1994) also listed *Gnidia polycephala*, *Melolobium candicans* and *Salsola kali* to normally occur in disturbed veld.

- According to Van Oudtshoorn (1999) the following grass species of the reserve's grassland unit are mostly associated with disturbed areas: *Aristida adscencionis*, *A. bipartita*, *A. congesta*, *Brachiaria eruciformis*, *Chloris virgata*, *Cynodon dactylon*, *Eragrostis biflora*, *E. curvula*, *E. gummiflua*, *E. lehmanniana*, *E. obtusa*, *E. plana*, *E. superba*, *E. trichophora*, *Pogonarthria squarrosa* and *Urochloa panicoides*. Malan (1998) also listed the following species to be characteristic of overgrazed or selectively grazed, degraded vegetation: the karroid species *Pentzia globosa*, *Melolobium candicans*, as well as the grasses *Eragrostis lehmanniana*, *E. obtusa* and *Fingerhuthia africana*.

- When an area is disturbed, it is usually colonised by annual pioneer species in order to restore the area back towards climax grassland by means of secondary succession (Van Oudtshoorn 1999). In case of continuous grazing, climax grasses may be replaced by unpalatable grasses, woody plants, herbs, etc. (Grainger 1992). The high concentration of karroid shrubs in the areas where the climax grasses have a low concentration, or where the grasses are completely absent, underlines this statement.

- In this regard it was found that *Themeda triandra* (climax grass) was mostly absent in relevés where *Eragrostis trichophora* (normally growing in disturbed areas) has high cover values, and *vice versa*. This is most evident in the *Eragrostis trichophora - Lycium horridum* subcommunity (1.1.1 on Table 9.1), but was also found in the grassland communities (**Table 8.1**).

- It proved difficult to classify the vegetation of the karroid grassland into communities, due to the high constancy of most of the species (Table 9.1). Three major communities, incorporating seven communities, are ranging from the best karroid grassland in the reserve with the highest concentration of climax grasses, to the most degraded veld with the least number of climax grasses and a very high concentration of dwarf karroid shrubs and grasses normally associated with disturbed areas.

- The grassland of the Ae land type of the **southern Free State** compared well to that of Soetdoring Nature Reserve, which for a large part falls on the Ae land type. Soetdoring Nature Reserve and the southern Free State also have a lot of species in common. All these concurrent species were classified into one major community for the southern Free State and was also noted to occur in disturbed, overgrazed grassland.

- A large number of species were found to be common for the **northern Free State** and Soetdoring Nature Reserve. However, some of these species were rather associated with the grassland communities of the reserve, than with the karroid communities. Some species recorded to occur more on hills and foothills for the northern Free State were also found in the karroid grassland of the reserve. These species could possibly be part of a transition zone between lowland grassland and grassland found on hills. Furthermore, the northern Free State's grassland also seems to have a patchy appearance, similar to the reserve's mosaic grassland pattern.

- The **Willem Pretorius Nature Reserve** in the northern Free State compared the best with Soetdoring Nature Reserve. It was also divided into a pristine grassland community and a disturbed grassland community, where most of the species were found to also occur in the karroid grassland of Soetdoring Nature Reserve. The disturbed grassland of Willem Pretorius Nature Reserve was subdivided into a pioneer phase and a climax phase. This disturbance of the grassland was mostly attributed to the grazing patterns of the game, which is also the case in Soetdoring Nature Reserve.

- The results indicate the grassland of Soetdoring Nature Reserve to be either overgrazed, or it may be that the Eastern Mixed Nama Karoo has invaded the Dry Sandy Highveld Grassland in this area, since this vegetation type is also characterised by many dwarf karroid shrubs, grasses and herb species. However, there seems to be more evidence to support the first hypothesis of the reserve being overgrazed. Many of the species in the reserve indicate disturbance, like overgrazing, which concurs with other areas that have also been subjected to overgrazing. The mosaic pattern, or patchy appearance, seems to be characteristic of overgrazed grassland.

CHAPTER 10: A GENERAL DISCUSSION ON THE VEGETATION OF THE PANS, GRASSLAND AND KARROID GRASSLAND

10.1 INTRODUCTION

The grassland biome of South Africa is (or was in many places) a place of korhaans and bustards, of drab-coloured birds and colourful widow and bishop finches. It was a place into which surged, each summer, a massive contingent of migrants, like kestrels, storks and Cattle Egrets, all coming to the seasonal harvest of grassland insects (Tarboton 1997a). It was also once a place populated by unimaginably large numbers of black wildebeest, blesbok and other antelope. What has happened to South African grasslands is the story of grasslands across the world: they have been so extensively transformed by the hand of man that one is hard put to find any landscapes in them that match the original (Tarboton 1997a).

Vegetation and general ecological surveys of conservation areas are considered to have high priority (Nakor 1979), as a sound knowledge of the ecology of these areas is an essential prerequisite for the establishment of sound wildlife management programmes (Bredenkamp & Theron 1990, 1991) which could aid in protecting the grasslands. Different ecosystems will not react similarly to certain management practices, for example grazing or burning, and therefore a management programme should be based on the recognition of the various ecosystems as meaningful ecological entities within the area (Bredenkamp & Theron 1976). Every plant community is a result of a unique combination of certain environmental conditions and therefore represents a certain ecosystem (Bredenkamp & Theron 1976).

As the Grassland Biome is currently being threatened, mostly by man's activities, it becomes necessary to understand and study the vegetation ecology thereof as well as the plant communities that comprise the grassland. This chapter **aims** to present a general view of the vegetation, as represented by different plant communities of the wet (excluding the riparian areas) and dry grassland (excluding the hills) present in Soetdoring Nature Reserve. A synoptic table and DECORANA ordination (Hill 1979b) were used to indicate the differences and similarities between the pan and grassland vegetation, be it only moderately overgrazed or completely disturbed grassland.

LEGEND OF FIGURE 10.1

Group A = **Disturbed, overgrazed grassland**

Group B = **Transitional zone between the more pristine grassland and the disturbed, overgrazed grassland.**

Group C = **Moderately overgrazed grassland that is in a more pristine condition.**

Group D = **Brackish pan (Open *Diplachne* Pan) on the southern side of the Modder River.**

Group E = **Permanently wet areas inside the brackish pan that are exposed to saltwater. It includes the earth dams, the hot spring, the drainage canal and the disturbed area in the pan where a stormwater drainage pipe was inserted.**

Group F = **Freshwater pan (Grass Pan) on the northern side of the Modder River.**

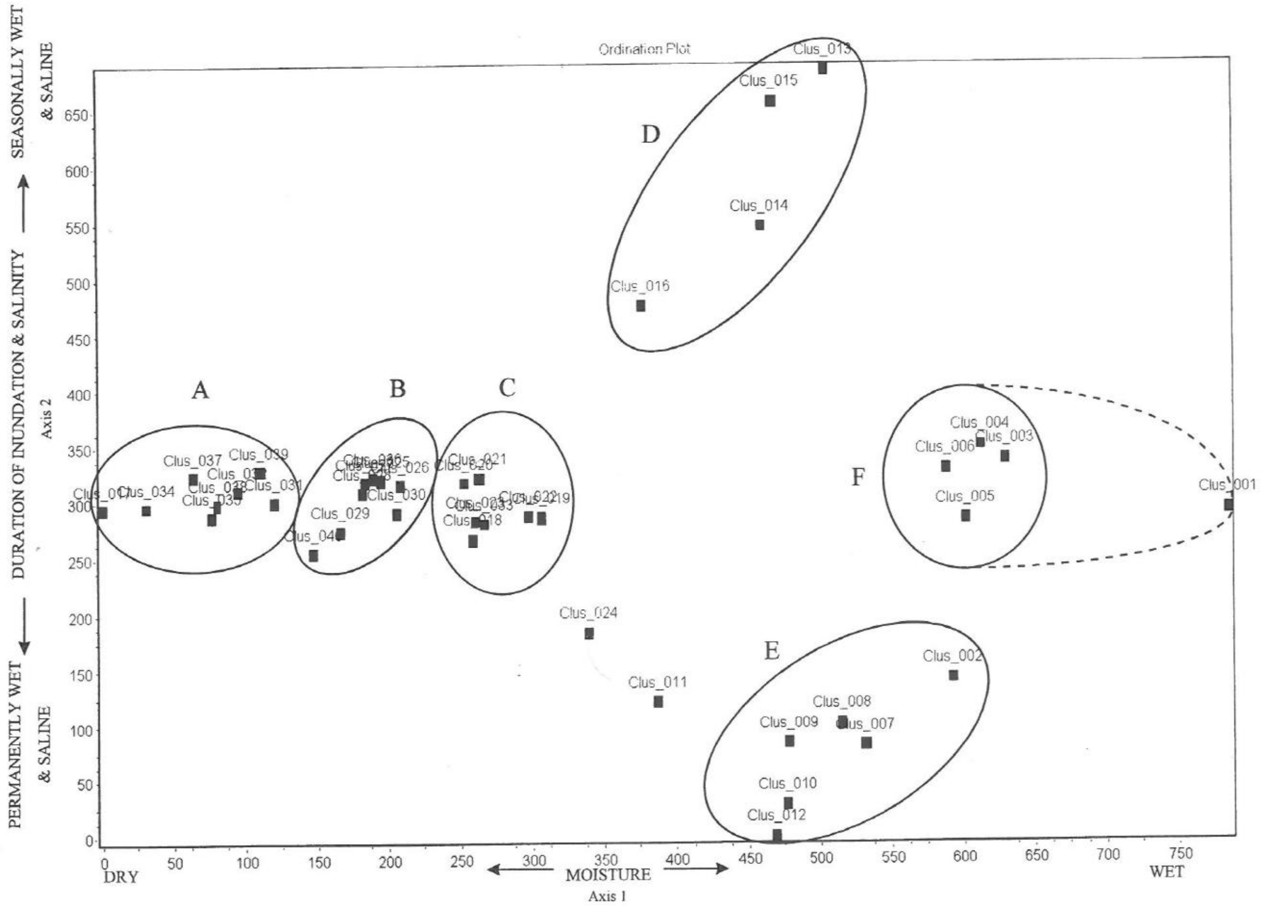


Figure 10.1: A DECORANA ordination of the pans, grassland and karroid grassland of Soetdoring Nature Reserve.

10.2 RESULTS

The following classification was made from the synoptic table (**Table 10.1 – Appendix 2**):

A. *Cynodon dactylon – Polygonum aviculare* pan vegetation

A.1 *Cynodon transvaalensis* freshwater unit

A.1.1 *Eleusine coracana* earth dam unit

A.2 *Juncus rigidus* saltwater unit

A.3 *Diplachne fusca* brackish pan unit

B. *Eragrostis obtusa – Eragrostis lehmanniana* grassland vegetation

B.1 *Themeda triandra – Digitaria eriantha* grassland unit

B.T. *Themeda triandra – Salsola glabrescens* transitional zone

B.2 *Salsola glabrescens – Chloris virgata* disturbed grassland unit

Figure 10.1: DECORANA ordination analysis

10.3 DISCUSSION

Soetdoring Nature Reserve falls in the Grassland Biome and, according to Rutherford and Westfall (1994), the vegetation of the biome is physiognomically monolitic and characterised by the strong dominance of hemicryptophytes of the Poaceae. Acocks (1988) broadly classified the grassland vegetation of the Free State as Dry *Cymbopogon – Themeda* veld, while Du Preez and Bredenkamp (1991) specifically classified the dry grasslands of the western plains, where the reserve is situated, as *Eragrostis obtusa – Eragrostis lehmanniana* grassland, incorporating three *Cymbopogon – Themeda* veld types (A48, A49 & A50).

The dominance of graminoids is consistent throughout the grassland of Soetdoring Nature Reserve (**Chapter 11**), as could be expected for the Grassland Biome, except for severely overgrazed or disturbed patches where karroid shrubs and forbs are dominant; rocky outcrops that are mostly dominated by woody species; and riparian areas that are mostly dominated by sedges, woody species and reeds. Prominent grass species encountered throughout this grassland (Table 10.1) include: *Themeda triandra*, *Digitaria eriantha* (Species Group AC), *Panicum coloratum*, *Eragrostis obtusa*, *Aristida congesta* (Species Group AJ) and *Eragrostis lehmanniana* (Species Group AK). However, these species are mostly absent from the pan vegetation. Prominent grass species in the seasonally moist areas (Table 10.1), include: *Cynodon transvaalensis* (Species Group G), *Cynodon dactylon* and *Eragrostis bicolor* (Species Group P).

The vegetation of the pans is represented on Table 10.1 by Species Groups A - P, and by the first 16 vegetation units (columns). The vegetation of the freshwater pan can be found in Species Groups A - G and P, while that of the more brackish pan, including the hot spring, is present in Species Groups H - P.

The dry grassland, including both moderately grazed and disturbed areas, is represented by Vegetation Units 17 - 40 and Species Groups Q - AK (Table 10.1). The biggest difference between moderately grazed and disturbed grassland can be seen when comparing Species Groups AC and AI, with a transitional zone present at Vegetation Units 25 - 29.

Forty synrelevés were used in an ordination algorythm, namely Detrended Correspondence Analysis (DECORANA) (Hill 1979b) in order to determine possible vegetation and associated environmental gradients, as well as floristic relationships between the communities (Malan 1998). The ordination results concur to a large extend with those of the synoptic table. DECORANA divided the data into a moisture gradient (Axis 1 on Figure 10.1) and a gradient indicating the duration of inundation and salinity (Axis 2).

10.3.1 The synoptic table and ordination results

A. *Cynodon dactylon – Polygonum aviculare* pan vegetation.

This major vegetation group, represented by Species Group P, incorporates the vegetation of both the freshwater pan (north of the Modder River) and brackish pan (south of the river). These pans are only seasonally inundated and when the water dries up, a thin layer of salt precipitates here and there in the brackish pan. The following species (Species Group P) were found to be present in both the freshwater and brackish pans of the reserve: *Cynodon dactylon*, *Polygonum aviculare*, *Eragrostis bicolor* and *Frankenia pulverulenta*. However, the difference between the vegetation of these two pans is evident in the absence of species more associated with the freshwater pan (Species Groups A – F) from vegetation units 7 – 16, where the species of the more brackish pan (halophytes) are present, and *vice versa*.

A.1 *Cynodon transvaalensis* freshwater pan unit

Cynodon transvaalensis and *Phyla nodiflora* (Species Group G) are dominant and both are known to occur in wet, damp areas. This vegetation group (Species Groups A - F) is completely absent from the brackish pan (Vegetation Units 7 – 16), except for the species of Species Groups G and P, that were found in both the freshwater and brackish pans. All of the species present in this vegetation group were also absent from the drier grassland (Vegetation Units 17 - 40), except for *Agrostis lachnantha* (Species Group D), *Portulaca oleracea* (Species Group E) and *Cynodon transvaalensis* (Species Group G) which were found in depressions in the grassland that collects rainwater, or in trenches that run through the grassland in connecting vleis.

Cynodon transvaalensis (Species Group G) covers the entire basin of the pan, along with *Panicum schinzii* and *Echinochloa holubii* (Species Group C). The presence of a thick carpet of these grasses was the main reason for this pan being classified as a Mixed Grass Pan (**Chapter 5**). However, the pan vegetation occurs in concentric zones, from the outside, to the core area of the pan. Wetter areas on the outside of the pans are adjacent to the drainage canal that connects the pan to the river and acts, along with rainwater, as a source of water to the pan in the wet season. The vegetation in the last bend of the s-shaped drainage canal differs completely from that of the adjacent pan vegetation (Vegetation Unit 1), since this area is permanently exposed to water. The diagnostic species of this **permanently wet area** are the hydrophyte *Hemarthria altissima*, as well as the hygrophytes *Xanthium strumarium* (Species Group A) and *Cyperus denudatus* (Species Group D). Although other species also occur in this area, these are mostly present in a transitional area between the ephemeral pan and this water saturated area, which was difficult to evade since the zones are too narrow.

The concentric zones of the pan vegetation start next to the permanently wet area. The first zone is characterised by moist soil that gradually dries up as the water retreats back to the river in the dry season. On the slightly higher areas surrounding the pan and also the drainage canal, that dries out faster, a greyish zone is visible. This first zone (Vegetation Unit 1) is characterised by the grey herb *Gnaphalium declinatum* (Species Group G).

The second pan zone is mostly characterised by pioneers that give it a greenish colour. This zone is present on the moist soil where the drainage canal ends in the pan, thus, right next to the water. It was only found next to the drainage canal and nowhere else in the pan. The diagnostic species of the second zone (Vegetation Unit 4) are: *Portulaca oleracea*, *Chenopodium murale*, *Cotula* *microglossa*, *Limosella longiflora* (Species Group E), *Alternanthera sessilis* (Species Group F) *Cynodon transvaalensis* and *Gnaphalium declinatum* (Species Group G).

The last zone of the freshwater pan, inside the smaller outside zone(s), makes up the actual vegetation normally associated with a Mixed Grass Pan. The vegetation is dominated by grasses that form a thick carpet covering the whole basin of the pan. The characteristic species (Vegetation Unit 3) are: *Cynodon transvaalensis* (Species Group G), *Alternanthera sessilis* (Species Group F), *Panicum schinzii*, *Echinochloa holubii* (Species Group C), *Verbena brasiliensis* (Species Group G) and *Chascanum pinatifidum* (Species Group C).

The DECORANA ordination (Figure 10.1) also grouped these synrelevés (vegetation units) of the **freshwater pan** together in Group F. The **permanently wet area** next to the drainage canal was, however, separated from the freshwater pan communities (Cluster 001) and occupies the wettest position on the moisture gradient of the ordination. On the duration of inundation gradient, Group F should, however, also be classified as seasonally wet. The reason for the centre position on this gradient is possibly that the pan remains inundated for quite a long time (Figure I, Appendix 1). The **brackish pan group** (Group D) are present in the centre (from left to right) of the moisture gradient. The concentration of salt during the long dry phase may possibly render the pan drier than the freshwater pan, and hence the distance between Groups D and F.

A.1.1 *Eleusine coracana* earth dam unit

The vegetation represented by Vegetation Unit 2, is associated with the banks of the manmade earth dam that occurs inside the brackish pan. However, this earth dam's water does not contain very high concentrations of salt. This vegetation unit is classified with the permanently water saturated area of the drainage canal (Vegetation Unit 1), next to the freshwater pan. The characteristic species of the earth dam are: *Eleusine coracana*, *Bulbostylis burchellii* (Species Group B), *Agrostis lachnantha* (Species Group D), *Althernanthera sessilis* (Species Group F), *Gnaphalium declinatum* and *Phyla nodiflora* (Species Group G).

This community can be found in Group E of the DECORANA ordination (Figure 10.1), along with the *Juncus rigidus* saltwater communities. It does occur inside the brackish pan and its habitat possibly contains some salts, but in relatively low concentrations. The position of Cluster 002 away from the rest of the group, and closest to the freshwater pan group (Group F), indicates the lower salt content.

A.2 *Juncus rigidus* saltwater unit

Inside the brackish pan, a hot spring and two manmade earth dams (a more freshwater dam and a saltwater dam) are present. These earth dams are permanent water bodies. The vegetation of these areas that are permanently exposed to saltwater differs completely from the rest of the pan vegetation. The species of the salt rich earth dam (Vegetation Unit 8) are: *Cynodon transvaalensis*, *Phyla nodiflora*, (Species Group G), *Juncus rigidus*, (Species Group J), *Polygonum aviculare* and *Cynodon dactylon* (Species Group P).

There is also a disturbed area inside the brackish pan, next to the dirt road, where a stormwater pipe diverts water away from the road. This depression collects rainwater and remains damp for a longer period than the rest of the pan. The vegetation associated with it can be found in Vegetation Unit 9, and are characterised by *Helictotrichon turgidulum* (Species Group I), *Phyla nodiflora*, *Verbena brasiliensis* (Species Group G), *Eragrostis biflora* (Species Group H), *Eragrostis plana* (Species Group I), *Sporobolus ioclados* (Species Group M) and *Cynodon dactylon* (Species Group P).

