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ECOLOGICAL MANAGEMENT OBJECTIVES AND MONITORING PROCEDURES FOR RUSTENBURG NATURE RESERVE, NORTH WEST PROVINCE

BY

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To Monique, Larize and Pierre

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Ecological management objectives and monitoring procedures for Rustenburg Nature Reserve, North West Province

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ABSTRACT

The physical and biological components of the Rustenburg Nature Reserve were analysed in order to classify and describe the vegetation on the reserve. This data was used to delineate homogenous management units for management and monitoring purposes. Four management units were identified. Multivariate processing techniques were used to create degradation gradients to developed an understanding of the dynamics of the vegetation in the different management units, as well as the response thereof to disturbances. The Integrated System for Plant Dynamics was used to develop degradation gradients and species response curves. Degradation gradients were interpreted in terms of species composition and appearance or disappearance of species along the gradient. Suggestions were also made with regards to a monitoring system to determine the direction and rate of change in each homogenous management unit. Past management strategies were evaluated and the effect it had on game and vegetation composition and structure were analysed. Future management actions, focussed at achieving the primary objective, *viz.* sustained yield of quality water, are suggested. The principle of adaptive management is also suggested as a management strategy.

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CHAPTER 1

INTRODUCTION

Enclosed protected areas are not independent, self-supporting ecosystems and therefore require management. A fundamental principle is that no biotic system is fixed or static. Protected areas are subjected to constant change through the effect of external events on the natural ecosystem (Scholes & Walker 1993), and also the ever-changing influence of modern man. Biotic systems are to a greater or lesser extent dynamic in space and time (Siegfried *et al.* 1982) and continuous review and adaptation of management policies and actions need to be recognised in the management of protected areas.

Determining the nature and direction of change is an important prerequisite to manage a dynamic system. It is also important to assess whether the change that occurred is within the permissible limits of that system, and whether it is conducive to the achievement of ecological management objectives. This can only be ascertained if management objectives have been determined (Coombes & Mentis 1992)

Scientific management involves strategies that are testable and refutable or irrefutable (Mentis 1980). Strategies in applied ecology may be classified as either of the deferred action type, or the adaptive type (Schmidt 1992). The deferred action is that systems cannot be managed until they are understood, therefore least disturbance is allowed until key processes are defined. In contrast, by applying adaptive management, problems are solved by taking a course of action of which the effect is then measured to establish to what extent objectives are achieved. The inherent variability of ecosystems and errors in observing and interpreting them is recognised (Mentis 1980).

Through the process of adaptive management, continuous monitoring improves the manager's knowledge of ecosystems and helps refine management plans (Ringold *et al* 1996). The aim of this process of adaptive management should be the achievement of the reserves' goals and objectives through the effective use of resources. Quantifying goals for the conservation of biological diversity provides a challenge to the manager, as it should be an achievable, testable and auditable target, with specified time and confidence limits (Bestbier *et al.* 1996).

Disturbance is regarded as an important component in many ecosystems, and variations in a disturbance regime can influence the structure and functioning of an ecosystem (Hobbs & Huenneke 1992). Before a desired disturbance regime can be applied to manage for a specific objective, its effect on the system needs to be verified. The Adaptive Management Approach allows management to use current knowledge to model possible effects to predict the outcome of a specific disturbance regime, i.e. herbivory. By interpreting the model it is possible to quantify the desired state of the ecosystem to achieve predetermined objectives. Subsequent monitoring will reveal any progress or regress in the achievement of reserve objectives.

The aims of the study are to investigate and quantify the changes that take place in an ecosystem when subjected to management practises such as herbivory or fire. Changes will be evaluated and interpreted according to degradation gradients to determine the influence on the achievement of reserve objectives. A further objective of this study is to develop a monitoring system to determine the direction and rate of change in each homogenous management unit. The aim of the monitoring system for Rustenburg Nature Reserve is to evaluate the progress or regress in achieving the ecological goals for the reserve, identified through the document "'n Prosedurele bestuursmodel vir provinsiale natuurreservate" (Fourie *et al.* 1993). This document gives an outline of the management process as it should be applied on provincial reserves. It specifically mentioned that the approach to resource management should be at ecosystem level, because of the immense number of species of which the majority is still unknown (Franklin 1993), and that it must be aimed at achieving reserves goals and objectives. It also showed the three requirements pertaining to the development of operational goals for reserve management (Coombes & Mentis 1992):

- realisable - possible to achieve
- measurable - the degree of attainment can be measured
- attainable - the time within which it must be attained is realistic and specified

In this study multivariate processing techniques were used to develop degradation gradients to determine ecological objectives for the reserve, and to interpret monitoring results. To minimize the effect of variation in the gradients in determining ecological goals for Rustenburg Nature Reserve, it was necessary to identify management units based on their homogeneity and practical application. Since plant associations reflect a particular range of uniform environmental variables, the description and classification of homogenous vegetation units form the primary basis for delineating homogenous management units for management and monitoring purposes (Schulze *et al.* 1994), which must be related to environmental factors. A full description of the physical components, i.e. geology, soil, hydrology and climate were therefore needed.

The integrative approach of the ISPD-system was considered essential to attempt to form an understanding of the dynamics of the vegetation in the different management units on Rustenburg Nature Reserve, as well as the responses thereof to disturbances, be it "artificial" (man-made, eg. stocking rate, species composition, controlled burning) or natural. Managing a system according to specific ecological objectives, requires an understanding of the response of the system to various external influences. The ecological management objectives of Rustenburg Nature Reserve are the conservation of the biological diversity associated with that system, as well as the sustained delivery of high quality effluent from this mountain catchment. The objectives of management of the vegetation component are therefore aimed at satisfying these above-mentioned goals.

By constructing a vegetation gradient depicting only the influence of external disturbances (or management actions) on vegetation composition and structure, the constancy or change and the direction of change in a system (Bosch & Kellner 1991) to be revealed by monitoring, can improve knowledge and provide guidance as to the type of management to be applied to most efficiently achieve the reserves' management objectives. This gradient will be interpreted in terms of species composition and appearance or disappearance of species along the gradient. The influence of management actions can then be quantified in terms of the position of a monitoring site along the gradient.

CHAPTER 2

GOALS AND OBJECTIVES OF RUSTENBURG NATURE RESERVE AND THE PRINCIPLES IN THE DESIGN OF A MONITORING SYSTEM

INTRODUCTION

Objectives are central to management, as management is not an end in itself, but only a means of achieving predetermined objectives and goals (Ferrar 1983; Coombes & Mentis 1992). To manage without clear objectives is a contradiction in terms and can be regarded as an aimless exercise (Coombes & Mentis 1992), with consequent inconsistent behaviour (von Gadow 1978). Socio-economic and political influences impacting upon protected areas also require clear objectives and goals and achievement thereof.

A vision is a broad philosophical statement of intent, while an objective is seen as more precise than the vision, but not necessarily achievable (Bestbier *et al.* 1996). The objective must support the vision in that it should expand upon the key elements of the vision and therefore provide a broad base to define the goals (Bestbier *et al.* 1996). A goal expands on the objectives and is considered as an achievable, testable and audible target, with specified time and confidence limits

(Bestbier *et al.* 1996) against which progress can be measured and provides a basis for rational planning (Coombes & Mentis 1992).

Applied ecology involves the accumulation and application of ecological knowledge to achieve predetermined goals in managing ecosystems (Mentis 1980; Schmidt 1992). Objectives range from pure conservation involving minimal management, through conservation for specific purposes requiring specific management activities, to exploitation of wildlife resources involving complete manipulation and control. Managing a reserve according to one or other economic objective, is simple in the sense that the habitat can artificially be altered and manipulated to provide for the specific needs of the animal or the desired vegetational composition to obtain maximum yields and to increase profits. The conservation of dynamic processes within a natural ecosystem is complex in the sense that it is impossible to manage it according to a specific baseline. A fixed baseline will not allow for the dynamic processes in the resource, as management will tend to recover any distortions from the baseline. It will therefore be necessary to determine the permissible change in the system that will not jeopardize ecological objectives and goals.

ECOLOGICAL OBJECTIVES FOR RUSTENBURG NATURE RESERVE

The vision for the Rustenburg Nature Reserve is:

To contribute to the socio-economic well-being of the people of the region through appropriate management of the wetland, its associated catchment and surrounding natural environment and allow for controlled nature-based outdoor activities

The key objectives of the reserve that would form the basis for prioritizing management activities in and around the reserve are:

- to ensure a supply of high quality water
- to maintain the scenic beauty and integrity of this area in the Magaliesberg
- to conserve biological diversity and natural processes and preserve the cultural and archaeological heritage
- to allow public access for
  - environmental education and research
  - outdoor nature-based recreation
- to increase the land area managed under the above objectives
- to more fully integrate the Rustenburg Nature Reserve with the surrounding community and to contribute to the local economy
- to manage the area in a cost-effective way and strive to at least achieve operational sustainability

Management of the natural resources in the reserve will focus on the conservation of biological and genetic diversity and the maintenance of the dynamic processes to ensure environmental sustainability. Parallel to this is the encouragement of sustained utilization of natural resources, which is primarily focussed upon tourism and the creation of opportunities for the public to experience nature.

Biodiversity involves more than species diversity(O'Connell & Noss 1992). According to Risser (1995) it occurs at several hierarchical levels, from genes to individuals, from populations, species, communities and ecosystems to landscapes. At each of these levels there are important relationships between biodiversity and ecosystem processes and between biodiversity and the way the ecosystem responds to disturbance and changing environmental conditions (Risser 1995). These relationships are complex and operate at many spatial and temporal scales.

Franklin (1993) recognizes three attributes of ecosystems:

- Composition
- Structure
- Function

These three attributes constitute the biodiversity of an area (Noss 1990). Composition includes measures of species and genetic diversity. Structure is the physical arrangement of the different elements of a system, and is a measure of the pattern of patches and other elements at a landscape scale. Function contains the ecological and evolutionary processes, and includes processes such gene flow, disturbance and nutritional cycles (Noss 1990).

Analysing the current objectives of the reserve - maintenance of biodiversity and setting limits to preserve soil - can be used as basis for determining ecological goals for Rustenburg Nature Reserve. As the overall statement of intent of the reserve implies the sustained yield of high quality water from the Waterkloofspruit, this parameter is an important indicator of the minimum condition of change that will be allowed in the proportional species composition and structure of the system on the reserve. If accepted, diversity at functional, structural and compositional scale must be maintained to meet the minimum condition requirement to obtain this.

An important fact is that Foran (1976) determined in the Mist Belt, Highland Sourveld and the Moist- and Dry tall grassveld that maximum diversity seems to occur in the mid to upper range of veld condition. Changes in veld condition over a wide range apparently involve mostly a change in proportional species composition. Species are however gained or lost only at the extremes. This is supported by Whyte *et al* (1999), stating that the intermediate hypothesis claims that the highest biodiversity at one point in time, will result from intermediate disturbance regimes, whereas fewer species will be present at extreme levels of disturbance, that is very high disturbance, or no disturbance. This fact provides a motivation to base this study on proportional herbaceous species composition or ß - diversity. Beta (ß) diversity is a measure of how different or similar a range of habitats or samples is in terms of the variety and abundance of species found in them. This is also necessary as the quantitative descriptive nature of this data is of value in the understanding of vegetation patterns.

Small mammals are important biological components of any natural system. They are important for nutrient recycling, habitat modification and soil dynamics, and as herbivores, predators or prey (Armstrong & van Hensbergen 1996). Small mammals have regularly been overlooked in the management strategies of protected areas, largely due to the fact that they are difficult to census. It is therefore important to understand how these animals relate to environmental features (Els & Kerley 1996). Studies have indicated that plant cover and structure (shrub canopy cover) are the most important correlates of small mammal communities and structure (Kerley 1992; Els & Kerley 1996). Fire has a marked effect on the floral and faunal composition of a region (Edwards 1984). The major impact of fire is not so much the killing of any animal (Breytenbach 1987), as the change in the physical environment and the vegetation structure (Els & Kerley 1996). Diurnal species, dependant on cover against predation, disappear from a burn within days (Breytenbach 1987). Studies in the Natal Drakensberg indicated that small mammal numbers peak after the third year, to levels higher than the pre-burn period.

These facts provide the framework for the formulation of broad ecological goals for Rustenburg Nature Reserve:

1. Ensuring the maintenance of a resilient ecosystem inside the reserve, capable of enduring excessive runoff and maximise absorption of water to deliver good quality runoff at a delayed rate
2. Ensuring the maintenance of diversity at all levels of the ecosystem
3. Managing faunal populations within the restrictions of 1 and 2 mentioned above, but ensuring a diverse and viable range of species to meet the objectives of 4
4. Improving the visitors' experience to the reserve by offering a variety and number of ungulates, habitats and landscapes, managed in an ecological sustainable way.
5. Sensitive and responsible development of infrastructure

Monitoring actions derived directly from these ecological goals have to be designed within the ecological limits of the goals, funding and statistical power to show change (Reilly & MacFayden 1992).

MONITORING THE DYNAMICS OF THE VEGETATION

Successful management of large areas of natural vegetation depends on the knowledge of the state of the vegetation and the extent and rate of change in response to herbivory and fire (Walker 1976). By measuring the state of the vegetation on a regular basis, trends and changes can be identified and the effect of management policies can be evaluated.

According to Mentis (1984), the general reason for monitoring is to detect the degree to which the objectives of management are achieved. Monitoring is defined as maintaining regular surveillance to test a null hypothesis of no change in predefined properties of a system that is vulnerable to impacts of which the nature, timing and location are not necessarily known (Mentis 1984). Hinds (1984) defined ecological monitoring as "the purposeful and repeated examination of the state or condition of specifically-defined biotic groups in relation to external stress". While research is conducted to increase our understanding of the ecological components and processes of ecosystems, monitoring measure the direction and rate of these processes (Macdonald & Grimsdell 1983) Macdonald & Grimsdell (1983) mentioned that where management is carried out to maintain a particular component of a system, monitoring should concentrate on the factors that have a direct bearing on that component. Monitoring is geared as an early warning system to detect changes or trends as a result of management or natural events (Coombes & Mentis 1992). Data collection should be sensitive enough to provide feedback to management to maintain that component within acceptable limits. Figure 1 describes the steps that are important in the development of a monitoring programme.

Efficient management cannot be achieved without an effective monitoring programme. For a monitoring programme to be effective and not an aimless activity, the objectives for the monitoring programme must be stated clearly (Aucamp *et al.* 1992). A monitoring programme should be focussed at providing the minimum information required to assess change and to interpret trends. Before a monitoring programme is initiated, the following should be considered:

- identification of important indicators
- objectives with each of these indicators
- determining the most effective monitoring technique and scale of monitoring to measure change and direction of change
- identification of the most appropriate procedures for data analysis and interpretation

Hinds (1984) identified three requirements for a successful monitoring system :

- It must be ecologically relevant
- It must be statistically credible
- It must be cost-effective

After the monitoring programme has been implemented and established, an initial

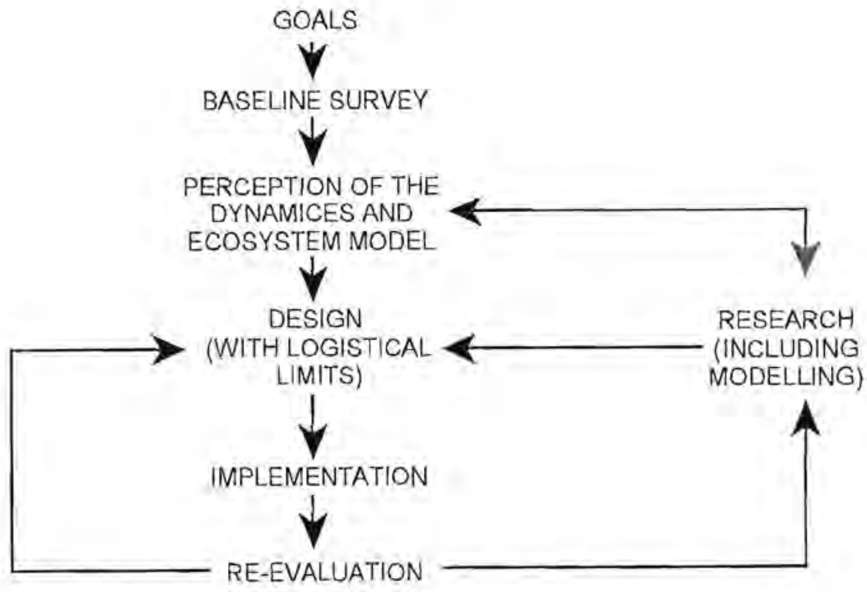

Figure 1: A framework for the development of a monitoring system (Ferrar 1983)

evaluation should be carried out to get confirmation for the following four questions (Macdonald *et al.* 1983):

- Do the data identify any weaknesses that should be researched?
- Have any important components of the system been left out in the initial monitoring?
- Are the procedures adequate and are the accuracy and the precision of the data collected satisfactory?
- Which measurements can be left out in future?

A well-designed monitoring technique becomes important when long-term trends in ecological structure and function have to be researched. The challenge is to develop monitoring techniques that is not only objective, but also more interpretable and quantifiable.

The hierarchy concept as suggested by Noss (1990) requires biodiversity to be monitored at multiple spatial and temporal scales, as the impacts of environmental stresses will be manifested at different levels of the system.

CHAPTER 3

STUDY AREA

PHYSICAL ENVIRONMENT

This study was done in the Rustenburg Nature Reserve, in the North West Province of South Africa. This reserve falls within the boundaries of the Magaliesberg Protected Nature Area and encloses a 17km^2 catchment area. This catchment is the main source of the Waterkloofspruit, a north-flowing perennial stream which flows into the Hex River which in turn feeds the Bospoortdam. Other smaller streams also have their origin in the reserve, a fact that underlines the importance of conserving this area. The reserve accommodates various forms of wildlife and has the potential to be one of the important centres for environmental education in the area.

The Magaliesberg forms a distinct climatic boundary (van Vuuren & van der Schijff 1970) between two major biomes, the savanna and the grassland (Rutherford & Westfall 1994; Low & Rebelo 1996). The mountain range, in which the reserve is situated, is according to Acocks (1988) a transition between the Sour Bushveld (veld type 20) and the Sourish Mixed Bushveld (veld type 19). However, Low and Rebelo (1996) regarded the vegetation type of this region as Mixed Bushveld (Veld type 18). The authors combined the Mixed Bushveld (veld type 18) and Sourish Mixed Bushveld (veld type 19) into one distinctive veld type and discarded the Sour Bushveld (veld type 20) as a separate veld type.

LOCATION

Rustenburg Nature Reserve borders the southern outskirts of Rustenburg, approximately 120 km west of Pretoria (Fig 2) at 25° 41' - 25° 45' South and 27°9' - 27°13' East. The reserve, which covers an area of 4 257 ha, comprises the two original farms Rietvallei 824JQ and Baviaanskrans 308JQ.

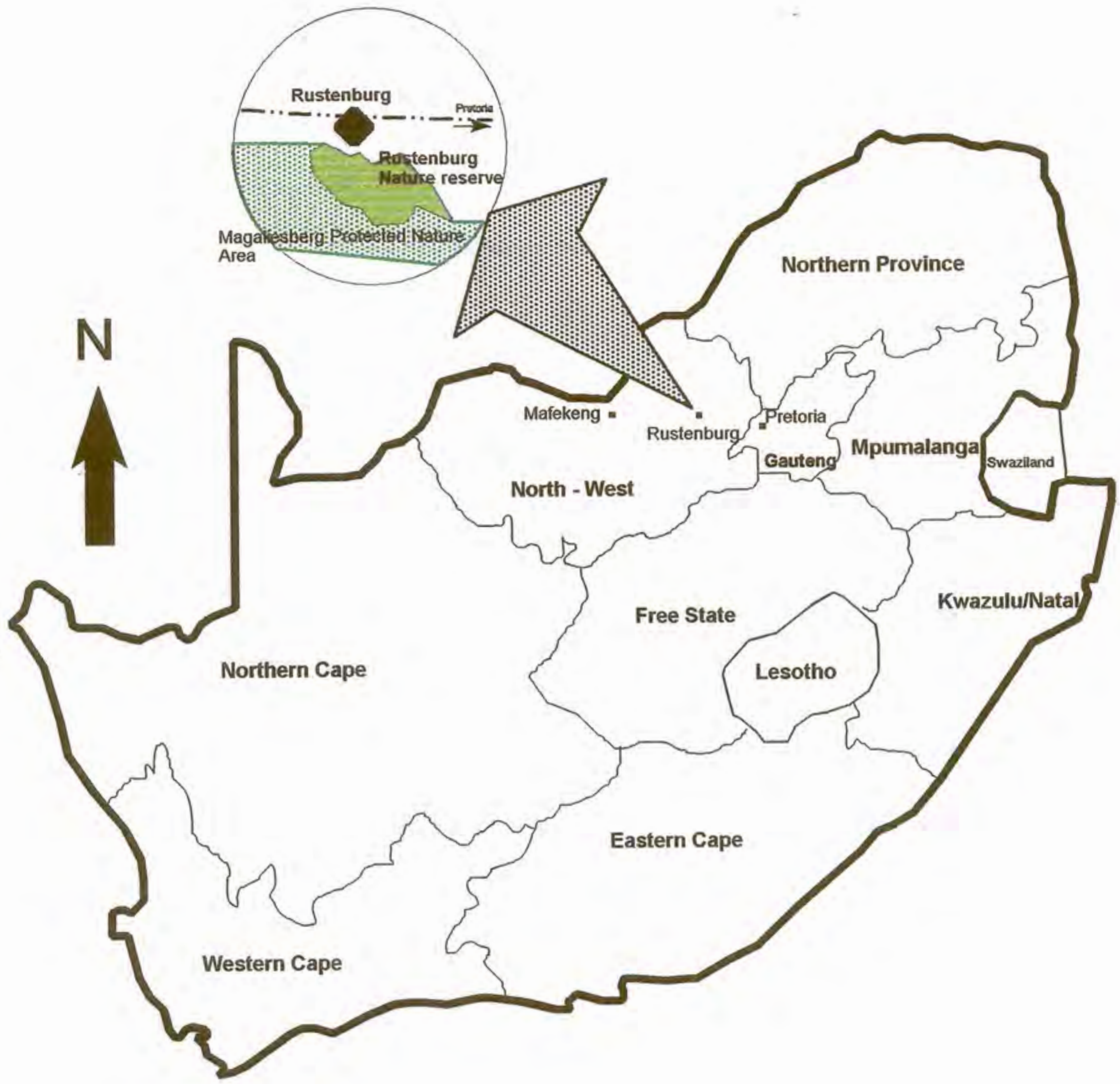

Figure 2: Location map for Rustenburg Nature Reserve

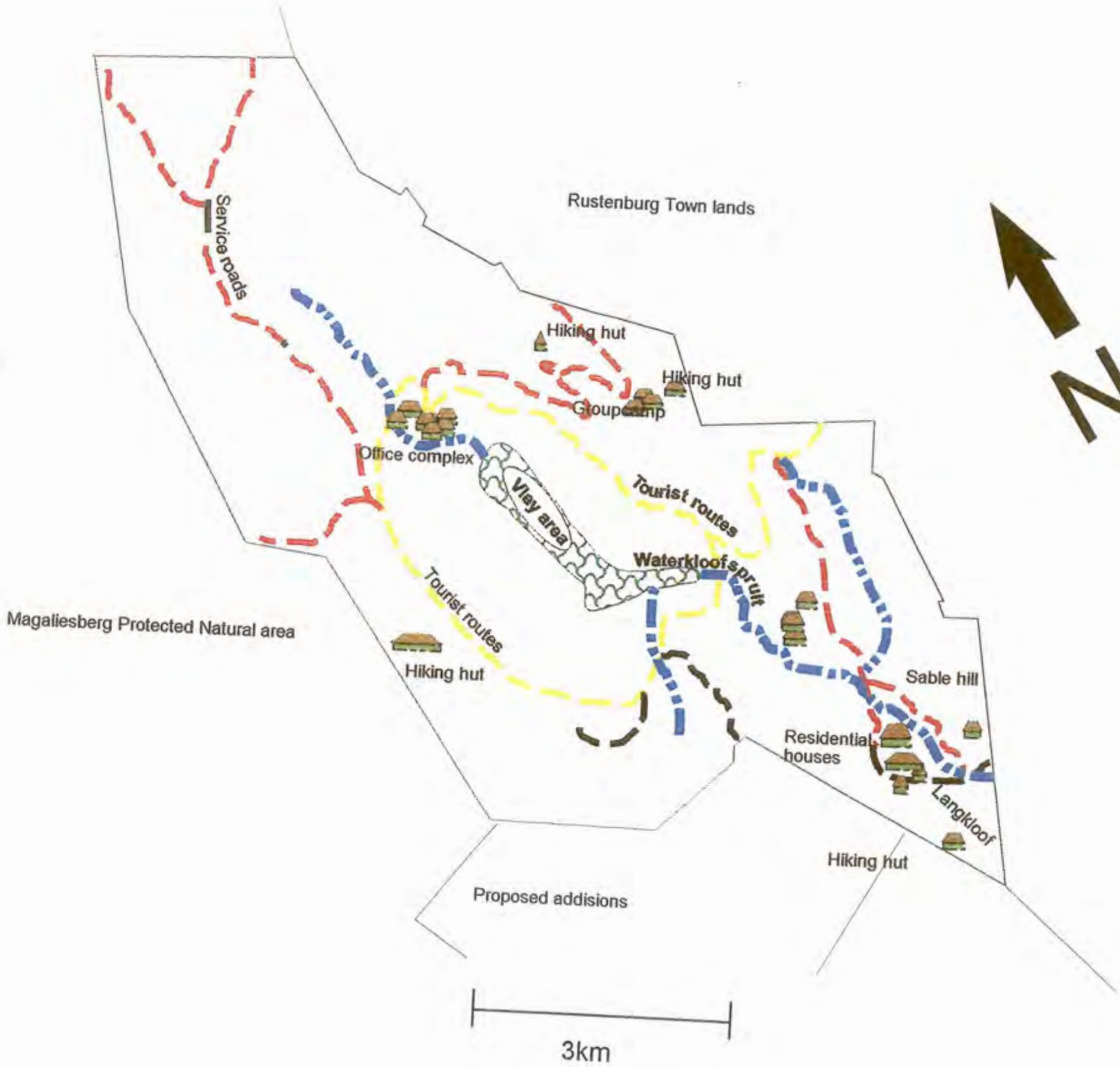

Figure 3: Management map for Rustenburg Nature Reserve

HISTORY

The Rustenburg Nature Reserve was used as grazing for cattle and game since time immemorial by black tribesmen and subsequently white farmers since the middle of the last century.

President Paul Kruger of the Zuid Afrikaansche Republiek owned several farms in the Rustenburg district before the war, among which were Rietvallei, Baviaanskrans and the adjacent Waterkloof (Labuschagne 1983). Kruger had several farming divergences on his properties. According to Coetzee (1975) he used the farm Rietvallei as summer grazing for his horses. Baviaanskrans was used for crops, orchards, and grazing (Juta 1936). These forms of land use were continued by subsequent land owners (Wulfsohn 1993).

The farm Rietvallei later became the property of the Rustenburg Town Council, who leased the area to adjacent farmers for grazing, mainly cattle (Kendall *pers. comm*[1])

In 1966 the town council of Rustenburg donated the farm Rietvallei 824 JQ and a portion of the farm Rustenburg Town and Town lands 272 JQ to the former Transvaal Provincial Administration to be developed as a nature reserve. In 1967 the reserve was formally proclaimed (Du Plessis 1973).

The reserve was fenced and stocked with a large variety of game. Species found mainly in the grasslands of the mountain plateau were springbok *Antidorcas marsupialis* (38), red hartebeest *Alcelaphus buselaphus* (33), blesbuck *Damaliscus dorcas phillipsi* (32), zebra *Equus burchelli* (23), black wildebeest

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1 Mr K Kendall, Inhabitant Rustenburg Town

Connachaetus gnou (17), oribi *Ourebia ouribi* (2) and steenbok *Raphicerus campestris* (1). While sable *Hippotragus niger* (21) were found mostly in the woodland on the plateau, kudu *Tragelaphus strepsiceros* (10) were observed in the woodland in the series of valleys. Mountain reedbuck *Redunca fulvorufula* (73+) occurred widespreadly on the slopes. Waterbuck *Kobus ellipsiprymnus* (12) concentrated in the densely wooded areas near the water, while impala *Aepyceros melampus melampus* (114) and common reedbuck *Redunca arundinum* (8) were usually observed in the woodlands.

At the time of proclamation the reserve covered an area of 2 898 ha. In 1981 the farm Baviaanskrans 308 JQ, which included rocky habitats and a waterfall was acquired, adding 1 359 ha to the reserve (Krige 1993).

PHYSIOGRAPHY

Due to drastic geomorphological events in this region of the Magaliesberg, Rustenburg Nature Reserve is very mountainous and altitudes vary from 1 230 m in the low-lying eastern parts of the reserve, to 1 660 m on the high lying western summits. The reserve is situated on the summit, eastern slopes and foothills of the Magaliesberg (Coetzee 1975). Two distinct geomorphological regions can be distinguished on the reserve; the high-lying plateaus and the low-lying valleys. The high-lying plateau contains a flat, convex area of exposed quartzite, at an altitude of 1 500 m - 1 650 m (Coetzee 1975). This high-lying plateau descent southwards into a basin of deep alluvial soil and marsh land which forms the largest natural wetland on the Magaliesberg (Carruthers 1990). The wetland is at altitudes 1 425 m - 1 440 m. The brim emerges at altitudes of 1 440 m in the south and at 1 500 m in the north, east and west (Coetzee 1975).

The second geomorphological region is a northwest to southeast series of valleys, underlain by diabase. These valleys separate the larger part of the summit plateau from a chain of quartzite hills extending from the northern plateau to the south east (Coetzee 1975). Altitudes of the valleys varies between 1 250 m and 1 320 m (Coetzee 1975).

GEOLOGY

From a management perspective, the reserve comprises two opposing geological formations (Fig. 4) *viz.* recrystallized quartzite from the Transvaal System and norite intrusions of the Bushveld Igneous Complex (Dept. Mineral and Energy Affairs 1981)[2].

Transvaal Sequence

The geology of the study area is relatively homogenous. The high-lying summit and slopes are underlain by well-bedded recrystallized quartzite areas with minor hornfels. These are sedimentary rocks of the Transvaal Sequence. The Transvaal Sequence includes all the sedimentary and volcanic rocks deposited in an east-west basin in the south-central part of Transvaal (Walraven 1981). In the North West Province, the Transvaal Sequence is represented as three series *viz.* The Black Reef-, Dolomite- and Pretoria Series. The Pretoria Group comprises four stages, Timeball Hill-, Daspoort-, Magaliesberg- and Smelterskop Stage. Within the Magaliesberg Stage two distinct formations can be distinguished *viz.* Magaliesberg quartzite and Silverton Shale (Kent 1980). Both formations are found on Rustenburg Nature Reserve. The Magaliesberg quartzite consists of considerable coarse quartzite, a feature undoubtedly related to recrystallisation caused by the Bushveld Igneous Complex with which it is often in contact (Walraven 1981). It forms a prominent escarpment along the entire Magaliesberg

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2 Dept. Mineral and Energy Affairs, Private Bag , Pretoria

range and conformably overlies the Silverton Shale. These shales are represented as interbedded hornfels in the northwestern region of the reserve (Coetzee 1975).

Bushveld IgneousComplex

The Bushveld Igneous Complex intruded the Transvaal Sequence, which resulted in it subsequently being encircled by the Transvaal Sequence. Three main rock groups have been recognised in the complex: the basic rocks, the granophyres and the granites and these form the basis for the present threefold division of the complex into the Rustenburg Layered Suite, the Rashoop Granophyre Suite and the Lebowa Granite Suite, respectively (Walraven 1981). The Rustenburg Layered Suite, which represents the Bushveld Igneous Complex in the reserve, comprises all the basic layered rocks of the Complex.

According to the stratigraphic nomenclatural system, advocated by the South African Commission for Stratigraphy (SACS), the Rustenburg Layered suite are informally divided into four zones *viz.*; an Upper-, Main-, Critical- and Lower zone. A marginal zone or chill phase of the Bushveld Igneous Complex exists in the western Transvaal (Kent 1980). Rocks of this zone are mostly confined to areas on the northern foothills of the western parts of the Magaliesberg, where they are underlain by a thick succession of Magaliesberg quartzite (Coertze 1974). This marginal zone forms the lowermost part of the Rustenburg Layered Suite and comprises Kolobeng Norite. Quartz is an important constituent in this zone, which suggests that this zone incorporated some of the floor sediments and cooling must have been relatively fast. Local wedging of floor rocks by Kolobeng Norite has taken place (Kent 1980).