The vegetation of the hot spring is represented by Vegetation Units 10 – 12. A dense stand of *Phragmites australis* (Species Group K) covers the area. This area is surrounded by a dense stand of *Juncus rigidus* (Species Group J), along with *Polygonum aviculare*, *Frankenia pulverulenta* (Species Group P), *Eragrostis trichophora* (Species Group AB), *Atriplex semibaccata* and *Dipcadi viride* (Species Group J) that occur on the outside of the *Juncus* stand. On the outskirts of the reedbed, *Cirsium vulgare*, *Setaria verticillata* (Species Group K), *Oxalis depressa* (Species Group Z) and *Eragrostis trichophora* (Species Group AB) are to be found along with *Phragmites australis*. In the zone between the two dense *Phragmites* and *Juncus* stands, on a slightly elevated level, a high concentration of *Digitaria eriantha* (Species Group AC), *Chrysocoma ciliata* and *Selago dinteri* (Species Group AK) occur, along with lower concentrations of *Cynodon dactylon* (Species Group P) and *Eragrostis lehmanniana* (Species Group AK). This seems to correspond with the vegetation of the grassland, except for the absence of *Themeda triandra* (Species Group AC). A white salt layer of about 1 – 2 cm thick is visible in the *Juncus* zone.

These saltwater communities were also grouped together in Group E of the DECORANA analysis (Figure 10.1). These communities are positioned at the bottom of the ordination gradient of seasonally wet to permanently wet areas. Since the species of these communities are all permanently exposed to saltwater, as opposed to the dry pan communities, and all occur inside the brackish pan, the ordination results are easily explained.

A.3 *Diplachne fusca* brackish pan unit

The vegetation inside the pan basin itself is sparse, leaving the soil bare in most places. *Diplachne fusca* (Species Group O) dominates the pan basin, although *Sporobolus virginicus* (Species Group L) becomes dominant in the patch between the hot spring and the lunette dune surrounding the pan. The dominance of *Diplachne fusca* along with the presence of salt resulted in the pan being classified as a *Diplachne* Pan (*vid.* **Chapter 5**). Other species that were also found in the pan basin (Vegetation Units 13 - 15), in order of dominance, are: *Eragrostis bicolor*, *Polygonum aviculare* (Species Group P), *Sporobolus ioclados* (Species Group M), *Lycium horridum* (Species Group AJ), *Cynodon dactylon* (Species Group P), *Phyla nodiflora* (Species group G), *Sporobolus fimbriatus* (Species Group AK) and *Hibiscus trionum* (Species Group W).

On the lunette dune (*vid.* **Chapters 4 & 5**) that surrounds the pan, the vegetation forms an ecotone between the pan and the grassland. Species of both the pan and grassland are found on this dune (Vegetation Unit 16). The pan species are: *Diplachne fusca* (Species Group O), *Sporobolus ioclados* (Species Group M), *Eragrostis bicolor* and *Cynodon dactylon* (Species Group P). The grassland species are: *Salsola glabrescens* (Species Group AI), *Tragus koelerioides* (Species Group AJ) and *Chrysocoma ciliata* (Species Group AK) in high concentrations, as well as *Cynodon dactylon* (Species Group P), *Pogonarthria squarrosa* (Species Group AC), *Gnidia polycephala* (Species Group Z), *Eragrostis trichophora* (Species Group AB), *Themeda triandra*, *Commelina africana*, *Digitaria eriantha* (Species Group AC), *Chloris virgata*, *Aristida adscensionis*, *Mestoklema arboriforme* (Species Group AI), *Rosenia humilis*, *Lycium horridum*, *Thesium hystrix* (Species Group AJ), *Selago dinteri* and *Eragrostis lehmanniana* (Species Group AK). Interesting to note is the presence of the fern, *Ophioglossum polyphyllum* (Species Group N) that was only found on the lunette dune after the pan was flooded by the first heavy rains. The lunette dune of the freshwater pan looks very much the same, except for the absence of the brackish pan vegetation.

DECORANA grouped the vegetation of the brackish pan together in Group D (Figure 10.1). These communities are on the opposite side of the duration of inundation gradient, than the permanent saltwater group (Group E), because of the ephemeral nature of the pan where the water dries up in the dry season. The salt in the pan is present in a powder or a crust form and this exposes the pan vegetation to a physiological drought. Cluster 16 represents the vegetation of the lunette dune and is thus positioned almost in the middle between the grassland communities (Group C) and the pan communities.

B. *Eragrostis obtusa – Eragrostis lehmanniana* grassland unit

This major vegetation group (Vegetation Units 17 – 40) incorporates the complete grassland of the area, including the moderately grazed and the disturbed areas. Most of the species of Species Groups AJ and AK have high constancies in or around the pans, as well as in the grassland, and are present in both the grassland and the karroid grassland. The prominent species of this major grassland group are *Nidorella resedifolia*, *Panicum coloratum*, *Eragrostis obtusa*, *Ledebouria luteola*, *Berkheya pinnatifida*, *Tragus koelerioides*, *Rosenia humilis*, *Pentzia globosa*, *Aristida congesta* (Species Group AJ), *Chrysocoma ciliata*, *Selago dinteri*, *Eragrostis lehmanniana*, *Sporobolus fimbriatus* and *Pentzia incana* (Species Group AK).

DECORANA classified the grassland unit into Groups A, B and C (Figure 10.1) at the driest part of the moisture gradient, away from the permanently wet areas in the pans and also away from the ephemerally inundated pan vegetation itself. This indicates the difference between the dry grassland and the ephemerally inundated pan vegetation, although both are mostly dominated by grasses.

B.1 *Themeda triandra – Digitaria eriantha* grassland

Vegetation Units 17 – 24 represent the moderately overgrazed grassland areas inside the larger grassland unit. Grasses dominate these areas, with herbs and some dwarf karroid shrubs also present (*vid.* **Chapter 8**). Species Group AC, along with AJ and AK, contain the species associated with this more pristine grassland, of which *Themeda triandra* and *Digitaria eriantha* (Species Group AC) are the dominant species.

Variations on this vegetation unit occur in Species Groups W and Z, where species associated with *Cymbopogon plurinodis* and *Nenax microphylla* intermingle in patches within the *Themeda* - *Digitaria* grassland. Species Groups Q – V, X and Y contain species that were scarcer in the grassland, but also made certain small associations inside the large unit. The most prominent smaller associations are dominated by *Aristida canescens* (Species Group Q) and *Melolobium candicans* (Species Group R), respectively. Both of these smaller associations are also strongly associated with *Cymbopogon plurinodis* (Species Group W) and *Themeda triandra* (Species Group AC).

DECORANA also made a distinction between the moderately overgrazed grassland and the disturbed grassland areas. These moderately overgrazed grassland areas are present in Group C (Figure 10.1) and are grouped closely together indicating the similarity of the relevés.

BT. *Themeda triandra* - *Salsola glabrescens* transitional zone

A transitional zone (Vegetation Units 25 – 29) is present between the moderately overgrazed grassland areas (B1) and the disturbed grassland areas (B2), where grasses as well as dwarf karroid shrubs are dominant. Although dwarf karroid shrubs are considered to be a normal component of grasslands in this area, it is not supposed to dominate the vegetation of the Grassland Biome. The ordination by DECORANA clustered the transitional synrelevés together in Group B (Figure 10.1).

B.2 *Salsola glabrescens – Chloris virgata* disturbed grassland

Vegetation Units 30 – 40 indicate the disturbance of the grassland, which most probably occurred through overgrazing. Most of the palatable grasses are removed and the dwarf karroid shrubs, herbs, unpalatable grasses and pioneer grasses dominate the area (*vid.* **Chapter 9**). These overgrazed areas occur inside the grassland unit and alternates with the patches of grass to create a type of mosaic pattern in the grassland. The dominant species are: *Salsola glabrescens*, *Felicia muricata*, *Chloris virgata*, *Aristida adscensionis*, *Mestoklema arboriforme* (Species Group AI), *Nidorella resedifolia*, *Panicum coloratum* and *Eragrostis obtusa* (Species Group AJ).

A variation on this pattern is evident in Species Group AB (Vegetation Units 30 – 33), where *Eragrostis trichophora* dominates the vegetation, along with *Salsola glabrescens* and *Chloris virgata* (Species Group AI). Other species that are also more prominent in this variation than elsewhere, are, *Hypertelis salsoloides*, *Trichodiadema barbatum*, *Chortolirion angolense* and *Salsola kali* (Species Group AB). Other smaller associations that occur occasionally in the disturbed grassland are evident in Species Groups AA and AD - AH.

DECORANA clearly reflects the different areas inside the grassland unit and groups the disturbed grassland areas into Group A (Figure 10.1), the more pristine grassland areas into Group C and even indicates the transitional zone between these two areas in Group B. DECORANA did, however, place Cluster 17 in the same group as the disturbed grassland vegetation. This differs from the synoptic table, where the species of Cluster 17 were grouped into the pristine communities, because of the high presence of *Themeda triandra*. This community should, however, rather be associated with the rocky hills of the reserve. It is interesting to note that the disturbed grassland group (Group A) is positioned on the absolute driest position on the moisture gradient, while the pristine areas are positioned closer to the wet areas. This could prove that areas covered by grasses maintain moisture in the soil and that when the grass cover is removed, the soil dries out and this leads to the erosion of the topsoil.

10.4 COMPARISON WITH THE VEGETATION CLASSES OF THE FREE STATE

Du Preez and Bredenkamp (1991) made a reclassification of the vegetation of the southern and eastern Free State and the highlands of Lesotho. Several vegetation classes were identified. The vegetation class applicable to Soetdoring Nature Reserve is the *Eragrostis obtusa – Eragrostis lehmanniana* vegetation class for the dry grasslands of the western plains. This vegetation class is characterised by *Aristida congesta*, *Eragrostis lehmanniana*, *E. obtusa*, *Panicum coloratum* and *Pentzia globosa*. The most prominent grass species include *Aristida diffusa* Trin., *A. junciformis* Trin. & Rupr., *Eragrostis plana*, *Trichoneura grandiglumis* (Nees) Ekman, *Cynodon dactylon*, *Eragrostis curvula*, *E. chloromelas*, *E. racemosa* (Thunb.) Steud., *Heteropogon contortus*, *Cymbopogon excavatus* (Hochst.) Stapf ex Burtt, *Digitaria eriantha*, *Tragus koelerioides*, *Eragrostis gummiflua*, *Setaria sphacelata*, *Cymbopogon plurinodis*, *Elionurus muticus* and *Themeda triandra*. Associated forbs are *Anthospermum rigidum* Eckl. & Zeyh., *Selago densiflora* Rolfe, *S. dinteri*, *Felicia muricata*, *Helichrysum dregeanum*, *Berkheya pinnatifida* and *Gazania krebsiana* (Du Preez & Bredenkamp 1991).

Of these twenty nine species mentioned above, only eight are not present on the synoptic table of Soetdoring Nature Reserve, namely *Aristida diffusa*, *A. junciformis*, *Trichoneura grandiglumis*, *Eragrostis racemosa*, *Cymbopogon excavatus*, *Anthospermum pumilum*, *Selago densiflora* and *Gazania krebsiana*. However, it is known that some of these species do occur in the reserve, even though not included in the table, like *Aristida diffusa*, *Trichoneura grandiglumis* and *Gazania krebsiana*. This broad comparison of the vegetation of Soetdoring Nature Reserve shows a clear correlation to the *Eragrostis obtusa – Eragrostis lehmanniana* vegetation class of Du Preez and Bredenkamp (1991).

10.5 THE NEGATIVE IMPACT OF ANIMALS IN SOETDORING NATURE RESERVE

The short grass grazers, particularly black wildebeest, blesbok, springbok, etc., are mostly seen as the culprits in bringing about most of the above mentioned degradation and disturbance in the grassland. These animals maintain territories in the grassland and only graze in these territories (Figure XI, Appendix 1). The signs of overgrazing are most prominently seen in Soetdoring Nature Reserve inside the territories, where most of the palatable grasses have been replaced by unpalatable annuals, dwarf karroid shrubs and herbs; the topsoil has been eroded away, probably through splash, wind and plate erosion; the exposed soil has been compacted and trampled, and the territories are characterised by large bare areas. From a vegetation point of view the areas seem to be overgrazed beyond recovery. Animal trails also contribute to the fragmentation of the vegetation in the reserve (**Chapter 7**).

The rest of the reserve is not really better off (*vid.* **Chapter 9**). The grassland is fragmented, resembling a mosaic pattern with alternating patches of climax grasses, pioneer grasses and dwarf karroid shrubs, which seem to be the result of overgrazing. A large area of the reserve was previously used as farmland before it was converted into a nature reserve. This could have contributed to the overgrazed character of the veld.

Eighteen of the thirty five grass species (51.4%) in Soetdoring Nature Reserve' grassland are usually associated with disturbed areas, old farm-lands, bare areas or trampled areas (**Chapters 8** & **9**). The Karoo encroacher species *Chrysocoma ciliata*, *Felicia filifolia* and *Pentzia globosa* indicate karoo invasion in the grassland of Soetdoring Nature Reserve (Le Roux *et al.* 1994). In general, the vegetation of overgrazed areas in the southern Free State can be considered as a *Chrysocoma ciliata* - *Pentzia globosa*, short, closed shrubland (Edwards 1983).

10.6 POSITIVE EFFECTS OF ANIMALS IN SOETDORING NATURE RESERVE

The impact of animals on grasslands, especially that of the short grass grazers, is mostly seen in a negative light. However, the animals also have some positive effects on these grazing areas. The patch selecting of short grass grazers can be seen in a positive light, in the creation of different communities, such as tall and short grass areas, as discussed in **Chapter 7**. This is important as the height distribution of the sward is evidently one of the main factors determining niche separation among African grazers (Owen-Smith 1985). The specific animals of Soetdoring Nature Reserve influence each other in the following way, as described by Grossman *et al.* (1999)

where grazing animals were divided into different groups or species types. Type I animals (zebra, white rhino, etc.), being the long to medium grass feeders, influence the sensitive Type II animals (eland, gemsbok, springbok, waterbuck, etc.) by changing the habitat (**Chapter 7**) they require - open woodland/mesic grassland mosaic. Type III animals (black wildebeest, red hartebeest, impala, etc.) are mostly the short grass grazers, impala being a mixed feeder, which benefit by exploiting the new vegetation state created by the impacts of Type I species. Type IV animals (kudu, etc.) are influenced by, and may thus increase due to the changes brought about by Types I and III species but have little further impact on the vegetation.

Black wildebeest, blesbok, springbok and red hartebeest are associated with each other, and when driving through the reserve you will mostly find them together in the same area, while zebra will also be found in the same vicinity. The reserves two white rhino's also frequent the short grass wildebeest territories. White rhino's are adapted through lip-feeding to cropping short grass (Owen-Smith 1999). All these animals are thus sort of dependent upon each other for the creating and maintaining of their preferred food and habitat needs and also influence the vegetation character in this way.

The territorial animals open up the veld, creating different plant communities in the process which provide variation in the reserve between tall and short grass, and allow the game viewer to see some of the reserve's animals. The large herds of territorial animals may also have a positive effect in planting and distributing seeds and in fertilising the area with their excretions (**Chapter 7**). The animals of Soetdoring Nature Reserve are further seen in a positive light in the sense of hunting, game viewing, attracting overseas tourists, the preserving and conservation of animal species, etc.

CHAPTER 11: FLORISTIC ANALYSIS OF THE PLANT SPECIES PRESENT IN THE PANS, GRASSLAND AND KARROID GRASSLAND

Soetdoring Nature Reserve is part of the Grassland Biome, the third largest biome in southern Africa (Rutherford & Westfall 1994). Floristically, the Grassland Biome is distinct and comprises a centre of diversity for many large genera (Gibbs Russel 1987). The vegetation of the Grassland Biome is physiognomically monolithic and is characterised by a strong dominance of hemicryptophytes of the Poaceae, according to Rutherford and Westfall (1994).

The vegetation of Soetdoring Nature Reserve discussed here, occurs mostly in wet or dry grassland (excluding the riparian areas and the rocky outcrops) where karroid shrubs have invaded the grassland unit. The plant species incorporated in List 11.1, include all the Pteridophyta and Angiospermae collected in the pans, grassland and karroid grassland of the reserve at the time of study. Some of the species do not occur on the phytosociological tables, because the relevés proved to be in ecotonal areas and were consequently deleted (*vid.* Disadvantages of the Braun-Blanquet method, **Chapter 3**).

A total of 171 species, representing 120 genera and 42 families, were collected in the studied units of the reserve. The relationship between the species, genera and families of the Pteridophyta, Monocotyledonae and Dicotyledonae are indicated in Table 11.1. Floristically, the Dicotyledonae are clearly dominant in the reserve, even though the grasses sort under the Monocotyledonae, and the reserve falls in the Grassland Biome. However, when comparing the most prominent families of the reserve (Table 11.2), it becomes evident that the grasses (Poaceae) are the most species rich taxon and that it is mostly the Asteraceae that are responsible for the high proportion of the Dicotyledonae in the reserve (Table 11.1 & List 11.1). The members of the Pteridophyta are rather unimportant in the reserve, with only one species present (List 11.1), namely *Ophioglossum polyphyllum*, that was found on the edge of the pan after high rainfall.

The most species rich genera in the reserve (Table 11.3) are *Eragrostis*, *Cyperus*, *Setaria* and *Sporobolus*, of which only *Cyperus* (Cyperaceae) is not part of the Poaceae. Overall, seven of the 26 prominent genera are part of the Poaceae and only four are part of the Asteraceae.

Table 11.1: Relationship between the number of families, genera and species of the Pteridophyta, Monocotyledonae and Dicotyledonae of Soetdoring Nature Reserve.

	FAMILIES		**GENERA**		**SPECIES**	
	No.	**%**	**No.**	**%**	**No.**	**%**
Pteridophyta	1	2.4	1	0.8	1	0.6
Monocotyledonae	10	23.8	43	35.8	75	43.9
Dicotyledonae	31	73.8	76	63.3	95	55.5
TOTAL	**42**		**120**		**171**	

Table 11.2: Most prominent families (families represented by more than 3 species) in Soetdoring Nature Reserve and the number of species they represent.

Poaceae	51	Mesembryantemaceae	6
Asteraceae	30	Hyacinthaceae	5
Cyperaceae	7	Asphodelaceae	4
Fabaceae	7	Solanaceae	4
Chenopodiaceae	6	Verbenaceae	4

Table 11.3: Genera represented by 2 or more species in Soetdoring Nature Reserve and the number of species they represent.

Eragrostis	10	*Asparagus*	2
Cyperus	4	*Bulbine*	2
Aristida	4	*Scirpoides*	2
Setaria	4	*Juncus*	2
Sporobolus	4	*Digitaria*	2
Dipcadi	3	*Berkheya*	2
Panicum	3	*Pentzia*	2
Felicia	3	*Chenopodium*	2
Helichrysum	3	*Crassula*	2
Cynodon	3	*Hibiscus*	2
Salsola	3	*Hermannia*	2
Indigofera	3	*Verbena*	2
Ruschia	3		
Lycium	3		

Table 11.4: Naturalised exotic species in Soetdoring Nature Reserve, following Bromilow (2001) and Arnold and De Wet (1993). Species marked with a □ are not listed by Bromilow and those marked with a □ are not listed by Arnold and De Wet as exotics.

Althernanthera sessilis □
Atriplex semibaccata □
Bidens pilosa
Chenopodium album
Chenopodium murale
Cirsium vulgare
Persecaria lapathifolia □
Polygonum aviculare
Portulaca oleracea
Salsola kali □
Schkuhria pinnata
Sphaeralcea bonariensis
Taraxacum officinale
Verbena bonariensis
Verbena brasiliensis □
Xanthium strumarium

Sixteen of the 171 species present in the vegetation units studied in the reserve are listed as naturalised exotic species (Table 11.4). These species have all been introduced from other parts of the world. Most of the species do not seem to pose a big threat to the indigenous plants. The exotic species are all marked with an asterisk (*) in Species List 11.1.

The Conservation of Agricultural Resources Act, 1983 (Act 43 of 1983) is administered by the National Department of Agriculture, Directorate Agricultural Land and Resource Management. In Regulations 15 & 16 of this act, the alien plants have been divided into three categories and it is stipulated how the plants in each category should be dealt with (Bromilow 2001). Those alien plants that occur in the pans, grassland and karroid grassland of the reserve, are classified accordingly. No plants that occur in the communities studied fall into Category 2 (declared invader plants with a value) or Category 3 (mostly ornamental plants). Only Category 1 plants are present.

Category 1 plants: Declared weeds
Cirsium vulgare
Xanthium strumarium
These are prohibited plants, which must be controlled or eradicated. These plants serve no economical purpose and possess characteristics that are harmful to humans, animals or the environment (Bromilow 2001).

A list of all the species collected and recorded in the grasslands and pans of Soetdoring Nature Reserve is presented (List 11.1). The families and species are arranged alphabetically (Pteridophyta, Monocotyledonae and Dicotyledonae, separately), making the location of species easier. In the list, taxon names are followed by author names and conform to those of Arnold and De Wet (1993) and / or the PRECIS Species List of the NBI (August 2001), as incorporated in the TURBOVEG database of southern African flora (Hennekens 1996a). Where the names have been changed rather recently, the old name is indicated in square brackets [ ] to aid in the comparison with older data. The present collector's number (s) for each species is also indicated in round brackets ( ) at the end. Some of these species from Soetdoring Nature Reserve will be taken up in the Geo Potts Herbarium (BLFU), Department of Plant Sciences, University of the Free State.

<u>List 11.1: Species collected in the pans, grassland and karroid grassland of Soetdoring Nature Reserve.</u>

PTERIDOPHYTA

Ophioglossaceae

O*phioglossum polyphyllum* A.Br. in Seub. (184)

ANGIOSPERMAE

MONOCOTYLEDONAE

Amaryllidaceae

Haemanthus montanus Bak. (66)

Asparagaceae

Asparagus glaucus Kies (91)
Asparagus suaveolens Burch. (125)

Asphodelaceae

Bulbine frutescens (L.) Willd. (9)
Bulbine narcissifolia Salm-Dyck (152)
Chortholirion angolense (Bak.) Berger [*Haworthia angolensis* Bak.] (22)
Trachyandra saltii (Bak.) Oberm. (116)

Commelinaceae

Commelina africana L. (5)

Cyperaceae

Bulbostylis burchellii (Fical. & Hiern) C.B. Cl. (189)

Cyperus bellus Kunth (193)

Cyperus denudatus L.f. (187)

Cyperus difformis L. (98)

Cyperus rupestris Kunth (208)

Scirpus dioecus (Kunth) Boeck. (93)

Scirpus nodosus Rottb. (212)

Eriospermaceae

Eriospermum cooperi Bak. (133)

Hyacinthaceae

Dipcadi ciliare (Zeyh. ex Harv.) Bak. (6)

Dipcadi marlothii Engl. (87)

Dipcadi viride (L.) Moench (196)

Drimia angustifolia Bak. (28)

Ledebouria luteola Jessop (4)

Iridaceae

Moraea polystachea (Thunb.) Ker-Gawl. (181)

Juncaceae

Juncus dregeanus Kunth (140)

Juncus rigidus Desf. (195)

Poaceae

Agrostis lachnantha Nees (86, 169)

Antephora pubescens Nees (162)

Aristida adsenscionis L.   (29)

Aristida bipartita (Nees) Trin. & Rupr.   (107)

Aristida canescens Henr.   (128)

Aristida congesta Roem. & Schult.   (10)

Brachiaria eruciformis (J.E. Sm.) Griseb.   (40)

Chloris virgata Swartz   (21)

Cymbopogon plurinodis (Stapf) Stapf ex Burt Davy   (74)

Cynodon dactylon (L.) Pers.   (84, 122)

Cynodon hirsutus Stent   (58)

Cynodon transvaalensis Burt Davy   (192)

Digitaria argyrograpta (Nees) Stapf   (27, 70)

Digitaria eriantha Steud.   (82)

Diplachne fusca (L.) Beauv. ex Roem. & Schult.   (179)

Echinochloa holubii (Stapf) Stapf   (142, 172)

Elionurus muticus (Spreng.) Kunth   (161)

Eleusine coracana (L.) Gaertn.   (188)

Enneapogon scoparius Stapf   (123)

Eragrostis bicolor Nees   (185)

Eragrostis biflora Hack. ex Schinz   (41, 64)

Eragrostis chloromelas Steud   (60)

Eragrostis curvula (Schrad.) Nees   (92, 144)

Eragrostis gummiflua Nees   (148)

Eragrostis lehmanniana Nees   (75)

Eragrostis obtusa Munro ex Fical. & Hiern   (14)

Eragrostis plana Nees   (96, 166)

Eragrostis superba Peyr.   (76)

Eragrostis trichophora Coss. & Dur.   (1, 183)

Fingerhuthia africana Lehm.   (126)

Helictotrichon turgidulum (Stapf) Schweick.   (194)

Hemarthria altissima (Poir.) Stapf & C.E. Hubb.   (174)

Heteropogon contortus (L.) Roem. & Schult.   (100, 121)

Koeleria capensis (Steud.) Nees   (153)

Panicum coloratum L.   (39)

Panicum maximum Jacq.   (97)

Panicum schinzii Hack.   (173)

Phragmites australis (Cav.) Steud. (197)
Pogonarthria squarrosa (Roem. & Schult.) Pilg. (137)
Setaria nigrirostris (Nees) Dur. & Schinz (45)
Setaria pumila (Poir.)Roem & Schult. [*S. pallide-fusca* (Schumach.)Stapf & C.E. Hubb.] (145)
Setaria sphacelata (Schumach.) Moss (42)
Setaria verticillata (L.) Beauv. (198)
Sporobolus fimbriatus (Trin.) Nees (170)
Sporobolus ioclados (Trin.) Nees (182)
Sporobolus ludwigii Hochst. (34)
Sporobolus virginicus (L.) Kunth (199)
Themeda triandra Forssk. (111)
Tragus koelerioides Aschers. (207)
Triraphis andropogonoides (Steud.) Phill. (149)
Urochloa panicoides Beauv. (52)

DICOTYLEDONAE

Acanthaceae

Barleria macrostegia Nees (35)
Blepharis integrifolia (L.f.) E. Mey. (206)
Crabbea acaulis N.E. Br. (71)

Aizoaceae

Hypertelis salsoloides (Burch.) Adamson (38)
Limeum aethiopicum Burm. (32)

Amaranthaceae

Althernanthera sessilis (L.) DC. * (95, 147)

Asteraceae

Arctotis venusta T. Norl. (213)

Berkheya onopordifolia (DC.) O. Hoffm. ex Burtt Davy (119)

Berkheya pinnatifida (Thunb.) Thell. (108)

Bidens pilosa L. * (55)

Chrysocoma ciliata L. (65)

Cineraria lyratiformes Cron [*Cineraria lyrata* DC.] (12)

Cirsium vulgare (Savi) Ten. * (168)

Conyza podocephala DC. (46, 57)

Cotula microglossa (DC.) O.Hoffm. & Kuntze ex Kuntze (191)

Dicoma macrocephala DC. (160)

Felicia fascicularis DC. (205)

Felicia filifolia (Vent.) Burtt Davy (2)

Felicia muricata (Thunb.) Nees (18)

Gazania krebsiana Less. (78)

Geigeria filifolia Mattf. (67)

Gnaphalium declinatum L.f. (175)

Helichrysum dregeanum Sond. & Harv. (150)

Helichrysum herbaceum (Andr.) Sweet (155)

Helichrysum zeyheri Less. (99, 139)

Hertia pallens (DC.) Kuntze (89)

Lactuca inermis Forssk. (106)

Laggera decurrens (Vahl) Hepper & J.R.I. Wood [*Blumea gariepina* DC.] (88, 202)

Nidorella resedifolia DC. (19)

Pentzia globosa Less. (24)

Pentzia incana (Thunb.) Kuntze (11, 129)

Pseudognaphalium oligandrum (DC.) Hilliard & Burtt (117)

Rosenia humilis (Less.) Bremer (203)

Schkuhria pinnata (Lam.) Cabr. * (80, 151)

Taraxacum officinale Weber * (51)

Xanthium strumarium L. * (186)

Brassicaceae

Lepidium africanum L. (8)

Chenopodiaceae

Atriplex semibaccata R. Br.   *   (30)
Chenopodium album L.   *   (20, 56)
Chenopodium murale L.   *   (209)
Salsola calluna Fenzl ex C.H. Wr.   (16)
Salsola glabrescens Burt Davy   (7, 61)
Salsola kali L.   *   (33, 49)

Convolvulaceae

Dichondra repens J.R. & G.Frost   (146)
Ipomoea oenotheroides (L.f.) Raf. ex Hallier.f. [*Turbina oenotheroides* (L.f) A.Meeuse] (25)

Crassulaceae

Crassula nudicaulus L.   (127)
Crassula setulosa Harv.   (130)

Euphorbiaceae

Chamaesyce inaequilatera (Sond.) Sojak   (48)
Phyllanthus parvulus Sond.   (114)

Fabaceae

Indigofera alternans DC.   (120, 156)
Indigofera cryptantha Benth. ex Harv.   (115)
Indigofera rhytidocarpa Benth. ex Harv.   (138)
Lotononis laxa Eckl. & Zeyh.   (165)
Melolobium candicans (E.Mey.) Eckl. & Zeyh.   (103)
Senna italica Mill.   (158)
Tephrosia capensis (Jacq.) Pers.   (110)

Frankeniaceae

Frankenia pulverulenta L. (200)

Geraniaceae

Monsonia angustifolia E.Mey. ex A.Rich (23, 73)

Lamiaceae

Salvia verbenaca L. (101, 159)
Teucrium trifidum Retz. (118)

Malvaceae

Hibiscus pusillus Thunb. (26)
Hibiscus trionum L. (68, 176)
Sphaeralcea bonariensis (Cav.) Griseb. * (154)

Mesembryanthemaceae

Delosperma cooperi (Hook.f) L. Bol. (136)
Mestoklema arboriforme (Burch.) N.E. Br. ex Glen (204)
Ruschia hamata (L. Bol.) Schwant. (163)
Ruschia spinosa (L.) Dehn [*Eberlanzia spinosa* (L.) Schwant.] (62)
Ruschia unidens (Haw.) Schwant. (43, 109)
Trichodiadema barbatum (L.) Swant. (15)

Nyctaginaceae

Commicarpus pentandrus (Burch.) Heimerl (37, 132)

Oxalidaceae

Oxalis depressa Eckl. & Zeyh. (135)

Papaveraceae

Papaver aculeatum Thunb. (53, 83)

Pedaliaceae

Pterodiscus speciosus Hook. (17)

Polygonaceae

Persicaria lapathifolia (L.) S.F. Gray * (141)
Polygonum aviculare L. * (113, 177)

Portulacaceae

Portulaca oleracea L. * (190)
Talinum caffrum (Thunb.) Eckl. & Zeyh. (54)

Rubiaceae

Nenax microphylla (Sond.) Salter (36, 90)

Santalaceae

Thesium hystrix A.W. Hill (102, 124)

Scrophulariaceae

Aptosimum indivisum Burch. ex Benth. (77)
Limosella longiflora Kuntze (171)

Selaginaceae

Selago dinteri Rolfe [*Walafrida saxatilis* (E.Mey.) Rolfe] (79)

Solanaceae

Lycium cinereum Thunb.   (201)
Lycium horridum Thunb.   (3, 178)
Lycium pilifolium C.H. Wr.   (131)
Solanum supinum Dun.   (134)

Sterculiaceae

Hermannia coccocarpa (Eckl. & Zeyh.) Kuntze   (105)
Hermannia comosa Burch. ex DC.   (210)

Thymelaeaceae

Gnidia polycephala (C.A.Mey.) Gilg   (157)

Vahliaceae

Vahlia capensis (L.f.) Thunb.   (72)

Verbenaceae

Chascanum pinnatifidum (L.f.) E. Mey. [*Plexipus pinnatifidus* (L.f.) R. Fernandes] (211)
Phyla nodiflora (L.) Green   (69, 94)
Verbena bonariensis L.   *   (85)
Verbena brasiliensis Vell.   *   (143)

Zygophyllaceae

Tribulus terrestris L.   (50)

CHAPTER 12: CONCLUDING REMARKS

All the aims, as listed in **Chapter 1**, were successfully met in this study, namely:

- to identify, classify, describe and ecologically interpret the plant communities of the pans, the moderately grazed grassland in a good condition and the overgrazed, retrogressed grassland in Soetdoring Nature Reserve;
- to compile a phytosociological synthesis of the vegetation of these vegetation units and to compare them to other similar units where possible;
- to provide the reserve with a general view of the status of these important grazing units and
- to provide a baseline vegetation study which could serve as an ecological basis for future management, conservation and research in this area.

How these aims were met, will be discussed further in random order.

This study could eventually serve as a basis for the compilation of a management programme for Soetdoring Nature Reserve. It was found that, what was concluded for the Boskop Dam Nature Reserve, also applies to Soetdoring Nature Reserve, in that each of the plant communities described, represents a type of ecosystem with its own potential carrying capacity for game. It would be ideal if the habitat and grazing potential of each community could also be assessed (Bredenkamp *et al.* 1994) and not to only focus on a large vegetation unit, like for example the grassland unit.

The Braun-Blanquet method was successfully applied in obtaining and interpreting most of the plant communities. However, some plant communities, subcommunities and variations could only be related to subtle environmental conditions, which rendered the interpretation in terms of its ecology more difficult. The classification of each phytosociological table is supported by the synoptic table, as well as the ordination results of DECORANA (Hill 1979b).

The ordination analysis placed the data on the scattergram according to the following gradients: from a dry to a wet gradient, and further divided the wet phase into permanently wet to seasonally wet conditions. The pans and permanently waterlogged areas were placed into the wet half of the scattergram, while the grassland was placed in the dry half. The permanently waterlogged, salty areas (the two earth dams, the hot spring, etc. that occur inside the brackish pan) were all grouped together in the **permanently wet** part of the gradient. The synrelevés of the brackish pan itself were, however, all grouped together in the **seasonally wet** side, at the opposite side of the permanently wet area of this gradient. The brackish pan occupies the driest position on this permanently wet to seasonally wet gradient. The reason may probably be that the presence of salt results in the area being more dry than for instance the freshwater pan and may even account for a type of physiological drought in this area.

The vegetation of the two pans differs completely. The freshwater pan is situated north of the Modder River that runs through the reserve, and is characterised by a thick carpet of grasses, like *Cynodon transvaalensis*, *Panicum schinzii* and *Echinochloa holubii*. The high presence of grasses, as well as the absence of salt, resulted in this pan being classified as a Grass Pan or Mixed Grass Pan. Other species that can also be found inside the pan basin, are: *Verbena brasiliensis*, *Frankenia pulverulenta*, *Alternanthera sessilis*, *Phyla nodiflora* and *Polygonum aviculare*.

Conversely, the more brackish pan is situated on the southern side of the Modder River. Inside this pan two earth dams and a hot spring can be found. Salt crystallises in the form of a powder or a crust on the floor of the pan basin. Vegetation is rather sparse, leaving the soil bare in most places. *Diplachne fusca* is dominant in the pan basin and its dominance, as well as the presence of salt, resulted in this pan being classified as an Open *Diplachne* Pan. Species found frequently in the pan basin, are: *Eragrostis bicolor*, *Sporobolus ioclados*, *Salsola glabrescens*, *Lycium horridum* and *Polygonum aviculare*. *Sporobolus virginicus* was only found in the patch between the hot spring and the lunette dune that surrounds the pan, where it becomes dominant.

The vegetation of the hot spring is characterised by a dense stand of mostly *Phragmites australis* surrounded by another dense stand of mostly *Juncus rigidus*. The spring is situated at Vlakkraal 23 (a farm now incorporated in the reserve) and is one of three mineral springs within a relatively small area near the Modder River. The ground water in the area is rich in sodium chloride ($NaCl$) (Grobler & Loock 1988) and this can probably account for some of the salt that accumulates on the pan floor.

The vegetation of the two permanent earth dams inside the pan, also differs completely from that of the ephemerally inundated pan habitat. The freshwater earth dam is characterised, in order of dominance, by *Eleusine coracana*, *Cynodon dactylon*, *Phyla nodiflora*, *Gnaphalium declinatum*, *Cynodon transvaalensis*, *Agrostis lachnantha*, *Alternanthera sessilis*, *Cyperus denudatus* and *Panicum schinzii*. The more salty earth dam is characterised, in order of dominance, by *Cynodon dactylon*, *Cyperus bellus*, *Eragrostis biflora*, *Phyla nodiflora*, *Polygonum aviculare*, *Cynodon transvaalensis* and *Juncus rigidus*.

The results found in the two pans mostly concur with those found in that specific type of pan in the northern and southern Free State, as well as in the Mpumalanga and North-west Provinces (Transvaal highveld). However, the more permanent water bodies inside the pans were not a prominent part of pans from the other areas.

The pans seem to play an important role in the reserve, firstly, by acting as a reservoir for water from the overflowing river, because drainage canals end in both pans. The drainage canals themselves act as storage areas for the water from the river, but when the river is very high, the water overflows into the pans. In this way the pans act as buffers against floods. Secondly, the pans are important for the animals of the reserve in supplying water. Although the Modder River runs through the reserve and contains water most of the time, the water of the river is mostly inaccessible. The banks of the river are in places very steep and in other areas covered by dense thicket. Those animals that are adapted to this habitat, like Kudu, Waterbuck and Impala, would, however, be able to access the river. Other animal species rely heavily on the water of the drainage canals, and the pans when inundated, for their daily water intake. Thirdly, the vegetation of the pans is much sought after by grazers when the pan dries up and the vegetation is still green and fresh.

The grassland of the reserve is the most important food source for the herbivores. However, it is exactly these grazers that have caused, and still cause, the degradation of the grassland through overgrazing and trampling. The grassland is in such an overgrazed state in areas that much of it has been converted to karroid grassland. The retrogression of grassland to karroid grassland is not uniform over Soetdoring Nature Reserve, but forms a mosaic pattern of dwarf karroid shrub dominated patches alternating with grass dominated patches.

Causes for this mosaic pattern in the grassland seem to be mostly overgrazing and trampling with the consequent erosion of the topsoil, which leaves the clayey horizon exposed. The dwarf karroid shrubs seem to be the only plants that survive in this clay substrate, resembling the Karoo in this sense.

The grassland of the dry western plains of the Free State was classified by Du Preez and Bredenkamp (1991) as an *Eragrostis obtusa – Eragrostis lehmanniana* grassland, and the survey at Soetdoring Nature Reserve also confirm this classification. Acocks (1988) classified it as a *Cymbopogon - Themeda* grassland, but *Cymbopogon plurinodis* is not prominent in the grassland of Soetdoring Nature Reserve and this is probably the reason why Bredenkamp and Van Rooyen (1996) rather classified the large unit as Dry Sandy Highveld Grassland.

Although the grassland unit is classified as mentioned above, the specific type of grassland that occurs inside the reserve had to be classified as a type inside the larger unit. According to the two dominant species, the Soetdoring grassland was classified as a *Themeda triandra – Digitaria eriantha* grassland, incorporating a mosaic of pioneer grasses, dwarf karroid shrubs, forbs and bulbous plants. This high number of pioneer grasses and dwarf karroid shrubs in the grassland indicates retrogression. The presence of pioneer species may, however, also indicate the process of secondary succession taking place. Pioneers are able to inhabit the disturbed environment - thereby starting the process of rehabilitation through succession, but only if the disturbing factors are removed will succession succeed in the restoration of the area.

However, after the above normal amount of rainfall received (400.64 mm rain between October and January 2002, specifically in Soetdoring Nature Reserve) the grassland changed completely. Grasses now totally dominate the whole grassland unit of the reserve, overshadowing the dwarf karroid shrubs. The grasses grow so lush, taller than 0.7 meter, that the grazers have mostly left the grassland for the southern pan where the vegetation is less lush. According to Rutherford and Westfall (1994), canopy cover is moisture dependent and decreases with lower annual rainfall and grazing.