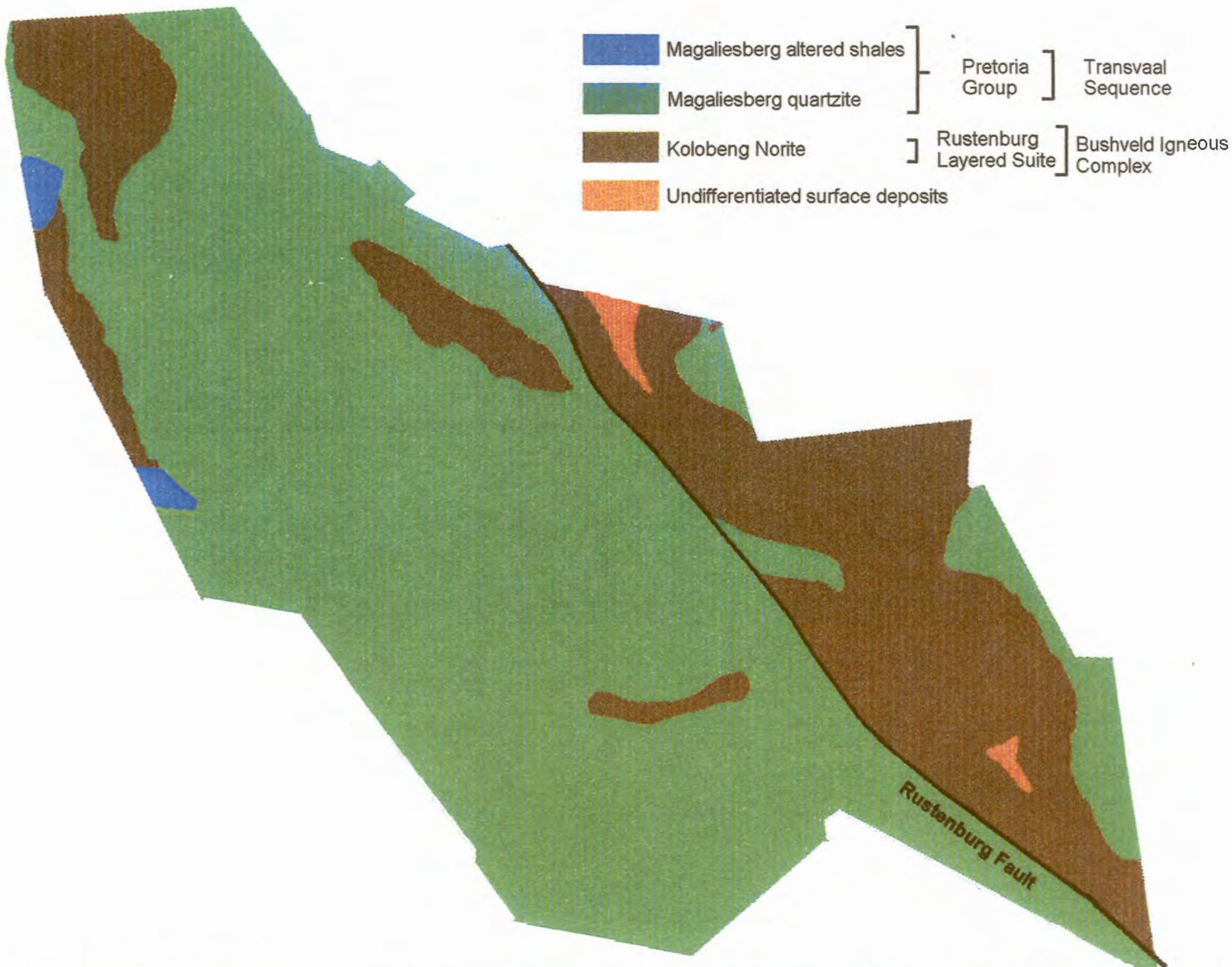

Figure 4: The Geology of the Rustenburg Nature Reserve (Dept. Mineral and Energy Affairs Geological Series 19 81; Coetzee, 197
Coertze, 1974)

From a wildlife management perspective, the informal zonal nomenclature as used by Coertze (1974) are more appropriate. Coertze (1974) divided the Rustenburg Layered Suite into eight rock units, on the basis of their field relations. These are the basal norite units, which consist of quartz norite and marginal norite subunits; the harzburgite unit; the pyroxenite unit; the anorthosite unit; the norite unit; porphyritic pyroxenite unit; the gabbro unit and the ferro gabbro-unit. Only the first unit, basal norite and particular the quartz norite subunit is of importance for the geology of the reserve. This subunit occurs where the basal norite unit rests directly on the Magaliesberg which indicates that it was probably formed by the incorporation of quartzite in the basic magma from which the basal norite unit formed (Coertze 1974). The quartz norite subunit merge into the overlying marginal norite subunit by a decrease in the quartz content and an increase in crystal sizes.

The basal norite zone consists of rocks previously described as diabase (Jansen 1977; Coertze 1974). The rocks of this subunit contain, apart from orthopyroxene and plagioclase, abundant clinopyroxene (Kent 1980), amphibole, biotite, quartz, magnetite and in places olivine (Coertze 1974).

Quaternary and Tertiary Deposits

A diminutive quantity of Quaternary and Tertiary deposits are also found on the low-lying areas of the reserve. These deposits formed *in situ* by weathering of underlying rocks, or alluvial deposits along drainage lines and streams (Walraven 1981). An important aspect here is that these surface depositions occurred in successional layers and subsequent layers might differ in structure and texture (Hugo 1979).

SOILS

Soil can be viewed as a mixture of mineral and organic particles of varying size and composition with regards to plant growth (Scholes & Walker 1993). Soil interacts with plants through a combination of chemical exchanges and physical effects and provides it with water, nutrients and oxygen, as well as all essential elements for growth and subsistence. The nutrients in soil primarily influences plant nutrition, while its physical characteristics' plays a crucial role in plant water supply (Scholes & Walker 1993).

Soil is a distinct and important environmental determinant of vegetation structure and distribution (Louw 1970; Bredenkamp & Theron 1976; Fraser *et al.* 1987; Pauw 1988; Prins & van der Jeugd 1992; O'Connor 1992; Smith 1992). Several studies described the influence of local topo-edaphic conditions on the prevailing floristic and structural character of South African savannas (Werger *et al.* 1979; O'Connor 1992). On a global scale, the distribution of savannas is determined by climate, but within this area of broad distribution, however, the occurrence and type of savanna at any given point are strongly influenced by topography and substrate (Scholes & Walker 1993), and there is usually an associated variation in the vegetation. Le Roux (1979) determined that clay and moisture content of soil were the most important components affecting the vegetation in the Etosha National Park. Janse van Rensburg and Bosch (1990) furthermore concluded that the same species of plants often react differently to grazing between sub-habitats of different soil-depth and stoniness in the same topographical unit.

Vegetation often has a modifying effect on soil (Brady 1984; Pauw 1988; Smith 1992). In secondary succession, as well as primary succession, plant growth usually leads to change and often an "improvement" of the soils' properties

(Huston 1994). The autogenic influence of plants adds organic matter to the soil, influencing the physical and chemical properties of soils such as soil carbon and effective soil depth. The most significant contribution of soil organisms to higher plants is organic matter decomposition. Other biologically instigated biochemical reactions are responsible for other effects such as inorganic transformations and nitrogen fixation (Brady 1984).

A study of the vegetation of an area cannot be executed without considering the intrinsic relation between the vegetation and its environment. This relation is a useful aid in the mapping of these resources and a pedological survey is therefore necessary in a study of plant ecology on the reserve.

Methods

By studying 1:15 000 orthophotos and stereo aerial photos of the reserve, the various terrain units and soil/landscape associations were established. Assuming that differences in soil properties result in different vegetation associations and structure (Bredenkamp & Theron 1976; Fraser *et al.* 1987; Pauw 1988; Smith 1992), apparent soil types were demarcated. The correctness of these tentative borders was determined by correlating it with samples taken with a soil auger. In areas where there were no apparent boundaries between different soil types, auger holes along a transect were used to establish the location of the transition.

Soil profiles (78 in total) were studied by means of excavation pits, road cuttings and exposures through erosion, selectively sited within these recognized soil types. Soils were classified according to the binominal classification system of MacVicar *et al.* (1991), correlated with the binomial system of MacVicar *et al.* (1977). This correlation was done to include the soil series which is mainly based on clay content and sand fractions of the soil. The new version system (MacVicar *et al.* 1991) only distinguish soil families . A soil map was compiled, using the orthophotos as base map. The nodal profiles, which represent the dominant soil properties in each mapping unit, were described according to its colour, depth of the different horizons, texture, particle size fractions, structure, consistency and stoniness. Due to cost considerations, certain subjective assessments had to be used to describe the physical character of the different soil types. Particle size fractions and stoniness, consistency and structure classes of selected sites were determined using the limits described by MacVicar *et al.* (1977). The texture classes were determined in the field using a subjective method ("Sausage method")[3] . Soil colour was determined using Standard Soil Colour charts[4]

Thirty-eight samples from the A-horizon of selected sites were taken for further chemical analysis, as well as particle size distribution. Two additional samples were taken as control samples. These samples were chosen to represent the two extremes of soil types on the reserve, *viz.* pure quartzite and black turf. All chemical and physical analysis were conducted by the Climatological and Soil Research Institute[5]. The following chemical and physical analysis were performed:

* Particle size distribution (%)
* Percentage carbon (%)
* Resistance (Ω)
* Exchangeable cations me.$100g^{-1}$ oven dry (100°C) soil
    - K
    - Na
    - Ca
    - Mg
    - S - value
    - T - value (CEC)
* pH (H_2O)
* Electrical conductivity ($mS.m^{-1}$)

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3 National Working Group for Vegetation Ecology. Technical Communication No. 3. 1986

4 Revised Standard Soil Color Charts. Oyama, M & Takehara, H. 1989

5 Institute for Soil, Climate and Water, Belvedere street Arcadia, Pretoria, South Africa

All analysis was done according to the techniques described in the "Handbook of Standard Soil Testing Techniques for Advisory Purposes" (1990).

Results

The soils on Rustenburg Nature Reserve were studied and interpreted to explain vegetation distribution on the reserve and ultimately assist in the identification of homogenous management units.

Generally the soils on the reserve can be divided into six groups:

1. Shallow soils of the Mispah soil form (Orthic A horizon on hard rock) on the crests and upper slopes
2. Medium-deep stoney soils of the Glenrosa soil form (Orthic A horizon on lithocutanic B horizon) on the foothills
3. Deep and very deep well differentiated soils of the Hutton soil form (Orthic A horizon on red apedal B horizon) in the central basin and northern plateau region
4. Young soils of the Oakleaf (Orthic A horizon on neocutanic B horizon) and Dundee soil forms (Orthic A horizon on stratified alluvial) in the bottom lands of the valleys
5. Deep, sand clay loam soils of the Swartland (Orthic A horizon on pedocutanic B horizon) and Katspruit soil forms (Orthic A horizon on gley)
6. The black clayish soils of the Willowbrook soil form (Melanic A horizon on a G-horizon) , which underlie the *Phragmites australis* reed bed in the central basin area.

by a rocky surface, consisting of norite boulders (>30cm) with little weathering and little topsoil between the boulders.

One family - Myhill (Ms 1100) - of the Mispah soil form can be distinguished on the reserve (MacVicar *et al.* 1991). The A horizon of these soils is not bleached or calcareous and overlie a quartzite substrate. It has a coarse gravel texture (Table 1 & 2), with a low clay content. The colour of the A horizon is a brownish black colour, indicating the presence of decomposed organic matter.

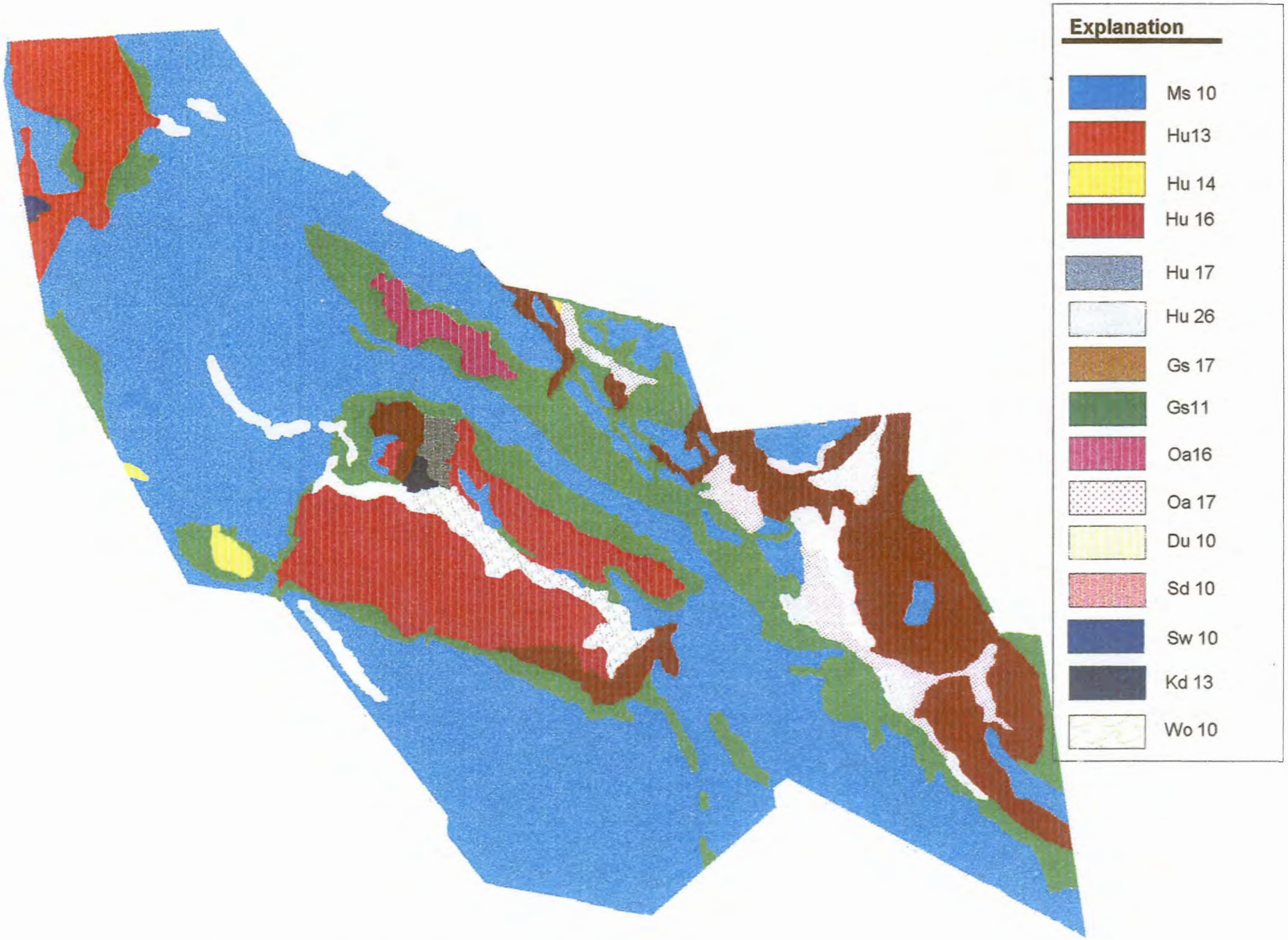

Figure 5 : The soils of the Rustenburg Nature Reserve

2 The medium-deep stoney soils of the Glenrosa soil form on the foothills

The slopes and foothills on the reserve are predominantly covered by shallow to medium deep soils of the Glenrosa soil form. These soils form the transition between the shallow soils of the crests and plateaus and the deeper well-differentiated soils found in the vlei-area and series of valleys to the east of the reserve. On the basis of the hardness of the lithocutanic B horizon, two soil families can be distinguished *viz.*; Dumisa (Gs 1111) and Tsende (Gs 1211) (MacVicar *et al.* 1991). Dumisa contains less than 70% fresh or partly weathered bedrock, while 70% and more of the B horison of the Tsende family consist of hard parent bedrock. Tsende is predominately present on the reserve.

According to the South African Binomial soil classification system (MacVicar *et al.*, 1977) differentiation into series is based upon clay content, sand grade and whether the B horizon is calcareous. Using this classification system, two distinct series in this soil form can be differentiated on the reserve *viz.* Oribi (Gs11) and Trevanian (Gs17). Differentiation between these two series are predominately based on the difference in clay content in the A horizon, which can be relayed to the underlying parent bedrock. The soils on the north western plateau and on the foothills of the central basin, as well as the slopes facing a north eastern direction is underlaid by Magaliesberg quartzite. The reddish brown soils overlying these areas have a low clay-content (10% - 15.6%) (Tables 1 & 2). The sand fraction forms the major constitute of the soils with levels in excess of 75% of the sample.

Table 1: A summary of selected properties of the different soil types on Rustenburg Nature Reserve

Profile no.	Soil form and family	Horizon	Depth (mm)	Colour (Dry)	Structure	Consistence	Stoniness	Texture
Ms 10/11	Ms1100	A - Orthic	150	5Y3/1	1	Loose	Common/medium/angular	Loamy sand
		B - Hard rock(Quartzite)						
	Gs1111	A - Orthic	30	7.5YR 4/6	12	Slightly hard	Common/medium/angular	Sand clay loam
		B - Lithocutanic	30+	5 YR 4/8		Slightly hard	Common/medium/angular	Sand clay
Gs 11/3	Gs1211	A - Orthic	250	5 YR 3/4	13	Loose	Common/medium/angular	Loamy sand
		B - Lithocutanic	250+	2.5 YR 3/4		Slightly hard	Common/medium/angular	Sand clay loam
Gs 17/2		A - Orthic	250	5 YR 4/8	33	Loose	Common/medium/angular	Sand clay loam
		B - Lithocutanic		5 YR 4/8		Slightly hard	Common/medium/angular	Sand clay loam
Hu13/5	Hu1100	A - Orthic	350	2.5 YR 3/4	11	Loose	Few/small/angular	Sand
		B - Red apedal	350+	2.5 YR 4/8		Loose	Few/small/angular	Loamy sand
Hu14/9	Hu1100	A - Orthic	300	2.5 YR 5/4	22	Loose	Few/small/angular	Loamy sand
		B - Red apedal	300+	2.5 YR 5/6		Loose	Common/small/angular	Loamy sand
Hu16/6	Hu1100	A - Orthic	400	5 YR 4/4	11	Loose	Few/small/angular	Sand loam
		B - Red apedal	400+	5 YR 4/6		Loose	Common/small/angular	Sand loam

Profile no.	Soil form and family	Horizon	Depth (mm)	Colour (Dry)	Structure	Consistence	Stoniness	Texture
Hu17/8	Hu2100	A - Orthic	400	5 YR 4/4	31	Soft	Few/small/angular	Sand clay
		B - Red apedal	400+	2.5 YR 4/8		Loose	Few/small/angular	Sand clay
Hu26/7	Hu1100	A - Orthic	350	5 YR 3/4	11	Loose	Many/small/angular	Sand loam
		B - Red apedal	350+	5 YR 4/6		Loose	Few/small/angular	Sand loam
Oa17/12	Oa 1210	A - Orthic	200	7.5 YR 3/4	32	Loose	Few/small/angular	Sand clay loam
		B - Neocutanic	200+	5 YR 4/3		Hard	Few/small/angular	Sand clay
Du 10/4	Du2110	A - Orthic	100	5YR 5/3	11	Loose	Few/small/round	Sand
		Stratified Alluvium	100 - 250	7.5 YR 2/2		Loose	Few/small/round	Sand
Sw10/6	Sw1221	A - Orthic	350	5 YR 3/6	24	Soft	Common/small/angular	Loamy snad
		B - Pedocutanic	350 - 520	2.5 YR 5/6		Hard	Few/small/angular	Sand clay loam
		Saprolite						
Sd 10/15	Sd1120	A - Orthic	100	5 YR 4/4	22	Slightly hard	None	Sand loam
		B - Red structured B	100+	2.5 YR 3/6		Slightly hard	None	Sandt loam
Wo10/3	Wo1000	A - Melanic	200	10 YR6/1	12	Loose	None	Sand clay loam
		B - G-horizon	200+	10 YR 4/6		Very firm (Moist)	None	Sand clay
Kd 14/16	Kd 2000	A - Orthic	280	5YR 3/6	323	Loose	None	Sand loam
		E - horizon	280-530	7.5 YR 4/2		Loose	Few/small/angular	Loamy sand
		B - Gleycutanic	530+	10 YR 4/4		Slightly firm (Moist)	None	Sand clay loam

Explanation:

Structure:	1	Structureless with no observable aggregation or no orderly arrangement of natural lines of weakness
	2	Weakly developed. Peds are indistinct, poorly formed and barely observable
	3	Moderately developed. Peds are well formed and durable but not distinctly seperated from one another in undisturbed soil
	4	Strongly developed. Peds are well formed and durable and distinctly separated from one another in undisturbed soil
Consistency	Dry soil	Loose, soft slightly hard, hard or very hard
	Moist soil	Loose, friable, slightly firm or very firm
	Wet soil	Non-sticky, slightly sticky, sticky or very sticky
Stoniness	Occurence	None, few, common
	Size	Small, medium, large
	Shape	Flat, angular, rounded

In contrast, the soils on the slopes and foothills facing southwestwards, is underlaid by Kolobeng norite of the Bushveld Igneous Complex. These soils have a dark reddish brown colour and a significantly higher clay content (25.1 to 29.5%) than similar soils on the quartzite substrate. (Table 2). The higher clay content of these soils resulted in a significantly higher CEC value than those underlaid by quartzite. The S-value (determined by the amount of leaching Smith (1992) of these soils is also significantly higher than in the quartzite soils. The electrical conductivity values of all the soils in this group indicate no accumulation of soluble salts.

3 The deep, well-differentiated soils of the Hutton soil form

The central basin area, as well as an area on the northwestern plateau (Fig. 4) is predominantly underlaid by deep, well-differentiated soils of the Hutton soil form. This soil form also occurs in certain isolated areas in the valleys in the eastern part of the reserve.

According to the South African Binomial soil classification system (MacVicar *et al.*, 1977) differentiation of the Hutton soil form into series is based upon the clay and sand content in the B21 - horizon. Five series in this soil form can therefore be distinguished on the reserve, *viz.* Wakefield (Hu13), Middelburg (Hu14), Hutton (Hu16), Farningham (Hu17) and Msinga (Hu26). The clay content in these soils varies according to its position in the landscape. The soils with a higher clay content (16,9% - 32.2%) occur on the bottom lands, while those with a high percentage of sand are to be found on the high lying ground, underlaid by quartzite. Farningham (Hu17) is confined to an area in the north of the basin. These soils have a relative high clay content (>35%) compared to the values of other samples taken in the basin.

Table 2: The results of an analysis of selected properties of the A-horizon of the soil on Rustenburg Nature Reserve.

Profile number	Sand %	Clay %	Silt %	Carbon %	P $mg.kg^{-1}$	Exchange cations cmol (+).kg^{-1} soil					Sum of exchange=ables cations	CEC	Water pH	EC $mS.m^{-1}$
						Na	K	Ca	Mg	S-value				
The shallow soils of the Mispah soil form on the crests and upper slopes														
3	71.80	6.00	22.20	3.93	11.40	0.00	0.09	0.07	0.10	0.26	4.33	4.60	4.26	20.00
4	72.00	6.00	22.00	3.26	17.80	0.06	0.06	0.14	0.03	0.29	4.83	6.22	4.24	22.00
5	76.40	6.00	17.60	3.21	9.80	0.02	0.06	0.17	0.03	0.28	4.67	5.46	4.46	26.00
26	83.10	7.20	9.70	4.95	13.20	0.01	0.09	0.24	0.10	0.44	6.14	-	4.52	-
37	85.30	6.70	8.00	3.04	13.80	0.01	0.08	0.45	0.08	0.62	9.21	-	4.48	-
Tthe medium-deep stoney soils of the Glenrosa soil form on the foothills,														
9	79.70	10.00	10.30	1.15	1.90	0.02	0.14	0.15	0.06	0.37	3.70	1.88	4.89	37.00
10	78.00	10.00	12.00	1.45	2.70	0.02	0.08	0.04	0.02	0.16	1.60	2.58	5.04	11.00
13	69.50	14.00	16.50	1.95	2.00	0.00	0.28	0.85	0.95	2.08	14.86	5.66	5.96	36.00
14	75.20	10.00	14.80	0.52	1.10	0.06	0.12	0.62	0.78	1.58	15.80	1.73	6.37	14.00
27	80.90	10.90	8.20	1.34	2.80	0.02	0.10	0.88	0.19	1.19	10.88	-	4.04	-

Profile number	Sand %	Clay %	Silt %	Carbon %	P mg.kg^{-1}	Exchange cations cmol (+).kg^{-1} soil					Sum of exchange= ables cations	CEC	Water pH	EC mS.m^{-1}
						Na	K	Ca	Mg	S-value				
33	76.30	11.60	12.10	2.56	3.20	0.01	0.21	0.77	0.10	1.10	9.46	-	4.97	-
36	80.70	8.10	11.20	1.17	12.20	0.01	0.15	0.67	0.25	1.08	13.27	-	5.67	-
17	38.90	36.00	25.10	2.00	1.10	0.00	0.43	2.70	2.51	5.64	15.67	9.51	6.44	27.00
19	38.50	32.00	29.50	2.42	1.20	0.03	0.57	2.97	4.01	7.58	23.69	15.48	6.12	29.00
The deep and very deep well differentiated soils of the Hutton soil form in the central basin and northern plateau region,														
1	81.60	8.00	10.40	1.35	5.20	0.00	0.06	0.13	0.06	0.25	3.13	3.80	4.76	19.00
6	79.40	10.00	10.60	1.25	1.90	0.03	0.02	0.23	0.12	0.40	4.00	2.65	4.69	8.00
8	74.10	14.00	11.90	1.43	1.10	0.00	0.04	0.68	0.66	1.38	9.86	3.73	5.98	14.00
38	69.80	15.60	14.60	2.09	13.20	0.01	0.11	0.09	0.03	0.24	1.52	-	4.54	-
11	79.10	12.00	8.90	1.97	2.00	0.05	0.16	0.62	0.50	1.33	11.08	4.18	5.34	14.00
21	72.70	13.40	13.90	1.48	5.20	0.01	0.08	0.20	0.08	0.36	2.69	-	4.50	-
22	85.01	5.00	9.99	1.47	4.20	0.01	0.09	0.03	0.10	0.24	4.74	-	4.56	-
20	31.80	36.00	32.20	2.61	1.10	0.03	0.77	3.38	3.95	8.13	22.58	11.58	6.34	32.00
35	40.80	37.20	22.00	2.54	2.40	0.01	0.22	0.48	0.21	0.92	2.48	-	5.35	-
28	41.00	42.10	16.90	1.95	2.40	0.02	0.28	0.11	0.03	0.43	1.03	-	5.68	-

Profile number	Sand %	Clay %	Silt %	Carbon %	P $mg.kg^{-1}$	Exchange cations cmol (+).kg^{-1} soil					Sum of exchange= ables cations	CEC	Water pH	EC $mS.m^{-1}$
						Na	K	Ca	Mg	S-value				
The young soils of the Oakland and Dundee soil forms in the bottomlands of the valleys														
12	60.50	20.00	19.50	1.70	1.30	0.04	0.61	2.37	1.14	4.16	20.80	7.68	5.80	22.00
24	70.00	15.50	14.50	1.29	10.20	0.01	0.16	0.05	0.02	0.23	1.50	-	5.11	-
29	69.70	15.80	14.50	1.37	2.00	0.02	0.13	0.95	0.29	1.39	8.80	-	5.09	-
15	27.30	32.00	40.70	3.02	1.10	0.00	0.48	1.41	2.52	4.41	13.78	10.87	5.40	17.00
16	23.20	36.00	40.80	3.28	1.70	0.03	0.08	1.08	1.21	2.40	6.67	5.28	5.06	14.00
30	42.00	32.30	25.70	5.18	13.60	0.02	0.14	0.81	0.14	1.10	3.42	-	4.67	-
31	66.30	18.50	15.20	1.86	16.20	0.01	0.19	1.78	0.40	2.38	12.84	-	5.51	-
23	24.20	50.90	24.90	2.45	13.40	0.02	0.12	0.06	0.03	0.22	0.44	-	5.43	-
25	62.80	25.00	12.20	2.75	3.20	0.01	0.24	1.31	0.33	1.89	7.56	-	5.18	-
The deep, sand clay loam soils of the Swartland and Shortlands soil forms														
2	68.20	16.00	15.80	2.84	1.80	0.00	0.18	1.00	1.00	2.18	13.63	5.44	5.54	17.00
18	65.80	20.00	14.20	1.21	1.10	0.00	0.32	2.47	0.43	3.22	16.10	5.52	7.26	24.00
The black clayish soils of the Willowbrook and Kroonstad soil form, which underlie the marsh in the central basin area.														
7	10.50	12.00	77.50	12.08	4.80	0.09	0.07	0.35	0.46	0.87	8.08	28.39	5.14	11.00
34	35.10	37.90	27.00	9.80	2.80	0.02	0.22	0.28	0.13	0.65	1.70	-	4.38	-

The soil classification system of MacVicar *et al.* (1991) differentiated between the families in this soil form according to the amount of leaching, as well as the ratio of the clay content between the A horizon and the B1 horizon. According to this classification system only two soil families can be distinguished on the reserve *viz.* Lillieburn (Hu1100) and Hayfield (Hu2100). These soils are non-luvic with no significant difference in clay content between the A horizon and the B1 horizon. The soils are generally dystrophic, except in the bottom lands on the eastern side of the reserve. The S-value of the soils in this area is 8.13 (Table 2), mesotrofic (MacVicar *et al.* 1991) and therefore the need to differentiate between the two families.

Distinct differences in chemical properties occur in the soils of the different landscapes. The cation exchange capacity (CEC) of the soils in the eastern bottomlands is significantly higher than that of the Hutton soils on the plateau and central basin area. As the CEC of soils is affected mainly by the amount of clay and organic matter (Van Rooyen 1984), it can be regarded as an indication of its nutritional status.

The pH-values decrease with altitude between 4.5 and 4.7 on the plateau to 5.6 and 6.3 in the bottom lands. The pH values of the soils in the central basin vary between 5.3 and 5.9. The electrical conductivity values of all the Hutton soils indicate that they are relative free from soluble salts. However, the Hutton soils in the bottom lands (EC = 32 $mS.m^{-1}$) showed a significantly higher salt content than the other Hutton soils (EC = 14 - 19 $mS.m^{-1}$).

4 The young soils of the Oakleaf and Dundee soil forms in the bottom lands of the valleys

Tertiaries to recent alluvial soils underlie the valleys in the east of the reserve (Coetzee 1975). Although no distinctive diagnostic horizon can be recognised in these soils, an amount of reorganisation of material did occur and stratifications that were present, have been eradicated. These alluvial deposits developed into young soils of the Oakleaf form. The families in this soil form are distinguished according to colour and clay content of the horizons (MacVicar *et al.* 1991). These soils have a dull reddish brown colour with non-luvic characteristics. Only one family can be distinguished on the reserve *viz.* Caledon (Oa1210). The B horizon of these soils has a high clay content (>15%), and according to the classification system of MacVicar *et al.* (1977) only two soil series can be differentiated *viz.* Leeufontein (Oa16) and Highflats (Oa17). Alluvial soils usually have a variable texture (van Rooyen 1983) as is evident in the soils on the reserve. The clay content of the Oakleaf soil samples in Langkloof is higher than 30%, whereas those of the valley between Witkruiskrans and Sable Hill are below 20%. The soils are deep (>1.5m).

The Oakleaf soils of Langkloof have a relative high carbon content (>3% - 5.18). The exchangeable potassium content is low (<0.04%) and the electrical conductivity indicates no accumulation of soluble salts.

Another group of young undeveloped soils are confined to the drainage lines in the upper regions of the reserve where weathered quartzite pebbles and decomposed organic matter are laid down in alternating layers. Pedogenetic development is minimal and definite layers of a deposition process is evident. Aggregation of soil fragments to form larger units have not yet taken place and the soil conglomerations in the drainage lines are sometimes washed down in a single severe rain storm, even in the presence of a healthy vegetation cover.

The greater part of the stratified alluvium of the Dundee soil form has a brownish black colour, which disqualifies it as a red stratified alluvium. Only one family can be distinguished *viz.* Nonoti (Du 1110) which has a gravelly texture and lateral variability (MacVicar *et al.* 1977). Analysis of these soils was done with samples taken from each recognisable stratified layer which was mixed into one. Only two samples were analysed and, because of the variability of these soils (Table 1 & 2) a representative view of the general characteristics of these soils could not be obtained. These soils are shallow and are found on the slopes, underlain by quartzite parent rock. It also occurs in drainage lines in the central basin area where it is deeper than 2m and overgrown with bracken fern *Pteridium aquilinum*.

5 The deep, sand clay loam soils of the Swartland and Shortlands soil forms

These soils occur in small isolated areas throughout the reserve. The Swartland soil form can be found in a depression on the north western side of the plateau. The hornfels saprolite (Magaliesberg altered shales)(Coetzee 1975) weathered into soils high in clay content and fertility[6]. An unbleached A horizon, underlaid by a red, medium angular B horizon without any calcareous characteristics distinguished only one family, *viz.* Mtini (Sw1221) (MacVicar *et al.* 1991). The soils are ± 500mm deep and although the clay content of the A horizon is relative low , the B horizon has a high clay content. The cation exchange capacity of the soils is also relative low (5.44 - 5.52) and the electrical conductivity indicates no accumulation of soluble salts.

The Shortlands soils occur on the foothills of the eastern hill range, originating from the underlying norite intrusions. One family, Groothoek (Sd1120), can be distinguished. These soils have a mesotrofic character. The pH-value (7,26) of the topsoil is alkaline due to the basic parent rock. No exchangeable potassium is available.

6 The black clayish soils of the Willowbrook and Kroonstad soil form which underlie the marsh in the central basin area.

These soils are confined to the marshy area in the central basin as well as insignificant little areas in the kloofs on the reserve. It is characterised by a high carbon content (>9.50%), responsible for its brownish gray to brownish black colour.

The soils in the marshy area are of the Willowbrook soil form (Melanic A horizon followed by a non-calcereous G horizon). One family, Ottawa (Wo1000), can be

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distinguished. The A horizon has a low clay content (12%) and S-value (0.97)(Table 3). The cation exchange capacity is high (28.39), compared with other soils on the reserve (Table 3). The silt content of the soils is high (<75%) and no soluble salts accumulated in these soils. The underlying G horizon has signs of water saturation for long periods and gleying occurs in these soils.

The Kroonstad soil form is limited to an area adjacent to the marsh. This soil form is recognised by the presence of a distinct well-leached E horizon abruptly underlaid by a G horizon. The A horizon has a high clay (>35%) and carbon content (9.80%). These soils lie on a slight slope, which is an important factor in the genesis of the E horizon. The occurrence of a less permeable G horizon causes a temporarily accumulation of water above the B horizon, which is discharged in a lateral direction (MacVicar *et al.* 1991). Soil families are distinguished on the basis of colour of the E horizon and only the Morgendal (Kd1000) family could be differentiated

CLIMATE

Climatic factors mediated through light, heat, and water directly affect biochemical and physiological processes in plants (Tchebakova *et al.* 1993). Botanists and geographers have long been aware that plants are highly responsive to differences in climate. Climate is also considered to be the ultimate determent in savanna distribution (Scholes & Walker 1993), as plant form and vegetation structure are primarily determined by temperature and climatic water balance.

The water regime had a dominant effect at almost all levels. Temperature and light were less important. Heat effects, metabolic rates, water loss and uptake rates are considered to be only important at extreme levels (Rutherford & Westfall 1994). According to Schulze (1965) the following factors are primarily responsible for the existing climatic conditions at a specific locality *viz.* latitude, position relative to distribution of land and sea, height above sea level, general circulation of the atmosphere, influence of ocean currents and position relative to hills or mountains, nature of the underlying surface and vegetation type. This is confirmed by Tyson (1987), although he stated more specifically that the climatic conditions in southern Africa are strongly influenced by the position of the subcontinent in relation to the major circulation features in southern Africa.

The ecological climate diagram provides clear information on the seasonal course of the climate. It contains the most essential climatic data from an ecologists point of view and is comprehensible at a glance (Walter 1979). Climate diagrams not only show the monthly temperature and precipitation values, but also the duration of the relative wet and dry periods and the duration and severity of winter. The climate diagram for Rustenburg Nature Reserve is illustrated in Figure 6. Climatological information had been collected on the reserve since 1980. Initially only rainfall information was recorded using a standard rainfall gauge. In 1989 a small weather station was established using a Stevenson screen as prescribed by the Weather Bureau (Weather bureau 1988). Since 1989 the average minimum and maximum temperatures, absolute minimum and maximum temperature, rainfall and days of frost are recorded each day. Comparisons between the rainfall and temperature data of the reserve and that of the region, obtained from Rustenburg Agricultural Institute (Station 0511523 4, ϕ 25° 43' S, λ 27° 18' E; Ht 1157m) and although no significant differences could be found in the long-term climatic data, some differences were significantly obvious in the short term (Table 3).

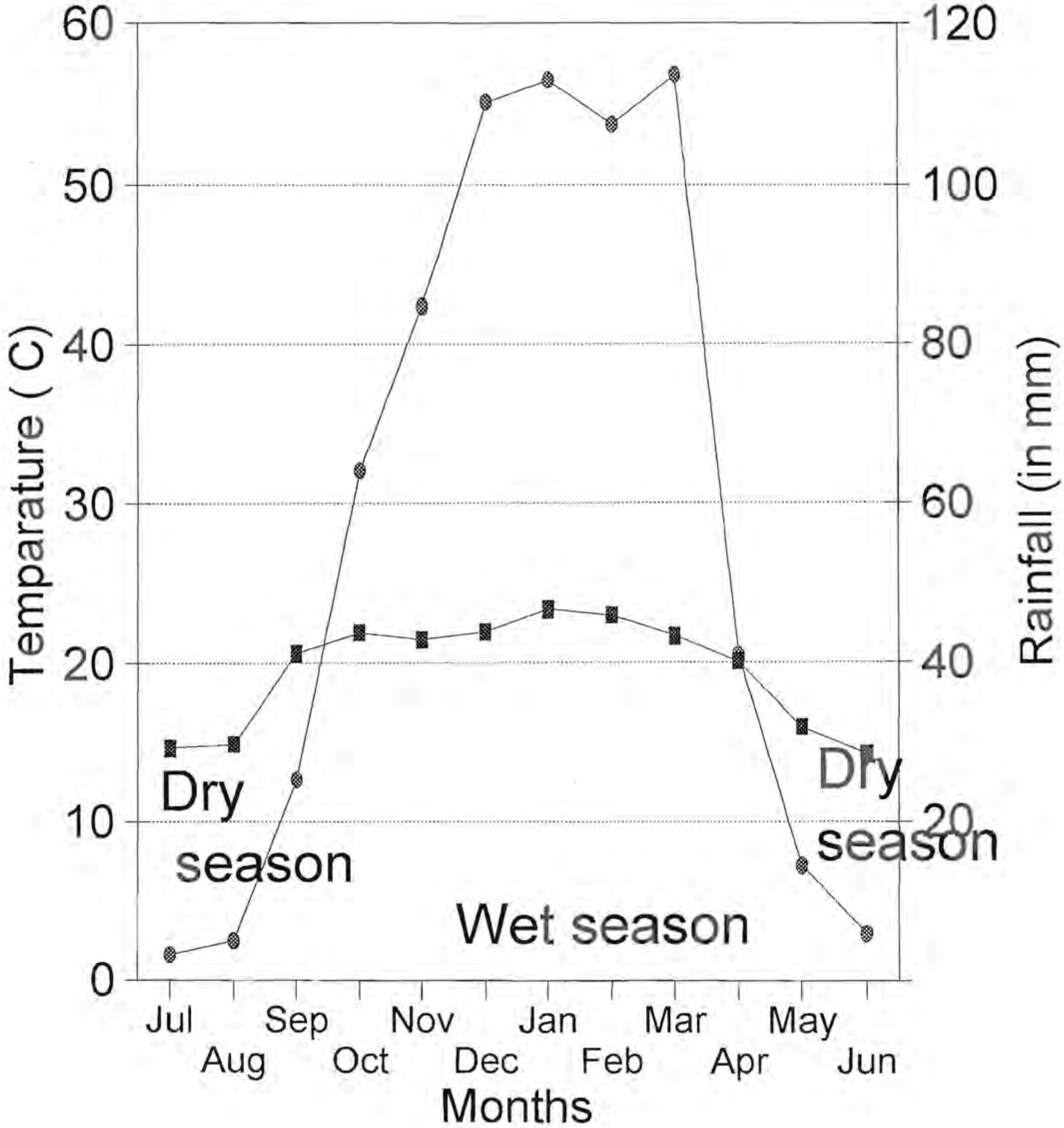


Figure 6: Ecological Climate diagram for Rustenburg Nature Reserve

According to Köppen's classification of the climates of South Africa, Rustenburg Nature Reserve is situated in a transition between two types (Schulze 1947). Firstly, the *Cwa* - type, implying an area where:

C	-	warm temperate climate with the coldest month 18°C to -3°C
W	-	winter dry season
a	-	warmest month over 22°C

and the *Bshw* - type, meaning:

B	-	an arid climate
S	-	Steppe (steppe *BS*)
h	-	Hot and dry mean annual temperature exceeds 18°C Rustenburg mean annual temperature = 18.7°C (Weather Bureau, unpublished)
w	-	dry season in winter

However, Hugo (1979) classified the climate of Rustenburg as a "Steppe" climate and thus the *Bshw*-subtype of Köppen.

According to the Thornthwaite-classification, which uses the concept of "Precipitation Effectiveness Index" and "Temperature Efficiency Index" as the basis of this system, the reserve is situated in the CB'd - climatic zone, where a sub-humid (C), mesothermal warm temperature (B) prevail, and (d) where moisture is deficient in all seasons (Schulze 1947).

Temperature

The distribution and composition of vegetation communities are largely influenced by extremes of climatic factors (Coombes 1991). Temperatures recorded over the past seven years since 1989 at the station on the reserve give an indication of the temperatures that may be expected. The seasonal trends in air temperature are illustrated in Table 3. The average daily temperature varies from 6.7°C to 21.7°C in the coldest month, June, to 16.8°C to 30°C in the hottest month, January. The mean daily temperature varies from 14.2°C in winter to 23.4°C in summer. Frost is occasional and very light, and occurs during June to August, and is limited to the basin area and high lying plateau. No frost was recorded in the eastern valleys. Frosts may be a limiting factor for the distribution of tropical plant species such as *Rauvolfia caffra, Pittosporum viridiflorum, Ilex mitis, Englerophytum magalismontanum* and *Mimusops zeyheri.*

Table 3: Monthly average temperature and rainfall figures for Rustenburg Nature Reserve from 1980 - 1997

Month	Average Daily Minimum	Average Daily Maximum	Max + Min / 2	Rainfall
January	16.80	30.00	23.40	113.00
February	16.00	29.90	22.95	107.60
March	15.30	28.00	21.65	113.60
April	12.80	27.30	20.05	40.90
May	8.90	22.90	15.90	14.50
June	6.70	21.70	14.20	5.90
July	6.90	22.40	14.65	3.20
August	7.40	22.40	14.90	4.90
September	12.50	28.70	20.60	25.20
October	13.10	30.60	21.85	64.00
November	14.80	28.10	21.45	84.80
December	15.30	28.50	21.90	110.20
Average/Total	12.21	26.71	19.46	687.80

The average weekly temperatures are on either side of the Magaliesberg higher at the foot slopes than on the crests. The differences between the average maximum temperatures on the foot slopes and the crests on north-facing slopes are 1,82°C and on the southern slopes 4,45°C (van Vuuren & van der Schijff 1970)

Rainfall

The total annual rainfall for the reserve is illustrated in Table 3 and Figure 6. The mean annual rainfall (July to June) for the period 1980 to 1997 is 687.8 mm (± 208.4 mm). The high interannual variability in rainfall is typical of the semi-arid regions (Scholes & Walker 1993). A very distinct aspect of the variability in the annual rainfall is the periods of above and below average rainfall. From 1972-1979 there was a period of above average rainfall, followed by a relative dry period lasting until 1986. Since 1986 there was a decline in rainfall variation, except for 1992, during which only 360.9 mm of rain was recorded, and 1996, during which exceptional high rainfall were recorded (1 222 mm).

The wettest months are December and January with a monthly average of 111.7 mm and 110.2 mm respectively. Although no rainfall data had been recorded for the low lying areas in the east, Van Vuuren and van der Schijff (1970) found that the crests of the north-facing slopes received more rain than the foot slopes, the difference being 113 mm. The difference on the southern slopes was less pronounced and the foot slope only received 26 mm less than the crests.

The rainfall in the region is highly seasonal, as over most of southern Africa (Tyson 1987). Based on data since 1980, it is evident from Table 3 that 95.9% of the annual rainfall falls during September to April, and only 4.1% in the winter months from May to August.

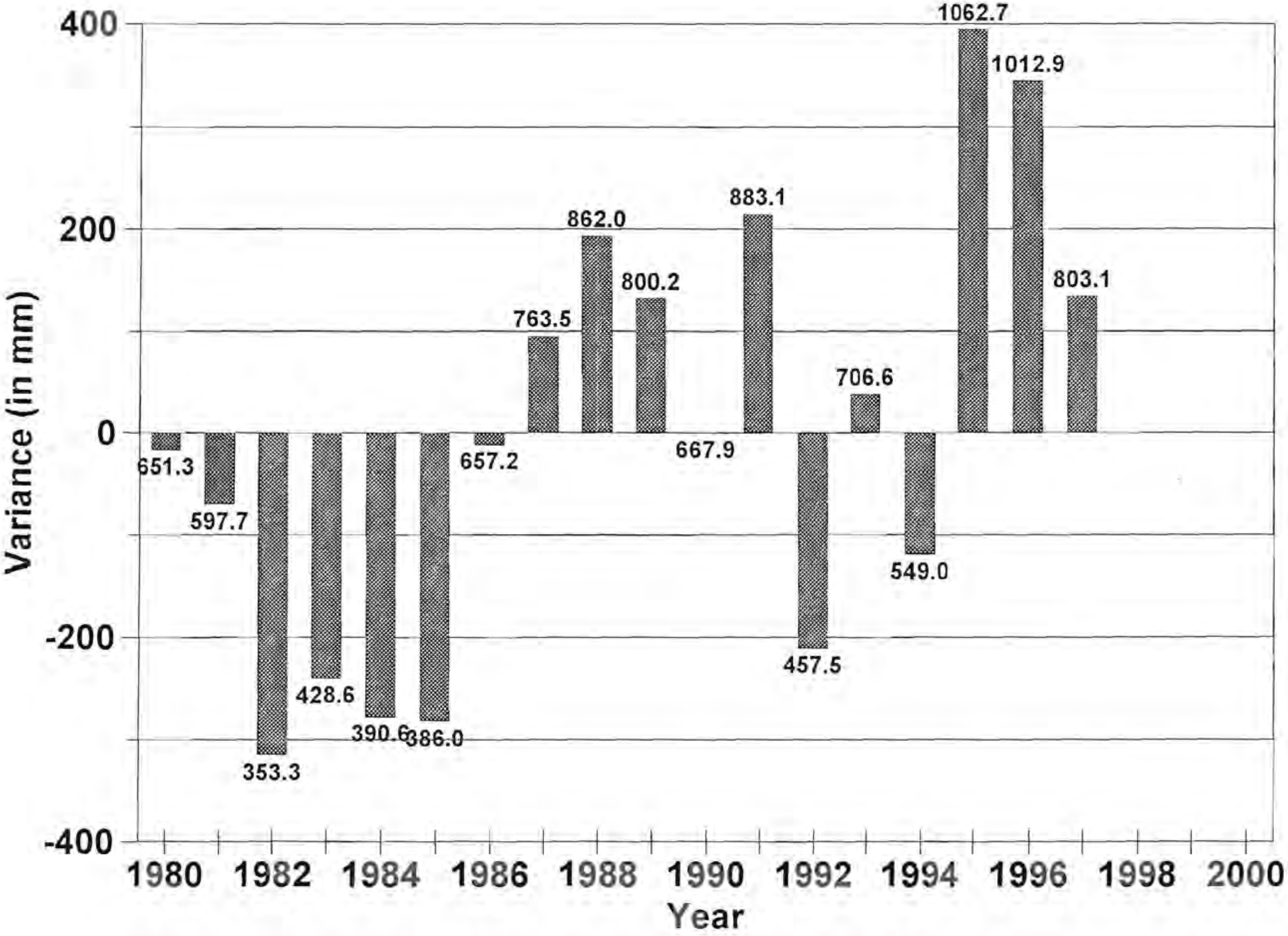


Figure 7 : The variance in the mean annual rainfall for Rustenburg Nature Reserve

HYDROLOGY

The Magaliesberg serves as catchment for numerous little streams (Hugo 1979). The absence of notable vegetation cover on the crest and upper slopes, increases runoff from these surfaces, which flows into cracks and crevices in the underlying rock strata only to emerge through seepage sites further down the northern slopes. Small streams are therefore abundant in the Magaliesberg, especially on the northern slopes (Carruthers 1990). The reserve's boundary includes the upper catchment of the Waterkloofspruit. This catchment comprises a 17 km^2 area on the northern plateau and central basin. The stream flows through a unique *Phragmites australis* reed marsh in the central basin area of the reserve, drops over a 60 m high waterfall and flows further through the farm Baviaanskrans to join the Hex River north of the reserve. Figure 8 illustrates the annual runoff measured at two gauging points in the Waterkloofspruit. A weak correlation (top measure plate: $r^2 = 0.518$; bottom measure plate: $r^2 = 0.465$) exist between rainfall and runoff. This is due to the considerable potential of the underlying substrate to absorb a high percentage of rainfall water, while only floodwater runs down the streams (Hugo 1979).

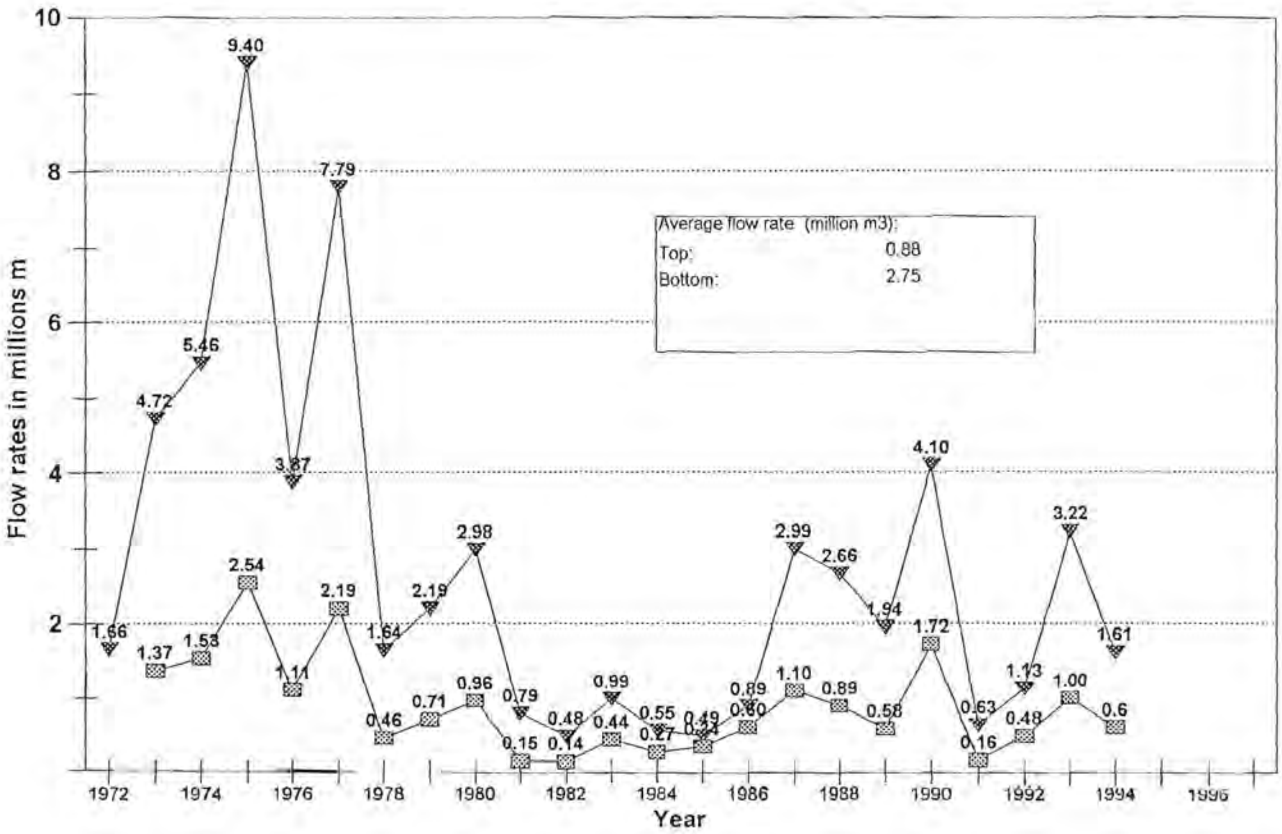


Figure 8: Annual flow rate of the Waterkloofspruit in the Rustenburg Nature Reserve

Several smaller streams also have their origin on the reserve. The rock strata dip to the north and the south-flowing streams are therefore mostly annual while the north-flowing streams are perennial (Hugo 1979; Carruthers 1990). Runoff on the bare northern rock faces is extremely fast and is contained in small spongy areas along the slope. Smaller streams flow from these areas. The Dorpspruit, an important small stream with its source on the northern plateau, flows northwards to join the Hex River north of Rustenburg.

CHAPTER 4

THE VEGETATION OF RUSTENBURG NATURE RESERVE

INTRODUCTION

A detailed analysis of the physical environment and associated plant communities of a conservation area is necessary to enable a manager to compile an efficient wildlife management programme (Bredenkamp & Theron 1976; Bredenkamp & Theron 1991; Bezuidenhout 1995). This will contribute to ecologically sound land use planning and management and ensure sustainable resource utilization. The description and classification of homogenous vegetation units form the primary basis for the delineation of homogenous physiographic units for management purposes (Schulze *et al.* 1994).

Vegetation types are the result of a specific set of environmental factors and therefore constitute different habitats (Dekker *et al.* 1995) which respond differently to similar environmental impacts and management practises (Bredenkamp & Theron 1976). An analysis of the vegetation of an area is important to determine and explain the relationships between plant associations and environmental variables.

The aim of this study was to classify, describe and map the vegetation of Rustenburg Nature Reserve. This will be used to delineate homogenous physiographic units for management purposes.

Classification and mapping of landscape features and habitats are an essential first step in ecological monitoring, as it enables the delineation of the ecosystem that will serve as basis for data collection and analysis (Grimsdell 1978). These management units and associated vegetation communities will form the basis of a monitoring programme to establish trends in vegetation changes. Successful management of natural vegetation depends on a knowledge of the composition of the vegetation, the extent it is being utilized and the rates and direction of changes that may take place in response to management practises such as herbivory and fire (Walker 1976). This knowledge depends on a reliable and efficient programme to monitor whether the management practices in place do have the desired effect on the attainment of specific goals for conservation areas.

METHODS

Species Composition

The Braun-Blanquet approach of vegetation classification was used to describe the vegetation of Rustenburg Nature Reserve. These procedures have been used successfully by various researchers (Bredenkamp & Theron 1978; Schulze 1992 Bezuidenhout 1993, 1994; Brown & Bredenkamp 1994; Brown *et al.* 1995) and has been recommended by Scheepers (1983) for the standardization of phytosociological studies in South Africa. It is an informal method using ecological knowledge of the area to arrange species and samples to best described the inherent structure of the data. The Braun-Blanquet approach is based on three principles (Gaugh 1989):

- Plant communities are conceived as vegetation types recognised by floristic composition, apart from environmental information
- Certain species in a vegetation community are more sensitive indicators of a given environmental or competitive gradient than others
- Communities are arranged into a hierarchical classification on the basis of diagnostic species.

An arranged table is a species-by-sample data matrix that displays at once both the general and the full detail of the data set. This method of classification is the earliest classification technique in community ecology. The most frequently used method for analysing plant community data through table arrangement is the Braun-Blanquet method. It is an informal, subjective method.

The Braun-Blanquet method proceeds in three phases

- The analytical phase consists of reconnaissance and data collection
- The synthetic phase involves arranging samples and species to show the inherent structure of the data by an arranged table
- The syntaxinominal phase involves the assignment of samples to previously recognised associations or the establishment of new associations, the hierarchical arrangement of associations into higher units and the development of formal standardized nomenclature

Coetzee (1975) used Braun-Blanquet procedures to classify the vegetation of the farm Rietvallei. Vegetation data for the farm Baviaanskrans was collected and consolidated with Coetzee's data to develop a single vegetation map for the reserve. The entire data set was re-analysed to investigate possible rearrangements which may result as certain vegetation groups become more or less pronounced. To ensure compatibility between the two data sets, the procedures as described by Coetzee (1975) were being adhered to as far as possible.

With a fair knowledge of the terrain and associated vegetation and geological and soil type boundaries, the farm Baviaanskrans was investigated with the aid of a stereoscope and 1:10 000 scale paired stereophotographs. The area was stratified into relative homogenous physiographic and physiognomic units and 113 sampling plots were randomly placed in these physiographic-physiognomic units.

As one is not bound to a fixed plot size (Werger 1974), a 16 m^2 quadrant was considered sufficient for studying the herbaceous stratum. A plot size of 200 m^2 was adequate to represent the structural composition of the woody layer (Schulze

1992; Schmidt 1992; Bredenkamp & Deutschländer 1995, Brown & Bredenkamp 1994; 1996). This follows the plot sizes suggested by Coetzee (1975). In each plot, all plant species together with the following information, were recorded:

- Braun-Blanquet cover-abundance values for each species were estimated using the Braun-Blanquet scale described by Werger (1974)
- Percentage rock cover (0 = no rocks, 1= 1-10%, 2 = 10%+)
- Size of rocks: Boulders, Large rocks, Medium rocks, Gravel — absent, rare, frequent, abundant
- Slope (in degrees)
- Aspect
- Terrain unit (5,4,3,2,1)
- Surface erosion (1=none, 2 = splash erosion, 3 = donga erosion)

The raw data sets from Rietvallei (Coetzee 1975) and Baviaanskrans were consolidated into one data set. Two-way indicator species analysis (TWINSPAN) (Hill 1979b) was applied to the full data set as a first approximation. The resulting classification was refined by means of Braun-Blanquet procedures (Bredenkamp & Theron 1978; Matthews *et al.* 1992, 1994; Schmidt 1992; Schulze 1992; Smit *et al.* 1993; Fuls *et al.* 1993; Bezuidenhout 1993, 1994; Brown & Bredenkamp 1994; Brown *et al.* 1995).

A synoptic table was compiled using the final phytosociological tables. An ordination algorithm, Detrended Correspondence Analysis (DECORANA) (Hill 1979a) was applied to the synoptic data set to determine possible gradients between communities and to detect possible habitat gradients associated with vegetation gradients (Matthews *et al.* 1992; Bezuidenhout *et al.* 1994; Schulze *et al.* 1994; Bezuidenhout 1995). The association of the different communities along the first and second axes of the ordination diagram was used to determine the different management units (Schulze *et al.* 1994).

The naming of the vegetation units was done according to the method used by Schmidt (1992). The first species name was that of a species diagnostic to the vegetation unit and the second species name that of a dominant species. A physiogonomic term, as described by Edwards (1983) was used to described the vegetation structure of the unit.

Structural Analysis of the Woody Vegetation

Additional information on the structure of the woody vegetation was determined by the Variable quadrant-size method as described by Coetzee and Gertenbach (1977). The woody structure In accordance with this method the following information for each sampling site were determined:

- Species compositional data of the tree and shrub layer
- Density and distribution of the trees and shrubs in each of the following height classes:
  - <0.75m
  - 0.75m - <1.5m
  - 1.5m - <2.5m
  - 2.5m - <3.5m
  - 3.5m - <5.5m
  - >5.5m
- The growth form of the stem:
  - Tree form - Individual with single stem
  - Light shrub form - Individual with 2-4 stems
  - Bushy shrub form - Individual with more then 5 stems
- The total density of the tree and shrub layer, expressed as individuals. hectare^{-1}

Thirty-one plots were randomly placed in vegetation communities with notable woody stratums and were analysed separately with the use of Quattro Pro Spreadsheet functions.

RESULTS

Classification

In total 611 plant species were recorded. Through the application of TWINSPAN, four main vegetation groups were identified from the initial data set. The delineation of the four groups was based on underlying mother rock, soil depth, clay content and moisture content:

Vegetation associated with very shallow soils and bedrock, underlaid by quartz, mainly on the northern slopes

Vegetation associated with deep to medium-deep soils, underlaid by quartz, in the central basin and north western plateau

Vegetation associated with deep clayish soils, underlaid by diabase, mainly in the eastern valleys

Vegetation associated with the moist habitats along Waterkloofspruit and drainage lines

Four phytosociological tables were developed for the vegetation in Rustenburg Nature Reserve. From the final phytosociological tables 51 vegetation communities and their associated sub-communities and variations were identified.

1. *Englerophytum magalismontanum - Ancylobotrys capensis* Tall Open Shrub land

- 1.1 *Aristida transvaalensis - Bulbostylis burchellii* Tall Sparse Shrub land
- 1.2 *Ceterach cordatum - Tristachya leucotrix* Tall Sparse Shrub land
- 1.3 *Croton gratissimus - Combretum molle* Short Sparse Woodland
- 1.4 *Faurea saligna - Cyperus sphaerospermus* Short Open Woodland
- 1.5 *Diospyros lycioides - Cymbopogon validus* Tall Sparse Shrub land
- 1.6 *Asparagus krebsianus - Senecio venosus* High Open Shrub land
- 1.7 *Loudetia flavida - Tristachya biseriata* Tall Closed Shrub land

2. *Eragrostis nindensis - Cyperus rupestris* Short Open Grassland

2.1 *Lopholaena coriifolia - Lapeirousia sandersonii* Short Open Grassland

2.1.1 *Diheteropogon amplectens - Tristachya biseriata* Tall Open Grassland

2.1.2 *Themeda triandra - Aristida diffusa* Short Open Grassland

2.1.3 *Frithia pulchra- Selaginella dregei* Low Sparse Grassland

2.1.4 *Coleocloa setifera - Indigofera comosa* Short Open Grassland

2.1.5 *Trachypogon spicatus - Bulbostylis burchellii* Short Open Grassland

2.2 *Themeda triandra - Eragrostis racemosa* Short Open Grassland

3 *Bulbostylis burchellii - Themeda triandra* Short Open Grassland

4 *Tristachya biseriata -Protea caffra* Short Sparse Woodland

4.1 *Blumea alata - Parinari capensis* sub-community

4.2 *Indigofera burkeana-Rhynchosia totta* Short Closed Woodland

4.3 *Diheteropogon amplectens - Ficinia filiformis* Short Closed Woodland

4.4 *Cryptolepis oblongifolia - Loudetia simplex* Tall Sparse Woodland

4.5 *Trachypogon spicatus - Sphenostylis angustifolia* Tall Closed Grassland

4.6 *Burkea africana - Setaria sphacelata* Tall Open Woodland

4.6.1 *Combretum zeyheri - Trachypogon spicatus* Tall Sparse Woodland

4.6.2 *Burkea africana - Themeda triandra* Tall Open Woodland

4.7 *Aloe greatheadii- Themeda triandra* Tall Open Woodland

5 *Protea gaguedi - Monocymbium ceresiiforme* Short Open Shrub land

6 *Indigofera comosa - Schizachyrium sanguineum* Tall Closed Grassland

7 *Plexipus hederaceus - Cymbopogon excavatus* Tall Closed Grassland

8 *Tristachya leucotrix - Setaria sphacelata* Tall Sparse Woodland

8.1 *Heteropogon contortus - Trachypogon spicatus* Tall Open Woodland

8.2 *Ruellia cordata - Senecio venosus* Tall Sparse Woodland

8.3 *Trachypogon spicatus - Bulbostylis burchellii* Short Sparse Woodland

9 *Acacia caffra - Ziziphus mucronata* Tall Closed Woodland

9.1 *Cheilanthes viridus - Combretum molle* Short Open Woodland

9.2 *Digitaria eriantha - Lippia javanica* Tall Closed Woodland

9.3 *Setaria lindenbergiana - Artemisia afra* Tall Closed Woodland

9.4 *Becium obovatum - Protea caffra* Tall Closed Woodland.