The vegetation of the grassland survey for the southern and northern Free State is to a large extend similar to that of Soetdoring Nature Reserve. However, it proved difficult to compare the specific detail of the grassland in the reserve with other areas, because of different stages of degradation. This resulted in different communities being recognised, and different species becoming dominant in the different grasslands. The overall view of the grasslands, however, is the same and most of the species, along with a few communities and subcommunities, concurred between the areas. All the grasslands have a patchy appearance, or mosaic character, in common.

The vegetation of Willem Pretorius Nature Reserve, in the northern Free State, concurred to a large extend to that of Soetdoring Nature Reserve. Its grassland was also classified as pristine grassland and karroid communities and the same species were mostly found. Overgrazing, thus, also seem to occur in the grassland of Willem Pretorius Nature Reserve.

There are no significant habitat differences inside Soetdoring Nature Reserve – the macro climate is constant and the grassland occurs on the same type of clay soil, covered by a sandy topsoil. The differences in species composition could then only be ascribed to the animals' feeding preferences and to the different concentrations of the game in certain areas.

The main reason for the degradation of the veld, seems to be overgrazing. The reserve is overgrazed, probably because the carrying capacity levels are exceeded to lure more visitors and game buyers, in order to generate income for financial survival. The short term benefits may seem promising, but in the long run these large numbers of animals will be detrimental to the existence of the grassland, by exerting too much grazing pressure, and thereby also to the existence of the reserve. When the grassland is disturbed on a large scale and a continual basis, it may become so degraded that it is transformed completely into karoo-like vegetation.

The fact that nearly half of the bird species listed in the Red Data Book of South Africa's Endangered Birds occur in dry or wet grasslands indicates the conservation potential of grasslands all over the country. Grasslands and wetlands are the most poorly managed and heavily transformed of the country's vegetation types and the same undoubtedly applies to Soetdoring Nature Reserve. This should inspire conservation authorities to pay particular attention to the well being of the wet and dry grasslands, as these are South Africa's singular most important asset - both naturally and economically.

The following are suggested, by the author, for the conservation of the wet and dry grasslands of Soetdoring Nature Reserve:

- The numbers of animals and their population structure should be monitored with care on a continual basis and kept on the carrying capacity levels.
- The status of the grassland in the reserve should be monitored continually. The appointment of a resident ecologist should be considered, in this regard.
- The use of fire is not normally suggested for the sweet grassland areas (**Chapter 7**), but it may be used periodically where the grassland is badly degraded, in order to remove the unwanted species. A mixture of grass seed that can be bought or even harvested on the reserve itself, can then be sown in the burnt areas to reclaim lost sweet grasses and to accelerate succession towards climax grassland.
- When an area in the grassland **starts** to show serious signs of disturbance, it should be fenced off form the rest of the grassland in order to give it a chance to rest and restore itself. A simple movable electrical fence would be the ideal solution. If finances for fencing structures are a

problem, it is suggested that the area be protected from grazers in another way. The *Acacia* trees that invade the grassland could for instance be cut down and the branches placed on smaller areas to deter grazers from the re-establishing grasses, because the veld would not be able to rehabilitate on its own.

- The most visible problem is the territoriality of the short grass grazers. The only way to improve the grassland in these areas will be to fence the animals out and this would result in other bare territorial patches. When Black Wildebeest and Blesbok are present in a reserve, bare patches are bound to be present. The only way to protect the reserve against overgrazing is to regulate the amount of short grass grazers, in order to prevent young Black Wildebeest bulls to establish too many new territories.

A final thought that may inspire the continuous conservation of nature reserves and other conservation areas, was found in an article on plant ecology in the service of man in southern Africa, by Bayer (1970):

"It seems that man has an inborn need for contact with the unspoiled natural environment. How else can we explain the craving for the peace and quiet of the country that seems to be so strongly developed in practically all men. The unity of all our people, for which we in South Africa hope so earnestly, can be developed only on an intrinsic love of our country, which depends less on the extend to which it can satisfy our material needs as on the extend on which it can satisfy our deeper spiritual hunger. A great part of our culture, our literature, art and religion developed out of the stimulus to creative thinking occurring under conditions of quiet contemplation and not in the hurly-burly of the concrete humanaria in which so many are forced to exist today. If we destroy the few remaining unspoiled places, such as our nature reserves, we deprive ourselves of the opportunity to appreciate much that is best of our cultural heritage. By reminding planners of this, ecologists may confer a great benefit upon mankind, as we may yet persuade them that by converting nature reserves into missile ranges they may leave unfulfilled our hopes of unity and **destroy what may be civilised man's last great cathedrals**."

SUMMARY

OPSOMMING

SUMMARY

VEGETATION ECOLOGY OF SOETDORING NATURE RESERVE: PAN, GRASSLAND AND KARROID COMMUNITIES.

Keywords: Game animals, Brackish pan, Braun-Blanquet method, Conservation, Decorana ordination, Fire, Free State province, Grassland Biome, Impact of humans, Overgrazing, Playa and hot spring, Phytosociology, Wildlife.

The main aim of this study was to identify, classify, describe and ecologically interpret the plant communities and their variations for the pans, grassland and karroid grassland of Soetdoring Nature Reserve and to compare it to other similar units where possible. A further aim of the study was to provide the Department of Environmental Affairs & Tourism of a baseline study of the grassland and pan vegetation and to provide results which could serve as an ecological basis for future management, conservation and research.

Soetdoring Nature Reserve is situated in the Free State Province, about 35 kilometres north-west of Bloemfontein and covers approximately 6 000 ha. The Modder River divides the reserve in two and the Krugersdrif Dam is also included in the reserve's boundaries.

The main aim was achieved by undertaking a phytosociological investigation by means of the Braun-Blanquet method. The total data set consists of 229 relevés and 171 species. After refinement, the Braun-Blanquet procedures yielded 17 plant communities. Phytosociological tables were compiled for each of the pan, grassland and karroid grassland, and a synoptic table for the total data set, in order to determine the communities and their variants. An ordination algorithm (DECORANA) (Hill 1979b) was also used to indicate the floristic relationships among the vegetation units.

The pan unit was classified into five communities and eleven subcommunities. Two pans are present in the reserve, on the southern and northern side of the Modder River respectively. The northern pan was classified as a Grass Pan and characterised by *Cynodon transvaalensis*, *Panicum schinzii* and *Echinochloa holubii*. The southern pan was classified as a *Diplachne* Pan and is dominated by *Diplachne fusca* and *Eragrostis bicolor*. Two permanent earth dams and a hot spring are also present inside the southern pan basin. Earth Dam A is dominated by *Eleusine*

coracana and *Phyla nodiflora*, while Earth Dam B is characterised by *Cyperus bellus* and *Eragrostis biflora*. The vegetation of the hot spring consists of a dominant zone of *Phragmites australis*, surrounded by a dense zone of *Juncus rigidus*.

The grassland unit was divided into grassland and karroid communities, due to the state of degradation thereof. The classification resulted in five grassland communities and seven karroid communities. The grassland communities are characterised by climax grasses, with the dominant species being *Themeda triandra* and *Digitaria eriantha*. The karroid communities are dominated by dwarf karroid shrubs, like *Salsola glabrescens*, *Rosenia humilis* and *Felicia muricata*, as well as subclimax and pioneer grasses, like *Eragrostis obtusa*, *Chloris virgata* and *Aristida adscensionis*.

This study provides important information on especially the pans in the reserve, since little information is available for the vegetation of pans in the Free State. The chapters on pans serve to bring all the available information together and to apply the information to the reserve's pans. This study is further of importance in indicating the degree of disturbance in the grassland unit. The impact of the animals and the importance of these mentioned areas for the game in the reserve, were taken into consideration for each vegetation type.

OPSOMMING

VEGETATION ECOLOGY OF SOETDORING NATURE RESERVE: PAN, GRASSLAND AND KARROID COMMUNITIES.

Keywords: Game animals, Brackish pan, Braun-Blanquet method, Conservation, Decorana ordination, Fire, Free State province, Grassland Biome, Impact of humans, Overgrazing, Playa and hot spring, Phytosociology, Wildlife.

Die hoofdoel van die studie was om die panne, grasveld en bossieveld in Soetdoring Natuurreservaat se plantgemeenskappe en hulle variasies te identifiseer, te klassifiseer en ekologies te interpreteer en om dit dan te vergelyk met ander soortgelyke plantegroei-eenhede waar moontlik. ‘n Verdere doelstelling van die studie was om vir die Departement van Omgewingsake en Toerisme navorsing en resultate te verskaf van die grasveld en pan-plantegroei wat as basis kan dien vir toekomstige bestuur, bewaring en navorsing.

Soetdoring Natuurreservaat is in die Vrystaat Provinsie geleë, ongeveer 35 kilometer noord-wes van Bloemfontein en beslaan ongeveer 6 000 ha. Die Modder Rivier verdeel die reservaat in twee en die Krugersdriftdam word ook ingesluit in die reservaat se grense.

Die hoofdoel is bereik deurdat ‘n fitososiologies studie onderneem is deur gebruik te maak van die Braun-Blanquet metode. Die totale datastel bestaan uit 229 relevés en 171 spesies. Na verfyning, het die Braun-Blanquet prosedures 17 gemeenskappe opgelewer. Fitososiologiese tabelle is saamgestel vir die panne, grasveld en bossieveld onderskeidelik, asook ‘n sinoptiese tabel vir die hele datastel, om sodoende die gemeenskappe en hulle variante te bepaal. ‘n Ordeningsalgoritme (DECORANA) (Hill 1979b), wat die floristiese verwantskappe tussen die plantegroei-eenhede aandui, is gebruik om die klassifikasies aan te vul.

Die pan-eenheid is ingedeel in vyf gemeenskappe en elf subgemeenskappe. Twee panne kom in die reservaat voor, aan die noorde en suidekant van die Modderrivier onderskeidelik. Die noordelike pan is geklassifiseer as ‘n Gemengde Graspan en *Cynodon transvaalensis, Panicum schinzii* en *Echinochloa holubii* is kenmerkend. Die suidelike pan is geklassifiseer as ‘n *Diplachne* Pan met die dominante *Diplachne fusca* en *Eragrostis bicolor*. Twee permanente gronddamme en ‘n warmwaterfontein kom ook binne-in die suidelike pan voor. Gronddam A word gedomineer deur *Eleusine coracana* en *Phyla nodiflora*, terwyl gronddam gekenmerk word deur *Cyperus*

bellus en *Eragrostis biflora*. Die plantegroei van die warmwaterfontein bestaan uit ‘n dominante sone van *Phragmites australis*, omring deur ‘n digte *Juncus rigidus* sone.

Die grasveld-eenheid is verdeel in grasveld en bossieveld gemeenskappe, as gevolg van die degradasie daarvan. Die klasifikasie het gelei tot vyf grasveld gemeenskappe en sewe bossieveld gemeenskappe. Die grasveld gemeenskappe word gekenmerk deur klimaksgrasse met *Themeda triandra* en *Digitaria eriantha* as die dominante spesies. Die bossieveld gemeenskappe word gedomineer deur karoobossies, soos *Salsola glabrescens*, *Rosenia humilis* en *Felicia muricata*, asook subklimaks en pioniersgrasse, soos *Eragrostis obtusa*, *Chloris virgata* en *Aristida adscensionis*.

Die studie voorsien belangrike inligting, spesifiek vir panne, aangesien daar relatief min inligting oor die plantegroei van panne in die Vrystaat beskikbaar is. Die hoofstukke wat handel oor die panne, dien die doel om al die beskikbare inligting bymekaar te bring en om dit ook toe te pas op die reservaat se panne. Die studie is van verdere belang deurdat dit die graad van versteuring van die grasveld-eenheid aandui. Die impak van diere en ook die belangrikheid van die genoemde areas vir die wild van die reservaat, is ook telkens in ag geneem by die bespreking van elke plantegroei-tipe.

ACKNOWLEDGEMENTS

The assistance and co-operation of the following persons and organisations are gratefully acknowledged:

- Dr P.J. du Preez (supervisor) for comments, guidance, time, effort and especially for help with the phytosociological tables and the photographs;
- Prof H.J.T. Venter (co-supervisor) for guidance, advice, sharing of his knowledge, positive criticism, encouragement, enthusiasm, time and effort;
- Dr P.W.J. van Wyk of the Department of Plant Sciences (UFS), for interest shown in reading some of the chapters, for help with special functions of the computer and for assistance, time and effort with the scanning and correction of some of the figures;
- Dr A.M. Venter of the Department of Plant Sciences (UFS), for encouragement and time;
- The Department of Plant Sciences for the opportunity and time granted to finish the study while employed in the department;
- The friendly personnel of Soetdoring Nature Reserve and the Department of Environmental Affairs and Tourism for information, assistance and permission to do research on the reserve;
- Mr M.T. Seaman of the Centre for Environmental Studies (UFS) for literature; Mr J.C. Loock and other staff of the Department of Geology (UFS) for assistance, literature and maps supplied and Mr S.W. Slabbert of the department of Geography (UFS) for drawing a map.

I am indebted to many others who helped and supported in different ways, to name just a few:

- My Lord and Saviour, Jesus Christ, who gave me the ability and opportunity to study and who provided protection against some of the more dangerous animals of the reserve. May this thesis only be to His honour and glorification;
- My friends and family, especially my mother, Foxie Janecke, for moral support, encouragement, interest, a sympathetic ear and many more;
- Mr A.J. du Plessis for help, time and effort with processing of data;
- Mrs S. Botha for some language tips, and last but not least
- The students of the Ecology section of the Department of Plant Sciences (UFS) for their co-operation and interest throughout this work.

REFERENCE LIST

All references follow the instructions of the South African Journal of Botany (2000).

ABEL, N.O.J. & BLAIKE, P.M. 1990. Land degradation, stocking rates and conservation policies in the communal rangelands of Botswana and Zimbabwe. Pastoral Network Paper 29a, Overseas Development Institute, London.

ACOCKS, J.P.H. 1988. Veld types of South Africa. 3rd edn. *Mem. bot. Surv. S. Afr.* 57: 1-146.

AGNEW, A.D.Q. & FLUX, J.E.C. 1970. Plant dispersal by hares (*Lepus capensis* L.) in Kenia. *Ecology* 51: 735-737.

ALLAN, D. 1987a. Transvaal highveld pans. *African wildlife* 41: 233-235.

ALLAN, D. 1987b. Types of pan in South Africa. *African wildlife* 41: 230-231.

ALLAN, D.G., SEAMAN, M. & KALEJTA, B. 1995. The endorheic pans of South Africa. In: Wetlands of South Africa, ed. G.I. Cowan, SA Wetlands Conservation Programme Series. pp. 75-101. Department of Environmental Affairs, Pretoria.

ARCHER, S. 1996. Assessing and interpreting grass-woody plant dynamics. In: The ecology and management of grazing systems, eds. J. Hodgson & A.W. Illius. pp. 101-136. Cab International, United Kingdom.

ARNOLD, T.H. & DE WET, B.C. 1993. Plants of southern Africa: names and distribution. *Mem. bot. Surv. S. Afr.* 62: 1-825.

BARBOUR, M.G., BURKE, J.H. & PITTS, W.D. 1987. Terrestrial plant ecology. 2nd edn. The Benjamin / Cummings Publishing Company, Inc., California.

BARNES, D.L. 1979. Cattle ranching in the semi-arid savannas of east and southern Africa. In: Management of semi-arid ecosystems, ed. B.H. Walker, Developments in Agricultural and managed-forest ecology 7. pp. 9-54. Elsevier Scientific Publishing Company, Amsterdam.
BARTHOLOMEW, P.E. 1991. A stocking rate model. Natal Pastures Extension Pamphlet. Dept. Agric. Development Natal Region, Pietermaritzburg.

BAYER, A.W. 1970. Plant ecology in the service of man in southern Africa. *S. Afr. J. Science* 66 (3): 71–77.

BECKING, R.W. 1957. The Zürich-Montpellier school of phytosociology. *The Botanical Review* 23: 412-488.

BEEBY, A. & BRENNAN, A. 1997. First ecology. Chapman & Hall, London.

BEHR, C.M. & BREDENKAMP, G.J. 1988. A phytososiological classification of the Witwatersrand Botanical Garden. *S. Afr. J. Bot.* 54: 525-533.

BELL, R.H.V. 1970. The use of the herb layer by grazing ungulates in the Serengeti. In: Animal populations in relation to their food resources, ed. A. Watson. pp. 111-123. Blackwell Publishers, Oxford.

BELL, R.H.V. 1982. Decision making in wildlife management with reference to problems of overpopulation. In: Management of large mammals in African conservation areas, ed. R.N. Owen-Smith. pp. 145-172. HAUM, Pretoria.

BEST, E.P.H. 1988. The phytosociological approach to the description and classification of aquatic macrophytic vegetation. In: Vegetation of inland waters, ed. J.J. Symoens, Handbook of vegetation science 15/1. H. Lieth (Editor in chief). pp. 155-182. Kluwer Academic Publishers, Dordrecht.

BEZUIDENHOUT, H. 1993. Syntaxonomy and synecology of the western Transvaal grasslands. Unpublished Ph.D. thesis, University of Pretoria, Pretoria.

BEZUIDENHOUT, H. & BREDENKAMP, G.J. 1990. A reconnaisance survey of the vegetation of the dolomite region in the Potchefstroom-Ventersdorp-Randfontein area, South Africa. *Phytocoenologia* 18: 387-403.

BEZUIDENHOUT, H. & BREDENKAMP, G.J. 1991a. Plantegroeiklassifikasie van die A-landtipe van die Mooirivieropvanggebied, Transvaal. *S.A. Tydskrif vir Natuurwetenskap en Tegnologie* 10(1): 4-11.

BEZUIDENHOUT, H. & BREDENKAMP, G.J. 1991b. Die plantgemeenskappe van die Ba-landtipe van die Mooirivieropvanggebied, Transvaal. *S.A. Tydskrif vir Natuurwetenskap en Tegnologie* 10(2): 85-92.

BEZUIDENHOUT, H., BREDENKAMP, G.J., THERON, G.K. & MORRIS, J.W. 1994. Braun-Blanquet reclassification of the *Cymbopogon – Themeda* grassland in the Lichtenburg area, south-western Transvaal. *S. Afr. J. Bot.* 60: 306-314.

BILLINGS, W.D. 1972. Plants, man and the ecosystem, 2nd edn. Macmillan Press, London.

BOND, G.W. 1946. A geochemical survey of the underground water supplies of the Union of South Africa, with particular reference to their utilisation in power production and industry. *Mem. geol. Surv. S. Afr.* 41.

BOND, W.J., STOCK, W.D. & HOFFMAN, M.T. 1994. Has the Karoo spread? A test for desertification using carbon isotopes from soils. *S. Afr. J. Science* 90: 393-397.

BONYONGO, M.C., BREDENKAMP, G.J. & VEENENDAAL, E. 2000. Floodplain vegetation in the Nxaraga Lagoon area, Okavango Delta, Botswana. *S. Afr. J. Bot.* 66: 15-21.

BORCHERS, R. 1949. Salt pan investigations. Unpublished Interm. Report, Rand mines.

BOSCH, O.J.H. 1989. Degradation of the semi-arid grasslands of southern Africa. *J. Arid. Environ.* 16: 165-175.

BOSCH, O.J.H., JORDAAN, E.E. & BREDENKAMP, G.J. 1986. A reconnaisance survey of the vegetation types and grazing capacity of the Thaba 'Nchu area, Bophuthatswana. Potchefstroom University for C.H.E., Potchefstroom.

BRAUN-BLANQUET, J. 1932. Plant sociology. Transl. By G.D. Fuller & H.S. Conrad. McGraw-Hill, New York.

BRAUN-BLANQUET, J. 1964. Pflanzensociologie. Springer Verlag, Wien.

BREDENKAMP, G.J. 1975. 'n Plantsosiologiese studie van die Suikerbosrand Natuurreservaat. Unpublished M.Sc. thesis, University of Pretoria, Pretoria.

BREDENKAMP, G.J. & BEZUIDENHOUT, H. 1990. The phytosociology of the Faan Meintjies Nature Reserve in the western Transvaal grassland, South Africa. *S. Afr. J. Bot.* 56(1): 54-64.