9.4.1 *Turbina oblongata - Phyllanthus glaucophyllus* High Closed Shrub land

9.4.2 *Diospyros lycioides - Rhus rigida* Tall Closed Woodland

9.4.3 *Themeda triandra - Elionurus muticus* Tall Closed Woodland

9.5 *Ruellia patula - Melinus nerviglumis* Short Open Woodland

9.5.1 *Hypericum aethopicum - Acacia karroo* Short Closed Woodland

9.5.2 *Loudetia flavida - Andropogon schirensis* Short Open Woodland

9.6 *Heteropogon contortus - Faurea saligna* Tall Open Woodland

9.7 *Senecio venosus - Heteropogon contortus* Tall Closed Woodland

9.8 *Setaria sphacelata - Themeda triandra* Tall Closed Woodland

9.9 *Euclea crispa - Panicum maximum* Tall Closed Woodland

9.10 *Asparagus virgata - Celtis africana* Tall Closed Woodland

9.11 *Olea europaea - Grewia occidentalis* Tall Closed Woodland

10 *Mimusops zeyheri - Hypoestes forskaoli* Tall Forest

11 *Brachylaena rotundata - Englerophytum magalismontanum* High Open Shrub land

11.1 *Pittosporum viridiflorum - Halleria lucida* Short Open Shrub land

11.2 *Ancylobotrys capensis - Tricalysia lanceolata* Short Open Shrub land

12 *Cynodon dactylon - Panicum maximum* Tall Sparse Woodland

12.1 *Tagetes minuta - Commelina africana* Sparse Open Woodland

12.2 *Hyparrhenia hirta - Bidens pilosa* Short Sparse Woodland

13 *Pteridium aquilinum - Miscanthus junceus* Tall Closed Grassland

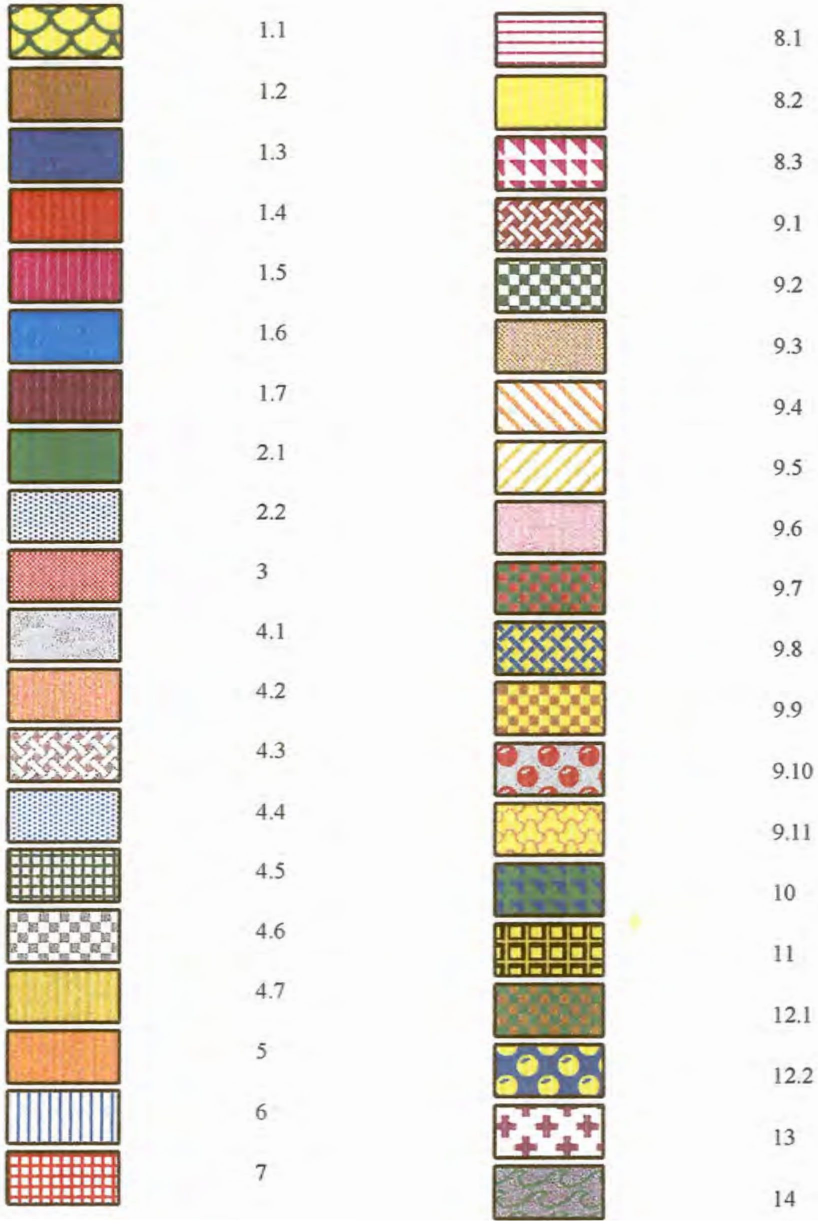
13.1 *Phragmites australis - Cyperus* species Reedswamp

13.2 *Vernonia hirsuta - Pteridium aquilinum* Tall Closed Grassland

13.3 *Pycnostachys reticulata - Buddleja saligna* Tall closed Shrub land

14 *Aristida junciformis - Arundinella nepaliensis* Tall Closed Grassland

Vegetation map of the Rustenburg Nature Reserve



The numbers next to the legend corresponds with the numbers of the communities and variations as outlined on page 57-59 of the text

Description of the vegetation units

1. *Englerophytum magalismontanum - Ancylobotrys capensis* Tall Open Shrub land community

This community is generally confined to the steep northern and north eastern slopes (>20°) of the reserve and extends onto the banks of the deeply insized ravines, characteristic of the northern face of the Magaliesberg (Carruthers 1990). Soils are shallow lithosols, restricted to the Mispah and Glenrosa soil forms. A lithosol-rock complex of sheetlike to broken quartzite occurs on the steep upper slopes (Coetzee 1975). Exposed rock and shallow Mispah soils are limited to the crest of the Magaliesberg, although a mosaic of these exposed areas is interspersed among the deeper soils on the middle- and footslopes. Deep Glenrosa soils are found further down the slope where eroded material accumulate. Characteristic of the Mispah soil form on the reserve is the high content of decomposed organic matter (Coetzee 1975), the result of a high occurrence of pioneer plant roots in the top layer (% carbon > 3.04%).

This community corresponds with the *Englerophytum magalismontanum - Ancylobotrys capensis* Shrub land identified by Coetzee (1975). Coetzee (1975) regarded this community as inferior to the *Loudetia simplex - Aristida aequiglumis* Woodlands, Shrub lands and Grasslands. The inclusion of the vegetation of the farm Baviaanskrans in the classification elevates this community to be prominent in the reserve. The *Englerophytum magalismontanum - Ancylobotrys capensis* Shrub land is extensively spread over the northeast facing slopes of Baviaanskrans.

The community is represented by 35 relevès and is characterised by species group A (Table 4). Dominant species in this community are *Englerophytum magalismontanum, Ancylobotrys capensis, Ochna pulchra, Indigofera melinoides* and *Tapiphyllum parvifolium*. This community is also recognised for the extensive occurrence of the pioneer plant *Selaginella dregei* (Species group T), which forms extensive mats on seasonally wet sheetrock and flat rock surfaces (Jacobsen 1989).

On the basis of presence and absence of species groups in this community, seven sub - communities can be recognised.

1.1 *Aristida transvaalensis - Bulbostylis burchellii* Tall Sparse Shrub land

This shrub land is situated on the shallow soils on the upper regions of the north eastern facing slopes of Baviaanskrans. Conspicuous species present in this community are *Aristida transvaalensis* (species group B; Table 4), *Indigofera melinoides* (species group A;Table 4), *Cetarach cordatum* (species group C; Table 4) and the sedge *Bulbostylis burchellii* (species group T;Table 4). The cover abundance value of the grass species *Aristida transvaalensis* in this sub-community varies between 1 and 25%. This species is confined to this sub-community and validates this distinction. The shrub stratum in this sub - community is inconspicuous and limited to individual stands of *Englerophytum magalismontanum* (cover abundance value 1%-25%).

Table 4: Phytosociological table for the *Englerophytum magalismontanum - Ancylobotrys capensis* shrubland and *Eragrostis nindensis - Cyperus rupestris* Short Grassland vegetation communities.

Species	035	071	032	044	038	056	047	053	052	079	078	077	036	048	064	249	228	248	250	317	370	372	373	342	371	386	310	299	302	206	312	313	212	369	207	300	305	306	301	303	351	308	309	304	307	338	339	340	327	328	329	345	298	333	334	343	326	336	337	318	315	332	319	321	311	314	323	325	331	350	341	367	322	324	344	335	346	330	347	348	349	352	358	362	037	050	046	034	035
Vegetation communities	1																																			2																																																	3				
Sub-communities	1.1						1.2									1.3				1.4				1.5			1.6			1.7						2.1																																							2.2															
Variations																																				2.1.1				2.1.2						2.1.3															2.1.4											2.1.6															
Species group A																																																																																									
Englerophytum magalismontanum			2						R				2	R	1		2	2	1	2	2	2	2	2	2	3	2	2	2	+	2	2	+	3	1																							+			+																						
Ancylobotrys capensis	R			+					+	+				2		+	1	+	1	1		1	+	+	+	2	3	1	+		1	+	+	1	+																														+																					
Ochna pulchra				R					+			+						+	+	+												+	+				1		+																																																					
Indigofera melanadenia	1		1	+		+				+		1		+		+			+	+										+	+		+	+					+			+											+																																							
Tapiphyllum parvifolium					+				R	+		R			+	+	2	+		+	+			+	+	2	+	+		2	1	+	+	1	+																							+																												
Species group B																																																																																									
Aristida transvaalensis	2		+	+	+	+									+																									+																																															+
Species group C																																																																																									
Celerach cordatum		+	+	+	+	+	R	+	+	+	+	+		+	+																																																																									
Tristachya leucothrix	+	1				1			1	+	1	+																																																																													
Tephrosia longipes				+	+		+	+				+	+			+	+																								+																																													+	
Species group D																																																																																									
Crassula argyrophylla																+	+	+	+																																																																						
Combretum molle									+						+	+	+	+		+								+	+																																																												
Croton gratissimus subsp. *gratissimus*																+		2	1																																																																						
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Anthospermum hispidulum																	+	+	+				+			+								+																													+	+																												
Species group E																																																																																									
Faurea saligna																					+	+	1	2							+	3				+																																																								
Cyperus sphaerospermus																	+			+	1	2	+				+	+	1																																																												
Oxalis obliquifolia																				+	+	+	+							+															+																		+																							
Setaria lindenbergiana																		+	+	+	+	+						+							+																																																						
Scadoxus puniceus																				+	+	+	+																																																																		
Gerbera piloselloides																				+		+	+																																																																		
Species group F																																																																																									
Diospyros lycioides																				+	+	+		+	+	+																																	+																												
Clutia pulchella																				+	1	1	+		+	+								+																																																						
Plectranthus madagascariensis																					+	+	+	+		+								+																											+											+															
Canthium gilfillanii																					1	+	+		+						+																																																									
Species group G																																																																																									
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Canthium suberosum																				+		+					+		+											+																																																
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Maytenus tenuispina																	+	+						+	+			+																																													+															

Table 4: (cont.) Phytosociological table for the *Englerophytum magalismontanum* - *Ancylobotrys capensis* shrubland and *Eragrostis nindensis* - *Cyperus rupestris* Short Grassland vegetation communities

Vegetation communities	1																																			2																																																	3				
Sub-communities	1.1						1.2									1.3				1.4				1.5			1.6			1.7						2.1																																							2.2													
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	3	7	3	4	3	5	4	5	5	7	7	7	3	4	6	4	2	4	5	1	7	7	7	4	7	8	1	9	0	0	1	1	1	6	0	0	0	0	0	0	5	0	0	0	0	3	3	4	2	2	2	4	9	3	3	4	2	3	3	1	1	3	1	2	1	1	2	2	3	5	4	6	2	2	4	3	4	3	4	4	4	5	5	6	3	5	4	3	3
Species	9	1	2	4	8	6	7	3	2	8	8	7	6	8	4	9	8	9	0	7	0	2	3	2	1	6	0	9	2	6	2	2	2	9	7	0	5	6	1	3	1	8	9	4	7	8	9	0	7	8	9	5	8	3	4	3	6	6	7	6	5	2	9	1	1	4	3	5	1	0	1	7	2	4	4	5	6	0	7	8	9	2	8	2	7	0	8	4	5
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Zanthoxylum capense																+	+	+	+	+	+	+	+	+	+	+			+			+	+	+																																																							
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Commelina erecta																		+		+	+	+	+	+			+	+			+			+																																															+								
Crassula species																							+	+	+	+	+				+	+										+																				+																											
Loudetia flavida																+		+												2	+	+	+																																+																								
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Species group K																																																																																									
Eragrostis nindensis											+		+											+						+		+				1	+		+	3	+	+	+	2	+		+	+	1		+	+	+	+	+	+	+	+	+	+	+	2	+	+	1	+	+	1	+	+	+	1	+	+	+	+	+	+	+	1	1	+	+	+	+		+		
Indigofera comosa		+			1																								+	+					+	+	+			+		+	+	+	+	+		+	+		+	+	+		+		+		+	+	4	+		+				+	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+			1	+	
Andromischus umbraticola																		+	+							+								+			+	+	+	+				+	+	+	+	+		+		+	+	+	+	+	+	+	+				+		+		+	+			+				+	+			+	+	+		+						
Albuca setosa																							+												+	+	+		+									+				+			+	+		+	+	+	+	+			+				+		+	+	+		+	+	+	+	+	+	+	+							
Dicoma anomala																																				+	+	+						+								+			+				+					+									+			+		+				+	+	+					
Khadia acutipetala																																					+			+	+			+					+					+	+	+		+	+			+							+		+	+			+	+		+			+	+	+						
Species group L																																																																																									
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Lapeirousia sandersonii																								+												+			+	+	+	+	+	+		+	+		+	+		+				+		+	+		+		+	+	+		+		+	+	+	+	+	+															
Species group M																																																																																									
Oldenlandia herbacea										+		+					+	+		+				+		+						+	+			+			+	+			+	+		+																	+				+							+								+							
Aristida diffusa																+		+	+												+	+				1			+	+		+	+	1	+											1									+	+																							
Kalanchoe thyrsiflora																				+						+								+	+	+	+			+		+		+	+																+																												
Species group N																																																																																									
Frithia pulchra																																						+							+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+						+									+	+													
Species group O																																																																																									
Coleochloa setifera									+							2	+	+	3	+	1		1	+	2	+	+	+	+		2	+		1			+	+	2		1	3	3		3	3	2	2	1	2	2	+	1	2	+	1	2	2	+	3	2	+	2	2	+	2	2		2	+	+																		
Pellaea calomelanos																+	+	+	+	+		+	+	+	+	+	+	+	+	+	+		+	+	+		+					+	+						+					+		+	+			+	+		+	+		+	+	+	+											+	+								
Rhus magalismontanum							1								+		+				+	+				2	+	+			+	+				1			+		+	+	+	+	+			+	+	+	+	+	+		+			+	+			+	+		1		+	+			+																		
Cymbopogon validus		+							+							2		1	1	+			+	1	1	+	1	+	+		2		+	+	+										+			+	+	+	+	+		+		1			+	+		+	+		+		+																					+	
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Eragrostis racemosa												+																					+		+		+	+		+																												+								+		+	+	+		+	+				+	+	
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Euphorbia schinzii														T	R				+						+																			+		+	+	+				+	+			+	+			+	+				+			+	+		+				+		+		+	+	+								
Anacampseros [illegible]																			+																					+												+	+						+			+		+	+			+		+		+			+				+	+	+	+	+						
Microchloa caffra																															+																	+	+		+	+				+						+	+				+			+				+	+				+										2
Cleome monophylla																					+		+														+																			+							+	+		+	+			+							+			+									

Table 4: (cont.) Phytosociological table for the *Englerophytum magalismontanum* - *Ancylobotrys capensis* shrubland and *Eragrostis nindensis* - *Cyperus rupestris* Short Grassland vegetation communities

Vegetation communities	1																																			2																																																					3				
Sub-communities	1.1						1.2									1.3				1.4				1.5			1.6			1.7						2.1																																								2.2														
Variations																																				2.1.1				2.1.2						2.1.3															2.1.4											2.1.5																	
Species	039	071	032	044	038	056	047	053	052	079	078	077	036	048	064	249	228	248	250	317	370	372	373	342	371	386	310	299	302	206	312	313	212	369	207	300	305	306	301	303	351	308	309	304	307	338	339	340	327	328	329	345	298	333	334	343	326	336	337	316	315	332	319	321	311	314	323	325	331	350	341	367	322	324	344	335	346	330	347	348	349	352	358	362	037	050	045	034	035
Species group R																																																																																												
Raphionacme burkei																																				+				+	+	+	+	+		+	+	+	+				+	+	+						+	+	+	+	+		+		+			+		+		+		+	+	+	+	+	+	+		1			
Nidorella hottentotica																														+					+					+				+		+	+			+					+		+	+	+	+	+	+		+	+			+	+		+	+	+	+		+	+	+			+	+	+	+					
Xerophyta viscosa									+			+				+																								+				+				+			+	+	+		1	+		+	+			+		+	+				+	+		+	+	+	+	+	+				+		+						
Eragrostis stapfii																																									+		+		+		+		+					+	+			+	+		+	+		+					+			+	+	1				+					+	+					
Ledebouria revoluta												+																														+	+		+	+	+							+	+		+			+	+		+	+			+				+		+		+						+		+						
Helichrysum cerastioides																																								+				+										+															+	+		+		+						+		+	+						
Species group S																																																																																												
Aristida aequiglumis																	+							+				+	+	+			1		+	1	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+	2		+		+	+	+	+	+	+	+	+	2		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+						
Cyanotis speciosa																	+							+						+			+	+	+		+		+	+	+	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+		+	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+					
Anthospermum rigidum																	+								+		+	+	+	+			+		+	+	+	+		+			+	+	+	+	+	+			+	+	+	+	+	+	+	+	+		+	+		+	+			+	+	+	+	+		+	+		+		+	+	+	+	+						
Andropogon schirensis				+														+						+			+	+		+	+	+	1		2	+					+	+	+		+		+	+	+	+		+		+	+	+	+	+	+		+	+	+	+	+		+	+	+	+	+	+		+	+		+	+	+	+	+	1	+	+					
Tephrosia elongata																										+	+			+	+	+		+	+	+						+	+		+					+		+			+	+					+				+			+					+					+	+				+					
Species group T																																																																																											
Trachypogon spicatus						+		+	+	+	+			+			+					+			+	+	+	+		2	+	+	3		1	+	1	+	+	+	1	+		+	+			+		+		+	+	+		+				2	+	+		+	+			+		+	1	2	2	+	1		+		1	+	+	2	+		+	+		+	
Loudetia simplex		1			+	+	+		+	+	+		+	+	+		2						+					+		+	+		+	+	2		+	+								+	+	+			+	+	2	+			+		+	+	+			+	+			+			2		+		+								+	+		+	1	+	+
Schizachyrium sanguineum					+	+			+									+	+	+		+		+	+		+	+	+		+	+		+	+		+	+	1	+	+	+	+		+					+			+			+	+						+	+	+		+	+		+		+	+		+		+		+	+	1	+		+	+	+	+	+	
Bulbostylis burchellii	2	2	1	+	+	1	1	1	+	1	1	1	1		+	+	+	+	+	+		+	+	+	+		+	+	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+	1	+	+	+	+	+	+	1	+	+	+	+	+	+	+	+	+	+	+	+	2	+	+	2	2	2	+	1	+	+	+	+	1	1	1	+	2	+	+	1	1	1
Melinis nerviglumis			+			+		2		+				+			+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+			+	1	+	+
Cyperus rupestris			2		4		3							+																		+				+	+	+	+	+	+	+	+	+	+		+	+	+		+	+		+	+	+	+	+	+			+	+	+	+		+		+	+	+	+		+	+	+	+	+	+	+	+	+	+			1		2	2
Diheteropogon amplectens	+	+							+			+				+	+	+	+					+	+		+	+	+	+	+		1	+	1	+	2	2	+	+	1	+	+	+	+	+	+	+		+	+	+	+	+	1	+	+	+	1	+	+	+	+	+	+		+	1	+	+	+	1	+	+	+	+	1	+	+	2	+	2	1	2	1		+		
Selaginella dregei									1			+	3	1			+			+	+		+	+	+	+	+	+	+		+	2		+		2	+		1	+	+	+	+	+	+	+	+	+	+	+	+	+	1	+	+	1	+	+	1	+		1	+	+	+		+	+	+	1	+	+	+	1	+	+	+	+	+	+	1	+				1	+	1	+
Themeda triandra	+								+				+	+	+		1				+	+	1	+			+	+	1	1	1			+	+		1	+	2	2	1	+	+	2	+		+	1	1		+	2	+	+	1	+		1	1	+	1	+	+	1			+	+	+	2		+	1	+	1	3	2	3	3	2	1	1	2		+	+	+	+	
Brachiaria serrata	+				+	+	+				+		+		+							+	+		+					+	+		+		+	1		+	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+		1		+	+	+	+	1	+	+	1	+	+	+	+	+	+		+	+	+		+	+	+	1
Commelina africana		+	+			+				+					R	+	+	+		+			+	+					+	+			+		+	+	+	+	+	+	+	+		+	+						+	+	+		+	+				+	+		+				+	+		+		+		+			+		+	+		+			1	1	+	+	

The lithophyte *Selaginella dregei* (species group T) is distinctly absent in this sub - community. According to Gibbs-Russell *et al.* (1991) *Aristida transvaalensis* is a chasmophyte limited to dry, rocky outcrops, while *Selaginella dregei* prefers at least seasonally wet and flat rock surfaces (Jacobsen 1989).

1.2 *Ceterach cordatum - Tristachya leucotrix* Tall Sparse Shrub land

This sub - community can be found on the upper northeastern slopes of Baviaanskrans, as well as the upper southern slopes and the crests of a secluded quartzite hill in part of the study area. The habitat is rocky with huge boulders and the slope varies between 5° and 25°. The clay content of the soil is low and does not exceed 15%.

This sub-community is characterised by the occurrence of the fern *Ceterach cordatum* (species groups C; Table 4). Van Vuuren and van der Schijff (1970) also found this forb to be abundant in the crevices on the northern slopes. This forb is confined to sheltered and moist sub-habitats in the shade among rocks. Other prominent species in this community is *Bulbostylis burchellii*, *Loudetia simplex*, *Trachypogon spicatus* and *Selaginella dregei* (species group T; Table 4).

1.3 *Croton gratissimus - Combretum molle* Short Sparse Woodland

The *Croton gratissimus - Combretum molle* Short Sparse Woodland is situated on the northeastern facing foothills of the northern regions of the reserve. The community occurs on an incline that exceeds 30°. Large rocks occur in the relevés situated on a scree slope. The clay content of the subsoils is low, not exceeding 10%.

Diagnostic species for this sub-community are species group D (Table 4), including *Crassula argyrophylla*, *Combretum molle*, *Croton gratissimus*, *Portulaca kermesina* and *Anthospermum hispidulum*. This sub-community is distinguished by the presence of species from species groups A, H, I, M, O and T. The *Croton* *gratissimus* - *Ancylobotrys capensis* variant, identified by Coetzee (1975) corresponds to this sub-community. According to Coetzee's (1975) classification *Combretum molle* is prominent in the *Englerophytum magalismontanum* - *Ancylobotrys capensis* shrub land. However, with the inclusion of the Baviaanskrans sub-data set, the prominence of *Combretum molle* was reduced. The forb *Coleocloa setifera* (Species group O; Table 4) is also prominent in this community. The grass layer is inconspicuous and limited to secluded stands of *Aristida diffusa, Cymbopogon validus, Diheteropogon amplectens* and *Melinis nerviglumis*.

1.4 *Faurea saligna - Cyperus sphaerospermus* Short Open Woodland

The *Faurea saligna* - *Cyperus sphaerospermus* Short Open Woodland sub-community is associated with the moist environments on the steep south and east facing slopes in the kloof opening in the northwestern slopes of the central basin. This habitat consists of barren rock faces and the dominant vegetation is limited to forbs and shrubs growing from crevices and narrow ledges associated with the deep drainage lines in the Magaliesberg. The slope is steep and varies between 27° and 44°. This sub - community reveals a resemblance to the *Faurea saligna - Ancylobotrys capensis* sub-variation identified by Coetzee (1975), which includes the vegetation associated with the deep drainage lines on the farm Rietvalley.

Species group E (Table 4) is diagnostic for this sub-community, including the woody species *Faurea saligna*, the forb *Scadoxus puniceus, Oxalis obliquifolia* and *Gerbera pilosa*, the sedge *Cyperus sphaerospermus* and the grass *Setaria lindenbergiana*. This sub-community is distinguished by the presence of species groups F, G, H, I, M, O and T. The shrub stratum, including *Diospyros lycioides* subs *guerkei* (species group F), *Brachylaena rotundata* (species group H), *Nuxia congesta* (species group H), *Zanthoxylum capense* (species group I) and *Rhus magalismontanum* (species group O) is more conspicuous than the tree stratum. Other prominent species are *Clutea pulchella* and *Canthium gilfillanii* (species group F), *Commelina erecta* (species group I) and *Coleocloa setifera* (species group O). The grass layer in this sub - community is restricted to the diagnostic grass species *Setaria lindenbergiana* associated with shaded rocky habitats (van Wyk & Malan 1988; van Oudtshoorn 1992). Other grass species associated with shallow soils that are less significant in this sub-community is *Melinis nerviglumis, Themeda triandra* and *Brachiaria serrata* (species group T).

1.5 *Diospyros lycioides - Cymbopogon validus* Tall Sparse Shrub land

Contrary to the *Faurea saligna - Cyperus sphaerospermus* Short Open Woodland, the *Diospyros lycioides - Cymbopogon validus* Tall Sparse Shrub land is confined to the steep, warm north and east facing slopes of the kloofs opening in the northwestern slopes of the central basin area, as well as certain ravines on the northern slopes of the Magaliesberg. Slope varies between 19° and 32°. Large rocks and boulders are absent.

The soil consists predominantly of fine quartzite gravel. Dominant shrub and forb species associated with the shallow soils and rock faces that characterise this sub-community includes the shrubs *Diospyros lycioides* (species group F), *Ficus ingens* (species group G) and *Zanthoxylum capense* (species group I) and the forbs *Clutea pulchella,* (species group F), an unidentified *Crassula* species (species group I), *Coleocloa setifera*, *Pellaea calomelanos* (species group O) and *Selaginella dregei* (species group T). Important grass species in the sub-community are *Cymbopogon validus, Melinis nerviglumis, Schizachyrium sanguineum* and *Diheteropogon amplectens* (species group T).

1.6 The *Asparagus krebsianus - Senecio venosus* High Open Shrub land

The *Asparagus krebsianus- Senecio venosus* High Open Shrub land is found in the shallow drainage lines on the northeastern and southeastern slopes in the southwestern part of the study area. The slopes are gradual and do not exceed 19°. The soil surface is covered with quartzite gravel and large rocks or boulders are absent.

This sub-community is represented by species groups G, H, I, O, S and T. Species included in this sub-community corresponds with the *Croton gratissimus* - *Ancylobotrys capensis* variation defined by Coetzee(1975). The absence of species group F distinguishes this sub-community from sub-communities 1.5. Trees are absent and the shrub layer is, excluding species group A, represented by *Asparagus krebsianus* (species group G), *Brachylaena rotundata* (species group H), and *Rhus magalismontanum* (species group O). Forbs in this sub-community include *Senecio venosus* (species group I), *Coleocloa setifera, Pellaea calomelanos* (species group O) , *Anthospermum rigidum* (species group S), the sedge *Bulbostylis burchellii* and the lithophyte *Selaginella dregei* (species group T) . The dominant grasses in this high open shrub land are *Cymbopogon validus* (species group O), *Schizachyrium sanguineum, Melinis nerviglume, Diheteropogon amplectens* and *Themeda triandra* (species group T) .

1.7 *Loudetia flavida - Tristachya biseriata* Tall Closed Shrub land

This shrub land is situated in various localities on the northern section of the study area. It occurs on the upper northeastern to southwestern slopes and crests with an incline of between 6° and 36°. The texture of the subsoil varies from a sand to sandclayloam (MacVicar *et al.* 1991).

The presence of species groups I, J, M, O, S and T characterise this sub-community. The grass *Tristachya biseriata* (species group J) is pronounced in this sub-community and cover-abundance values indicate that at least 25% of the area is covered by this species. Species group J, including *Tristachya biseriata* and *Vangueria infausta* represents a transitional species group between communities 1 and 2. The herbaceous layer in this sub-community is furthermore represented by the grasses *Loudetia flavida* (species group I), *Cymbopogon validus* (species group O), *Andropogon schirensis* (species group S) , *Trachypogon spicatus, Loudetia simplex, Schizachyrium sanguineum, Melinis nerviglumis, Diheteropogon amplectens, Themeda triandra* and *Brachiaria serrata* (species group T). Conspicuous forbs in this sub-community are *Senecio venosus* (species group I), *Coleocloa setifera, Pellaea calomelanos* (species group O), *Cyanotis speciosa,* *Tephrosia elongata* (species group S), the sedge *Bulbostylis burchellii* and *Selaginella dregei* (species group T). The species representing the shrub layer in this sub-community is confined to the shruby species in species group A.

2. *Eragrostis nindensis - Cyperus rupestris* Short Open Grassland

The largest part of the summit plateau and the south western brim of the central vlei area is covered by this community. It is situated on the warm, dry northeastern and southeastern gentle and relative flat slopes on the reserve. Excluding two relevés, the slope do not exceed 15°. The soils are shallow with interspersed sheet and quartzite boulder outcrops. The soils are characterised by an orthic A layer with a high content of decomposed organic matter (Coetzee 1975) (Table 2). The clay content of these soils is low and varies between sand and sandloam (MacVicar *et al.* 1991).

Coetzee(1975) recognised this community as a sub-community of the *Coleocloa setifera-Selaginella dregei* plant community. However, the inclusion of the Baviaanskrans data set resulted in different species groups and plant communities. Species group O (Table 4), virtually absent from sub-community 1.1 and 1.2., is regarded as a transitional group between communities 1 and 2. Species group K, L, Q and R (Table 4), diagnostic to community 2, are discernibly absent in community 1 and resulted in the differentiation between communities 1 and 2.

Fifty-five relevés represent this community. It is characterised by diagnostic species group K (Table 4). The grass species *Eragrostis nindensis* and the non-grassy herbaceous species *Indigofera comosa, Andromiscus umbraticola, Albuca setosa, Dicoma anomala* and *Khadia acupetala* are diagnostic species for this community. The lithophyte pioneer *Selaginella dregei* is also abundant is this community and covers large areas of exposed sheet outcrops.

Two sub - communities are recognised due to the presence and absence of species groups in this community.

2.1 *Lopholaena coriifolia - Lapeirousia sandersonii* Short Open Grassland

The *Lopholaena coriifolia - Lapeirousia sandersonii* sub-community occurs on shallow soils on slopes surrounding the central basin area. The soil is sandloam and the bedrock consists mainly of recrystallised quartzite gravel. Boulders and large rocks are absent. The slope is moderate and the gradient does not exceed 15°.

This sub-community is characterised by the presence of diagnostic species group L and the virtual absence of species group P (Table 4). Coetzee (1975) regarded the species of this sub-community as diagnostic species for the *Cyperus rupestris - Eragrostis nindensis* sub-community. The inclusion of the Baviaanskrans data set resulted in a clear distinction between sub-communities 2.1 and 2.2 (Table 4). The protected plant (Transvaal Ordinance, No 12 of 1983) *Lapeirousia sandersonii* has a significant cover abundance (1-25%) in this sub-community.

Five variations can be distinguished based on the presence and absence of species groups in this sub-community:

2.1.1 *Diheteropogon amplectens - Tristachya biseriata* Tall Open Grassland

This variation is found on the upper slopes and crests of the Magaliesberg in the southwestern region of the reserve. The soils are shallow sandloam . Exposed quartzite sheets cover large areas. The aspect is northeast and the slope does not exceed 6°. Huge rocks and boulders are absent and the substrate varies from small rocks to quartzite gravel.

This variation is characterised by the presence of species group J, K, L, M, O, S and T and the absence of species from species groups N, Q and R. Dominant species in this variation are the grasses *Tristachya biseriata* (species group J), *Aristida aequiglumis* (species group S), *Diheteropogon amplectens, Melinis nerviglumis, Trachypogon spicatus* and *Themeda triandra* (species group T), and the non-grassy herbaceous species *Coleocloa setifera* (species group O), *Bulbostylis burchellii* and *Commelina africana* (species group T). The shrub layer is inconspicuous and limited to individual stands of *Rhus magalismontanum* (species group O).

2.1.2 *Themeda triandra - Aristida diffusa* Short Open Grassland

The *Themeda triandra - Aristida diffusa* Short Open Grassland is situated on the northeastern facing slopes in the southwestern section, as well as on the slopes in the extreme northeastern regions of the reserve. The slopes are gentle with few boulders and rocks. The soil is sandloam.

This variation is distinguished by the presence of species groups M, O, R, S and T and the absence of species groups N, and Q (Table 4). This variation is not characterised by a diagnostic species group. Species that are abundant include the grasses *Eragrostis nindensis* (species group K), *Aristida diffusa* (species group M), *Aristida aequiglumis* (species group S), *Trachypogon spicatus, Schizachyrium sanguineum, Melinis nerviglumis, Diheteropogon amplectens, Themeda triandra* and *Brachiaria serrata* (species group T), the forbs *Kalanchoe thrysiflora* (species group M), *Coleocloa setifera, Aloe peglarae* (species group O), *Raphionacme burkei* (species group R), *Cyanotis speciosa* (species group S), and the sedges *Bulbostylis burchellii* and *Cyperus rupestris* (species group T), all of which occurred consistently in all relevés in this variant.

2.1.3 *Frithia pulchra- Selaginella dregei* Low Sparse Grassland

This low grassland occurs on the gravel soils of the undulating plains that lie below the northern summit plateau. It also occurs in the western regions of the reserve, where it is localized to small secluded areas on the upper northeastern aspect. Single relevés representing this variation was found on the southwestern aspect of the central quartzite ridge. The slope is less than 15°. The subsoil consists of quartzite gravel and small rocks. No boulders or large rocks are present in this variant.

This variation is differentiated by the presence of diagnostic species group N, consisting of the small xerophyte, *Frithia pulchra*, a plant endemic to the Magaliesberg (Carruthers 1990). Coetzee (1975) regarded this variation as part of the *Cyperus rupestris- Eragrostis nindensis* Grassland. Except for species groups K and L, this variation is also represented by species groups N, O, Q, R, S and T. *Selaginella dregei* were found to be growing in close association with *Frithia pulchra*. Abundant grass species in this variation are *Cymbopogon validus* (species group O) , *Aristida aequiglumis, Andropogon schirensis* (species group S), *Melinis nerviglumis, Diheteropogon amplectens, Themeda triandra* and *Brachiaria serrata*, (species group T). The herbaceous layer is dominated by the forbs *Coleocloa setifera* (species group O), *Cyanotis speciosa, Anthospermun rigidum* (species group S) and the sedge *Bulbostylis burchellii* (species group T). The shrub layer is limited to individual stands of *Rhus magalismontanum* (species group O).

2.1.4 *Coleocloa setifera - Indigofera comosa* Short Open Grassland

The *Coleocloa setifera - Indigofera comosa* Short Open Grassland variation is found on the gentle hill slopes surrounding the northern section of the central basin area. Except for two relevés, the gradient does not exceed 10°. The soil is coarse-grained sandloam. Boulders and rocks are absent.

Indications of similarity between variants 2.1.3 and 2.1.4 (Table 4) occur due to the presence of species groups O, Q, R, S and T, but they are distinguished by the absence of species group N in variation 2.1.4. No diagnostic species group has been identified for this variation. Species abundantly present in this variation include *Eragrostis nindensis* (species group K), *Lopholaena coriifolia, Lapeirousia sandersonii* (species group L), *Coleocloa setifera, Pellaea calomelanos* (species group O), *Aristida aequiglumis, Cyanotis speciosa, Andropogon schirensis* (species group S) as well as the species of species group T.

2.1.5 *Trachypogon spicatus - Bulbostylis burchellii* Short Open Grassland

Relevés representing this variation are scattered in community 2 on slopes of less than 4°. The soil is coarse-grained sandloam.

This variation is distinguished by the absence of species groups M, N and O and the presence of species groups K, L, Q, R, S and T (Table 4). The abundance of *Trachypogon spicatus* and *Bulbostylis burchellii* are also a conspicuous feature in this variation. Other species are the grasses *Aristida aequiglumis* (species group S), *Diheteropogon amplectens, Themeda triandra* and *Brachiaria serrata* (species group T) , the forbs *Nidorella hottentotica, Xerophyta viscosa* (species group R), *Cyanotis speciosa* (species group S) and the chasmophyte *Selaginella dregei* (species group T). The shrub and tree layer are absent.

2.2 *Themeda triandra - Eragrostis racemosa* Short Open Grassland

This open grassland is found scattered along the summit plateau. The slopes are gentle and the gradient does not exceed 10°. The soil texture is sand loam. Boulders and rocks are absent and the soil consists of quartzite gravel on bedrock. The aspect varies from northeastern to southeastern.

This sub-community is distinguished by the presence of the diagnostic species group P, including the forb *Becium obovatum* and the grass *Eragrostis racemosa*, as well as species groups K and Q, R, S and T (Table 4). Species that occur in this sub-community includes the forbs *Thesium transvaalense, Anacampseros subvelutinum* (species group Q), *Raphionacme burkei, Nidorella hottentotica* (species group R), *Cyanotis speciosa, Anthospermum rigidum* (species group S) and the sedges *Bulbostylis burchellii* and *Cyperus rupestris* (species group T). The dominant grass is *Themeda triandra* with a cover-abundance value of between 5% and 50%. Other conspicuous grasses are *Aristida aequiglumis* (species group S), *Melinis nerviglume, Diheteropogon amplectens* and *Brachiaria serrata* (species group T).

3 *Bulbostylis burchellii - Themeda triandra* Short Open Grassland

This grassland is confined to the upper northeastern and southeastern slopes of the southeastern valley of the study area. The soil is coarse-grained sandloam with rocks and boulders occurring frequently. The slope varies between 15° and 35°.

No diagnostic species group are characteristic of this community. It is distinguished from the other communities by the absence of all species groups, except the general species included in species group T (Table 4). Conspicuous species includes the grasses *Loudetia simplex, Schizachyrium sanguineum, Melinis nerviglumis, Diheteropogon amplectens, Themeda triandra* and *Brachiaria serrata*, the sedges *Bulbostylis burchellii* and *Cyperus rupestris* and the chasmophyte *Selaginella dregei.*

4 *Tristachya biseriata -Protea caffra* Short Sparse Woodland

This community is spread on the slopes of the valley between the summit and the eastern range of quartzite ridges running through the reserve. The *Tristachya biseriata -Protea caffra* Short Sparse Woodland is confined to the shallow Glenrosa soils on the foothills and mid-slopes. The gradient varies between 3° and 30°, except for three relevès on slopes of up to 40°. The soil texture are sand loam to sand clay loam (MacVicar *et al.* 1991).

The differentiation of this community in the study area is confirmed by the findings of Coetzee (1975). He identified a *Tristachya biseriata - Protea caffra* woodland, but regarded it as a sub-community in a larger phytocoen, the *Loudetia simplex - Aristida aequiglumis* Woodlands, shrub lands and grasslands. This phytocoen were divided in two, one occurring on deep litholitic soils and the second on shallow litholitic soils and bouldery outcrops. In this classification the *Tristachya biseriata -Protea caffra* Short Sparse Woodland is regarded as a transition between the shallow and deep soils on the reserve which explains the amount of variation in the habitat features.

The grasses *Tristachya biseriata* (cover-abundance values 1%-75%), *Loudetia simplex* (cover-abundance values 1%-50%) *Themeda triandra* (cover-abundance values 1% - 75%), *Trachypogon spicatus* (cover-abundance values 1%-50%) and *Diheteropogon amplectens* (cover-abundance values 1%-25%) dominate the herbaceous layer (Table 5).

Based on the presence and absence of species, seven sub-communities can be identified (Table 5):

4.1 *Blumea alata - Parinari capensis* sub-community

This sub-community is located on the eastern slopes of the central quartzite ridge in the study area. The slope varies between 9° and 23°, with an eastern and north eastern aspect. Shallow Glenrosa soils, with protruding quartzite are dominant in this sub-community. An abundance of gravel was recorded in al the relevès, with smaller rocks occurring frequently and solitary rocks and boulders scattered throughout the sub-community. The soil is sand clay loam (MacVicar *et al.* 1991).

Species group B (Table 5) is diagnostic for this sub-community, including the forbs *Blumea alata, Conyza aegyptica, Dicoma zeyheri* and *Gazania krebsiana*. This sub-community is represented by the species in species groups E, F, I, N, S, X and the general species in species group Y. Coetzee (1975) regarded relevés in this sub-community as representative of the *Cryptolepis oblongifolia-Protea caffra* variation of the *Tristachya biseriata-Protea caffra* woodland. Other abundant species in this sub-community are the forbs *Athrixia elata, Pearsonia aristata, Bulbostylis oritrephes* (species group E), *Sphenostylis angustifolia, Helichrysum coriaceum,* (species group F) *Cryptolepis oblongifolia* (species group H), *Kohoutia amatymbica, Chamaecrista mimosoides, Tephrosia elongata, Chaetachantus setiger, Diplacne biflora, Pentharidium insipidum* (species group S), *Parinari capensis* (species group X) and *Becium obovatum* (species group Y).

Table 5: Phytosociological table for the *Tristachya biseriata - Protea caffra, Protea guagedi - Monocymbium ceresiiforme, Indigofera comosa - Shizachyrium sanguineum, Plexipus hederaceus - Cymbopogon excavatus, Tristachya leucotrix - Setaria sphacelata* and *Themeda triandra - Brachiaria serrata* vegetation communities

Communities	4																																														5											6								7								8																						
Sub-communities	4.1							4.2					4.3					4.4					4.5						4.6							4.7																																							8.1						8.2													8.3				
Variations																													4.6.1			4.6.2																																																															
Species	246	216	217	238	235	240	241	243	244	245	394	391	219	220	221	222	223	225	224	226	230	234	211	213	218	286	267	297	251	252	209	288	280	290	291	390	294	295	296	318	359	363	364	365	357	292	293	273	353	354	271	356	269	268	380	381	285	286	287	289	320	272	274	275	276	277	278	279	281	282	283	284	019	020	023	024	070	088	089	095	099	100	103	104	105	107	069	101	111	112	112	033	014	015	017	018
Species group A																																																																																																
Tristachya biseriata	3	3	4	3	3	3	3	3	3	3			2	2	2	2	3	3	2	3	+	3	3	2	2	4	4	3	3	2	+						2	2	1	2									+																																														
Protea caffra		2	2	2	2	2		3	2	2	2	3	2	2	2	2	2				2	1												2			2	2	3	3	2	4	3	3	3																								+		2	1													R											
Indigofera hedysantha	+	+	+	+	+	+		+	+	+		+		+	+	+						+						+						+			+		+	+		+	+								+																				+				+																								
Vernonia natalensis		+		+	+	+		1	+	+	1	+			+		+			+	+						+										1			+		+	+		+																												+																							
Oxalis obliquifolia		+	+					+	+	+	+	+	+	+		+	+										+									+				+			+	+	+	+	+									+															+	+	+	+																							
Digitaria diagonalis	+	+	+		+	+		+	+	+		+											+															+	+			+	+	3	+	+																													+	1											+													
Nolletia rarifolia	+							+	+									+	+												+							+										+					+	+																																												
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Bulnea alata		+	+	+	+	+													+																			+			+																																																							
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Dicoma zeyheri		+	+		+	+																												+																																											+									+										+						
Gazania krebsiana	+	+	+				+								+											+																									+																				+																									
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Setaria bulbifera				+	+			+	+	+									+	+																																																																						
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Anomatheca laxa								+	+	+		+	+	+	+	+	+																																																																																
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Ficinia filiformis											+		+	+	+	+	+																																																																															
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Abildgaardia ovata	+	+		+	+	+		+	+	+	1	1		+	+	+	+				+	+														+														+					+																				+								+		+		+					
Pearsonia aristata	+	+	+		+	+		+	+	+				+	+	+	+	+		+		+			+				+																																																																	
Bulbostylis oritrephes	+	+	+	+			+	+	+	+			+	+	+		+			+	+	+														+																																																								
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Helichrysum coriaceum	+		+	+	+	+	+	+	+	+			+	+	+	+	+			+	+	+	+			+	+	+										+													+										+																																			
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Pellaea calomelanos		+				+				+	+	+		+	+	+	+	+	+		+	+	+			+			+	+	+	+																+				+	+									+	+	+																												
Cryptolepis oblongifolia	+	+	+	+	+		+											1	1	1	+	+	1					+	+	1	+	+		+				+																+			+		+	1	+																																		
Ruellia patula	+		+	+	+	+	+													+		+						+																																																																

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Table 5: (cont.) Phytosociological table for the Tristachya biseratta - Protea caffra, Protea gaguedi - Monocymbium ceresiiforme, Indigofera comosa - Shizachyrium sanguineum, Plexipus hederaceus - Cymbopogon excavatus, Tristachya leucotrix - Setaria sphacelata and Themeda triandra - Brachiaria serrata vegetation communities

Communities	4																																												
Sub-communities	4.1							4.2					4.3					4.4					4.5						4.6							4.7									
Variations																													4.6.1			4.6.2													
Species	246	216	217	238	239	240	241	243	244	245	304	301	219	220	221	222	223	225	224	229	230	234	211	213	218	266	267	297	251	252	209	288	280	290	291	390	294	295	296	318	359	363	364	365	357
Species group J																																													
Protea gaguedi																																		+											
Monocymbium ceresiiforme										+																																			
Digitaria monodactyla									+																																				
Species group K																																													
Aloe greatheadii							+																			+	+										+		+	+	+		+	+	
Silene burchellii																																+		+	+		+	+		+					
Species group L																																													
Aristida aequiglumis																		+	+	+			+	+	+	+		+		+		+			+				+						1
Raphionacme burkei																		+						+		+								+	+		+	+							+
Commelina africana																			+				+		+	+			+	+	+	+	+	+	+				+	+					
Cyanotis speciosa													+					+	+	+				+	+	+	+	+	+	+															+
Dichapetalum cymosum																			+							+	+	+	+				+	+	+					+					
Species group M																																													
Indigofera comosa													+		+		+	+					+	+	+	+	+	+		+		+		+											+
Albuca setosa														+	+	+		+	+				+	+	+	+											+	+	+	+	+	+			
Species group N																																													
Loudetia simplex			+	1	+	+	2	+	1	2			2	2	2	3	2	2	2	2	+	+	1	1	2		+	+	+	1	2	+		+	+		+	+	+						2
Panicum natalense	2	2	+	1	1	+	+	1	+	1			+	+	+	+	2	+		+	1	1				1	+	+	+	+							+	+	+						+
Nidorella hottentotica		+	+				+						+	+	+	+						+	+	+	+	+	+	+	+			+							+	+					+
Andropogon schirensis		+	+	+	+		+	+	+	+			+	1	+	+			+		+		+						+			+			+	+		+	+	+				+	+
Urelytrum agropyroides	1	+	1	+	+	+	+	+	+	+					+	1	1	+				1		+			+			+				+			+	+	+	+					+
Schizachyrium sanguineum	1	+	+	+	+	+											+	+	+	+		+			+	+		+	+	+		+					2			2					
Thesium cytisoides		+	+			+				+										+								+								+	+	+		+					
Species group O																																													
Plexipus hederaceus																																		+	+										
Raphionacme hirsuta																																	+							+					
Species group P																																													
Digitaria brazzae													+																						+				+					+	+
Acalypha angustata											+																		+				+				+	+	+	+	+	+	+	+	
Ledebouria marginata																											+		+				+				+			+	+	+	+	+	
Tristachya rehmannii									+																										+		+		+	+					
Cymbopogon excavatus			+			+																														1	+		+	+	+			+	
Crabbea hirsuta																																	+						+	+	+	+		+	
Crassula transvaalensis																													+																
Rhynchosia nervosa																																					+		+	+	+	+	+		
Species group Q																																													
Pygmaeothamnus zeyheri																			+				+	+			+			+	+	+	+	+	+		+	+	+	+	+	+		+	+
Rhynchosia monophylla																			+	+				+		+		+									+		+	+					
Species group R																																													
Senecio erubescens								+	+	+			+	+	+	+	+				+													+	+						+			+	
Thesium transvaalense													+	+	+	+		+	+	+				+	+			+				+							+						
Nidorella resedifolia									+																																	+			
Felicia muricata									+		+																		+				+				+	+		+			+		

Communities	5											6								7								8																							
Sub-communities																												8.1						8.2													8.3				
Species	292	293	273	353	354	271	356	269	268	360	361	285	286	287	289	220	272	274	275	276	277	278	279	281	282	283	284	019	020	023	024	070	088	089	095	090	100	103	104	105	107	069	101	111	112	012	033	014	015	017	018
Species group J																																																			
Protea gaguedi	+	2		2	2		2	1		2	2																																								
Monocymbium ceresiiforme		+	+	+	+	+	+	+	+																																										
Digitaria monodactyla				+			+			1	+																																								
Species group K																																																			
Aloe greatheadii	+			+	+	+	+	+	+	+									+	+																															
Silene burchellii	+		+			+		+	+								+																																		
Species group L																																																			
Aristida aequiglumis		+	+	+	+		+			1	1	+	+	+		+			+					+																											
Raphionacme burkei	+		+	+		+		+	+			+			+	+	+	+																																	
Commelina africana	+		+			+						+	+	+			+																				+						+						+		
Cyanotis speciosa				+										+	+		+																																		
Dichapetalum cymosum												+				+		+																										+							
Species group M																																																			
Indigofera comosa	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+																																
Albuca setosa				+	+		+		+	+	+		+			+	+	+	+																																
Species group N																																																			
Loudetia simplex		+	+	1		+	+				2	+	+	+	+	1	+	+	+									+																		1		+	+	+	
Panicum natalense	+	+	+			+		+		+	+		+				+															+						+					+	+							
Nidorella hottentotica	+		+	+	+	+	+	+	+	+		+	+		+	+	+		+				+																												
Andropogon schirensis		+		+					+		+	+	+	+			+	+						+	1																									1	
Urelytrum agropyroides		+			+		+	+		+	+					+		1											+						+			+					+								
Schizachyrium sanguineum		1	1						2			+	3	2	2	2	1													+	+																	+			
Thesium cytisoides				+	+		+			+	+	+	+	+		+	+		+																																
Species group O																																																			
Plexipus hederaceus		+													+				+	+	+	+		+		+	+																								
Raphionacme hirsuta											+					+				+	+					+	+																								
Species group P																																																			
Digitaria brazzae	+	+	1	+	+	+	+	1	+	+	+						+	1	+	+	+	1	2	1	1																										
Acalypha angustata				+	+		+					+		+	+	+			+	+	+		+	+		+	+																								
Ledebouria marginata	+			+	+	+	+		+								+		+	+	+		+	+	+	+															R										
Tristachya rehmannii	+	1	1			+		1	+	+	+						+	+	1	+	1			+			+																	2							
Cymbopogon excavatus														+				+		+	+	+	+	1	2	+	1																								
Crabbea hirsuta										+				+					+		+	+			+	+	+																								
Crassula transvaalensis		+		+			+			+	+				+				+	+	+	+			+																										
Rhynchosia nervosa												+				+			+	+	+						+																								
Species group Q																																																			
Pygmaeothamnus zeyheri	+	+	+		+	+		+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+																								
Rhynchosia monophylla			+									+	+	+	3	+	+						+	+					+	+																					
Species group R																																																			
Senecio erubescens	+			+	+	+	+			+	+							+							+		+																								
Thesium transvaalense					+		+		+		+			+	+							+	+		+																										
Nidorella resedifolia																		+		+	+			+		+	+																								
Felicia muricata		+						+														+	+	+	+	+																									

Table 5: (cont.) Phytosociological table for the Tristachya biseratta - Protea caffra, Protea gusgedi - Monocymbium ceresiiforme, Indigofera comosa - Shizachyrium sanguineum, Plexipus hederaceus - Cymbopogon excavatus, Tristachya leucotrix - Setaria sphacelata and Themeda triandra - Brachiaria serrata vegetation communities

Communities	4																											
Sub-communities	4.1							4.2					4.3					4.4					4.5					
Species	246	216	217	238	239	240	241	243	244	245	394	391	219	220	221	222	223	225	224	229	230	234	211	213	218	266	267	297
Species group S																												
Dihaleropogon amplectans		+	+	+	+	1	1	+	+	+	+	+	1	+	1	1	+	+	1	1	+	+	1	1	1	+	+	+
Eragrostis racemosa	+	1		+			+	+	+	+			1	1	+	+	+	+	+	+	+	+		+	+	+	+	+
Vernonia galpinii	+	+		+	+		+	+	+	+	+		+	+	+		+	+	+	+	+	+	+				+	
Kohoutia amatymbica	+	+	+	+	+	+	+	+		+		+			+	+	+			+	+	+					+	+
Chamaecrista mimosoides	+	+	+	+	+	+												+					+		+	+	+	
Dicoma anomala	+			+				+	+	+				+	+		+	+		+		+		+				+
Tephrosia elongata	+	+	+	+	+	+	+						+		+		+	+	+	+	+	+	+		+	+	+	+
Chaetacanthus setiger	+	+	+	+		+	+	+	+	+			+	+	+		+	+	+	+	+	+			+	+		
Conyza albida		+	+	+	+	+			+		+	+																
Pentharrhinum insipidum	+	+	+	+	+	+	+		+	+	+	+					+									+	+	+
Ipomoea ommaneyi		+	+							+							+											
Pentanisia angustifolia			+		+	+																					+	
Hypoxis rigidula		+					+	+																			+	
Species group T																												
Tristachya leucotrix																												
Setaria sphacelata											3	1										+						
Species group U																												
Rusilia cordata																												
Thesium utile																												
Species group V																												
Chaetacanthus costatus																												
Mariscus congesta																												
Polygala uncinata																												
Acrotome hispida																												
Species group W																												
Elephantorrhiza elephantina					+																							
Heteropogon contortus																							+					
Opthresia oblongifolia																												
Species group X																												
Parinari capensis	+	+	+	+	+	+	+											+	+	+			+	+	+			+
Senecio venosus	+	+		+	+	+	+					+	+						+	+	+	+			+		+	
Bewsia biflora	+	+	+	+	+	+	+		+									+		+	+	+	+			+	+	+
Elionurus muticus	+			+	+	+	+				2	+					+				+		+					
Lotononis calycina	+	+											+															+
Protasparagus suaveolens							+	+		+		+			+	+			+		+		+					
Species group Y																												
Themeda triandra	+	2	2	1	1	2	+	1	1	+	1	4	1	+	+	1	+	1	+	+	+	+	1	+	+	+	+	
Trachypogon spicatus	+	1	1	+	+	1	2	2	2	2	1	1	2	2	2	1	1	1	+		+	2	3	2	2	1	2	2
Brachiaria serrata	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Melinis nerviglumis	+	+	+		+	2							+			+		+	2	1	+	+		+	+	+		+
Becium obovatum	+	+	+	+	+	+	+	+	+	+	+	+								+	+		+			+	+	+
Bulbostylis burchellii						+							+		+			+	+					1	+	+	+	1

Communities	4																	5										
Sub-communities	4.6							4.7																				
Variations	4.6.1			4.6.2																								
Species	251	252	209	288	280	290	291	390	294	295	286	318	359	363	364	365	357	292	253	273	353	354	271	356	369	268	360	361
Species group S																												
Dihaleropogon amplectans	+	1	2	+			+	+	+	+	+	+	+	+	+		+	2	2	2	+	+	2	1	+	2	+	+
Eragrostis racemosa	+	+		+			+	+			+		+	+			+	+	+	+	+	+	+	1	+	+	1	+
Vernonia galpinii		+		+			+		+	+		+	+	+		+		+	+			+	+	+		+		+
Kohoutia amatymbica						+		+	+	+	+	+	+			+	+		+	+				+			+	+
Chamaecrista mimosoides	+	+		+	+	+	+		+	+	+	+					+	+	+	+	+		+		+		+	+
Dicoma anomala	+			+			+				+	+					+	+	+	+	+	+	+	+	+		+	+
Tephrosia elongata	+	+			+				+	+	+	+				+	+					+			+	+		
Chaetacanthus setiger	+	+			+				+	+	+	+	+						+					+				
Conyza albida				+	+	+							+		+			+				+	+	+	+			
Pentharrhinum insipidum									+	+	+							+					+					
Ipomoea ommaneyi					+						+	+	+	+	+	+		+	+		+		+		+	+		
Pentanisia angustifolia					+								+					+					+	+	+	+		
Hypoxis rigidula								+	+	+	+	+	+		+	+				+								
Species group T																												
Tristachya leucotrix																												
Setaria sphacelata	2	2	2	3	4	4	4		2	2	4	2	1	1	1													
Species group U																												
Rusilia cordata																												
Thesium utile																												
Species group V																												
Chaetacanthus costatus																												
Mariscus congesta																												
Polygala uncinata																												
Acrotome hispida																												
Species group W																												
Elephantorrhiza elephantina						+	+		+		+	+		–				+			+	+	+	+	+	+	+	+
Heteropogon contortus	–											–	+															
Opthresia oblongifolia										+	+													+				+
Species group X																												
Parinari capensis		+		+							+	+					+	+	+	+	+	+	+			+	+	+
Senecio venosus		+				+	+		+	+	+	+				+	+	+		+			+	+				
Bewsia biflora	+				+				+	+		+				+		+	+				+		+		+	
Elionurus muticus	+		+					2			+					+											+	+
Lotononis calycina																			+									+
Protasparagus suaveolens					+				+	+	+	+	+	+	+	+												
Species group Y																												
Themeda triandra	+			+	+	2	+	3	3	3	4	3	3	+	3	4	2	2	+	2	+	2	2	2	1	2	+	+
Trachypogon spicatus	2	2	1	2	+	+	+	2	1	1	1	1	2	2	2	2	3	2		1	4	3	2	4	2	3	4	3
Brachiaria serrata	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+		+	1	+	1	+	+	+	+
Melinis nerviglumis	+	+	+	1	+	+	+		+		1	+		2	+			2	2		+	+	2	+	3	+		
Becium obovatum				+	+	+		+	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+		+	+	+
Bulbostylis burchellii	+	+	1	+			+				+	+					+	+	+	1	+	+	+	+	+	+	+	+

Communities	6								7								8					
Sub-communities																	8.1					
Species	285	286	287	289	320	272	274	375	276	277	278	279	281	282	283	284	019	020	023	024	070	088
Species group S																						
Dihaleropogon amplectans	2	2	2	+	+	+	2	2	1	1	2	1	1	1	2	+						
Eragrostis racemosa			+	+	+	+	+	1	+	+	1	+	+	+	+							
Vernonia galpinii							+		+	+	+	+	+	+	+	+	+					
Kohoutia amatymbica		+	+	+	+		+		+	+		+		+	+	+						
Chamaecrista mimosoides		+	+	+	+	+	+	+	+	+	+	+	+	+	+							
Dicoma anomala	+		+	+	+			+	+	+		+	+			+						
Tephrosia elongata		+		+		+		+			+	+			+							
Chaetacanthus setiger				+		+								+	+	+						
Conyza albida				+		+	+	+	+	+	+	+	+	+	+	+						
Pentharrhinum insipidum						+			+	+		+				+			+			
Ipomoea ommaneyi						+	+	+	+	+	+	2	+		+	+						
Pentanisia angustifolia						+		+	+	+	+	+				+						
Hypoxis rigidula	+								+	+					+	+						
Species group T																						
Tristachya leucotrix																	+	1				2
Setaria sphacelata		+													+	+	+	+				
Species group U																						
Rusilia cordata																	+	+				+
Thesium utile																	+		+			
Species group V																						
Chaetacanthus costatus																						+
Mariscus congesta																						
Polygala uncinata																						
Acrotome hispida																			+			
Species group W																						
Elephantorrhiza elephantina						+	+			+	+	+	+	+	+		+		+			1
Heteropogon contortus	+		+	+			+							1		+	+	+	1	+	2	+
Opthresia oblongifolia							+	+	+	+		+	+		+	+		+	+			
Species group X																						
Parinari capensis	+	+	+	+		+	+		+	+	+		+			+	+	2		2		
Senecio venosus			+	+			+						+	+	+	+		+			+	
Bewsia biflora		+	+	+		+		1	+	+	+	+				+						
Elionurus muticus								2	+	+	1	+				+		+				+
Lotononis calycina				+		+									+							
Protasparagus suaveolens													+		+	+						+
Species group Y																						
Themeda triandra	2	1	3	+		4	2	+	2	2	2	2	2	+	3	2		+	+	+	+	+
Trachypogon spicatus	1	2	1	2		3	1	+	3	3	3	2	3	2	2	3	1	1	+		1	+
Brachiaria serrata	+	+	+	+		+	+	+	2	2	1	+	+	+	1	+	+	+	+	+	+	
Melinis nerviglumis	2	+	+	+		2	+	+	1	1			+	+	+	+						
Becium obovatum	+		+	+		+		+	+	+	+	+	+	+	+	+				+	+	
Bulbostylis burchellii	2	2		+	1	+		+						+			+	+	+	+		

Communities	8																	
Sub-communities	8.2													8.3				
Species	089	095	099	100	103	104	105	107	069	101	111	112	012	033	014	015	017	018
Species group S																		
Dihaleropogon amplectans		+		+						+								
Eragrostis racemosa	+	+															+	
Vernonia galpinii																		
Kohoutia amatymbica																		
Chamaecrista mimosoides				+						+								
Dicoma anomala		+							+									
Tephrosia elongata				+														
Chaetacanthus setiger																		
Conyza albida																		
Pentharrhinum insipidum					+			+										
Ipomoea ommaneyi																		
Pentanisia angustifolia																		
Hypoxis rigidula					+						+							
Species group T																		
Tristachya leucotrix	5	3	+	3	4	2	+	4	2	3	4	2	+		1	2	3	3
Setaria sphacelata		+	3	1	+		+	1	+			2					+	
Species group U																		
Rusilia cordata		+		+	+	+	+	+		+	+	+						
Thesium utile	+	+	+	+	+	+	+	+							+			
Species group V																		
Chaetacanthus costatus		+				+	+			+	+	+	+					
Mariscus congesta		+		+	+					+	+							
Polygala uncinata						+	+	+				+	+					
Acrotome hispida								+	+	+								
Species group W																		
Elephantorrhiza elephantina					+				+									
Heteropogon contortus	+	+	+		+	+	+			+								
Opthresia oblongifolia		+	+							+	+						+	+
Species group X																		
Parinari capensis	+				1	+	+			+					1	1	+	
Senecio venosus		+	+			+	+	+	+	+		+					+	+
Bewsia biflora	+	+		+				+	+	+					+	+		
Elionurus muticus	+			1		+				+	+							+
Lotononis calycina										+								
Protasparagus suaveolens					+	+	+		+		+	+						+
Species group Y																		
Themeda triandra	+	+	+	+		+	2		+			+	+	+	+	+		+
Trachypogon spicatus		+			+	+		+	+		+	+		+	1	1	+	+
Brachiaria serrata			+	+	+			+	+	+	+	+	+	+	+	1	+	+
Melinis nerviglumis				+			+				+		+		+			
Becium obovatum					1	+										R	+	+
Bulbostylis burchellii	+	+	+						+	+			+	2	1	1		+

The grass species *Tristachya biseriata* (species group A) dominate the herbaceous layer in this sub-community (cover-abundance values 25% to 75%), with *Loudetia simplex, Panicum natalensis, Urelytrum agropyroides, Schizachyrium sanguineum* (species group N) and *Themeda triandra* (species group Y) prominent. *Panicum natalensis* and *Themeda triandra* are conspicuous with cover-abundance values between 1% and 25%. The shrub and tree stratums are confined to *Protea caffra* (species group A).