BREDENKAMP, G.J., BEZUIDENHOUT, H., JOUBERT, H. & NAUDE, C. 1994. The vegetation of the Boskop Dam Nature Reserve, Potchefstroom. *Koedoe* 31: 19-33.

BREDENKAMP, G. & BROWN, L. 2001. Vegetation: a reliable ecological basis for environmental planning. *Urban Green File* 6(5): 38-39.

BREDENKAMP, G.J., JOUBERT, A.F. & BEZUIDENHOUT, H. 1989. A reconnaisance survey of the vegetation of the plains in the Potchefstroom-Fochville-Parys area. *S. Afr. J. Bot.* 55: 199-206.

BREDENKAMP, G.J. & THERON, G.K. 1976. Vegetation units for management of the grasslands of the Suikerbosrand Nature Reserve. *S. Afr. J. wildl. Res*. 6: 113-122.

BREDENKAMP, G.J. & THERON, G.K. 1980. A synecological account of the Suikerbosrand Nature Reserve. 2. The phytososiology of the Ventersdorp Geological system. *Bothalia* 13: 199-216.

BREDENKAMP, G.J. & THERON, G.K. 1990. The vegetation of the fersiallitic soils of the Manlyeti Game Reserve. *Coenoses* 5: 167-175.

BREDENKAMP, G.J. & THERON, G.K. 1991. The *Euclio divinori - Acacietum nigricentis*, a new association of the calcareous bottomlands of the Manlyeti Game Reserve, eastern Transvaal Lowveld, South Africa. *Vegetatio* 93: 119-130.

BREDENKAMP, G.J. & VAN ROOYEN, N. 1996. Dry Sandy Highveld Grassland. In: Vegetation of South Africa, Lesotho and Swaziland, eds. A.B. Low & A.G. Rebelo. pp. 41-42. Department of Environmental Affairs and Tourism, Pretoria.

BREEN, C.M. 1988. Wetlands classification. In: Inventory and classification for wetlands in South Africa, eds. R.D. Walmsley & E.A. Boomker, Council for Scientific and Industrial Research Occasional Report No. 34, Foundation for Research Development.

BREEN, C.M. 1991. Are intermittently flooded wetlands of arid environments important conservation sites? *Madoqua* 17(2): 61-65.

BREEN, C.M. & BEGG, G.W. 1987. Wetlands - a valuable natural resource. *African wildlife* 41 (5): 219-221.

BREEN, C.M. & BEGG, G.W. 1991. Conservation status of southern African wetlands. In: Biotic diversity in southern Africa. Concepts and conservation, ed. B.J. Huntley. pp. 254-263. Oxford University Press, Cape Town.

BREEN, C.M., FURNESS, H.D., HEEG, J. & KOK, H. 1978. Bathymetric studies on the Pongolo River Floodplain. *Journal of the Limnological Society of southern Africa* 2: 95-100.

BREYTENBACH, P.J.J. 1991. Die fitososiologie van die Villiers-Grootvlei omgewing. Unpublished M.Sc. thesis, University of Pretoria, Pretoria.

BROMILOW, C. 2001. Problem plants of South Africa. Briza Publications, Pretoria.

BROWN, L.H., URBAN, E.K. & NEWMAN, K. (eds.) 1992. The birds of Africa, Vol. I. Academic Press, London.

BRUTON, M., JACKSON, P. & MERRON, G. 1987. Fishes and wetlands. *African wildlife* 41(5): 261-263.

BULLOCK, J.M. 1996. Plant competition and population dynamics. In: The ecology and management of grazing systems, eds. J. Hodgson & A.W. Illius. pp. 69-100. Cab International, United Kingdom.

BURGIS, M. & SYMOENS, J.J. (eds.) 1987. African wetlands and shallow water bodies. Editions de l'ORSTOM, Paris.

BUTTERWORTH, J.S. 1982. The chemistry of Mogatse Pan, Kgalagadi district. Botswana Geological Survey Department, Report JSB / 14 / 82.

CALDWELL, M.M. 1984. Plant requirements for prudent grazing. In: Developing strategies for rangeland management, Natl. Res. Council / Natl. Acad. Sci. pp. 117-152. Westview Press, Colorado.

CAPON, M.H. & O'CONNOR, T.G. 1990. The predation of perennial grass seed in some Transvaal savanna grasslands. *S. Afr. J. Bot.* 56: 11-15.

CHANNING, A. & VAN DYJK, D.E. 1995. Amphibia. In: Wetlands of South Africa, ed. G.I. Cowan. pp. 193-206. SA Wetlands Conservation Programme Series, Department of Environmental Affairs, Pretoria.

CHAPMAN, V.J. 1974. Salt marshes and salt deserts of the world. 2nd supplemented reprint edn. Verlag von J. Cramer, Germany.

CHAPMAN, S. & KREUTZWISER, R. 1999. A rapid hydrologic wetland evaluation technique for South Africa. In: Advances in planning and management of watersheds and wetlands in eastern and southern Africa, ed. J.E. Fitzgibbon. Environmental Capacity Enhancement Project, Environmental Round Table Series. pp 39-74. Weaver Press, University of Guelph, Canada.

CLAPHAM, W.B. 1973. Natural ecosystems. Macmillan Publishing Co. Inc., New York.

COETZEE, B.J. 1974. A phytosociological classification of the vegetation of the Jack Scott Nature Reserve. *Bothalia* 11: 364-365.

COETZEE, J.P. 1993. Phytososiology of the Ba and Ib land types in the Pretoria-Witbank-Heidelberg area. Unpublished M.Sc. thesis, University of Pretoria, Pretoria.

COETZEE, J.P., BREDENKAMP, G.J. & VAN ROOYEN, N. 1994. Phytosociology of the wetlands of the Ba and Ib land types in the Pretoria-Witbank-Heidelberg area of the Transvaal, South Africa. *S. Afr. J. Bot.* 60: 61-67.

COSTIN, A.B. 1964. Grasses and grasslands in relation to soil conservation. In: Grasses and grasslands, ed. C. Barnard. pp. 236-258. Macmillan & Co. Ltd., London.

COWARDIN, L.M., CARTER, V., GOLET, F.C. & LA ROE, E.T. 1979. Classification of wetlands and deepwater habitats of the United States. US Fish and Wildlife Service (Department of the Interior) Report FWS/OBS - 79/31. US Government Printing Office, Washington.

CRAWLEY, M.J. 1991. The structure of plant communities. In: Plant ecology, ed. M.J. Crawley. pp. 1-50. Blackwell Scientific Publications, London.

DANCKWERTS, J.E. & STUART-HILL, G.C. 1987. Adaptation of a decreaser and an increaser grass species to defoliation in semi-arid grassveld. *J. Grassl. Soc. South. Afr.* 4: 68-73.

DANCKWERTS, J.E. & STUART-HILL, G.C. 1988. The effect of severe drought and management after drought on the mortality and recovery of semi-arid grassland. *J. Grassl. Soc. South. Afr.* 5: 218-222.

DAVIES, B. & DAY, J. 1986. The biology and conservation of South Africa's vanishing waters. Centre for extra-mural studies, University of Cape Town.

DAVIES, B. & DAY, J. 1998. Vanishing waters. UCT Press, Cape Town.

DAUBENMIRE, R.F. 1974. Plants and environment. 3rd edn. John Wiley & Sons, New York.

DE BRUIYN, H. 1971. 'n Geologiese studie van die panne in die westelike Oranje Vrystaat. Unpublished M.Sc thesis, University of the Orange Free State, Bloemfontein.

DE SWARDT, B.H. 2001. Birds of Soetdoring Nature Reserve and adjacent areas, Central Free State. BirdLife South Africa, Randburg.

DE VILLIERS, A. 1987. A frog paradise. *African wildlife* 41(5): 257-260.

DU PLESSIS, W.P., BREDENKAMP, G.J. & TROLLOPE, W.S.W. 1998. Development of a technique for assessing veld condition in Etosha National Park, Namibia, using key herbaceous species. *Koedoe* 41(1): 19-29.

DU PREEZ, P.C. 1979. 'n Plantekologiese ondersoek van Naval Hill, Bloemfontein. Unpublished M.Sc. thesis, University of the Orange Free State, Bloemfontein.

DU PREEZ, P.J. 1986. Ekologie van die boomgemeenskappe van die Vredefort-distrik, Oranje-Vrystaat. Unpublished M.Sc. thesis, University of the Free State, Bloemfontein.

DU PREEZ, P.J. 1991. A syntaxonomical and synecological study of the south eastern Orange Free State and related areas with special reference to Korannaberg. Unpublished Ph.D. thesis, University of the Free State, Bloemfontein.

DU PREEZ, P.J. & BREDENKAMP, G.J. 1991. Vegetation classes of the southern and eastern Orange Free State (Republic of South Africa) and the highlands of Lesotho. *Navorsinge van die Nasionale Museum Bloemfontein* 7(10): 477-526.

DU PREEZ, P.J. & VENTER, H.J.T. 1990. The phytososiology of the woody vegetation in the southern part of the Vredefort Dome area. I. Communities of the plains, riverbanks and islands. *S. Afr. J. Bot.* 56: 631-636.

DU PREEZ, P.J. & VENTER, H.J.T. 1992. The classification of the vegetation of Korannaberg, eastern Orange Free State, South Africa. II. Grassland communities. *S. Afr. J. Bot* 58: 173-181.

DU TOIT, A.L. 1927. The geology of South Africa. Oliver & Boyd, Edinburgh.

DU TOIT, J.G. & VAN ROOYEN, J. 1996. Roads. In: Game ranch management, ed. J. du P. Bothma. pp. 109-112. JL van Schaik Publishers, Pretoria.

ECKARDT, H.C., VAN ROOYEN, N. & BREDENKAMP, G.J. 1996. Species richness and plant communities of the *Helichrysum rugulosum – Hyparrhenia hirta* Low-altitude grassland of northern KwaZulu-Natal. *S. Afr. J. Bot.* 62: 296-305.

EDWARDS, D. 1972. Botanical survey and agriculture. *Proc. Grassl. Soc. South. Afr.* 7: 15-19.

EDWARDS, D. 1983. A broad-scale structural classification of vegetation for practical purposes. *Bothalia* 14: 705-712.

EDWARDS, P.J. 1984. The use of fire as a management tool. In: Ecological effects of fire in South African ecosystems, eds. P. de V. Booysen & N.M. Tainton, Ecological studies - Analysis & synthesis, Vol. 48. pp. 350-366. Springer-Verlag Berlin, Heidelberg.

ELOFF, J.F. 1984. Die grondhulpbronne van die Vrystaatstreek. Unpublished Ph.D. thesis, University of Stellenbosch, Stellenbosch.

EVERSON, C.S. 1999. Veld burning in different vegetation types: Grassveld. In: Veld management in South Africa, ed. N.M. Tainton. pp. 228-236. University of Natal Press, Pietermaritzburg.

FAO UNESCO. 1987. Soils of the world. Elsevier Science Publishers, P.V. Amsterdam.

FRAME, J. 1992. Improved grassland management. Farming Press Books, UK, Ipswich.

FULS, E.R. 1992. Semi-arid and arid rangelands: a resource under siege due to patch-selective grazing. *J. Arid Envir.* 22: 191-193.

FULS, E.R. 1993. Vegetation ecology of the northern Orange Free State. Unpublished Ph.D. thesis, University of Pretoria, Pretoria.

FULS, E.R., BREDENKAMP, G.J., VAN ROOYEN, N. & THERON, G.K. 1992. The physical environment and major plant communities of the Vredefort-Kroonstad-Lindley-Heilbron area, northern Orange Free State. *S. Afr. J. Bot.* 58: 317-325.

FULS, E.R., BREDENKAMP, G.J., VAN ROOYEN, N. & THERON, G.K. 1993. The physical environment and major plant communities of the Heilbron-Lindley-Warden-Villiers area, northern Orange Free State. *S. Afr. J. Bot.* 59: 345-359.

FURNESS, H.D. & BREEN, C.M. 1980. The vegetation of seasonally flooded areas of the Pongola Floodplain. *Bothalia* 13: 217-231.

GELDENHUYS, J.N. 1981. Classification of the pans of the western Orange Free State according to vegetation structure, with reference to avifaunal communities. Unpublished Report of the Provincial Administration of the Orange Free State, Division of Nature Conservation.

GELDENHUYS, J.N. 1982. Classification of the pans of the western Orange Free State according to vegetation structure, with reference to avifaunal communities. *S. Afr. J. wildl. Res.* 12: 55-62.

GIBBS RUSSEL, G.E. 1987. Preliminary floristic analysis of the major biomes in southern Africa. *Bothalia* 17: 213–227.

GOUDIE, A. 1993. The human impact on the natural environment. 4th edn. Blackwell Publishers, Oxford.

GOUDIE, A.S. & THOMAS, D.S.G. 1985. Pans in southern Africa with particular reference to South Africa and Zimbabwe. *Zeitscrift für Geomorphologie N.F.* 29(1): 1-19.

GRAINGER, A. 1992. Characterisation and assessment of desertification processes. In: Desertified grasslands, their biology and management, ed. G.P. Chapman, Linnean Society Symposium Series Nr 13. pp. 17-33. Academic Press, London.

GRIZMEK, M. & GRIZMEK, B. 1960. A study of the game of the Serengeti plains. *Z. Saugetier* 25: 1-61.

GROBLER, N.J. & LOOCK, J.C. 1988. The Florisbad mineral spring: it's characteristics and genesis. *Navorsinge van die Nasionale Museum Bloemfontein* 5(17): 473-485.

GROBLER, N.J., LOOCK, J.C. & BEHOUNEK, N.J. 1988. Development of pans in palaeodrainage in the north-western Orange Free State. In: Palaeo-ecology of Africa and the surrounding islands, ed. K. Heine, Vol. 19. pp. 87-96. SA Society for Quarternary research, Proceedings of the VIIIth biennial conference.

GROSSMAN, D., HOLDEN, P.L. & COLLINSON, R.F.H. 1999. Veld management on the game ranch. In: Veld management in South Africa, ed. N.M. Tainton. pp. 261-279. University of Natal Press, Pietermaritzburg.

HENNEKENS, S.M. 1996a. TURBOVEG. Software package for input, processing and presentation of phytosociological data. User's guide. University of Lancaster, Lancaster.

HENNEKENS, S.M. 1996b. MEGATAB. A visual editor for phytosociological tables. University of Lancaster, Lancaster.

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

HILL, M.O. 1979b. DECORANA - A FORTRAN programme for Detrended Correspondence Analysis and Reciprocal Averaging. Cornell University, Department of Ecology and Systematics, Ithaca, New York.

HILL, M.O. & GAUCH, H.G. 1980. Detrended Correspondence Analysis, an improved ordination technique. *Vegetatio* 42: 47-58.

HOARE, D.B. & BREDENKAMP, G.J. 2001. Syntaxonomical and environmental gradients of the grasslands of the Stormberg / Drakensberg mountain region of the Eastern Cape, South Africa. *S. Afr. J. Bot.* 67: 595-608.

HOFFMAN, T. 1996. Eastern Mixed Nama Karoo. In: Vegetation of South Africa, Lesotho and Swaziland, eds. A.B. Low & A.G. Rebelo. pp. 55. Department of Environmental Affairs and Tourism, Pretoria.

HUNTLEY, B.J. 1984. Characteristics of South African Biomes. In: Ecological effects of fire in South African ecosystems, eds. P. de V. Booysen & N.M. Tainton, Ecological studies - Analysis & synthesis, Vol. 48. pp. 1-17. Springer-Verlag Berlin, Heidelberg.

JACOBSEN, N.H.G. 1995. Wetlands and reptiles - a review. In: Wetlands of South Africa, ed. G.I. Cowan. pp. 179-191. SA Wetlands Conservation Programme Series, Department of Environmental Affairs, Pretoria.

JANZEN, D.H. 1984. Dispersal of small seed by big herbivores: foliage is the fruit. *American Naturalist* 123: 338-353.

JARMAN, N.G. 1977. An evaluation of different types of aerial photographs for surveying and mapping grass and shrub vegetation. Unpublished M.Sc. thesis, University of the Witwatersrand, Johannesburg.

JARMAN, P.J. & SINCLAIR, A.R.E. 1984. Feeding strategy and the pattern of resource partitioning in ungulates. In: Serengeti, dynamics of an ecosystem, eds. A.R.E. Sinclair & M. Norton-Griffiths. pp. 130-163. University of Chicago Press, Chigaco.

JOUBERT, S.C.J. 1982. A monitoring program for an excessive national park. In: Management of large mammals in African conservation areas, ed. R.N. Owen-Smith. pp. 201-212. HAUM, Pretoria.

KELLY, R.D. & WALKER, B.H. 1976. The effect of different forms of land use on the ecology of a semi-arid region in south-eastern Rhodesia. *J. Ecol.* 64: 553-576.

KENT, M. & COKER, P. 1996. Vegetation description and analysis. A practical approach. John Wiley & Sons Ltd., England.

KENT, L.E. 1949. The thermal waters of the Union of South Africa and South West Africa. *Trans. Geol. Soc. S. Afr.* 52: 231-264.

KOK, D.J. 1987. Invertebrate inhabitants of temporary pans. *African wildlife* 41(5): 239.

KOOIJ, M.S., BREDENKAMP, G.J. & THERON, G.K. 1990a. The vegetation of the north-western Orange Free State, South Africa. 1. Physical environment. *Bothalia* 20: 233-240.

KOOIJ, M.S., BREDENKAMP, G.J. & THERON, G.K. 1990b. The vegetation of the north-western Orange Free State, South Africa. 2. The D land-types. *Bothalia* 20: 241-248.

KOOIJ, M.S., BREDENKAMP, G.J. & THERON, G.K. 1990c. Classification of the vegetation of the B land-types of the north-western Orange Free State. *S. Afr. J. Bot.* 56: 309-318.

KOOIJ, M.S., SCHEEPERS, J.C., BREDENKAMP, G.J. & THERON, G.K. 1992. The vegetation of the Kroonstad area, Orange Free State. 2. A description of the grassland communities. *S. Afr. J. Bot.* 58: 155-164.

KREULEN, D.A. 1980. Countrywide Animal and Range Assessment Project. Vol. 5. Special Subject Report: Interpretation of animal distributions. pp. 1-132. Unpublished Report to Department of Wildlife, National Parks and Tourism, Republic of Botswana.

KRUGER, F.J. 1984. Effects of fire on vegetation structure and dynamics. In: Ecological effects of fire in South African ecosystems, eds. P. de V. Booysen & N.M. Tainton, Ecological studies - Analysis & synthesis, Vol. 48. pp. 219-243. Springer-Verlag Berlin, Heidelberg.

LANCASTER, I.N. 1978. The pans of the southern Kalahari, Botswana. *Geogr.* 144: 80-98.

LANCASTER, I.N. 1979. Quarternary environments in the arid zone of southern Africa. Occasional paper No. 22. Env. Studies. pp 1-77. University of the Witwatersrand, Johannesburg.

LAND TYPE SURVEY STAFF. 1986. Land types of the maps SE 27/20 Witdraai, 2720 Noeniespruit, 2722 Kuruman, 2724 Christiana, 2820 Upington, 2822 Postmansburg. *Mem. agric. nat. Resour. S. Afr.*

LAND TYPE SURVEY STAFF. 1992. Land types of the map SE 2826 Winburg. *Mem. agric. nat. Resour. S. Afr.*

LEISTNER, O.A. 1967. The plant ecology of the southern Kalahari. *Mem. Bot. Surv. S. Afr.* 38: 1-172.

LE ROUX, J.S. 1978. The origin and distribution of pans in the Orange Free State. *S. Afr. Geogr.* 6: 167-176.

LE ROUX, P.M., KOTZE, C.D., NEL, G.P. & GLEN, H.F. 1994. Bossieveld. Grazing plants of the Karoo and karoo-like areas. Bulletin 428. Department of Agriculture, Pretoria.

LOOCK, J.C. & GROBLER, N.J. 1988. The regional geology of Florisbad. *Navorsinge van die Nasionale Museum Bloemfontein* 5(18): 489-497.

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

MACDONALD, I. (ed.) May 2000. Grasslands - our inherited future. *Our living world. Magazine of WWF-SA*, pp. 4 - 5.

MACDONALD, I.A.W. & BROOKS, P.M. 1982. Monitoring for the detection of mammal overabundance in small conservation areas. In: Management of large mammals in African conservation areas, ed. R.N. Owen-Smith. pp. 187-200. HAUM, Pretoria.

MAITLAND, P.S. & MORGAN, N.C. 1997. Conservation management of freshwater habitats. Lakes, rivers and wetlands. Chapman & Hall, London.

MALAN, P.W. 1992. Plantsosiologie van die Bloemfontein-wes distrik. Unpublished M.Sc. thesis, University of the Free State, Bloemfontein.

MALAN, P.W. 1998. Vegetation ecology of the southern Free State. Unpublished Ph.D. thesis, University of the Free State, Bloemfontein.

MALAN, P.W., VENTER, H.J.T. & DU PREEZ, P.J. 1994. Phytosociology of the Bloemfontein-West district: Vegetation of the Ae land type. *S. Afr. J. Bot.* 60: 245-250.

MALAN, P.W., VENTER, H.J.T. & DU PREEZ, P.J. 1999. Vegetation ecology of the southern Free State: Plant communities of the Zastron area. *S. Afr. J. Bot.* 65: 260–269.

MALTBY, E. 1986. Waterlogged wealth - why waste the world’s wet places? International Institute for Environment and Development, London.

MATTHEE, J.F. La G. & VAN SCHALKWYK, C.L. 1984. Inleiding tot grondbewaring. *Bull. Dept. Agric. S. Afr.* No 339.

MATTHEWS, W.S. 1991. Phytosociology of the north-eastern Mountain Sourveld. Unpublished M.Sc. thesis, University of Pretoria, Pretoria.

MATTHEWS, W.S., VAN WYK, A.E., VAN ROOYEN, N. & BOTHA, G.A. 2001. Vegetation of the Tembe Elephant Park, Maputaland, South Africa. *S. Afr. J. Bot.* 67: 573 – 594.

MAZOR, E. & VERHAGEN, B. Th. 1983. Dissolved ions, stable and radio-active isotopes and noble gasses in thermal waters of South Africa. *J. Hydrol.* 63: 315-329.

McNAUGHTON, S.J. 1979. Grazing as an optimization process: grass-ungulate relationships in the Serengeti. *American Naturalist* 113: 691-703.

McNAUGHTON, S.J. 1983. Serengeti grassland ecology: the role of composite environmental factors and contingency in community organization. *Ecological Monographs* 53: 291-320.

McNAUGHTON, S.J. 1984. Grassland-herbivore dynamics. In: Serengeti, dynamics of an ecosystem, eds. A.R.E. Sinclair & M. Norton-Griffiths. pp. 46-81. University of Chicago Press, Chigaco.

McNAUGHTON, S.J. 1985. Ecology of a grazing ecosystem: the Serengeti. *Ecological Monographs* 55(3): 259-294.

MEINTJIES, S. 1992. A contribution to the biology of *Triops granarius* (Lucas). Unpublished Ph.D. thesis, University of the Free State, Bloemfontein.

MENTIS, M.T. & COLLINSON, R.F.H. 1979. Management goals for wildlife reserves in grassveld and bushveld. *Proc. Grassl. Soc. South. Afr.*14: 71-74.

MENTIS, M.T. & HUNTLEY, B.J. 1982. A description of the grassland biome project. *S. Afr. Nat. Prog. Rep.* No. 62. CSIR, Pretoria.

MENTIS, M.T. & TAINTON, N.M. 1984. The effects of fire on forage production and quality. In: Ecological effects of fire in South African ecosystems, eds. P. de V. Booysen & N.M. Tainton, Ecological studies - Analysis & synthesis, Vol. 48. pp. 245-254. Springer-Verlag Berlin, Heidelberg.

MEPHAM, R.H. & MEPHAM, J.S. 1987. Seasonal and semi-permanent pans. In: African wetlands and shallow water bodies, eds. M.J. Burgis & J.J. Symoens. pp. 476-486. Editions de l'ORSTOM, Paris.

MEREDITH, D. (ed.) 1959. The grasses and pastures of South Africa. Central News Agency, Parow.

MILLAR, K.R. 1982. Matching conservation goals to diverse conservation areas: a global prospective. In: Management of large mammals in African conservation areas, ed. R.N. Owen-Smith. pp. 1-12. HAUM, Pretoria.

MILLER, G.T. Jr. 1996. Living in the environment. Principles, Connections & Solutions. 9th edn. Wadsworth Publishing Company, California.

MILSTEIN, P. le S. 1975. The biology of Baberspan, with special reference to the avifauna. *Ostrich supplement* 10: 6-15.

MILTON, S.J., DEAN, W.R.J., MARINCOWITZ, C.P. & KERLEY, G.I.H. 1995. Effects of the 1990 / 1991 drought on rangeland in the Steytlerville Karoo. *S. Afr. J. Science* 91: 78-84.

MORANT, P.D. 1983. Wetland classification: towards an approach for southern Africa. *Limnol. Soc. sth. Afr.* 9: 76-84.

MORGENTHAL, T.L., CILLIERS, S.S., KELLNER, K., VAN HAMBURG, H. & MICHAEL, M.D. 2001. The vegetation of ash disposal sites at Hendrina Power Station. I. Phytosoiology. *S. Afr. J. Bot.* 67: 506-519.

MORRIS, C.D., HARDY, M.B. & BARTHOLOMEW, P.E. 1999. Stocking rate. In: Veld management in South Africa, ed. N.M. Tainton. pp. 186-193. University of Natal Press, Pietermaritzburg.

MOSTERD, J.W.C. 1958. Studies of the vegetation of parts of the Bloemfontein and Brandfort districts. *Mem. bot. Surv. S. Afr.* No. 31. Government Printer, Pretoria.

MOSTERD, J.W.C., ROBERTS, B.R., HESLINGA, C.F. & COETZEE, P.G.F. 1971. Veld management in the O.F.S. region. Department of Agricultural Technical Services Bulletin 391. Government Printer, Pretoria.

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

MüLLER, D.B. 1986. Plantekologie van die Willem Pretorius-Wildtuin. Unpublished Ph.D. thesis, University of the Free State, Bloemfontein.

MWORIA, J.K., MNENE, W.N., MUSEMBI, D.K. & READ, R.S. 1997. Resilience of soils and vegetation subjected to different grazing intensities in a semi-arid rangeland of Kenia. *Afr. J. Range For. Science* 14(1): 26-31.

MYBURG, W.J. 1993. Die fitososiologie van die suurgrasveld in die suidoos Transvaalse Hoëveld. Unpublished M.Sc. thesis, University of Pretoria, Pretoria.

NAIDOO, Y. & NAIDOO, G. 1998. *Sporobolus virginicus* leaf salt glands: morphology and ultrastructure. *S. Afr. J. Bot.* 64: 198-204.

NAKOR. 1979. National plan for nature conservation. Department of Environmental planning and Conservation, Pretoria.

NEAL, J.T. (ed.) 1975. Playas and dried lakes: occurrence and development. Dowden, Hutchinson & Ross, Stroudsburg.

NOBLE, R.G. & HEMENS, J. 1978. Inland water ecosystems in South Africa - a review of research needs. *S. Afr. Nat. Scient. Prog. Rep.* No. 34: 1-150.

NOLTE, C.C. 1995. The geology of the Winburg area. Explanation of Sheet 2826, Scale 1:250,000. Council for Geoscience, Geological Survey of South Africa.

NOVELLIE, P. 1990. Habitat use by indigenous grazing ungulates in relation to sward structure and veld condition. *J. Grassl. Soc. South. Afr.* 7(1), 16 - 23.

NOVELLIE, P. & STRYDOM, G. 1987. Monitoring the response of vegetation to use by large herbivores: an assessment of some techniques. *S. Afr. J. wildl. Res.* 17(4): 109-117.

O'CONNOR, T.G. 1991a. Local extinction in perennial grasslands: a life history approach. *American Naturalist* 137: 753-773.

O'CONNOR, T.G. 1991b. Patch colonisation in a savanna grassland. *Journal of Vegetation Science* 2: 245-254.

O'CONNOR, T.G. 1994. Composition and population responses of an African savanna grassland to rainfall and grazing. *Journal of Applied Ecology* 31: 155-177.

O'CONNOR, T.G. 1995. Transformation of a savanna grassland by drought and grazing. *Afr. J. Range For. Science* 12(2): 53-60.

O'CONNOR, T.G. & BREDENKAMP, G.J. 1997. Grassland. In: Vegetation of southern Africa, eds. R.M. Cowling, D.M. Richardson & S.M. Pierce. pp. 215-257. Cambridge University Press, United Kingdom.

O'CONNOR, T.G. & PICKET, G.A. 1992. The influence of grazing on seed production and seed banks of some African savanna grasslands. *Journal of Applied Ecology* 29: 247-260.

ODUM, E.P. 1997. Ecology, a bridge between science and society. Sinauer Associates, Inc. Publishers, Sunderland, U.S.A.

OOSTING, H.J. 1956. The study of plant communities. An introduction to plant ecology. 2nd edn. Freeman, California.

OWEN-SMITH, N. 1985. Niche separation among African ungulates. In: Species and speciation, ed. E. Vrba, *Transvaal Museum Monographs* No.4. pp. 167-171. Transvaal Museum, Pretoria.

OWEN-SMITH, N. 1999. The animal factor in veld management. In: Veld management in South Africa, ed. N.M. Tainton. pp. 117-138. University of Natal Press, Pietermaritzburg.

PASSMORE, N. & CARRUTHERS, V. 1995. South African Frogs - a complete guide. Southern Book Publishers & Witwatersrand University Press, Johannesburg.

PARRIS, R. 1976. A study of the major components of the Kalahari pan ecosystem. Unpublished M.Sc. thesis, University of Pretoria, Pretoria.

PARRIS, R. 1984. Pans, rivers and artificial waterholes in the protected areas of the south-western Kalahari. *Koedoe Supplement*, pp 63-82.

PARRIS, R. & CHILD, G. 1973. The importance of pans to wildlife in the Kalahari and the effect of human settlement on these areas. *J. S. Afr. wildl. Mgmt. Ass.* 3(1): 1-8.

PAUW, J.C. 1988. Riglyne vir die bestuur van die natuurlewe in die bosveldgemeenskap van die Atherstone Natuureservaat in die Noordwes-Transvaal. Unpublished M.Sc. thesis, University of Pretoria, Pretoria.

PAWLOWSKI, B. 1966. Review of terrestrial plant communities. A composition and structure of plant communities and methods of their study. In: The vegetation of Poland, ed. W. Szafer. pp. 241-281. Pergamon Press/ PWN Polish Scientific Publishers, Warsaw.

PAYNTER, D. & NUSSEY, W. 1986. Die Kruger wildtuin in woord en beeld. Macmillan Press, Johannesburg.

POORE, M.E.D. 1955a. The use of phytosociological methods in ecological investigations: The Braun-Blanquet system. *J. Ecol.* 43: 226-244.

POORE, M.E.D. 1955b. The use of phytosociological methods in ecological investigations: Practical issues involved in an attempt to apply the Braun-Blanquet system. *J. Ecol.* 43: 245-269.

POORE, M.E.D. 1955c. The use of phytosociological methods in ecological investigations: Practical implications. *J. Ecol.* 43: 606-651.

POORE, M.E.D. 1956. The use of phytosociological methods in ecological investigations. IV. General discussion of phytosociological problems. *J. Ecol.* 43: 606-651.

POTGIETER, J.W. 1982. ‘n Plantekologiese studie van die Golden Gate Hoogland Nasionale Park, Clarens, Oranje Vrystaat. Unpublished M.Sc. thesis, University of the Free State, Bloemfontein.

PRICE, M. 1985. Introducing groundwater. George Allen & Unwin Ltd., London.

REARDON, P.O., LEINWEBBER, C.L. & MERRILL, L.B. 1972. The effect of bovine saliva on grasses. *Amer. Soc. Anim. Sci. West. Sect. Proc.* 23: 206-210.

RICKLEFS, R.E. 1990. Ecology. 3rd edn. W.H. Freeman and Company, New York.

ROBERTS, B.R., ANDERSON, E.R. & FOURIE, J.H. 1975. Evaluation of natural pastures: quantitative criteria for assessing condition in the *Themeda* veld of the Orange Free State. *Proc. Grassld. Soc. South. Afr.* 10: 133-140.

ROSSOUW, L.F. 1983. ‘n Ekologiese studie van die boomgemeenskappe van Bloemfontein-omgewing, Oranje-Vrystaat. Unpublished M.Sc. thesis, University of the Free State, Bloemfontein.

ROUX, P.W. 1981. Interaction between climate, vegetation and run-off in the Karoo. *Karoo. Agric.* 1(5): 15-16.

ROUX, P.W. & VORSTER, M. 1983. Vegetation change in the Karoo. *Proc. Grassld. Soc. South. Afr.* 18: 25-29.

RUSSEL, E.J. 1961. Soil conditions and plant growth. Longmans, London.

RUSSEL, B. 1997. Erosie verwoes produktiwiteit. *Landbouweekblad* No. 983: 24-26.

RUTHERFORD, M.C. & WESTFALL, R.H. 1994. Biomes of southern Africa, an objective categorization. 2nd edn. *Mem. Bot. Surv. S. Afr.* 63: 1-94.

SCHEEPERS, J.C. 1975. The plant ecology of the Kroonstad and Bethlehem areas of the Highveld Agricultural Region. Unpublished Ph.D. thesis, University of Pretoria, Pretoria.

SCHEEPERS, J.C. 1987. Grassland Biome Project: Proceedings of the workshop on the classification and mapping. *S. Afr. Ecosys. Prog. Occ. Rep.* Series 16: 1-31.

SCHULZE, E. 1992. Riglyne vir natuurlewebestuur op die Imberbe Game Lodge in die Noordwes-Transvaal. Unpublished M.Sc. thesis, University of Pretoria, Pretoria.

SCHULZE, E., THERON, G.K. & VAN HOVEN, W. 1994. The vegetation of management units of the Imberbe Game Lodge in the mixed bushveld of the north-western Transvaal. *S. Afr. J. Bot.* 60: 85-93.

SEAMAN, M. 1987. Pans of the Orange Free State. *African wildlife* 41(5): 237-238.

SEAMAN, M.T., ASHTON, P.J. & WILLIAMS, W.D. 1991. Inland salt waters of southern Africa. *Hydrobiologia* 210: 75-91.

SEMPLE, A.T. 1972. Grassland improvement. Leonard Hill Books, London.

SHAW, P.A. 1988. Lakes and pans. In: The geomorphology of southern Africa, eds. B.P. Moon & G.F. Dardis. pp. 120-140. Southern Book Publishers, Johannesburg.

SHEARING, D. 1994. Karoo – South African Wild Flower Guide 6. Botanical Society of South Africa, Kirstenbosch.

SHIMWELL, D.W. 1971. Description and classification of vegetation. Sidgewick & Jackson, London.

SIEGFRIED, W.R., FROST, P.G.H., COOPER, J. & KEMP, A.C. 1976. South African Red Data Book - Aves. *S. Afr. Nat. Scient. Prog. Rep.* No 7.

SKARPE, C. 1990. Shrub layer dynamics under different herbivore densities in an arid savanna, Botswana. *Journal of Applied Ecology* 27: 873-885.

SMIT, C.M., BREDENKAMP, G.J. & VAN ROOYEN, N. 1995. The grassland vegetation of the Low Drakensberg escarpment in the north-western KwaZulu Natal and north-eastern Orange Free State border area. *S. Afr. J. Bot.* 61: 9-17.

SMITHERS, R.H.N. 1971. The mammals of Botswana. *National museums of Rhodesia, Museum memoir* 4: 1-339.

SMITHERS, R.H.N. 1983. Die soogdiere van die suider-Afrikaanse substreek. University of Pretoria, Pretoria.

SNYMAN, D.D. 1989. Verwantskap tussen veldtoestand, reënval en dierebelading in die Mopanieveld. Unpublished M.Sc. (Agric.) thesis, University of Pretoria, Pretoria.

SNYMAN, H.A. 1993a. Streef na optimale veldtoestand en weidingkapasiteit. *S.A. Koop.* 9(5): 25-28.

SNYMAN, H.A. 1993b. Die ekonomie van veld in verskillende toestande. *S.A. Koop.* 9(11): 33-34.

SNYMAN, H.A. 1999a. Die weidingekositeem in ‘n vinnig veranderende omgewing. *S.A. Tydskrif vir Natuurwetenskap en Tegnologie* 18(2): 37-42.

SNYMAN, H.A. 1999b. Soil erosion and conservation. In: Veld management in South Africa, ed. N.M. Tainton. pp. 355-380. University of Natal Press, Pietermaritzburg.

SNYMAN, H.A. & FOUCHE, H.J. 1991. Production and water use efficiency of semi-arid grasslands of South Africa as affected by veld condition and rainfall. *Water S.A.* 17: 263-268.

SNYMAN, H.A. & VAN RENSBURG, W.L.J. 1990. Korttermyn invloed van strawwe droogte op veldtoestand en waterverbruiksdoeltreffendheid van grasveld in die sentrale Oranje-Vrystaat. *J. Grassl. Soc. South. Afr.* 7: 249-256.

TAINTON, N.M. 1999a. The grassland biome. In: Veld management in South Africa, ed. N.M. Tainton. pp. 25-33. University of Natal Press, Pietermaritzburg.

TAINTON, N.M. 1999b. Karoo, forest and fynbos (macchia). In: Veld management in South Africa, ed. N.M. Tainton. pp. 242-245 . University of Natal Press, Pietermaritzburg.

TAINTON, N.M. & MENTIS, M.T. 1984. Fire in grassland. In: Ecological effects of fire in South African ecosystems, eds. P. de V. Booysen & N.M. Tainton, Ecological studies - Analysis & synthesis, Vol. 48. pp. 117-147. Springer-Verlag Berlin, Heidelberg.

TARBOTON, W. 1997a. South Africa's grasslands: The Cinderella Biome. *Africa Birds & Birding* 2(1): 57 - 60.

TARBOTON, W. 1997b. Wither grasslands? *Africa Birds & Birding* 2(2): 49 - 53.

THOMPSON, G., COLDREY, J. & BERNARD, G. 1985. The pond. Oxford Scientific Films. MIT Press, Cambridge.

TURNER, B.J. 1989. A phytosociological study of the south-eastern Transvaal grasslands. Unpublished M.Sc. thesis, University of Pretoria, Pretoria.

URBAN, E.K., FRY, C.H. & KEITH, S. (eds.) 1993. The birds of Africa. Vol. II. Academic Press, London.

VALLENTINE, J.F. 1990. Grazing management. Academic Press Inc., California.

VAN DEN BERG, J.A., ROBERTS, B.R. & VORSTER, L.F. 1976. Die uitwerking van seisoensbeweiding op die infiltrasie-vermoë van gronde in 'n *Cymbopogon-Themeda*-veld. *Hand. Weidingsveren. S. Afr.* 11: 91-95.

VAN DER MERWE, A.J. 1973. Physico-chemical relationships of selected O.F.S soils – A statistical approach based on taxonomic criteria. Unpublished Ph.D. thesis, University of the Free State, Bloemfontein.

VAN OUDTSHOORN, F. 1999. Gids tot grasse van suider Afrika. Briza Publications, Pretoria.

VAN RIET, W., CLAASEN, P., VAN RENSBURG, J., VAN VIEGEN, T. & DU PLESSIS, L. 1997. Environmental potential atlas for South Africa. J.L. Van Schaik Publishers, Pretoria.

VAN WYK, S. & BREDENKAMP, G.J. 1986. ‘n Braun-Blanquet klassifikasie van die plantegroei van die Abe Bailey-Natuurreservaat. *S. Afr. J. Bot.* 52: 321-331.

VAN WYK, E., CILLIERS, S.S. & BREDENKAMP, G.J. 2000. Vegetation analysis of wetlands in the Klerksdorp Municipal Area, North West Province, South Africa. *S. Afr. J. Bot.* 66: 52-62.

VESEY-FITZGERALD, D.F. 1960. Grazing succession amongst East African game animals. *J. Mammal.* 41: 161-170.