4.2 *Indigofera burkeana-Rhynchosia totta* Short Closed Woodland

This woodland is restricted to the southern and southeastern slopes of the quartzite ridge northeast of Bosbokkloof. The soil associated with these slopes, is coarsely-grained lithocutanic. The texture varies from sand loam to sand clay loam.

Species groups C, D, E, F, I, N, R, S, X and Y characterise this sub-community. Diagnostic species include the forbs *Indigofera burkeana, Rhynchosia totta, Aster harveyanus, Hypericum aethiopicum* and *Scleria bulbifera* (species group C) (Table 5). The herbaceous layer is furthermore dominated by the grass *Tristachya biseriata* (species group A), *Alloteropsis semialata* (species group D), *Themeda triandra, Bewsia biflora* (species group X) and *Trachypogon spicatus* (species group Y) and the tree *Protea caffra*. Abundant forb species are *Vernonia natalensis, Oxalis obliquifolia* (species group A), *Anomatheca laxa* (species group D), *Athrixia elata* (species group E), *Vernonia galpinii, Pentharidium insipidum* (species group S) and *Becium obovatum* (species group Y). The tree and shrub layer are confined to *Protea caffra*.

4.3 *Diheteropogon amplectens - Ficinia filiformis* Short Closed Woodland

This sub-community is confined to a small area on the southern and southeastern slopes of the hill in the northern division between the farms Rietvallei and Baviaanskrans. The soil is restricted to the Glenrosa soil form with a coarse-grained texture. The soil is sandloam to sandclayloam and the slope varies between 16° and 40°.

Coetzee (1975) considered this sub-community as a variation of the *Tristachya biseriata - Protea caffra* Woodlands. This variation occurs on the southerly aspects in the series of valleys between the summit areas in the reserve and the western side of the Magaliesberg. The absence of species group C in this sub-community distinguished it from the *Indigofera burkeana - Rhynchosia totta* sub-community found further north on the central quartzite ridge.

No diagnostic species group has been identified for this sub-community (Table 5). The presence of species groups D, E, F, I, M, N, R, S and Y characterise this sub-community. Prominent species are the forbs *Anomatheca laxa, Ficinia filiformis* (species group D), *Athrixia elata, Pearsonia aristata*, the sedge *Bulbostylis orithrephes* (species group E), *Helichrysum coriaceum* (species group F), *Anthospermum rigidum, Pellaea calomelanos* (species group H), *Nidorella hottentotica* (species group N), *Senecio erubescens, Thesium transvaalense* (species group R), *Chaetachantus setiger* (species group S) and *Becium obovatum* (species group Y). Grass species dominant in this sub-community includes *Tristachya biseriata* (species group A), *Alloteropsis semialata* (species group D), *Loudetia simplex, Panicum natalensis* (species group N), *Diheteropogon amplectens, Eragrostis racemosa* (species group S), *Themeda triandra, Trachypogon spicatus* and *Brachiaria serrata* (species group Y). *Protea caffra* is the only tree species in the sub-community.

4.4 *Cryptolepis oblongifolia - Loudetia simplex* Tall Sparse Woodland

The *Cryptolepis oblongifolia - Loudetia simplex* Tall Sparse Woodland is located on the north eastern slopes of the valley between the summit and the eastern range of hills. The gradient range between 19° - 29°. The subsoil is coarsely-grained with large rocks and boulders occurring frequently. The soil texture varies from sandloam to sandclayloam (MacVicar *et al.* 1991)

Coetzee (1975) recognised a *Cryptolepis oblongifolia - Protea caffra* variation of the *Tristachya biseriata - Protea caffra* Woodlands. The *Cryptolepis oblongifolia - Protea caffra* variation identified by Coetzee (1975) contains the species in species group B (Table 5), which are diagnostic of the *Blumea alata - Parinari capensis* sub-community.

The presence of species groups E, F, I, L, N, Q, S, X and Y are characteristic of this sub-community. Dominant species are the small shrub *Cryptolepis oblongifolia* (species group I) and the grasses *Aristida aequiglumis* (species group L), *Loudetia simplex, Panicum natalensis, Andropogon schirensis, Schizachyrium sanguineum* (species group N), *Diheteropogon amplectens, Eragrostis racemosa* (species group S), *Bewsia* biflora (species group X), *Themeda triandra, Trachypogon spicatus, Brachiaria serrata* and *Melinis nerviglume* (species group Y). Forbs present are *Sphenostylis angustifolia* (species group F), *Anthospermum rigidum, Pellaea calomelanos* (species group I), *Vernonia galpinii* and *Chaetacanthus setiger* (species group S).

4.5 *Trachypogon spicatus - Sphenostylis angustifolia* Tall Closed Grassland

This sub-community occurs in isolated locations on the northeastern brim of the central basin and the summit of the hill in the northeastern section of the study area. A common habitat factor of this sub-community is a northwestern to southwestern aspect and slope that varies between 6° and 13°. Shallow, coarse-grained soils of the Glenrosa soil form with few rocks and boulders underlies this sub-community.

Prominent species in this sub-community are *Sphenostylis angustifolia* (species group F), *Cyanotis speciosa* (species group L), *Indigofera comosa* (species group M), *Nidorella hottentotica* (species group N), *Tephrosia elongata* (species group S) and the sedge *Bulbostylis burchellii* (species group Y). The grass layer is dominated by *Tristachya biseriata* (species group A), *Aristida aequiglumis* (species group L), *Loudetia simplex* (species group N), *Diheteropogon amplectens, Eragrostis racemosa* (species group S), *Themeda triandra, Trachypogon spicatus* and *Brachiaria serrata* (species group Y). A conspicuous feature of this sub-community is the absence of trees, in particular *Protea caffra* which is diagnostic for the *Tristachya biseriata - Protea caffra* community. This can be attributed to the fact that *Protea caffra* prefers cooler south facing slopes (van Wyk *et al.* 1988; Vogt 1982; van Gogh & Anderson 1988). This sub-community is further distinguished from the other sub-communities in this vegetation community by the absence of species groups B, C, D, E and G. It is characterised by the occurrence of species groups F, I, L, M, N, Q, S, X and Y.

4.6 *Burkea africana - Setaria sphacelata* Tall Open Woodland

This sub-community occurs in secluded areas with an eastern aspect on the northern foothills of the Magaliesberg as well as in the central basin area. The tree species *Burkea africana* and the shrub *Ochna pulchra* are the two diagnostic species of this sub-community(species group G). This Tall Open Woodland is further characterised by the dominance of *Setaria sphacelata* (species group T) with cover-abundance values of 25% to 75%. Species groups I, L, M, N, Q, R, S, X and Y are also present in this sub-community.

Two distinct variations are found in this sub-community. This distinction is due to a difference in soil depth between the two variations, resulting in distinct differences in species composition. Coetzee (1975) also distinguished two variations of the *Burkea africana - Ochna pulchra* Woodlands. He ascribed this distinction to a difference in soil depth, as well as a difference in aspect and locality.

4.6.1 *Combretum zeyheri - Trachypogon spicatus* Tall Sparse Woodland

This variation is associated with the litholitic soils on the northern foothills of the Magaliesberg. The aspect is east and the gradient varies between 15° and 31°. The soil is coarsely-grained with a sandloam to sandclayloam texture. Large rocks and boulders occur frequently throughout the variation.

This variation can be distinguished from the former by the presence of species group H, consisting of *Combretum zeyheri* and *Faurea saligna*. A significant feature of this variation is the absence of *Protea caffra*, because this plant prefers the cooler southern slopes of the Magaliesberg (van Wyk and Malan 1988; van Gogh & Anderson 1988).

4.6.2 *Burkea africana - Themeda triandra* Tall Open Woodland

The *Burkea africana - Themeda triandra* Tall Open Woodland variation occurs on the deep (>0.8m) sand loam Hutton soils in the central basin area. The slope is gradual and the gradient does not exceed 4°. Aspect is mostly northerly, but varies from northwesterly to northeasterly. No rocks or boulders are present.

This variant is further distinguished from the *Combretum zeyheri - Trachypogon spicatus* Tall Sparse Woodland variation in the sub-community by the absence of species group H (Table 5). It is characterised by species groups G, I, L, M, N, Q, S, T, X and Y. *Burkea africana* is the dominant tree species with a cover-abundance value of 25% - 75% (Coetzee 1975). The shrub layer is represented by *Ochna pulchra* (species group G). Other prominent species are the forbs *Commelina africana*, (species group L), *Pygmaeothamnus zeyheri* (species group Q) and *Chamaecrista mimosoides* (species group S).

The structural analysis depicted of the woody component of the *Burkea africana - Themeda triandra* Tall Open Woodland (Figure 9) indicates that the trees *Burkea africana, Combretum zeyheri* and *Protea caffra* represent the >5.5 m height class. The shrub stratum (< 0.75 m - 1.5 m) is dominated by *Ochna pulchra, Diospyros lycioides* and *Rhus rigida*.

Coetzee (1975) found however that the 5 - 8m tall *Burkea africana* trees covered up to 25% of the relevès, whereas the smaller *Burkea africana* trees covered 25%-55% of the relevès. It contributes significantly to the captivating view tourists' experienced when driving around the central basin. Game occurs regularly in this area and the view of this open savanna with its flat topped *Burkea africana* is highly valued. The *Burkea africana* tree clumps need to be conserved and maintained due to their aesthetic value in the reserve.

4.7 *Aloe greatheadii- Themeda triandra* Tall Open Woodland

This woodland represents the composite of vegetation on the deep Hutton soils of the *Tristachya biseriata - Protea caffra* community. It is found on the foothills on the southern side of the central basin area as well as on the plateau in the northern regions of the study area. These areas are flat and the gradient is 3°. The soil is finely grained with a sandloam texture. Aspect of the relevés is northeast.

The presence of species groups K, L, M, N, P, Q, R, S, W, X and Y characterise this sub-community. Dominant species are the grasses *Setaria sphacelata* (cover-abundance values 25%-75%) (species group T), *Themeda triandra* (cover-abundance values 50%-75%) and *Trachypogon spicatus* (cover-abundance values 25%-50%)(species group Y). Forbs included are *Indigofera hedyantha, Vernonia natalensis* (species group A), *Aloe greatheadii* (species group K), *Albuca setosa* (species group M), *Acalypha angusta, Ledebouria marginata, Crabbea hirsuta, Rhynchosia nervosa* (species group P), *Pygmaeothamnus zeyheri* (species group Q), *Kohoutia amatymbica, Hypoxis rigidula* (species group S), *Asparagus suaveolens* (species group X) and *Becium obovatum* (species group Y). Other prominent grass species are *Digitaria diagonalis* (species group A), *Urelytrum agropyroides*, (species group N), *Cymbopogon excavatus* (species group P), *Diheteropogon amplectens, Eragrostis racemosa* (species group S), and *Brachiaria serrata* (species group Y).

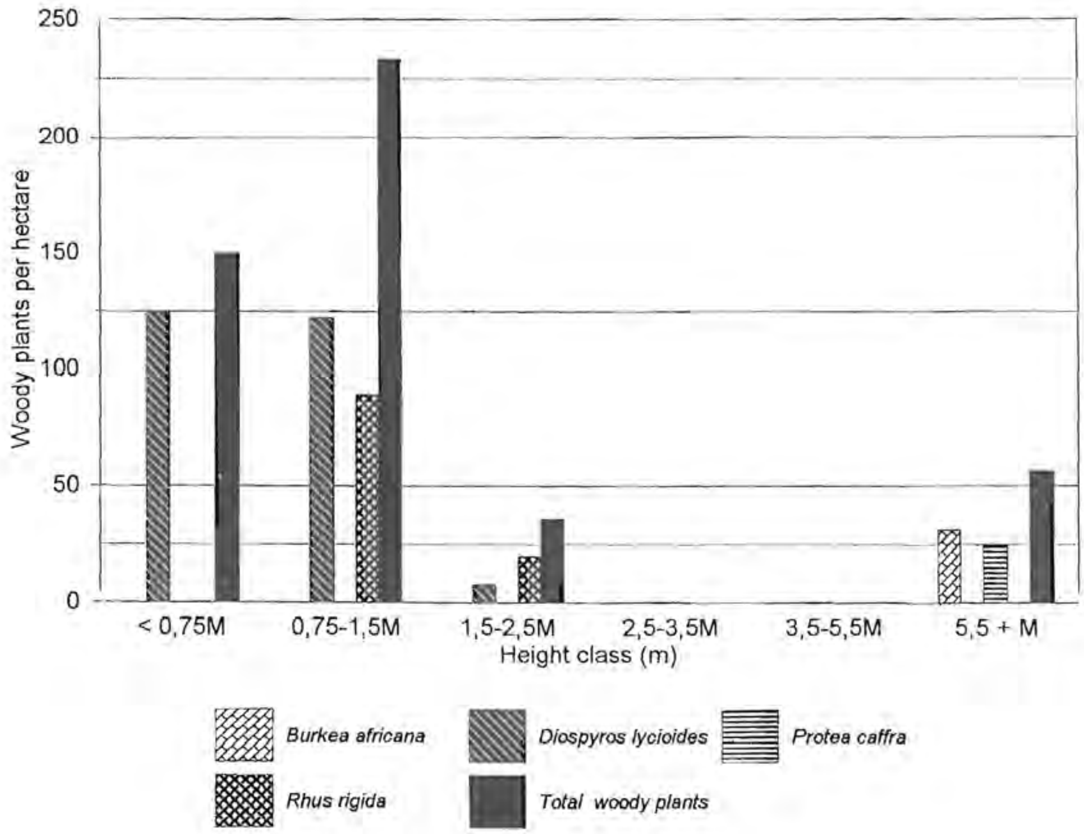

Figure 9: A histogram of the structure of the woody component of the *Burkea africana - Themeda triandra* Tall Open Woodland variation of the *Burkea africana - Setaria sphacelata* Tall Open Woodland sub-community on Rustenburg Nature Reserve.

The tree stratum is confined to *Protea caffra* trees with individual *Faurea saligna* trees. Figure 10 illustrates the structure of the tree and shrub layer in this sub-community. The tall height classes are represented by *Protea caffra* and individuals of *Faurea saligna*. *Ochna pulchra*, *Ozoroa paniculosa* and *Rhus rigida* represents the shorter height classes. The structure of the woody component in this section of the sub-community is open and a maximum of 175 trees per hectare were recorded. Most of the trees were in the tall height classes.

Figure 11 is a histogram of the density of the woody plants in the different height classes in this sub-community situated on the summit plateau in the northern regions of the study area. *Protea caffra* is only present in the 2.5m - 5.5+ m height classes (Figure 11), representing the total woody layer in these height classes. A severe fire in 1990 damaged the *Protea caffra* trees in the <2.5m height class, resulting in a visible reduction in the overall height structure of this sub-community. The trunks coppiced, resulting *Protea caffra* to become pronounced in the lower height classes.

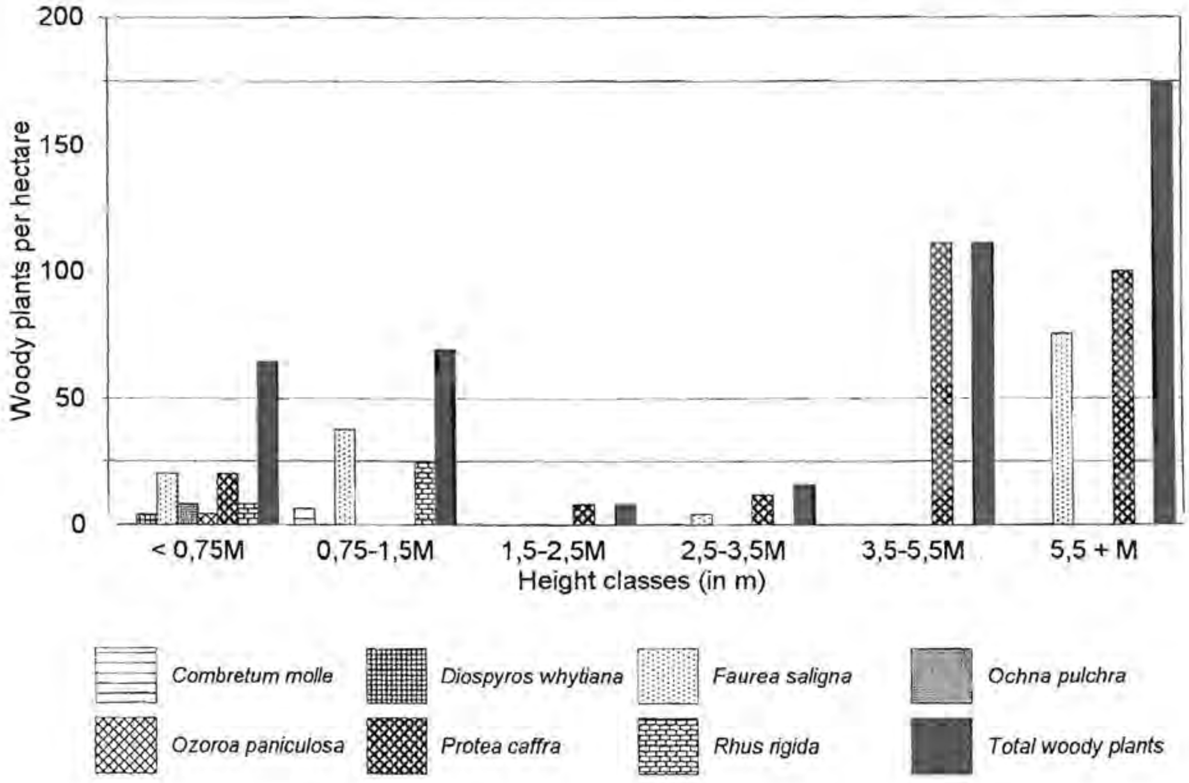

Figure 10: A histogram of the structure of the woody component of the *Aloe greatheadii-Themeda triandra* Tall Open Woodland in the southern section of the central basin on Rustenburg Nature Reserve.

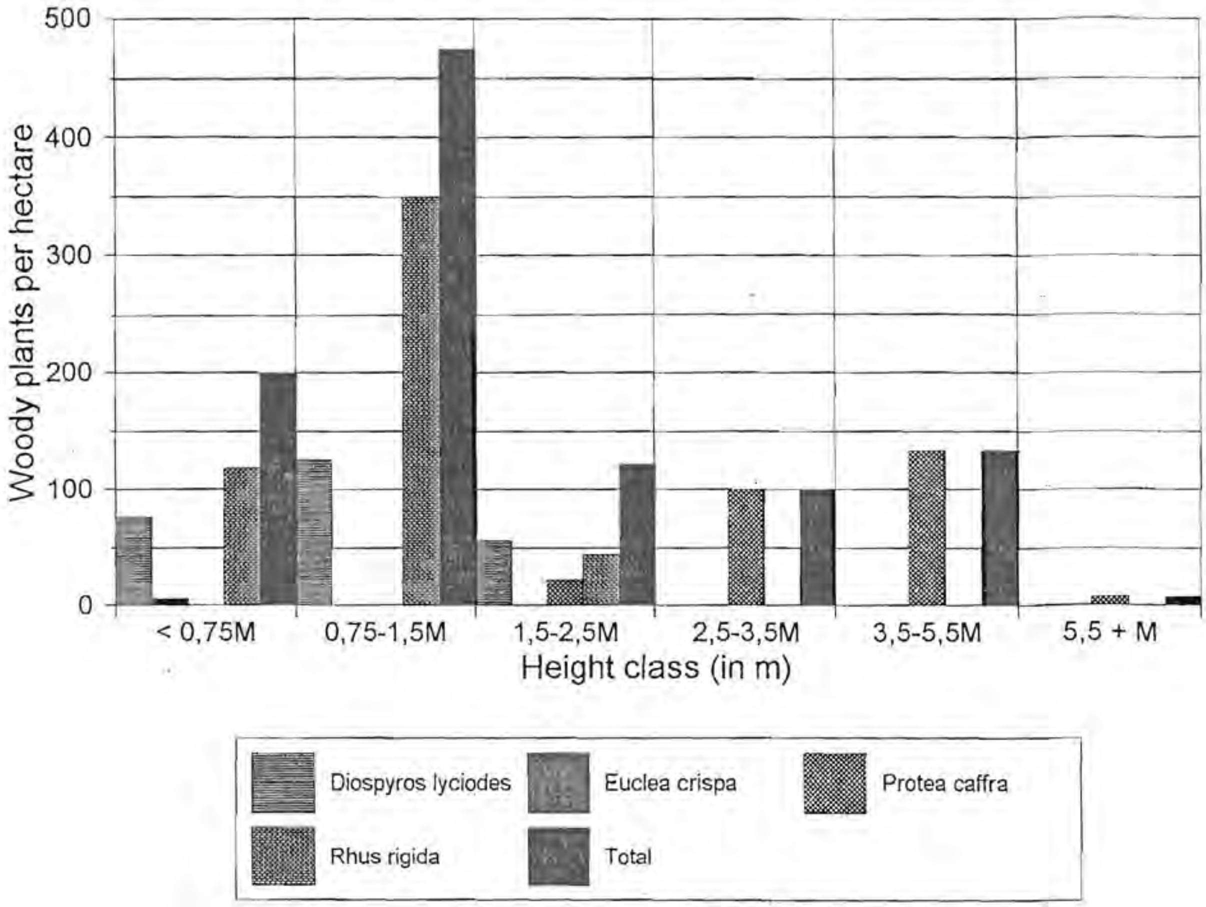

Figure 11: A histogram of the structure of the woody component of the *Aloe greatheadii-Themeda triandra* Tall Open Woodland on the northern plateau on Rustenburg Nature Reserve.

5 *Protea gaguedi - Monocymbium ceresiiforme* Short Open Shrubland

Coetzee (1975) distinctly differentiated the existence of this community in the study area, describing it as a variation of the *Digitaria brazzae- Tristachya rehmanni* Short Open Shrubland. It is distinguished from the *Tristachya biseriata - Protea caffra* community by the absence of species group A. This vegetation community is restricted to the concave areas with deep soils on the lower slopes of the summit plateau (Coetzee 1975) and the deeper soils on the southern slopes around the central basin area. The gradient in this community does not exceed 5°. The soil texture of the A-horizon varies from sandloam to sandclayloam.

The community is dominated by *Protea gaguedi* - shrubs (Table 5), which is restricted to the 0.75-1.5m height class (Figure 12). Species group J is diagnostic for this community, consisting of *Protea gaguedi* and the grass species *Monocymbium ceresiiforme* and *Digitaria monodactyla*. Coetzee(1975) also found this association of species on the reserve. Other species groups in this community are K, L, M, N, P, Q, R, S, W, X and Y (Table 5). Prominent forb species in this community includes *Aloe greatheadii* (species group K), *Indigofera comosa* (species group M), *Nidorella hottentotica* (species group N), *Pygmaeothamnus zeyheri* (species group Q), *Dicoma anomala* (species group S), *Elephanthorriza elephantina* (species group W), *Parinari capensis* (species group X), *Becium obovatum* and *Bulbostylis burchellii* (species group Y). The diagnostic grass species are *Monocymbium ceresiiforme*, where as *Aristida aequiglumis* (species group L), *Loudetia simplex* (species group M), *Digitaria brazzae*, *Tristachya rehmannii* (species group P) and *Eragrostis racemosa* (species group S) are prominent and *Diheteropogon amplectens* (species group S)(cover-abundance values 1%-25%), *Themeda triandra* (cover-abundance values 1%-25%), *Trachypogon spicatus* (cover-abundance values 1%-75%), *Brachiaria serrata* and *Melinis nerviglume* (cover-abundance values 1%-50%) (species group Y) dominant. No trees occur in this community.

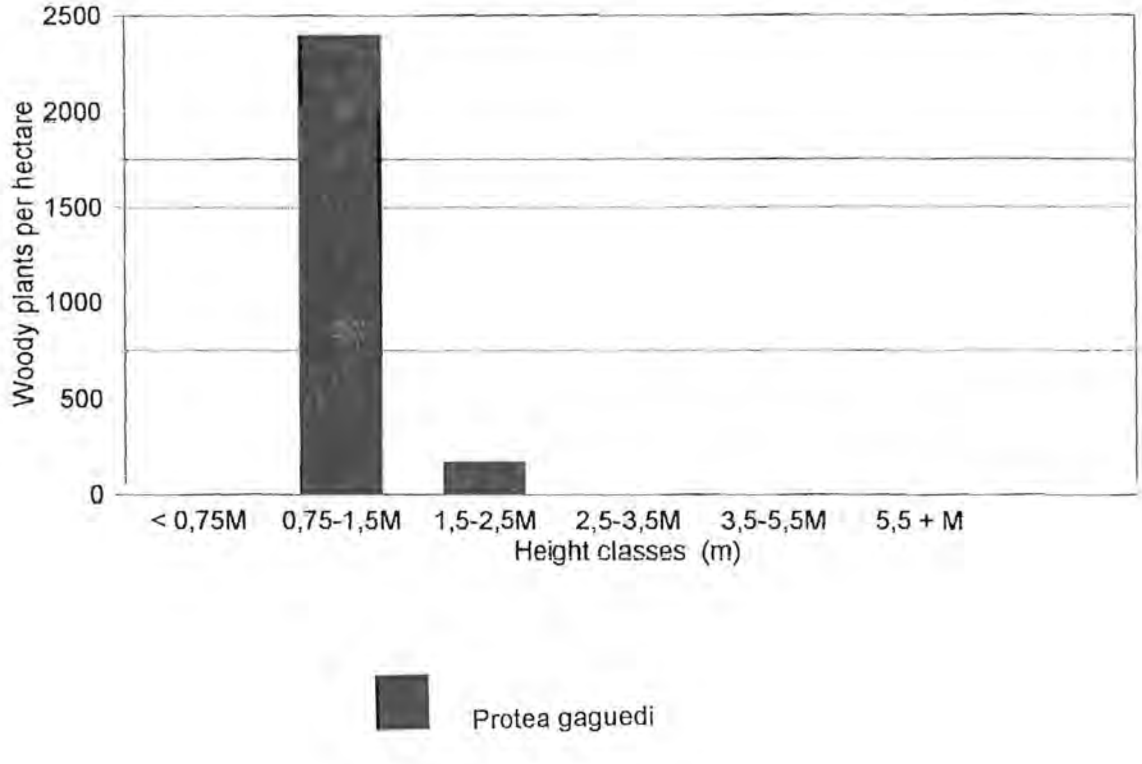

Figure 12: A histogram of the structure of the woody component of the *Protea gaguedi - Monocymbium ceresiiforme* Short Open Shrub land on the northern plateau on Rustenburg Nature Reserve.

6 *Indigofera comosa - Schizachyrium sanguineum* Tall Closed Grassland

Medium deep Glenrosa soils, restricted to northeastern facing slopes accommodate this community. The slopes are gentle and the gradient does not exceed 6°. The loamsand texture of the soil is caused by the coarse quartzite substrate. Soil depth is limited (≈0.6m) and surface rocks or boulders are absent.

Schizachyrium sanguineum (species group N) (cover-abundance values 1% - 50%), *Diheteropogon amplectens* (species group S), *Themeda triandra* (cover-abundance values 0% - 75%) and *Trachypogon spicatus* (species group Y) are the dominant species in this community (Table 5). Other important grass species are *Loudetia simplex* (species group N), *Diheteropogon amplectens* and *Eragrostis racemosa* (species group S). Forbs occurring in this community are *Nidorella hottentotica, Thesium cytisoides* (species group N), *Pygmaeothamnus zeyheri, Rhynchosia monophylla* (species group Q), *Chamaecrista mimosoides* (species group S) and *Parinari capensis* (species group X).

7 *Plexipus hederaceus - Cymbopogon excavatus* Tall Closed Grassland

This tall grassland are situated at the bottom of the central basin area. It is located on the deep soils (1m +) of the north eastern slopes. The area is flat and the gradient is between 3° and 4°. The loam sand to sandloam soils consists of finely-grained sand.

Species group O, diagnostic for this community, includes the forbs *Plexipus hederaceus* and *Raphionacme hirsuta* (Table 5). This community is characterised by dense stands of tufted, perennial grasses, consisting predominantly of *Cymbopogon excavatus* (species group P), *Diheteropogon amplectens* (species group S), *Themeda triandra, Trachypogon spicatus* and *Melinis nerviglume* (species group Y). Other prominent grass species include *Digitaria brazzae* (species group P) and *Eragrostis racemosa* (species group S). The abundant forb species include *Acalypha angustata*, *Ledebouria marginata* (species group P), *Pygmaeothamnus zeyheri* (species group Q), *Vernonia galpinii*, *Kohoutia amatymbica*, *Chamaecrista mimosoides*, *Conyza aegyptica*, *Ipomoea ommaneyi* (species group S), *Elephanthorriza elephantina* (species group W) and *Becium obovatum* (species group Y). Individuals of *Protea caffra* shrubs occur in this grassland community.

8 *Tristachya leucotrix* - *Setaria sphacelata* Tall Sparse Woodland

This woodland is associated with shallow Glenrosa soils found in the south eastern part of the study area. This community is situated on the crests or southern midslopes of the eastern range of hills. The slopes vary from flat (< 5°) to moderate (20°-35°). At least 10% of this community is covered with rocks.

This community is distinguished by the presence of diagnostic species group T, consisting of *Tristachya leucotrix* and *Setaria sphacelata*. The grass *Tristachya leucotrix* is dominant, covering an average of 50% of the relevés. Other prominent species are *Themeda triandra*, *Trachypogon spicatus*, *Brachiaria serrata* and *Melinis nerviglumis* (species group Y) and the sedge *Bulbostylis burchellii* (species group Y). The trees and shrub layer are inconspicuous and limited to scattered individuals of *Protea caffra* and *Burkea africana* (Table 5).

Three sub-communities can be distinguished in this community according to aspect:

8.1 *Heteropogon contortus* - *Trachypogon spicatus* Tall Open Woodland

This sub-community is confined to the east and north facing slopes. The occurrence of boulders and large rocks varies from absent or rare to abundant on the hillcrest in the southeast of the reserve. Splash erosion do occur in some of the relevés.

This Tall Open Woodland is differentiated from 8.2 by the absence of species group V (Table 5). The grasses *Heteropogon contortus* and *Trachypogon spicatus* are dominant in this sub-community. Other prominent grasses include *Themeda triandra* and *Brachiaria serrata* (species group Y). Forbs occurring in this sub-community are *Ruellia cordata* (species group U), *Elephantorrhiza elephantina, Ophresia oblongifolia* (species group W), *Parinari capensis* (species group X) and *Bulbostylis burchellii* (species group Y). The tree layer is inconspicuous and scattered individuals of *Faurea saligna* (species group H) (Table 5) are found.

8.2 *Ruellia cordata - Senecio venosus* Tall Sparse Woodland

The sub-community occurs on the rocky norite slopes in the eastern region of the study area. Aspect varies considerably in this sub-community and cannot be considered as a diagnostic habitat feature. This woodland occurs on the summit and the upper slopes of the eastern range of hills. Slope varies from flat on the summit to a gradient of 30° on the slopes. The soil has a sandclayloam to sandclay texture.

Dense stands of *Tristachya leucotrix* (cover-abundance values 25%-100%) is enclosed in this sub-community. It is further differentiated from the other two sub-communities by the presence of the diagnostic species groups V, including the forbs *Chaetacanthus costatus, Mariscus congesta* and *Polygala uncinata* (Table 5). Grasses abundant in this sub-community are *Setaria sphacelata*, (species group T), *Heteropogon contortus* (species group W), *Themeda triandra, Trachypogon spicatus* and *Brachiaria serrata* (species group Y). Prominent forbs include *Sphenostylis angustifolia* (species group F), *Ruellia cordata, Thesium utile* (species group V) and *Bulbostylis burchellii* (species group Y). The tree layer is inconspicuous and scattered individuals of *Faurea saligna* and *Protea caffra* in the 5.5 m height class are present (Figure 13). The shrub layer (0.75 m - 2.5 m) is inconspicuous and represented by *Englerophytum magalismontanum, Diospyros lycioides* and *Rhus rigida*.

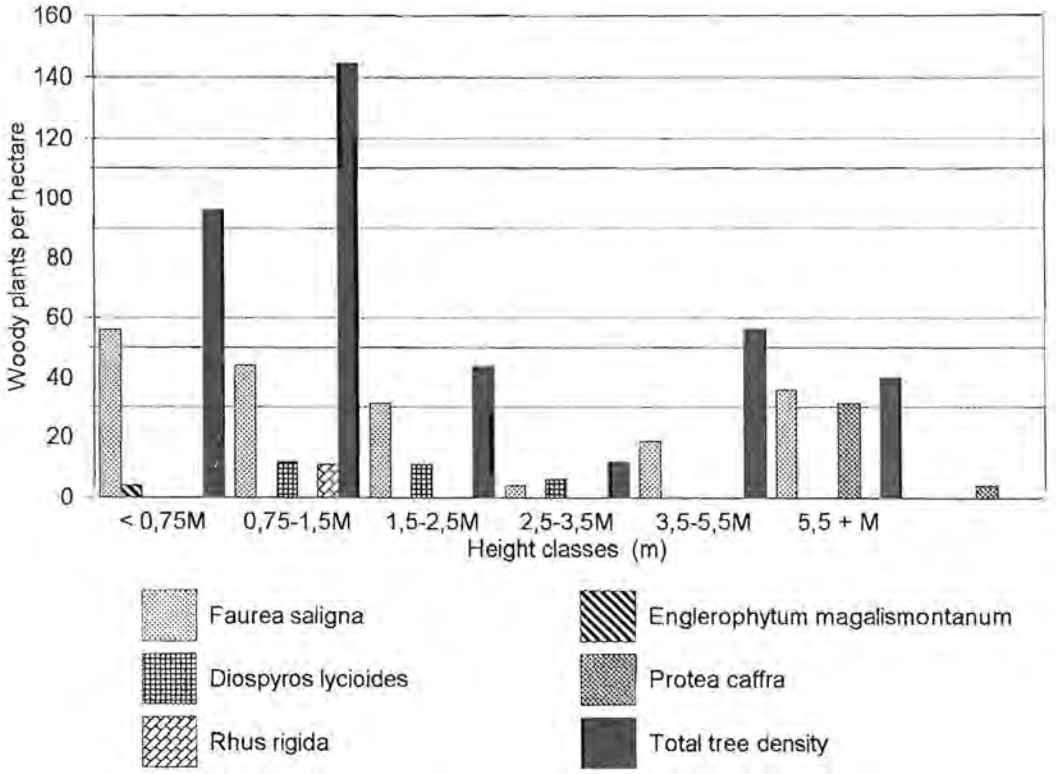

Figure 13: A histogram of the structure of the *Ruellia cordata - Senecio venosus* Tall Sparse Woodland sub-community of the *Tristachya leucotrix - Setaria sphacelata* Tall Sparse Woodland community on Rustenburg Nature Reserve.

8.3 *Trachypogon spicatus - Bulbostylis burchellii* Short Sparse Woodland

The *Trachypogon spicatus - Bulbostylis burchellii* Short Sparse Woodland is situated on the crests and upper western to northeastern facing slopes in the south eastern regions of the study area. It lies on sandloam to sandclayloam soils with boulders and large rocks. The soil texture are coarse-grained. Splash erosion was recorded in several relevés.

This sub-community is recognised by the absence of species groups U, V and W (Table 5). No diagnostic species group has been identified for this sub-community. The dominant forb species are *Parinari capensis* (species group X) and *Bulbostylis burchellii* (species group Y), whereas the dominant grasses are *Tristachya leucotrix* (species group T) and *Loudetia simplex* (species group N). Other grass species present are *Themeda triandra, Trachypogon spicatus* and *Brachiaria serrata* (species group Y). The tree layer is absent in this sub-community.

9 ***Acacia caffra - Ziziphus mucronata* Tall Closed Woodland**

Acacia caffra is a widely distributed species occurring in various habitats in the Magaliesberg (van Wyk *et al.* 1988; van Gogh *et al.* 1988; van Vuuren *et al.* 1970; Coetzee 1975). In various habitats in the study area, this species dominates where it is associated with different other species groups. The *Acacia caffra - Ziziphus mucronata* community is widely distributed throughout the study area. A general habitat characteristic associated with this community is shallow to moderately deep Glenrosa soil forms occurring on the rocky slopes and foothills of the eastern range of valleys in the study area. However, some variations occur in deep Hutton soils (>1.5m).

A gradient from a distinct open xeric environment to a closed mesic environment can be detected in this community. The open xeric woodlands are confined to the eastern and northern aspects, distinguished by species groups B, C and D (Table 6). The closed mesic vegetation is restricted to the foothills and drainage lines in the valleys and is distinguished by the presence of especially species groups T, U and W.

Evident from table 6, the woody component is very conspicuous in the *Acacia caffra - Ziziphus mucronata* vegetation community. General species (species group X) occurring throughout the community are predominantly woody species and includes prominent species *viz. Rhus leptodictya, Dombeya rotundifolia, Maytenus undata, Euclea crispa, Pappea capensis* and *Combretum molle*.

Eleven sub-communities and five variations were recognised based on soil depth and aspect:

9.1 *Cheilanthes viridus - Combretum molle* Short Open Woodland

This variation is confined to the mesic habitat associated with the rocky western to northeastern facing slopes on the foothills of the Magaliesberg. The gradient of the slope varies between 24°and 26°. The soil is shallow and the texture of the orthic A horizon is sand loam to sand clay loam.

Coetzee (1975) distinguished the *Kalanchoe paniculata - Acacia caffra* variation in the *Eustachys paspaloides - Acacia caffra* woodland that display a resemblance with the *Cheilanthes viridus - Combretum molle* Short Open Woodland sub-community. The *Kalanchoe paniculata - Acacia caffra* variation occurs below cliffs on the convex slopes on the western side of the Magaliesberg.

The diagnostic species for this sub-community is represented by species group B (Table 6), consisting of *Cheilanthes viridus, Tragia rupestris, Kalanchoe paniculata* and *Croton gratissimus* var. *subgratissimus*. Other species occurring in this sub-community are the forbs *Pellaea calomelanos* (species group N), *Thunbergia atriplicifolia* (species group N) and *Solanum panicoides* (species group R). The grass layer is represented by *Eustachys paspaloides, Elionurus muticus*

Table 6: Phytosociological table for the *Acacia caffra - Ziziphus mucronata* Tall Closed Woodland, *Mimusops zeyheri - Hypoestes forskaoli* Tall Forest, *Brachylaena rotundata - Englerophytum magalismontanum* High Open Shrubland and *Cynodon dactylon - Panicum maximum* Tall Sparse Woodland on Rustenburg Nature Reserve

Community	9														10	11		12	
Sub-community	9.1	9.2	9.3	9.4			9.5		9.6	9.7	9.8	9.9	9.10	9.11		11.1	11.2	12.1	12.2
Variation				9.4.1	9.4.2	9.4.3	9.5.1	9.5.2											
Species	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Species group A																			
Acacia caffra	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Ziziphus mucronata	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Commelina africana	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Species group B																			
Combretum viridis	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Tragia rupestris	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Kalanchoe paniculata	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Croton gratissimus var. *subgratissimus*	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Species group C																			
Digitaria eriantha	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Pavetta punctulata	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Polygala hottentotta	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Teucrium trifidum	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Tapinanthus natalitius subsp. *zeyheri*	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sporobolus fimbriatus	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Species group D																			
Setaria lindenbergiana	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Anemone alta	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mohria caffrorum	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Maytenus heterophylla	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Cussonia paniculata	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rhus discolor	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Satureja biflora	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Species group E																			
Protea caffra	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Helichrysum setosum	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rhus lancea	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Species group F																			
Turbina oblongata	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Elephantorrhiza elephantina	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Phyllanthus glaucophyllus	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Senecio inornatus	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Eucomis clavata	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Eulophia ovalis	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rubus rigidus	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Conyza podocephala	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Species group G																			
Asparagus laricinus	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Ledebouria marginata	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Aloe greatheadii	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rubia petiolaris	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Hypoxis rigidula	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Hyparrhenia filipendula var. *pilosa*	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Species group H																			
Kohautia amatymbica	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Cymbopogon excavatus / *Cryptanthus* [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Digitaria diagonalis	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Conyza aegyptiaca	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Species group I																			
Rhus rigida	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Vernonia natalensis	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Helichrysum rugulosum	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Athrixia elata	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Gerbera piloselloides	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Acalypha angustata	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Cymbopogon excavatus	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 6: (Cont). Phytosociological table for the *Acacia caffra - Ziziphus mucronata* Tall Closed Woodland, *Mimusops zeyheri - Hypoestes forskaoli* Tall Forest, *Brachylaena rotundata - Englerophytum magalismontanum* High Open Shrubland and *Cynodon dactylon - Panicum maximum* Tall Sparse Woodland on Rustenburg Nature Reserve

Community / Sub-community / Variation / Relevés	9.1	9.2	9.3	9.4.1	9.4.2	9.4.3	9.5.1	9.5.2	9.6	9.7	9.8	9.9	9.10	9.11	10	11.1	11.2	12.1	12.2
Relevé numbers	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Species group J																			
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rhynchosia nervosa	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Species group K																			
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Ipomoea ommanneyi	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Species group L																			
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Brachiaria brizantha	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Blumea alata	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Jatropha zeyheri	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Species group M																			
Loudetia flavida	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Andropogon schirensis	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Thesium magalismontanum	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Triumfetta sonderi	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Species group N																			
Vernonia oligocephala	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Eustachys paspaloides	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Ipomoea bathycolpos var. *bathycolpos*	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Pellaea calomelanos	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Elionurus muticus	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Vangueria infausta	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Thunbergia atriplicifolia	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rhynchosia totta	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Species group O																			
Brachiaria serrata	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Melinis nerviglumis	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Faurea saligna	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Species group P																			
Senecio venosus	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Trachypogon spicatus	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Burkea africana	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Species group Q																			
Setaria sphacelata	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Heteropogon contortus	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Eragrostis curvula	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Ledebouria species	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Solanum panduriforme	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Species group R																			
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Ruellia cordata	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Berchemia zeyheri	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sphedamnocarpus pruriens	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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Table 6: (Cont). Phytosociological table for the *Acacia caffra - Ziziphus mucronata* Tall Closed Woodland, *Mimusops zeyheri - Hypoestes forskaoli* Tall Forest, *Brachylaena rotundata - Englerophytum magalismontanum* High Open Shrubland and *Cynodon dactylon - Panicum maximum* Tall Sparse Woodland on Rustenburg Nature Reserve

Community: 9 (subcommunities 9.1, 9.2, 9.3, 9.4 [9.4.1, 9.4.2, 9.4.3], 9.5 [9.5.1, 9.5.2], 9.6, 9.7, 9.8, 9.9, 9.10, 9.11); 10; 11 (11.1, 11.2); 12 (12.1, 12.2)

Species	
Species group S	
[illegible]	[illegible]
Asparagus suaveolens	[illegible]
[illegible] javanica	[illegible]
[illegible] depressa	[illegible]
Lannea discolor	[illegible]
Combretum zeyheri	[illegible]
[illegible] repens	[illegible]
Species group T	
Asparagus virgatus	[illegible]
[illegible] megaphylla	[illegible]
Species group U	
Asparagus cooperi	[illegible]
Olea europaea	[illegible]
Maytenus polyacantha	[illegible]
Species group V	
Cassine [illegible]	[illegible]
[illegible] reticulum subsp. [illegible]	[illegible]
[illegible] rostratum	[illegible]
Mimusops zeyheri	[illegible]
Commelina benghalensis	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
Species group W	
Maytenus undata	[illegible]
Rhoicissus tridentata	[illegible]
Achyranthes aspera	[illegible]
Combretum erythrophyllum	[illegible]
Diospyros whyteana	[illegible]
Species group X	
Rhus leptodictya	[illegible]
Dombeya rotundifolia	[illegible]
Euclea crispa	[illegible]
Pappea capensis	[illegible]
Combretum molle	[illegible]
Rhus pyroides	[illegible]
Hypoestes forskaolii	[illegible]
Grewia occidentalis	[illegible]
Species group Y	
Englerophytum magalismontanum	[illegible]
Brachylaena rotundata	[illegible]
Species group Z	
Pittosporum viridiflorum	[illegible]
Ilex mitis	[illegible]
Halleria lucida	[illegible]
Rothmannia capensis	[illegible]
Myrsine africana	[illegible]
Cyperus albostriatus	[illegible]
Secamone alpini	[illegible]
Scadoxus puniceus	[illegible]

Table 6: (Cont). Phytosociological table for the *Acacia caffra - Ziziphus mucronata* Tall Closed Woodland, *Mimusops zeyheri - Hypoestes forskaoli* Tall Forest, *Brachylaena rotundata - Englerophytum magalismontanum* High Open Shrubland and *Cynodon dactylon - Panicum maximum* Tall Sparse Woodland on Rustenburg Nature Reserve

Community	9														10	11		12	
Sub-community	9.1	9.2	9.3	9.4			9.5		9.6	9.7	9.8	9.9	9.10	9.11		11.1	11.2	12.1	12.2
Variation				9.4.1	9.4.2	9.4.3	9.5.1	9.5.2											
Relevés	397 399 398 314	226 201 202 203 204	392 393 395 221 232 227	261 247 257 258 259 250	252 254 263	381 394	233 235 236 237 242	210 205 206	021 022 028 049 057 038 041 052 058 008 110 113 068	085 076 040 090 091 094 098 103 109	009 013 005 054 083 108 108 072 081 092 097 083	085 087 098 007 042	003 004 008 010 011 055 066	030 067 074 075 080 088	254 215 253 255 258 043 398	368 389	387 389	025 060 073 084	001 002 082 072 078 029
Species group AA																			
ychobotrys capensis									+	R R R							2 +		
icalysia lanceolata														+			+ 1		
ymbopogon validus									+								+ +		
electrica setifera									1								+ 1		
crine natalii																	2		
Species group BB																			
elia africana									+ + 1	+ R	+ + + + R	+ 1	1 1 2 1	+ + + +	+ 1 1 5	+		+	R
anthoxylum capense	+	+	+							R	+ + +	+	+ + 1 +	R + +	+ + +	+ +	+ +		
Species group CC																			
ynodon dactylon											+ + +							4 5 3 5	2 5 + 5 +
Species group DD																			
yparrhenia hirta			+ +						1 1 + +	+ + +			+						2 + + 3 4
idens pilosa													+						4 2 +
Species group EE																			
anicum maximum	+		+						1 +	+ 2 +	+ 2 + + 1	+ 2 2 5 +	1 5 + +	+ 2 + +	+ +			+ 1 2	1 + 3 1
agetes minuta	+ +		+ +	+ +	+		+		2 + + +	+ 1 + +	+ + +		2		+ + +			+ + 1	2 + +
cacia karroo	+	+ +	+ + 2	2	+ +		1 2 2 + 2		+ + +	+	+ + +			+	+				+ R R R
iospyros lycioides		+	+	+ + + +	+ + +		+ +		+ + R +		+ +	+ +	1 2	1 + 1 R	+ +		+	R	

(species group N) and *Heteropogon contortus* (species group R). Trees and shrubs in this sub-community are *Lannea discolor*, *Combretum zeyheri*, (species group S), *Pappea capensis* and *Combretum molle* (species group X).

9.2 *Digitaria eriantha - Lippia javanica* Tall Closed Woodland

The *Digitaria eriantha - Lippia javanica* Tall Closed Woodland is confined to deep alluvial soils in the valley in the northeastern section of the study area. The soil texture is sand clay loam and rocks and boulders are absent.

Coetzee (1975) differentiated the *Digitaria smutsii - Acacia caffra* variation in the *Eustachys paspaloides - Acacia caffra* woodland. This variation is restricted to the well-differentiated alluvial soils of the flats between the northeastern foothills of the Magaliesberg (Coetzee 1975) and demonstrates similarities with the *Digitaria eriantha - Lippia javanica* Tall Closed Woodland.

Diagnostic species group C distinguishes this sub-community from the other sub-communities. It consists of the forbs *Psiadia punctulata*, *Polygala hottentotta* and the grass *Sporobolus fimbriatus* (Table 6). Species groups J, N, Q, S, X and EE are also present in this sub-community. The tree and shrub layer are conspicuous. A prominent tree species is *Dombeya rotundifolia* (species group X). Figure 14 illustrates the structure of the woody component in this sub-community. The <0.75 m height class dominates the structure in this woodland sub-community, with *Combretum zeyheri* particularly prominent. The >3.5 m height classes is markedly inconspicuous in this sub-community.

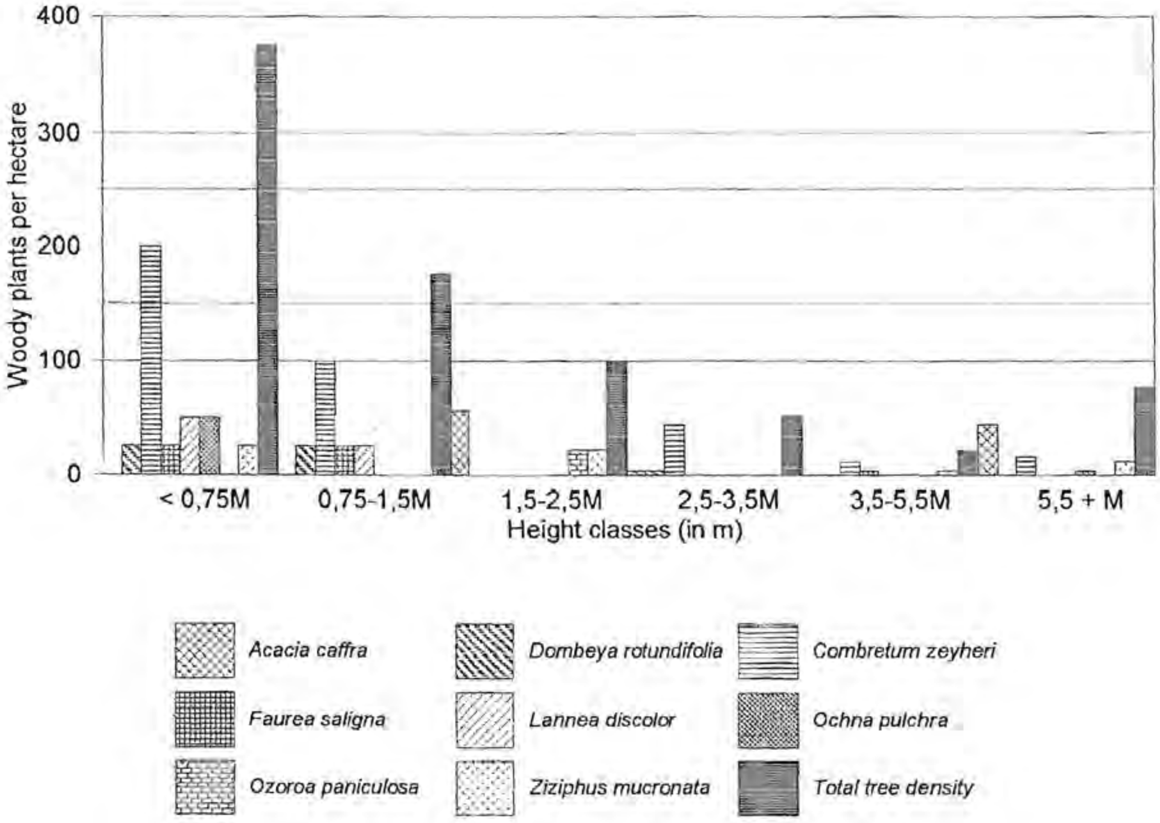

Figure 14: A histogram of the structure of the *Digitaria eriantha - Lippia javanica* Tall Closed Woodland of the *Acacia caffra - Ziziphus mucronata* Tall Closed Woodland on Rustenburg Nature Reserve.

The grass species in this variation are *Digitaria eriantha*, (cover-abundance values 1% - 50%), *Eustachys paspaloides* (species group N), *Setaria sphacelata, Heteropogon contortus* and *Eragrostis curvula* (cover-abundance value 50%-75%) (species group Q).

9.3 *Setaria lindenbergiana - Artemisia afra* Tall Closed Woodland

The *Setaria lindenbergiana - Artemisia afra* Tall Closed Woodland sub-community is confined to the shallow soils at the bottom of the valley situated between the summit areas in the northeastern regions of the study area. The slopes are fairly steep and vary between 19° and 44°. Aspect is southwest to east. Rocks and boulders occur frequently in the area. The soil has a sandclayloam texture.

This sub-community corresponds with the *Setaria lindenbergiana - Acacia caffra* woodland identified by Coetzee (1975). According to Coetzee (1975) the *Setaria lindenbergiana - Acacia caffra* woodland is regarded as a sub-unit within the *Eustachys paspaloides - Acacia caffra* Woodlands. This Tall Closed Woodland is restricted to the cool slopes in the valleys between the summit areas.

Diagnostic species for this sub-community are species group D (Table 6). These species include *Artemisia afra, Mohria caffrorum, Maytenus heterophylla, Cussonia panicoides* and *Rhus discolor*. Other species groups occurring in this sub-community are species group I, J, N, Q, X and EE. These species groups contain the grasses *Eustachys paspaloides* (species group N), *Setaria sphacelata* (cover-abundance values 50%) and *Eragrostis curvula* (species group Q). The grass *Setaria lindenbergiana,* diagnostic to this sub-community is dominant and cover-abundance values of between 25% and 75% were recorded. The *Acacia caffra - Setaria lindenbergiana* association was also described by van Vuuren *et al.* (1970). He found this sub-community to be distinctive of the south-facing slopes and characteristic of open woodlands.

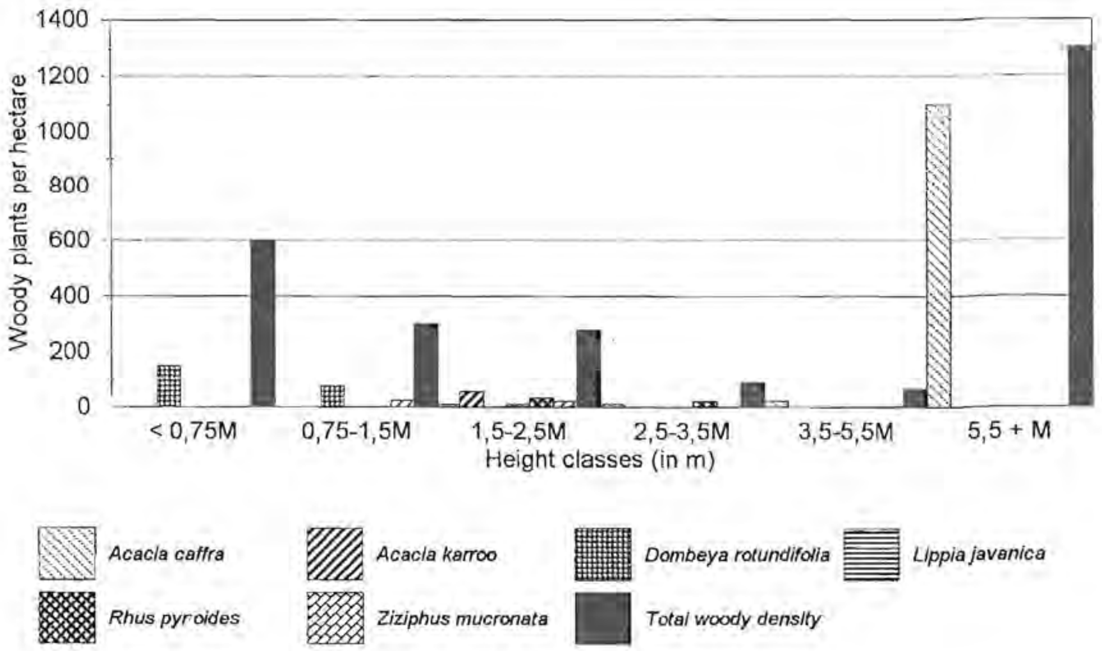

Figure 15: A histogram of the structure of the *Setaria lindenbergiana - Artemisia afra* Tall Closed Woodland sub-community of the *Acacia caffra - Ziziphus mucronata* Tall Closed Woodland community on Rustenburg Nature Reserve.

Trees and shrubs occurring in this sub-community are *Acacia caffra, Ziziphus mucronata* (species group A), *Maytenus heterophylla* (species group D), *Rhus rigida* (species group I), *Dombeya rotundifolia, Rhus pyroides* (species group X) and *Acacia karroo* (species group EE) (Figure 15). The shrub layer in the < 0.75m height class is dominated by *Dombeya rotundifolia*, while *Acacia caffra* is dominant in the >5.5m height class (Figure 15). The 2.5m to 5.5m height classes is inconspicuous in this sub-community (Figure 15).

9.4 *Becium obovatum - Protea caffra* Tall Closed Woodland.

This distinctive sub-community is restricted to the northern section of the central basin area where most of the reserve's infrastructure is situated. This sub-community is confined to deep Hutton soils, although one variation is found on shallow Glenrosa soils. The gradient in this sub-community varies from gentle to steeper slopes, not exceeding 33°. This sub-community occurs on the southeastern to southwestern facing slopes. Large rocks and boulders are limited to variation 9.4.3 of this sub-community.

Coetzee (1975) described the vegetation in this sub-community as the *Protea caffra - Acacia caffra* variation of the *Brachiaria serrata - Acacia caffra* sub-community. This variation is regarded by Coetzee(1975) as a transition between *Eustachys paspaloides - Acacia caffra* and the *Eragrostis racemosa - Bewsia biflora* communities because of the large amount of species shared.

In this classification, the differentiating species group is species group E, containing the trees *Protea caffra* and *Rhus lancea*, which, together with *Acacia caffra* (species group A) forms the main constituents of the tree layer (Table 6). Diagnostic forbs include *Helichrysum setosum* (species group E), *Ledebouria marginata* (species group G) and *Elephanthorriza elephantina* (species group F). Based on aspect and soil depth, three variations can be distinguished in this sub-community.

9.4.1 *Turbina oblongata - Phyllanthus glaucophyllus* High Closed Shrubland

This variation is found on westerly to southerly facing slopes on deep fine grained Hutton soils. Rocks and boulders are absent. The clay content of the soil in this variation is higher than the other two variations.

Species group F is diagnostic for this variation. This species group includes the forbs *Turbina oblongata, Phyllanthus glaucophyllus, Senecio inornatus, Eucomis clavata* and *Conyza podocephala*, and the geophyte *Eulophia ovalis.* Other species groups occurring in this variation are G, H, I, J, K, N, O, P, Q, S, X and EE (Table 6). Prominent grasses in this variation are *Hyparrhenia filipendula* var. *pilosa* (species group G), *Digitaria diagonalis* (species group H), *Setaria nigrirostis* (species group J), *Brachiaria serrata* (species group O), *Setaria sphacelata* (cover-abundance values 75% - 100%) (species group Q) and *Themeda triandra* (species group S). Significant forbs are *Aloe greatheadii, Rubia petiolaris, Hypoxis rigidula* (species group G), *Kohautia amatymbica, Chaetacanthus setiger* (species group H), *Conyza albida, Lantana rugosa* (species group J), *Becium obovatum* (species group K) and *Vernonia oligocephala* (species group N).

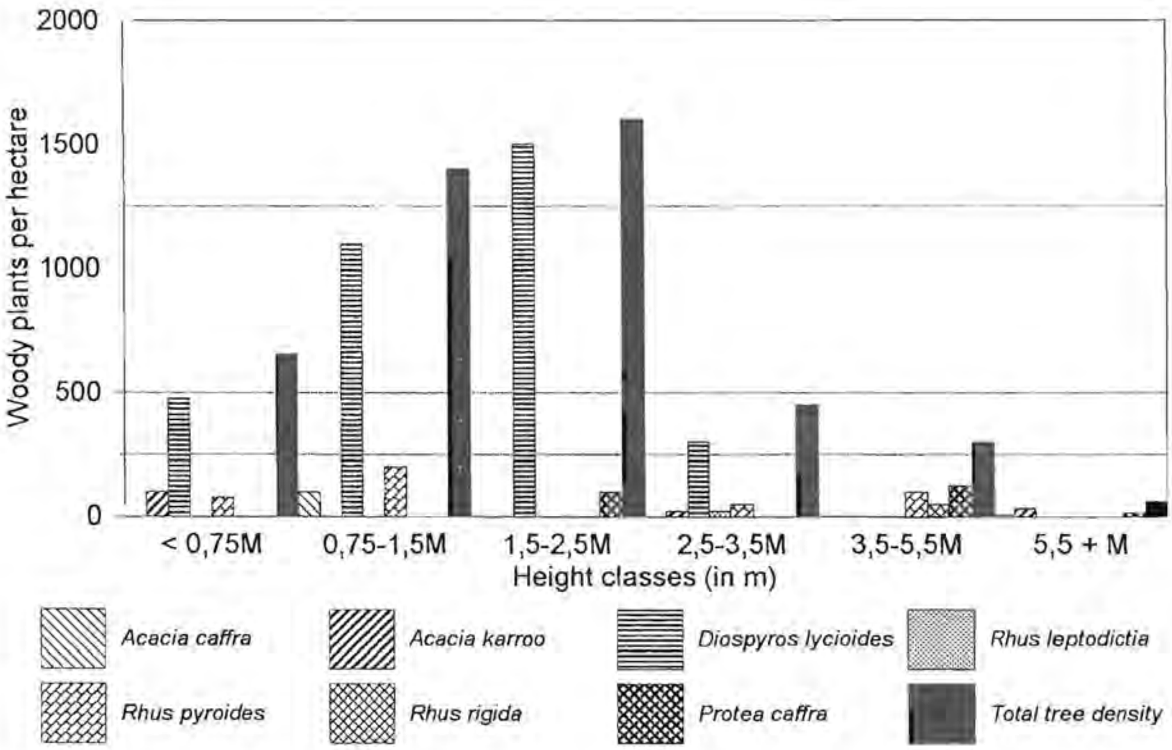

Figure 16: A histogram of the structure of the *Turbina oblongata - Phyllanthus glaucophyllus* High Closed Shrub land variation of the *Acacia caffra - Ziziphus mucronata* Tall Closed Woodland community on Rustenburg Nature Reserve.

Individual *Faurea saligna* and *Combretum zeyheri* trees are found in this variation. Figure 16 is a histogram illustrating the structure of the woody component of this variation. The 0.75 - 2.5 m height classes are well developed in this variation, representing a dense undergrowth consisting of *Asparagus laricinus* (species group G), *Rubus rigidus* (species group F), *Rhus pyroides* (species group X) and *Diospyros lycioides* (species group EE). The >2,5m - 5,5m height classes are less abundant and confined to *Protea caffra* and *Acacia caffra*.

9.4.2 *Diospyros lycioides - Rhus rigida* Tall Closed Woodland

The *Diospyros lycioides - Rhus rigida* Tall Closed Woodland is restricted to the southeast facing slopes in the northern section of the central basin. This variation occurs on slight slopes on soils varying in depth from shallow Glenrosa soils to deep, well-differentiated Hutton soils. The texture of the soil is sand clay loam (MacVicar *et al.* 1991) Rocks occur seldom throughout this variation.

Coetzee (1975) described this variation as the *Protea caffra - Acacia caffra* variation of the *Acacia caffra* dominated woodlands. The absence of species group F in this variation distinguished it from the previous variation. This variation is restricted to the southeastern facing slopes, contrary to the *Turbina oblongata - Phyllanthus glaucophyllus* variation, occurring predominantly on the western facing slopes. The presence of species groups A, E, G, H, I, J, K, N, O, P, Q, S, X and EE characterise this variation. The dominant trees and shrubs are *Acacia caffra*, *Ziziphus mucronata* (species group A), *Protea caffra* and *Rhus lancea* (species group E). Other prominent trees and shrubs in this variation are *Rhus rigida* (species group I), *Dombeya rotundifolia*, *Rhus pyroides* (species group X), *Acacia karroo* and *Diospyros lycioides* (species group EE).

Figure 17 is a histogram illustrating the structure of the woody component in this variation. The undergrowth in this variation(<2,5m) is dominated by *Diospyros lycioides* and *Rhus pyroides*. *Acacia caffra* and *Protea caffra* represents the 2,5m - 5,5m height classes.