VISSER, D.J.L. 1989. The geology of the Republics of South Africa, Transkei, Bophuthatswana, Venda and Ciskei and the Kingdoms of Lesotho and Swaziland. Explanation of the 1:1000 000 geological map. 4th edn. Geological Survey - Republic of South Africa. Government Printer, Pretoria.

WAISEL, Y. 1972. Biology of halophytes. Academic Press, New York.

WALKER, B.H. (ed.) 1979a. Management of semi-arid ecosystems. Developments in Agricultural and managed-forest ecology. Elsevier Scientific Publishing Company, Amsterdam.

WALKER, B.H. 1979b. Game ranching in Africa. In: Management of semi-arid ecosystems, ed. B.H. Walker, Developments in Agricultural and managed-forest ecology 7. pp. 55-81. Elsevier Scientific Publishing Company, Amsterdam.

WALMSLEY, R.D. & BOTTEN, M.L. (eds.) 1987. Proceedings of a Symposium on the Conservation of Wetlands in South Africa, Report Series No 28, Ecosystem Programmes. Foundation for Research Development, CSIR, Pretoria.

WALTER, H. 1973. Vegetation of the earth. Springer-Verlag, New York.

WALTER, H. & LEITH, H. 1960. Klimadiagram-Weltatlas. Jena, Fisher.

WATSON, J.P. 1993. Bestuursplan van Soetdoring Natuurreservaat. Unpublished Report for the Department of Environmental Affairs and Tourism, Free State Province.

WERGER, M.J.A. 1973a. Phytososiology of the Upper Orange River Valley, South Africa. Unpublished Ph.D. thesis, University of Nijmegen.

WERGER, M.J.A. 1973b. An account of the plant communities of Tussen-die-riviere Game Farm, O.F.S. *Bothalia* 11: 165-176.

WERGER, M.J.A. 1974. On concepts and techniques applied in the Zürich-Montpellier method of vegetation survey. *Bothalia* 11: 309-323.

WESTHOFF, V. & VAN DER MAAREL, E. 1978. The Braun-Blanquet approach. In: Classification of plant communities, ed. R.H. Whittaker. Junk, The Hague.

WHITTAKER, R.H. 1978. Classification of plant communities. Junk, The Hague.

WIEGAND, T., JELTSCH, F., BAUER, S. & KELLNER, K. 1998. Perspective article: Simulation models for semi-arid rangelands of southern Africa. *Afr. J. Range For. Science* 15(1 & 2): 48-60.

WILLIAMS, T.E. 1980. Herbage production: grasses and leguminous forage crops. In: Grass - it's production and utilization, ed. W. Holmes. pp. 6-69. Blackwell Scientific Publications, Oxford.

WILLIAMS, W.D. 1985. Biotic adaptations in temporary lentic waters, with special reference to those in semi-arid and arid regions. *Hydrobiologia* 125: 85-110.

WILLIAMS, D.D. 1987. The ecology of temporary waters. Croom Helm, London & Sydney.

YOUNG, E. 1984. Wildboerdery en natuurreservaatbestuur. Eddie Young Publishers, Swartklip.

ZALOUMIS, E.A. & MILSTEIN, P. le S. 1975. The conservation of wetland habitats for waterfowl in southern Africa. In: Wetlands and waterfowl - a vulnerable heritage. *Supplement to African Wildlife* 29 (1): 1-12.

APPENDIX 1

PHOTOS: Figures I – XII

Figure I: The outer edge of the Northern Pan. The pan remained inundated after the summer rains of 2002, for the entire growing season. Some of the grasses and pioneers have, however, already colonised the edges of the Northern Pan where the water has receded.

Figure II: The Southern Pan in Soetdoring Nature Reserve, as seen from the lunette dune. The large bare areas (A) between patches of mostly *Diplachne fusca* is visible, as well as the karroid shrubs and grasses of the lunette dune (B).

Figure III: An extensive *Diplachne fusca* stand in the Southern Pan basin, surrounded by bare areas.

Figure IV: Earth Dam A inside the Southern Pan, as seen from higher ground. The soil mound wall of the dam is visible on the left hand side.

Figure V: The dominant *Phragmites australis* and *Juncus rigidus* zones of the hot spring located inside the Southern Pan.

Figure VI: A grass covered island near the hot spring, present on a higher elevation than the pan floor.

Figure VII: A dominant stand of *Themeda triandra*, with *Digitaria eriantha*, *Sporobolus fimbriatus* and other climax grasses, representing the best grassland in the reserve.

Figure VIII: An example of the mosaic pattern of the grassland, incorporating patches dominated by (A) climax grassland, (B) *Nidorella resedifolia* communities, (C) pioneer grass communities, with *Aristida* and *Eragrostis* species, and (D) dwarf karroid shrubs.

Figure IX: A dominant stand of *Eragrostis trichophora* and dwarf karroid shrubs.

Figure X: Disturbed grassland, dominated by *Aristida* species and dwarf karroid shrubs.

Figure XI: An example of the mutual territories of Black Wildebeest, Blesbok, Red Hartebeest and Springbok. This karroid grassland covers a large area and is dominated by dwarf karroid shrubs, along with some pioneer grasses.

Figure XII: An area of the grassland that resembles the Karoo, in the sense of the dominance of dwarf karroid shrubs and the presence of few other species. This degraded grassland is an excellent example of the level of disturbance in areas of Soetdoring Nature Reserve.

APPENDIX 2

Table 6.1

Table 8.1

Table 9.1

Table 10.1

Table 6.1: Phytosociological table of the vegetation in the pans of Soetdoring Nature Reserve

Number in table	28	29	26	27	41	40	38	20	21	37	32	34	35	25	19	33	36	23	24	31	12	30	13	17	45	46	59	14	39	42	43	44	1	18	15	16	57	55	5	6	58	56	8	53	11	49	52	9	10	50	51	2	3	4
Database nr.	37089	37090	37087	37088	37102	37101	37099	37081	37082	37098	37093	37095	37096	37086	37080	37094	37097	37084	37085	37092	37073	37091	37074	37078	37106	37107	37120	37075	37100	37103	37104	37105	37062	37079	37076	37077	37118	37116	37066	37067	37119	37117	37069	37114	37072	37110	37113	37070	37071	37111	37112	37063	37064	37065
Community number														1														2					3										4										5	
Subcommunity number	1.1				1.2						1.3							1.4			1.5							2.1		2.2					4.1		4.2						4.3			4.4								
Species Group A																																																						
Hemarthria altissima	b	5	5	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Xanthium strumarium	1	.	b	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cyperus denudatus	5	.	.	3	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	b	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Species Group B																																																						
Panicum schinzii	.	.	.	.	.	.	.	.	.	.	1	4	5	b	.	4	1	.	.	.	.	b	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Echinochloa holubii	.	.	.	.	.	.	.	.	.	.	b	1	1	b	5	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Verbena brasiliensis	.	1	.	.	.	.	.	.	.	.	1	.	.	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	b	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Frankenia pulverulenta	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	+	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Species Group C																																																						
Portulaca oleracea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	b	b	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Chenopodium murale	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cotula microglossa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Limosella longiflora	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	b	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Species Group D																																																						
Eleusine coracana	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	b	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Bulbostylis burchellii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Species Group E																																																						
Cynodon transvaalensis	.	b	.	.	5	5	5	5	5	5	4	b	b	b	.	3	5	5	.	1	.	3	.	.	.	.	.	.	.	.	.	.	.	.	1	b	4	.	.	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.
Gnaphalium declinatum	.	b	1	.	.	.	+	.	.	4	.	.	.	4	.	.	+	1	+	1	1	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Alternanthera sessilis	.	.	.	.	.	.	.	.	.	.	1	.	.	1	+	.	+	.	3	3	1	.	b	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Agrostis lachnantha	.	.	.	1	.	.	.	.	.	.	.	.	.	b	.	.	.	.	.	.	.	1	b	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Species Group F																																																						
Sporobolus ioclados	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	b	.	.	.	b	b	.	.	.	.	b	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Salsola glabrescens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	b	b	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Species Group G																																																						
Eragrostis bicolor	.	.	.	.	.	.	.	.	.	b	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	3	3	4	4	3	.	.	.	.	b	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lycium horridum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Species Group H																																																						
Diplachne fusca	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	4	5	4	b	.	3	3	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Species Group I																																																						
Helictotrichon turgidulum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Panicum coloratum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	b	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eragrostis plana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	b	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eragrostis obtusa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Species Group J																																																						
Cyperus bellus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eragrostis biflora	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	b	b	b	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Species Group K																																																						
Digitaria eriantha	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	b	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	3	4	3	.	.	.	.	.	.	.	.
Selago dinteri	.	.	.	.	.	.	1	+	1	b	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	b	.	.	.	.	.	.	.	.	.	.	.	.	.	.	b	b	b	.	.	.	.	.	.	.	.	.
Species Group L																																																						
Phragmites australis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	b	b	5	5	5	5	.	.	.
Species Group M																																																						
Juncus rigidus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	4	b	5	5	3	4	.	3	3	5	1	3	1	b	.	.	.	.
Species Group N																																																						
Sporobolus virginicus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	4	b
Species Group O																																																						
Cynodon dactylon	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	3	.	4	.	.	.	.	.	.	.	.	3	5	.	4	5	b	5	.	.	3	4	b	.	.	.	4	.	.	.	.	.	.	.
Phyla nodiflora	.	.	.	1	.	.	1	+	.	.	.	.	.	.	b	.	1	b	.	.	b	1	b	.	.	.	.	.	.	.	.	b	b	b	b	b	.	b	.	.	b	b	.	.	.	.	.	.	.	.	.	.	.	.
Polygonum aviculare	.	1	.	.	.	.	.	1	+	.	.	.	.	.	1	.	b	b	.	.	.	.	.	+	.	.	.	.	.	1	b	1	.	.	b	b	b	1	b	1	.	b	.	.	.	.	.	.	.	.	.	.	.	b

Species with an occurance of less than 5 have been omitted from the table.

Table 8.1: Phytosociological table of the grassland of Soetdoring Nature Reserve

Table number	1	1 1 1 1	1 1 1 2	1 1 1 1 1 1 2 2 2 2	1 1 1 1 1 1 1 2 2	2 2 1 2 2 1	1 2 1 1 1 1	1 1 2	1 1 1 1 1 2 2	1 2 2 2 2	1 1 1
	4 6	5 1 2 4 3 8 1	1 1 9 1 8 3	1 2 4 4 5 7 8 1 2 2 2	2 3 3 4 5 5 6 6 0 3	1 2 6 6 2 2 3	9 1 7 9 8 9	5 6 6 6 7 7 3 3 0	1 2 4 4 5 0 0	5 6 8 7 0 1 1 2	3 9 9
	8 4 7	6 6 5 2 7 2 7	8 7 2 5 3 3 3	4 7 1 8 9 7 6 8 6 7 8	0 0 4 9 4 8 3 6 5 1	1 0 3 0 4 9 7	0 3 2 1 9 3	3 0 1 7 7 9 1 2 1	1 3 5 7 2 3 7	4 4 8 5 6 7 9 5	9 2 4
Database number	3 3 3	3 3 3 3 3 3 3	3 3 3 3 3 3 3	3 3 3 3 3 3 3 3 3 3 3	3 3 3 3 3 3 3 3 3 3	3 3 3 3 3 3 3	3 3 3 3 3 3	3 3 3 3 3 3 3 3 3	3 3 3 3 3 3 3	3 3 3 3 3 3 3 3	3 3 3
	6 6 6	6 6 6 6 6 6 6	6 6 6 6 6 6 7	6 6 6 6 6 6 6 7 7 7 7	6 6 6 6 6 6 6 6 6 7	7 7 6 6 7 7 6	6 7 6 6 6 6	6 6 6 6 6 6 6 6 6	6 6 6 6 6 6 6	6 6 6 6 6 7 7 7	6 6 6
	7 7 9	9 9 7 9 7 9 7	7 9 7 8 9 9 0	7 9 9 9 9 9 9 0 0 0 0	7 9 9 9 9 9 9 9 9 0	0 0 8 9 0 0 9	9 0 9 9 9 9	8 8 8 8 8 8 9 9 9	9 9 9 9 9 9 9	8 8 8 9 9 0 0 0	9 9 9
	6 9 5	4 0 7 3 9 7 7	7 0 5 8 0 7 2	6 1 3 3 4 6 7 0 1 1 1	7 1 2 3 4 4 5 5 9 2	0 0 5 4 1 1 2	7 0 6 8 7 8	4 4 5 5 6 6 2 2 9	0 1 3 3 4 9 9	4 5 7 6 9 0 0 1	2 8 8
	1 7 6	5 5 8 1 0 1 0	1 6 5 4 2 2 2	7 6 0 7 8 6 5 7 5 6 7	3 9 3 8 3 7 2 5 4 0	0 9 2 9 3 8 6	9 2 1 0 8 2	2 9 0 6 6 8 0 1 0	0 2 4 6 1 2 6	3 3 7 4 5 6 8 4	8 1 3
Community number	1	2		3		4	5				
Subcommunity number		2.1	2.2	3.1	3.2		5.1		5.2		5.3
Variant number							5.1.1	5.1.2	5.2.1	5.2.2	
Species Group A											
Salsola glabrescens	r 1 3	.	.	+ 1	1	1	.	.	1 +	.	.
Species Group B											
Eragrostis chloromelas	.	3 a	4 1	.	.	a	.	.	.	1	.
Brachiaria eruciformis	.	1 1 1	1	1 a b	.	.	.	+	.	.	1
Species Group C											
Hypertelis salsoloides	.	.	.	.	+ + + + +	.	.	.	r	.	.
Asparagus glaucus	.	.	.	.	1 1 1	.	.	1	.	.	.
Trichodiadema barbatum	.	.	.	.	1 1 a	.	.	.	.	.	.
Felicia muricata	.	.	.	+	a 1 1 1	.	.	.	.	.	.
Mestoklema arboriforme	r a	.	.	.	r 1	.	.	.	.	.	.
Species Group D											
Eragrostis trichophora	.	.	.	r 3 b 3 b 1 a a	5 5 4 5 5 4 4 4 4	.	.	3	.	.	.
Chloris virgata	.	.	.	b 1 a 4 a 1 1 1 a	1 1 + 1	a a	.	.	1	.	.
Aristida adscensionis	.	.	.	4 a 1 1	1 1 1	.	.	.	.	.	4 4 4
Sporobolus ludwigii	.	.	.	1 + + 1	1 a +	.	.	.	.	.	.
Salsola kali	.	.	.	1 1	+	.	.	.	.	.	.
Species Group E											
Sporobolus fimbriatus	1	.	.	.	a	1 4 a a 4 1	1 a	.	.	1 1 1 a a 3 a 3	.
Species Group F											
Hertia pallens	.	.	.	.	.	.	1 a b	+ 1 + + 1 r	.	r	.
Digitaria argyrograpta	.	.	.	.	.	.	b 1 a	a + 1	.	.	.
Hibiscus pusillus	.	.	.	.	.	+	+	+ r r r	.	.	1
Species Group G											
Melolobium candicans	.	.	.	.	.	.	1 a 1 a	+	r	.	.
Helichrysum herbaceum	.	.	.	.	.	.	b a 1	.	.	.	.
Eragrostis curvula	.	.	.	.	.	1	a 1	.	.	.	.
Species Group H											
Rosenia humilis	.	r	.	1 1	1	1	.	a + + + + +	.	.	.
Lycium horridum	.	.	.	1	+ 1 1 1	1 +	.	1 + + 1	1	.	.
Cyperus rupestris	+	.	r +	+	4 + + +	.	.	+ r +	+	.	.
Conyza podocephala	.	.	.	+ +	.	1	.	r r + +	.	.	.
Species Group I											
Eragrostis lehmanniana	a	.	.	a 4 a	.	.	.	1 1 a	4 1 a a a a 1	1 a 1 a a	.
Eragrostis superba	.	.	.	.	.	.	.	1 3 1	1 1 1 1 1	4 1 + 1 1	.
Species Group J											
Chenopodium album	.	.	.	3	.	+ 1	.	.	1 + 1 1	.	.
Heteropogon contortus	.	.	.	.	.	a	1	a	a 4 1	.	.
Species Group K											
Cymbopogon plurinodis	.	.	.	.	.	1 1	1 3 b 1 1	1 1 1 1 1	1 a	1 a 3 1 b 1 1	a b a
Nenax microphylla	.	a	1	.	.	a 1	1 b 3	+ a	a 1 1	1 1	a
Pentzia globosa	a	1	1	.	.	1 1	1 1	+ 1 1	+ 1	+	1
Species Group L											
Digitaria eriantha	a	.	1 3 5 1 a a	a a b a a 1 b	1 a 1 1 1	a a 3 a 3 4 a	4 4	1 a 3	1 a 1 b a	1 3 1 3 1 a a	.
Species Group M											
Themeda triandra	.	4 1 5 4 5 4 5	5 1 b 5 4	a b 4 a 4	1	5 5 5 1 1 4	4 b 3 1 b 4	4 5 + 5 5 a 5 5 3	3 1 1 4 3 4	1 1 b 3 a 1 1	1 1 1
Species Group N											
Nidorella resedifolia	a	1 + 1 a	+ 1 1	a 1 a a 3 3 + + 1 + 1	r + 1 + 1 + 1	+ + 1 1 1 1	+ + + +	r	1 1 1	1 + +	+
Panicum coloratum	1	1 a 1 1	a 1 1	a a 1 1 a	1 1	a 1	a	+ 1 1 1 1	1 +	1 r a	1
Commelina africana	.	+	1 +	.	+ + 1 +	1 1 1	.	+ r + + 1	r 1 1	r 1 1 1 1	.
Selago dinteri	1	1 1	.	1	+ a 1	+	1	+ 1 a 3	1 1 1 1	.	.
Berkheya pinnatifida	.	+ r +	1 r 1	+ +	1	+	+ 1 1	+ + +	r + +	+ + + + +	.
Schkuhria pinnata	.	.	a a 4 1	1 a	r + +	a	.	r +	r + a	+	.
Tragus koelerioides	.	+	r	.	+ + 1 +	+	+	1 r + r + 1 1	.	+	+
Eragrostis obtusa	r 1	1 1 r	1 1	a 1 a 1	1 1 + 1	1	.	1 1 1	1	.	1
Aristida congesta	5 a 1	1 1	.	b 1 1	1	1	.	1 1 1 1 1 1	a 1	r 1 1	a 1
Ledebouria luteola	.	r +	r 1	+ + + +	+ +	.	+ 1	+ + r	+	+ r +	.
Oxalis depressa	.	+	+	+	+ +	+	.	+	+ + + +	+	.
Agrostis lachnantha	.	.	.	.	1	r +	.	.	.	.	.
Chrysocoma ciliata	.	+ +	+	+ 1	1	.	1	+ +	+	.	.
Monsonia angustifolia	.	.	r	r	+	.	.	+ r +	.	+ +	.
Pogonarthria squarrosa	.	.	.	b	1	.	.	.	1 4	.	.
Urochloa panicoides	.	a	a	1	.	b + a	.	.	.	.	.
Pterodiscus speciosus	.	+	.	1	.	.	+	.	.	.	.
Hibiscus trionum	.	.	.	+	.	+	.	1 r	.	r +	.

The rare species with less than 4 ocurrances on the table, have been omitted.

Table 9.1: Phytosociological table of the karroid grassland of Soetdoring Nature Reserve

Table number		2 . . 2 . 1 .	1 . . . . . 1 1	1 . . 1 2	1 1 . 1 2 1 1	. 1 . . .	. . 1 1 1 1 1	 1	1 1 1 2 1 1	1 . . 1 . 2 . 2 1 .	1 . . . . 1 .	1 1 1 . 1 1 2 2 . . 2 1 .	. . 1 . . .
	2 . . 2	1 1 4 0 5 1 1	3 4 4 6 6 8 0 0	4 0 5 0 3	6 1 8 7 1 7 7	9 9 7 9 8	7 7 0 0 8 8 8	3 3 6 3 3 7 7 0	7 2 7 3 4 6	1 4 9 5 3 1 3 5 4 2	4 2 5 5 8 7 9 9 9 1 8	6 2 1 5 1 9 3 3 . 2 3 9 2	8 4 7 3 4 2
	8 7 9 2	6 0 7 4 8 4 1	8 0 2 2 6 7 2 3	6 7 9 6 8	9 9 5 3 5 1 8	3 4 6 1 0	4 5 0 5 0 1 5	0 4 8 3 1 3 8 8	4 0 9 9 3 4	9 0 8 6 6 6 5 7 0 1	9 6 0 1 3 2 0 9 2 2 4	1 5 5 2 8 6 4 6 6 4 7 9 7	1 1 0 6 5 9
Database number	3 3 3 3	3 3 3 3 3 3 3	3 3 3 3 3 3 3 3	3 3 3 3 3	3 3 3 3 3 3 3	3 3 3 3 3	3 3 3 3 3 3 3	3 3 3 3 3 3 3 3	3 3 3 3 3 3	3 3 3 3 3 3 3 3 3 3	3 3 3 3 3 3 3 3 3 3 3	3 3 3 3 3 3 3 3 3 3 3 3 3	3 3 3 3 3 3
	6 6 6 6	7 6 6 6 6 6 6	6 6 6 6 6 6 6 6	6 6 6 6 7	6 6 6 6 7 6 6	6 6 6 6 6	6 6 6 6 6 6 6	6 6 6 6 6 6 6 6	6 6 6 7 6 6	6 6 6 6 6 6 7 6 7 6	6 6 6 6 6 6 6 6 6 6 6	6 6 6 6 6 6 7 7 6 6 7 6 6	6 6 6 6 6 6
	7 7 7 7	0 7 8 9 8 9 7	9 7 7 8 8 8 8 8	7 8 8 8 0	9 9 8 9 0 9 9	8 8 9 8 8	8 8 8 8 9 9 9	7 7 8 7 7 8 8 8	9 9 9 0 9 9	7 9 8 8 9 7 0 8 0 9	8 9 8 8 8 8 8 8 8 9 8	9 9 9 8 9 9 0 0 7 7 0 9 7	8 7 9 7 7 7
	8 6 6 7	0 6 3 9 4 0 6	2 9 9 5 5 7 9 9	9 9 4 9 2	5 0 7 6 0 6 6	8 8 6 8 6	6 6 8 9 6 7 7	8 8 5 8 8 6 6 9	6 0 6 2 3 5	7 2 8 4 2 6 2 4 2 1	3 1 3 4 7 6 7 8 8 0 7	5 1 0 4 0 8 2 2 5 7 2 8 8	7 9 5 8 9 8
	1 0 2 5	5 3 6 3 7 3 4	7 3 5 1 5 6 1 2	9 6 8 5 7	8 8 4 2 4 0 7	2 3 5 0 9	3 4 9 4 9 0 4	3 7 7 6 4 2 7 7	3 9 8 8 2 3	2 9 7 5 5 9 4 6 9 0	8 5 9 0 2 1 9 8 1 1 3	0 4 4 1 7 5 3 5 9 7 6 8 0	0 4 9 9 8 2
Major community number	1						2			3			
Community number	1.1				1.2		2.1	2.2	2.3	3.1			3.2
Subcommunity number	1.1.1	1.1.2	1.1.3		1.2.1	1.2.2				3.1.1		3.1.2	
Variant number			1.1.3.1	1.1.3.2						3.1.1.1	3.1.1.2		
Species Group A													
Eragrostis trichophora	+ 5 5 3									. . . 1			
Species Group B													
Commelina africana	. + . +	+ + + ...	. . . + . r r .	. r . r .								. + ...	
Hibiscus pusillus		. r 1 . . . r	. . . r	. . + . +						. . . . + .			
Pterodiscus speciosus	. r r .	. r	. + ...	r									. + ...
Species Group C													
Themeda triandra	4 . . .	4 5 5 5 4 4 4	4 5 5 5 5 5 5 5	+ 1 1 1 +	3 5 1 5 b 1 4	1 1 1 . 4					. . 1 1		
Species Group D													
Eragrostis lehmanniana		. . . . . 1 .		. a + . .	. . 1 . . 1 .	b . . . 1	4 b + 4 1 5 4				. 1	. b	
Pentzia globosa			1 1 1 + + 1 1 1		1 1 1 1 1 . 1	. + . . 1	. . . 1 . 1 1	1 1 a . 1 + + 1	. . . 1 . .	1 a 1	. + ... r 1 . . .	. . . . 1 .	. + ...
Panicum coloratum	1 . . .	 1	. 1 1 a 1 . . .	a a . . .	. 1 . . 3 . .	. . . 1 1	+	. . 1 . 1 1 1 1	. 1 . 1 1 .		. . . 1 a	1 . . . . a . . .	1 4
Selago dinteri			a . . + ...	 1		. . 1 . .	3 + ...	 1	+ + . 1 1 .				
Asparagus glaucus		1	. . . . 1 . . .		. . . b . . .	 1		. . 1 . . + . .	. . . . . a		. . . + ... + . .		
Monsonia angustifolia	. . + .		. . . r		. + . + . . .	. . . . r	r r						
Species Group E													
Conyza podocephala		. . . + . . .	. . . r		1	. + . . .	+ . . . + . +	r + + . 1 1 . .	+ . . . + +		. . . . . + . . . + .		+ . . . . r
Species Group F													
Sporobolus ludwigii						. + . . 1				+ 1 a a 1 1 1 a + +	1 1 1 + 1 1 b + 1 . .		r . . . . .
Species Group G													
Felicia muricata	. . + 3	. + ... 1	. . . 1	a . . b b	. 1 + ...	. . 1 . .	. . b + . . .			+ 3 1 3 . a 3 3 b 1	1 b 1 3 + . 1 a a a a	4 a b b a a 1 3 b a 3 a a	
Cyperus rupestris	. . . b	. 1 1 . + . +	. . . . + . . .	. . r . .		. . . . +		+ 1 . + ...		1 + . + + . + + . .	+ . . . + r . r + r +	. + r r r . + . . 1 + . .	. . . . + 1
Species Group H													
Eragrostis chloromelas		. . . . . 1 .				4 3 b 4 a		. . . . 5 . . .			a . 4 . 1 . 1 1 . a .	. . . 1 . . . . +	. 4 . . . 1
Brachiaria eruciformis					. 1 . a 1 . 1	1 . a 1 1		. . 4 + ...	1	. 1	3 . . 1 1 3	. . . . 4 . . . 1 . a . .	1 1 . . . .
Mestoklema arboriforme	. + . .		. 1	a	. . . . . 1 .	r		1 . . + ...		. . . . . . 3 . . .	. b . . . . r . 1 . .	. . . . 1 1 + . . .	 1
Species Group I													
Chloris virgata			. . . . + . . .	. . . . b	b . r . . b 1	. . 3 r .	a 1 . . 1 b r		4 a b 1 1 1	. + . r a 1 1 . 1 a		3 . . . 1 b b 1 + . 1 1 +	. . b . . .
Aristida adscensionis		1		. . . r 3	. 1 . 1 . . .	. 1 1 . .	. . . . 1 1 .	 1	. 4 1 b 1 .	. . . + . . 1 . b 3	a . 1 1 . . 1 . . a 1	. 1 . 1 b . 3 b . . b . .	
Tragus koelerioides		. . . . + + +		1 1 r 1 .	. . . . . a .		1 . . + . . .	. . . . + . . 1	. + ...	. 1 . . 1 1	. . . . r 1 . . . r .	. . 1 . 1 . . + ...	
Aristida congesta				1 1 + a .	b	1	. . 1 1 . . +	. + . 1		. . + . 1	. . . . . 1 1	. . 1 . b . . + ...	
Lycium horridum	. + + r		. . . . + . . .	. . r r .	. . . . . . +		. + + 1 . + .	1 1 . r . r . .	. . . 1 1 .	. 1 . . . . . . 1 .	. 1	1 1 . . . . 1 . . .	
Species Group J													
Nidorella resedifolia	1 . . .	1 . 1 1 + . .	1 1 a + . + 1 1		3 . . 1 + . 3	+ r . . r	1 . . . . 1 1	a 4 3 4 a 4 1 4	a . 3 . 3 5	5 b r r 4 + 3 . . .	1 . + . r + 3 . . b r	1 . . . + 1 + + . . 1 3 .	4 1 . a 1 a
Salsola glabrescens	+ 1 1 b	1 . 1 . 1 1 .	. . . a + + . 1	1 . 1 . .	a + 1 . 1 3 .	+ 1 a + .	1 a r + 1 . .	. 1 1 1 1 1 1 1	1 1 . . 1 1	a . . b + 1 a a . a	1 1 + 1 1 a 1 1 a 1 1	a a a a b a 1 b 3 . a . a	1 1 a . . .
Rosenia humilis	1 + 1 .	+ . . 1 b . .	. + 1 . + . + .	. . b a .	. . 1 . 1 1 +	1 + 1 + +	. 1 1	. 1 . . 1 1 4 .	. . . b . .	. 1 1 . . . . 1 1 .	a . 1 1 . 3 + a 1 1 1	. . 1 + . . 1 1 . b a . a	. a 1 a 1 1
Eragrostis obtusa	. . . a	. . . 1 a 1 .	. . . 1 1 + . .	1 1 + 1 .	. 1 . 1 + 1 .	1 a 1 + .	a b . 1 . . .	. + 1 + 1 1 b .	. . . . 1 .	. 1 . + . + . + 1 1	. a . . . 1 . 1 . 1 .	1 1 . 1 a 1 a a . . 1 . .	. + 1 3 . +
Berkheya pinnatifida	r . . .	. + + . r . +	. + 1 . r + . .	 1	. . . + . . +	. . . r .	. . . r . . .	+ + . 1 . . + .	r	. . . . . . r . + .	+ . + ...	+	. + . . r +
Schkuhria pinnata		+	. . . . . . + 1		. 1		. . . . . . +		a		. . . . r		
Ledebouria luteola	. r . .	+ . + . + + r	. + . + . r . r	1 + + + .	. . + . . + .	1 r . + .	. . + + . . .		. . + . . .	. . . . + . .	+ . . + + . + . + . .	. . r + ... r	. . . . + +
Chrysocoma ciliata		. . . . . + .	1		. 1	 1	r		. + . 1 . .			1	. . . . r .
Blepharis integrifolia				r . r . .			r			. . . . + . .	. . . . r .		

The rare species with less than 5 occurances on the table, have been omitted.

Table 10.1: Synoptic table of the pan and grassland vegetation of Soetdoring Nature Reserve

Vegetation unit	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Number of relevés included	4	3	7	3	4	2	4	2	2	2	3	6	3	4	3	3	3	6	7	9	7	8	7	7	7	8	5	7	5	11	10	4	7	2	8	6	10	11	12	7
Major group									A																				B											
Group					A1						A2				A3					B1							T								B2					
Species Group A																																								
Hemarthria altissima	V																																							
Xanthium strumarium	IV																																							
Species Group B																																								
Eleusine coracana	II	V																																						
Bulbostylis burchellii		IV																																						
Species Group C																																								
Panicum schinzii		II	V																																					
Echinochloa holubii			V																																					
Chascanum pinnatifidum			I																																					
Species Group D																																								
Cyperus denudatus	III	II	I																																					
Agrostis lachnantha	II	IV	I																II									I			+									
Species Group E																																								
Portulaca oleracea				V																																			+	
Chenopodium murale				IV																																				
Cotula microglossa				IV																																				
Limosella longiflora				II																																				
Species Group F																																								
Alternanthera sessilis		IV	III	IV																																				
Species Group G																																								
Cynodon transvaalensis	II	II	V	IV	V	V	III	V																I																
Phyla nodiflora	II	V	II	II	II	III	IV	V	V						II																									
Gnaphalium declinatum	III	IV	II	V		V																																		
Verbena brasiliensis	II		III						III																															
Species Group H																																								
Eragrostis biflora								V	III											I			I			I										I				
Cyperus bellus								V																																
Species Group I																																								
Helictotrichon turgidulum									V																															
Eragrostis plana									III															I																
Species Group J																																								
Juncus rigidus							V	III		V	IV	V																												
Scirpus species		II								III																														
Atriplex semibaccata										III																			I				I						+	
Dipcadi viride											II																													
Species Group K																																								
Phragmites australis												V																												
Cirsium vulgare												II																												
Setaria verticillata												I																												
Species Group L																																								
Sporobolus virginicus													V																											
Species Group M																																								
Sporobolus ioclados									III					II		V																								
Species Group N																																								
Ophioglossum polyphyllum																II																								
Species Group O																																								
Diplachne fusca													II	V	V	II																								
Species Group P																																								
Polygonum aviculare	II		II	II	III		IV	V		V			II	II	V																									
Cynodon dactylon		IV		V			V	V	III		II	I			II	II			I		I		I	I																
Eragrostis bicolor			I			III	II							II	V	IV																								
Frankenia pulverulenta			III							III																														
Species Group Q																																								
Aristida canescens																	V		I																					
Indigofera alternans																	II	I			I							I												
Elionurus muticus																	II																							
Dicoma macrocephala																	II																							
Fingerhuthia africana																	II					I																		
Species Group R																																								
Melolobium candicans																		IV		I	I																			
Helichrysum herbaceum																		III																						
Salvia verbenaca																		II		I																				
Senna italica																		I																						
Lycium cinereum																		I																						
Species Group S																																								
Verbena bonariensis																			I																					
Species Group T																																								
Crabbea acaulis																				II		I																		
Vahlia capensis																				I																				
Species Group U																																								
Asparagus suaveolens																					I																			
Species Group V																																								
Hermannia comosa																						I						I												
Eragrostis gummiflua																						I	I								+									
Setaria sphacelata																			I			I																		
Laggera decurrens																						I																		
Bulbine frutescens								III														I																		
Species Group W																																								
Cymbopogon plurinodis																	V	V	II	III	II	V																		
Eragrostis superba																				II	IV	IV					I													
Hertia pallens																		III		IV		I											I							
Heteropogon contortus																		I	I	I	III																			
Digitaria argyrograpta																		III		II					I		II													
Hibiscus trionum															II				I	II		II			I	I				+								+		
Eragrostis curvula																		II	I																I					
Species Group X																																								
Bidens pilosa																							I			I														
Solanum supinum																							I																	
Talinum caffrum																							I					I			+									
Papaver aculeatum																							I																	
Taraxacum officinale																							I																	
Species Group Y																																								
Teucrium trifidum																								I																
Tephrosia capensis																								I																
Species Group Z																																								
Nenax microphylla																	II	III	II	II	III	II	I	I		I														
Oxalis depressa												I							I	I	III	I	I	I				I		+	I									
Barleria macrostegia																	II			I				I																
Helichrysum zeyheri																				I				I					I		+									
Commicarpus pentandrus																			I					I		I		I		+										
Geigeria filifolia																			I	I					I				II											
Gnidia polycephala																II		I		I																				
Pseudognaphalium oligandrum																			I				I			I														
Haemanthus montanus																					I				I		I													
Species Group AA																																								
Aristida bipartita																													I											
Lactuca inermis																													I											
Hermannia coccocarpa																													I											
Species Group AB																																								
Eragrostis trichophora										III		I				II				I										IV	V	V					+			
Hypertelis salsoloides																					I										III		II							
Trichodiadema barbatum																															II	II	I					+	+	
Chortolirion angolense																																II								
Salsola kali																														I	+									I
Crassula setulosa																															+									
Triraphis andropogonoides																															+									
Ruschia hamata																															+									
Species Group AC																																								
Themeda triandra																II	V	V	V	V	V	V	V	IV	V	V	V	V	IV	III	+	II						I		
Digitaria eriantha											V	I				II		II	V	II	IV	V		V						IV	III									
Commelina africana																II			III	III	III	IV	I	II	III	II	II				II	III							+	
Monsonia angustifolia																				II		II		I		I		II	I	+	+	II	II							
Hibiscus pusillus			I	II													II	I	I	III					III	I	II										+			
Pogonarthria squarrosa																II					II									+	+									
Species Group AD																																								
Dipcadi ciliare																																			I			+		
Chamaesyce inaequilatera																																			I					
Species Group AE																																								
Bulbine narcissifolia																																				I				
Species Group AF																																								
Lycium pilifolium																																					+			
Species Group AG																																								
Trachyandra saltii																																						+		
Species Group AH																																								
Setaria nigrirostris																																								I
Species Group AI																																								
Salsola glabrescens																IV			I		II				III	III	II	IV	IV	I	+	V	IV	V	V	IV	IV	V	V	III
Felicia muricata																									II	I	III	II	I	+	II	III	II				V	V	V	I
Chloris virgata																II			II		I					I	I	III	II	V	II		IV			V	IV		IV	I
Aristida adscensionis																II									I		II	II	II	II	II		II		I	IV	II	III	III	
Mestoklema arboriforme																II										I	I	I	I		I	II		V	II		+	II	II	I
Conyza podocephala																			I	III					I	I		I	I	I			III		IV	III		I		II
Sporobolus ludwigii																													II	II	II						V	V		I
Asparagus glaucus																				I					I	I		I	I		II				II	I		I		
Felicia fascicularis																												II	I	+						II				I
Koeleria capensis																												I		+			I			I				
Blepharis integrifolia																				II							II						I							
Felicia filifolia																											I						I	III			+	+		
Ipomoea oenotheroides																									I												+			
Phyllanthus parvulus																										I														
Sphaeralcea bonariensis																														+										
Species Group AJ																																								
Nidorella resedifolia																	II	IV	V	I	III	II	III	III	III	V		III	III	V	IV	II	III	III	V	IV	IV	IV	III	IV
Panicum coloratum									V								II	I	II	III	II	II	III	III	I	III	II	II	II	III	I	II	I	III	IV	III		I	+	III
Eragrostis obtusa									III								II	I	I	II	I		III	II	III	II	IV	III	IV	II	II	II	III	V	IV	I	III	II	IV	III
Ledebouria luteola																		II		II	I	II	II	II	IV	III	IV	II	III	II	I	II	II			I	+	III	II	II
Berkheya pinnatifida									III									III	I	II	III	IV	III	III	III	III	I	II	I	I	+	II	I		III	I	+	III	II	II
Tragus koelerioides																IV	II	I	I	IV		I	I	I	III		IV	I		I	+	II	I		III	I	I	I	+	III
Rosenia humilis																II			I	IV			I		III	III	II	III	V	I	+	IV	II		III	I	II	V	III	V
Cyperus rupestris																				II	I			II	III	I	I		I	+	II	II		III	II		III	IV	III	III
Lycium horridum															V	II			II	III	I					I	II	I		+	II	IV	III		III	II	I	+	II	
Pentzia globosa																	II	II	II	II	II	I	I	I		V		V	II				III		V	I	II	II	+	I
Aristida congesta																	IV		I	IV	II	II	II				IV	I	I	II	+		III	V	II		I	I	II	
Brachiaria eruciformis																	II			I			III	I				III	IV	II					II	I	+	II	I	III
Eragrostis chloromelas											II								I			I	II	II	I				V						I			III	I	II
Schkuhria pinnata																			I	II	III	I		III	I	II		I		I	II		I			I		+		
Aptosimum indivisum																				I		I					I		I											
Thesium hystrix																II				I	I		I					I	II	+					I	I	+			
Limeum aethiopicum																					I									+	+						I			
Ruschia spinosa																				I											+						+		+	
Eriospermum cooperi																			I									I		+										
Pterodiscus speciosus																		I					I		I	I	I			+		III								I
Urochloa panicoides																			III				I	I						+						I		+		I
Chenopodium album																			II		III						I			+			I						+	
Enneapogon scoparius																		I			I							I												
Indigofera rhytidocarpa																					I																			
Tribulus terrestris																		I									I	I												I
Species Group AK																																								
Chrysocoma ciliata								III			IV					IV		I		II	I		II	I	I	I		I	I	I	+		I			II			+	I
Selago dinteri					III	V					V					II		I	I	III	III		II			II	I		I	+	II		II		I	IV				
Eragrostis lehmanniana											II					II				II	V	IV			I		II	II	II	II			V					+	+	
Sporobolus fimbriatus								III							II			II	V			V					I		I		+			III				+	+	
Pentzia incana								III													I			I	I	I	I	II	II	+								+		