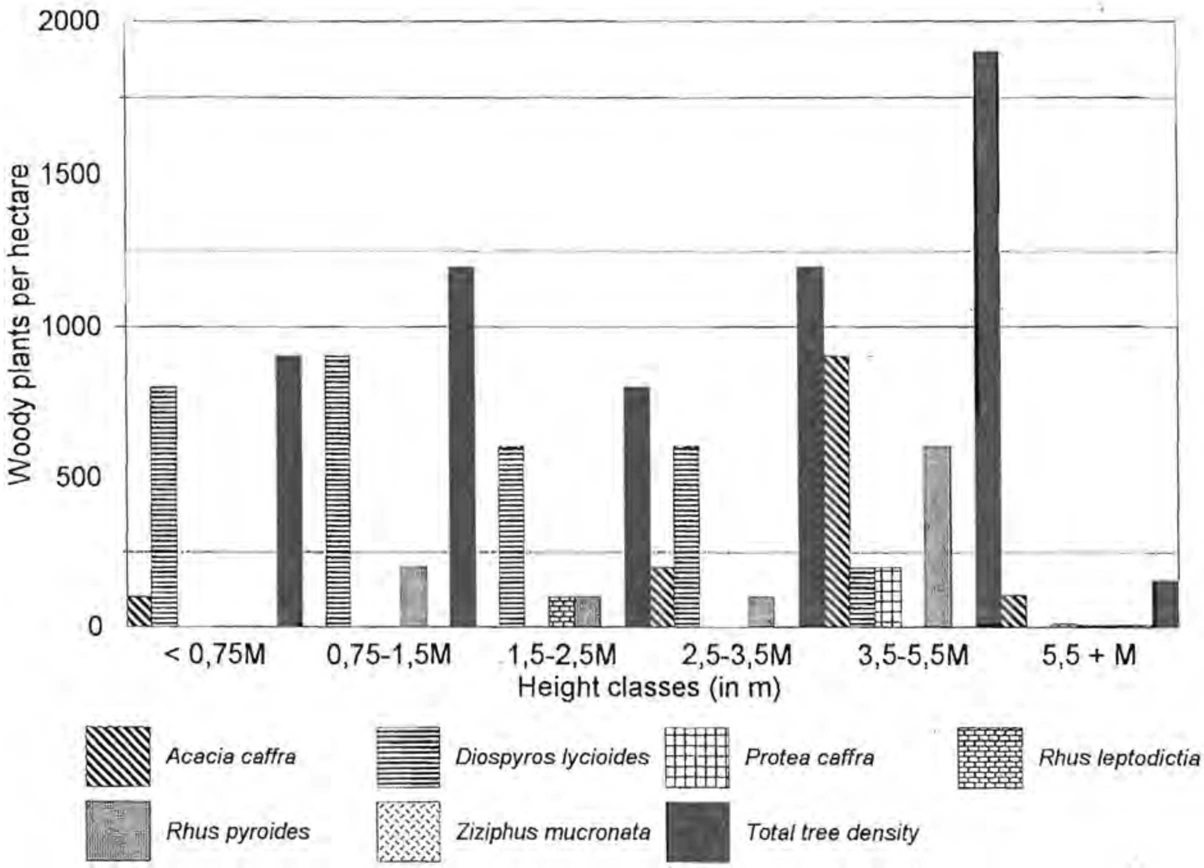

Figure 17: A histogram of the structure of the *Diospyros lycioides* - *Rhus rigida* Tall Closed Woodland variation of the *Acacia caffra* - *Ziziphus mucronata* Tall Closed Woodland community on Rustenburg Nature Reserve.

The dominant grass in this variation is *Setaria sphacelata* (cover-abundance values 25% - 50%). Other grasses present are *Hyparrhenia filipendula var. pilosa* (species group G), *Diheteropogon amplectens* (species group K), *Eustachys paspaloides* (species group N), *Brachiaria serrata, Melinis nerviglumis* (species group O), *Trachypogon spicatus* (species group P), *Themeda triandra* (species group S) and *Eragrostis curvula* (species group Q). Forbs constitute the larger part of the cover. Prominent forbs are *Ledebouria marginata, Aloe greatheadii* (species group G), *Kohautia amatymbica, Chaetachantus setiger* (species group H), *Conyza albida, Rhynchosia nervosa, Lantana rugosa* (species group J), *Becium obovatum* (species group K), *Vernonia oligocephala* (species group N) and an unidentified *Ledebouria* species (species group Q) (Table 6).

9.4.3 *Themeda triandra - Elionurus muticus* Tall Closed Woodland

Small areas of shallow clay soils on the western boundary of the study area are covered by this variation. This shallow clay soils developed from Magaliesberg altered shales (Coetzee 1975). The landscape is broken with rocks and boulders occurring frequently with a gradient varying between 22° and 23°. This variation is utilized by game, especially sable antelope (*Hippotragus niger niger*) and eland (*Taurotragus oryx).*

The dominant forbs in this variation are *Helichrysum setosum* (species group E), *Vernonia natalensis, Helichrysum nudifolium, Athrixia elata* (species group I), *Pentanisia angustifolia, Becium obovatum* (species group K) and *Pellaea calomelanos* (species group N). Grasses occurring in this variation are *Diheteropogon amplectens* (species group K), *Elionurus muticus* (species group N), *Brachiaria serrata* (species group O), *Trachypogon spicatus* (species group P), *Setaria sphacelata* (cover-abundance values 5%-50%)(species group Q) and *Themeda triandra* (cover-abundance values 5%-75%) (species group S).

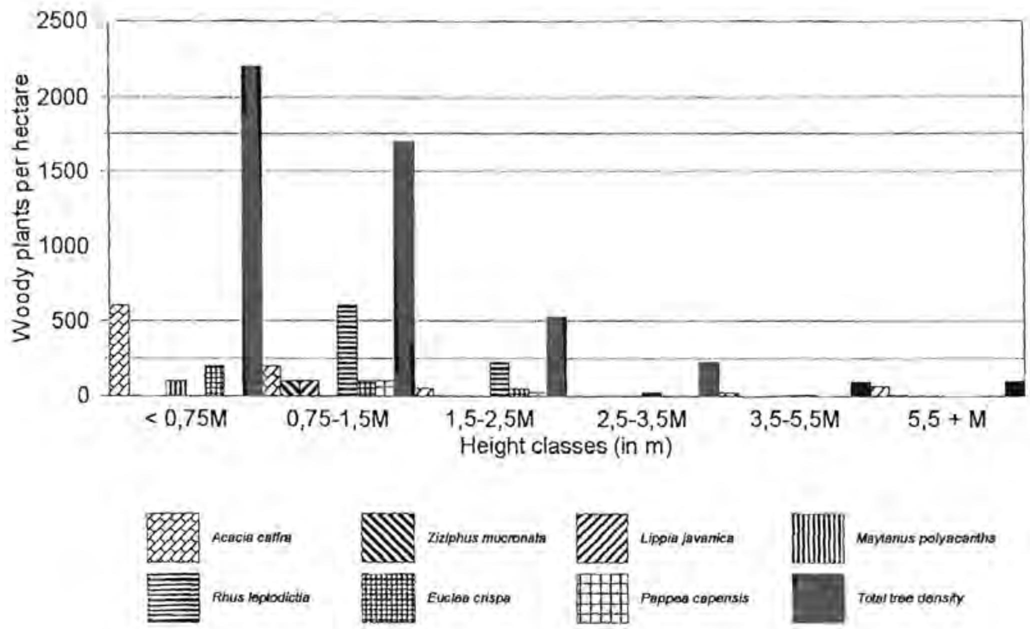

Figure 18: A histogram of the structure of the *Themeda triandra -Elionurus muticus* Tall Closed Woodland variation of the *Acacia caffra - Ziziphus mucronata* Tall Closed Woodland community on Rustenburg Nature Reserve.

Conspicuous tree and shrub species are *Acacia caffra, Ziziphus mucronata* (species group A), *Protea caffra, Rhus lancea* (species group E), *Rhus rigida* (species group I), *Asparagus suaveolens, Lippia javanica* (species group S), *Euclea crispa* and *Pappea capensis* (species group X). Figure 18 depicts the structure of the woody component in this variation. Evident from figure 18, is the density of the < 1.5 m height classes, consisting of *Lippia javanica, Maytenus polyacantha* and *Euclea crispa*.

9.5 *Ruellia patula - Melinis nerviglumis* Short Open Woodland

The *Ruellia patula - Melinis nerviglumis* Short Open Woodland occurs on shallow soils of the Glenrosa soil form on the north and eastern facing slopes. It is restricted to the northeastern section of the study area in particular the lower pediment of the valleys between the summit regions. The slopes are gentle, varying from 10° to 30°. Rocks and boulders are frequently found and the soils are sand to sandclayloam.

The *Ruellia patula - Melinis nerviglumis* Short Open Woodland is distinguished from the other sub-communities in this community by the presence of species groups L, diagnostic to this sub-community. Based on aspect, two variations can be distinguished.

9.5.1 *Hypericum aethiopicum - Acacia karroo* Short Closed Woodland

The *Hypericum aethiopicum - Acacia karroo* Short Closed Woodland variation is associated with the eastern facing slopes of the valley between the plateau and northeast lying ridge in the study area. Coetzee (1975) described this variation as the *Blumea alata - Acacia caffra* variation of the *Brachiaria serrata - Acacia caffra* Woodland, considered the more mesic environments on the northeastern facing slopes of these valleys.

This variation is differentiated from 9.5.2 by the presence of species groups H, I and J and the absence of species group M. Species groups H, I, J, K, L, N, O, P, Q, S and EE are also present (Table 6). Prominent grass and forb species in this variation are *Oxalis obliquifolia* (species group J), *Setaria nigrirostis* (species group J), *Ruellia patula* (species group L), *Eustachys paspaloides* (species group N), *Brachiaria serrata, Melinis nerviglumis* (species group O) , *Setaria sphacelata* (cover-abundance values 25% - 75%) (species group Q) and *Themeda triandra* (species group S). The tree layer in this variation is characterised by a very high occurrence of *Acacia caffra* (cover-abundance values 25% - 50%) (species group A) and *Acacia karroo* (cover-abundance values 1% - 50%)(species group EE). Other conspicuous trees and shrubs are *Rhus rigida* (species group I), *Faurea saligna* (species group O) and *Lannea discolor* (species group S).

9.5.2 *Loudetia flavida - Andropogon schirensis* Short Open Woodland

This variation is found on the low-lying north facing slopes of the valley situated furthermost northeasterly in the study area. The soil has a coarsely-grained texture and large rocks and boulders occur frequently throughout the variation.

Species group M, containing the grasses *Loudetia flavida* and *Andropogon schirensis*, and the forbs *Thesium magalismontanum* and *Triumfetta sonderii*, are diagnostic for this variation. Except for species groups A and L, species groups N, O, P, Q and S are also included in this variation (Table 6). The grasses' *Diheteropogon amplectens* (species group K), *Brachiaria brizantha, Tristachya biseriata* (species group L), *Loudetia flavida, Andropogon schirensis* (species group M), *Elionurus muticus* (species group N), *Brachiaria serrata, Melinis nerviglumis* (species group O), *Setaria sphacelata, Heteropogon contortus* (species group Q) and *Themeda triandra* (species group S) occur in the herbaceous layer. Prominent forbs in this variation are *Triumfetta sonderii* (species group M) and *Pellaea calomelanos* (species group N). A distinct feature of the tree layer in this variation is the absence of *Acacia caffra*. Conspicuous tree species in this variation are limited to *Faurea saligna* (species group O), *Burkea africana* (species group P), *Combretum zeyheri* (species group S) and *Combretum molle* (species group X). Shrubs occurring in this variation are limited to *Asparagus suaveolens* and *Lannea discolor* (species group S).

9.6 *Heteropogon contortus - Faurea saligna* Tall Open Woodland

This open woodland occurs in the western regions of the study area. It is found on slight to relatively steep slopes, varying from 3° to 40°. Aspect in this sub-community is not consistent, but occurs generally on east facing slopes. Soils varies from loamsand to sandloam (MacVicar *et al.* 1991) with a coarse-grained texture.

Rocks and boulders are frequently found throughout the sub-community. Erosion does occur in small areas, although it is currently confined to splash erosion.

This sub-community is characterised by the presence of species groups O, P, Q, R, S, T, X and EE (Table 6). Dominant trees and shrubs occurring in this sub-community are *Acacia caffra, Ziziphus mucronata* (species group A), *Faurea saligna* (species group O), *Asparagus suaveolens* (species group S) and *Combretum zeyheri* (species group S). The herbaceous layer is dominated by the grass *Heteropogon contortus* (species group Q). Other grasses present are *Brachiaria serrata, Melinis nerviglumis* (species group O), *Setaria sphacelata* (species group Q) and *Themeda triandra* (species group S). Forbs occurring in this sub-community are *Senecio venosus* (species group P) and *Tagetes minuta* (species group EE).

9.7 *Senecio venosus - Heteropogon contortus* Tall Closed Woodland

The *Senecio venosus - Heteropogon contortus* Tall Closed Woodland is associated with moderately deep Glenrosa soils on the foothills and flat hill crests of the southeastern regions of the study area. It is situated close to the current main gate complex, on either sides of the road. This area is utilized by game and sable have been recorded to use the open areas next to this sub-community frequently. This Tall Closed Woodland is confined to clay soils on noritic parent rock. The soils are finely-grained and large rocks are frequently encountered. Aspect is northeast to southeast.

Dominant species in this sub-community are the grasses *Setaria sphacelata* and *Heteropogon contortus* (species group Q). Other species include *Senecio venosus* (species group P), *Commelina africana* (species group A) and individual *Burkea africana* trees (Species groups P), as well as the grasses *Themeda triandra* (Species group S) and *Panicum maximum* (Species group EE).

Conspicuous woody species occurring in this sub-community are *Acacia caffra* (species group A), *Asparagus suaveolens, Lippia javanica* (species group S) and *Acacia karroo* (species group EE).

Figure 19 is a histogram of the structure of the woody component of this sub-community. Evident from this histogram is the dense <1.5m height class consisting of *Asparagus suaveolens, Grewia occidentalis, Ziziphus mucronata* and *Maytenus polyacantha*. The 1.5 - 5.5m height classes are represented by *Acacia caffra* and *Ziziphus mucronata*.

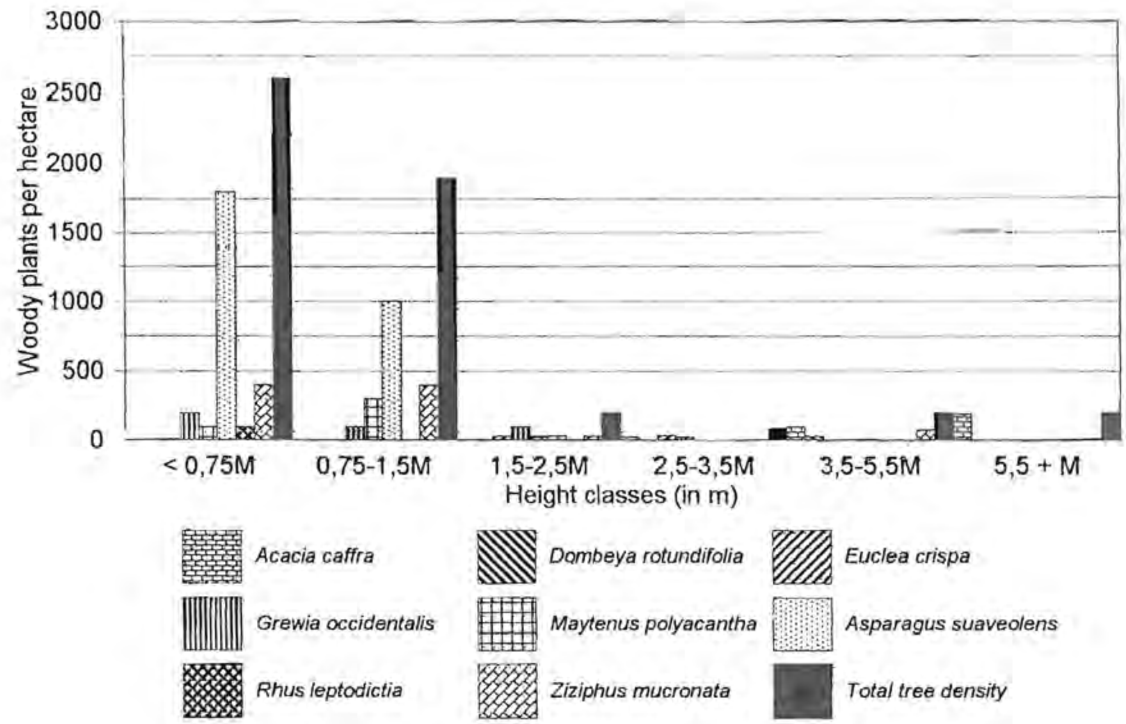

Figure 19: A histogram of the structure of the *Senecio venosus* - *Heteropogon contortus* Tall Closed Woodland of the *Acacia caffra* - *Ziziphus mucronata* Tall Closed Woodland community on Rustenburg Nature Reserve.

9.8 *Setaria sphacelata - Themeda triandra* Tall Closed Woodland

The *Setaria sphacelata - Themeda triandra* Tall Closed Woodland occurs on the fine-grained Glenrosa soil forms on the slopes in the southeastern section of the study area. The occurrence of large rocks and boulders in this sub-community is inconsistent and is only found in some relevés. The gradient of these relevés does not exceed 10°.

Woody species occurring in this sub-community are *Berchemia zeyheri* (species group R), *Lippia javanica, Combretum zeyheri* (species group S), *Rhus leptodictya, Dombeya rotundifolia, Euclea crispa* (species group X), *Celtis africana* (species group BB) as well as the species of species group A.

A dense undergrowth in the <0.75 - 1.5m height classes dominate the woody structure. The 1.5 m - 5.5m height classes consist of *Acacia caffra, Ziziphus mucronata.* (species group A), *Dombeya rotundifolia* (species group X) and *Zanthoxylum capense* (species group BB).

The herbaceous layer is less conspicuous. Prominent grass species in this sub-community are *Setaria sphacelata, Heteropogon contortus*, *Eragrostis curvula* (species group Q), *Themeda triandra* (species group S), and *Panicum maximum* (species group EE). The forbs are limited to *Ceterach cordatum* and *Ruellia cordata* (species group R).

This sub-community includes a disturbed area, previously a cultivated land used for crop production. This area had been cleared of trees and shrubs. Crop production were ceased in the mid to late seventies. Several pioneer plant species has since colonised this disturbed area. The presences of the grasses *Cynodon dactylon, Urochloa mosambicensis* and *Perotis patens*, indicated the disturbed nature of the areas (van Oudsthoorn 1992; Gibbs Russell *et al.* 1991). *Hyparrhenia hirta*, an important agent to stabilize disturbed open areas, (van Oudsthoorn 1992) as well as *Diheteropogon amplectens* and *Loudetia simplex* are currently dominating the herbaceous component (Nel 1992). The woody component in this old land is inconspicuous and *Ziziphus mucronata* and *Celtis africana* are the only trees present in the 0.75 - 1.5m class.

9.9 *Euclea crispa - Panicum maximum* Tall Closed Woodland

This sub-community is associated with the medium-deep Glenrosa soil forms on the slopes of the southeastern valley in the study area. The slopes are gentle and the gradient varies between 1° and a maximum of 25°.

This Tall Closed Woodland is distinguished from the other sub-communities by the presence of species groups R, S, X, BB and EE. The woody component is conspicuous and is dominated by *Acacia caffra* and *Ziziphus mucronata* (species group A). Other woody species include *Lippia javanica, Lannea discolor, Combretum zeyheri* (species group S), *Rhus leptodictya, Dombeya rotundifolia, Euclea crispa, Pappea capensis, Combretum molle, Grewia occidentalis* (species group X) and *Celtis africana* (species group BB). *Dombeya rotundifolia, Euclea crispa* and *Rhus leptodictya* dominates the <0.75m - 1.5 m height classes). *Acacia caffra, Celtis africana* and *Ziziphus mucronata* represents the 2.5m -5.5m height classes (Figure 20).

The herbaceous layer is inconspicuous and dominated by the grass *Panicum maximum* (cover-abundance values 1%-100%) (species group EE). Other grass species occurring in this sub-community are *Themeda triandra*, *Melinis repens* (species group S) and *Setaria nigrirostris* (species group J). Forb species are limited to single species that include *Ruellia cordata, Sphedamnocarpus pruriens,* (species group R) and *Hermannia depressa* (species group S).

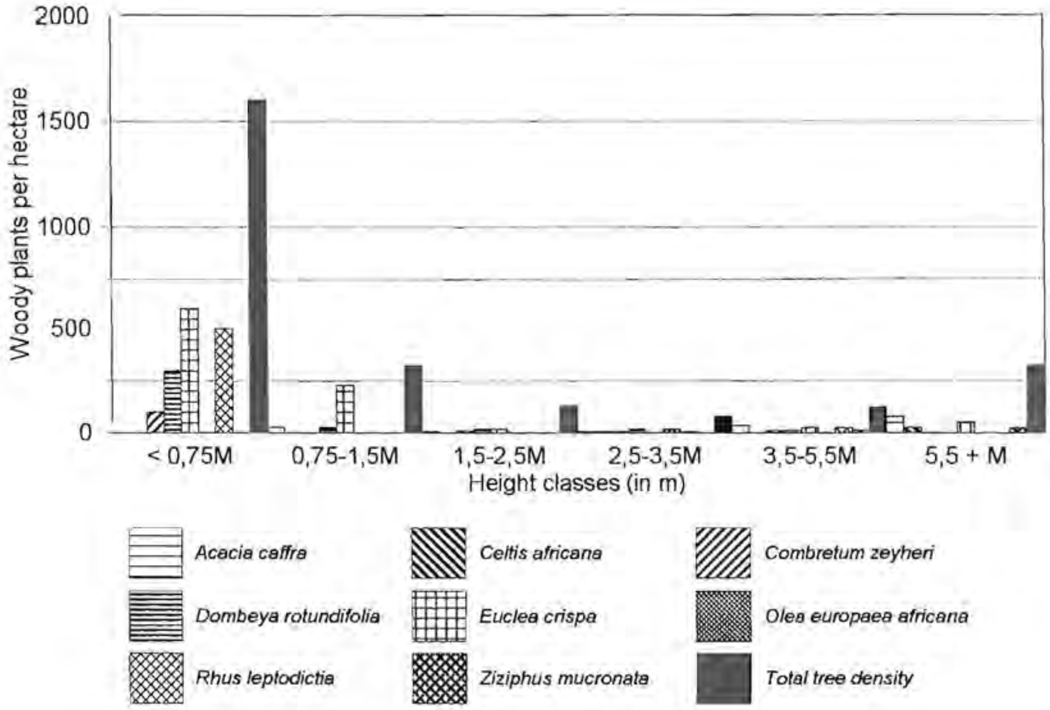

Figure 20: A histogram of the structure of the *Euclea crispa* - *Panicum maximum* Tall Closed Woodland of the *Acacia caffra* - *Ziziphus mucronata* Tall Closed Woodland community on Rustenburg Nature Reserve.

9.10 *Asparagus virgata* - *Celtis africana* Tall Closed Woodland

This sub-community is associated with the eastern facing foothills in the southeastern valley of the study area, as well as the southwestern slopes of Langkloof. Rock cover does not exceed 10%. The slope is gentle and the gradient is generally less than 15°.

The woody component dominates this sub-community. The diversity of the woody plants in this sub-community is illustrated in Table 7.

Seventeen woody species were recorded for this sub-community. The woody layer consists predominantly of species groups A, X and BB (Table 7) . Figure 21 illustrate the structural data of the woody component of this sub-community. Evident from the histogram, the sub-community is dense, containing some forest species such as *Diospyros whyteana* (species group V), *Euclea crispa, Pappea capensis, Combretum molle* (species group X), *Celtis africana* and *Zanthoxylum capense* (species group BB). Other prominent trees in this sub-community are *Acacia caffra*, *Ziziphus mucronata* (species group A) *Dombeya rotundifolia* (species group X) and *Diospyros lycioides* (species group EE).

Table 7: The number of individuals per hectare in the different height classes for the woody component of the *Asparagus virgata* - *Celtis africana* sub-community of the *Acacia caffra* - *Ziziphus mucronata* vegetation community.

Species	**Indivuduals per hectare Height class (m)**						
	< 0.75M	0.75-1.5M	1.5-2.5M	2.5-3.5M	3.5-5.5M	5.5 + M	Total
Acacia caffra	0	0	0	0	0	50	50
Apodetes dimidiata	0	0	0	25	0	0	25
Berchemia zeyheri	0	100	0	0	0	25	125
Celtis africana	600	200	0	25	25	50	900
Combretum molle	200	300	0	0	0	0	500
Combretum zeyheri	0	0	0	0	25	25	50
Diospyros lycioides	900	300	200	0	0	0	1400
Diospyros whyteana	500	600	500	75	25	0	1700
Dombeya rotundifolia	100	100	0	0	0	25	225
Ehretia rigida	0	100	0	0	0	0	100
Euclea crispa	600	600	400	275	0	0	1875
Ficus thonningii	0	100	0	0	0	0	100
Grewia occidentalis	1100	1000	300	425	25	0	2850
Pappea capensis	0	100	0	0	0	0	100
Rhus leptodictya	0	0	100	0	25	0	125
Rhus pyroides	0	200	0	0	50	0	250
Vepris undulata	100	0	0	0	0	0	100
Total woody density	**4100**	**3700**	**1500**	**825**	**175**	**175**	**10475**

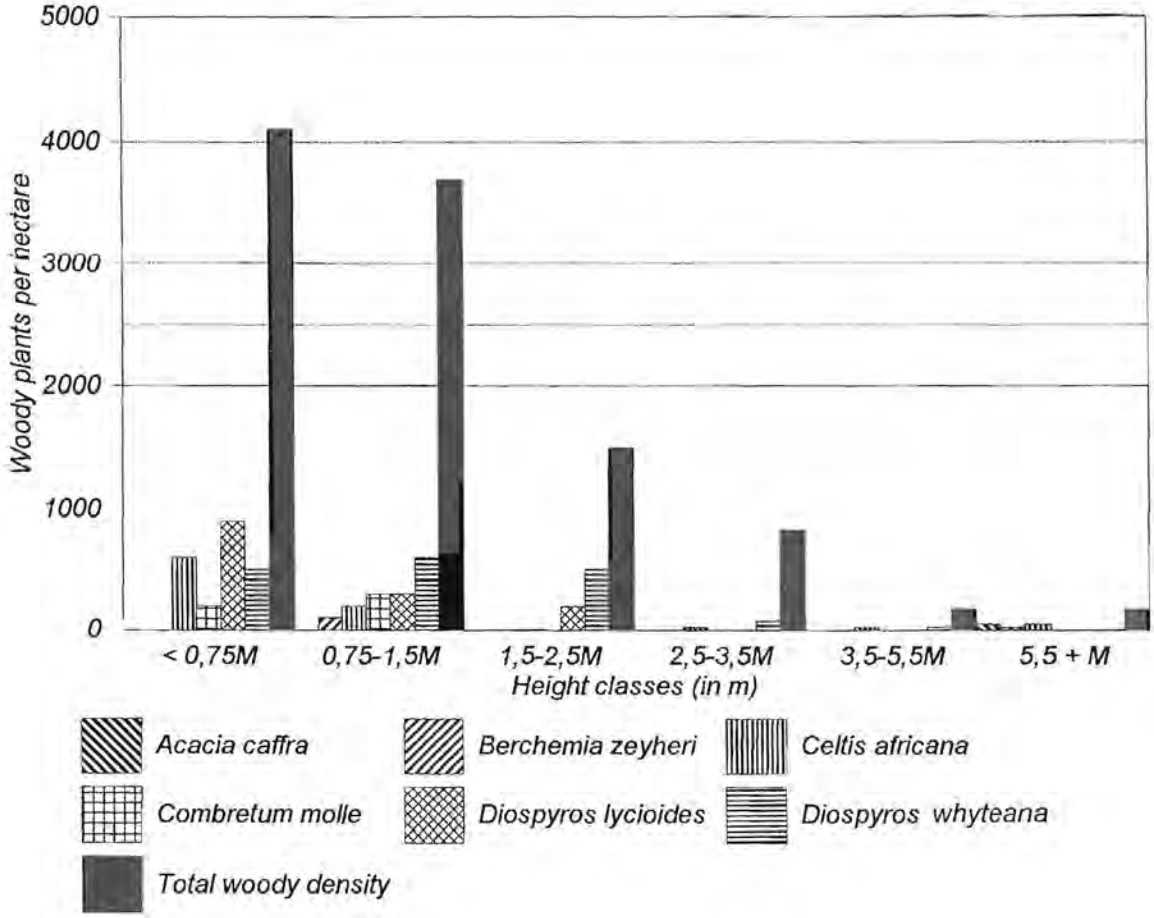

Figure 21: A histogram of the structure of the *Asparagus virgata - Celtis africana* Tall Closed Woodland of the *Acacia caffra - Ziziphus mucronata* Tall Closed Woodland community on Rustenburg Nature Reserve.

The herbaceous layer is limited to specimens of the shade loving grasses *Setaria megaphylla* (species group T) and *Panicum maximum* (species group EE) and the forb *Hypoestes forskaoli* (species group X).

9.11 *Olea europaea - Grewia occidentalis* Tall Closed Woodland

This sub-community is situated in the low lying areas of drainage lines in the southeastern parts of the study area. The shallow Glenrosa soil forms are fine grained with a sand loam to sand clay texture (MacVicar *et al.* 1991). Large rocks and boulders occur seldom throughout this sub-community. It is situated on a slight slope and the aspect varies from southeast to southwest. This sub-community was recognised and described by van Vuuren *et al.* (1970) as the *Acacia caffra - Olea europaea* var. *africana* variation of the *Acacia caffra* community restricted to western facing foothills.

Species group U is diagnostic to the *Olea europaea - Grewia occidentalis* Tall Closed Woodland sub-community. This species group contains the tree species *Olea europaea* var. *africana* and the shrubs *Asparagus cooperi* and *Maytenus polycantha*. Other woody species in this sub-community is *Grewia occidentalis* (species group X) (Table 6). Species groups V, X, BB and EE is also present in this sub-community is. Prominent species occurring in this sub-community are the scrambling shrub *Rhoicissus tridentata* (species group V),*Hypoestes forskaoli* (species group X) and the grasses *Setaria lindenbergiana* (species group D), *Setaria megaphylla* (species group T) and *Panicum maximum* (species group EE). Although species group X is well represented in this sub-community, *Rhus leptodictya* is absent. This is attributed to the preference of this species for open woodlands in rocky areas (Palgrave 1990; van Wyk *et al.*1988). It is seldom found in moist areas. The woody species *Acacia caffra, Ziziphus mucronata* (species group A), *Maytenus polycantha* (species group U), *Combretum erythrophyllum, Diospyros whyteana* (species group V), *Dombeya rotundifolia, Euclea crispa, Pappea capensis, Rhus pyroides* (species group X), *Celtis africana, Zanthoxylum capense* (species group BB) and *Diospyros lycioides* (species group EE) are also to be found in this sub-community. The occurrence of these species, and the presence of species groups V, X, BB and EE indicate that this sub-community is a transition between the relative drier open woodland communities and the cool forest's communities.

10 *Mimusops zeyheri - Hypoestes forskaoli* Tall Forest

The *Mimusops zeyheri - Hypoestes forskaoli* community represents the cool forest communities of the study area. These forests are restricted to the dry drainage lines in the eastern valleys of the study area, as well as a dry ravine on the western boundary. These drainage lines are seasonal and flow of water in these ravines only occur during an exceptional rainfall period. Coetzee (1975) has suggested the possibilty of a concentration of water deep under the soil surface, but within reach of the deep root system needed to support forest trees. Aspect varies, but is generally northeast to northwest. The slopes are relative-steep and the gradient varies 24 - 37°. The soil form varies from a shallow to moderately deep Glenrosa, with no gravel or large rocks.

Diagnostic species associated with this vegetation community are species group V. Species included are the tree *Mimusops zeyheri*, the shrubs *Acalypha angustata* var. *glabra, Cyphostemma cirrhosum* subs. *cirrhosum, Obetia tenax* and the forbs *Solanum rostratum, Commelina bengalensis, Droguetia iners* and *Helinus integrifolius*. Other prominent woody species in this community includes *Maytenus undata, Combretum erythrophyllum, Diospyros whyteana* (species group W), *Rhus leptodictya, Dombeya rotundifolia, Pappea capensis, Combretum molle, Grewia occidentalis, Rhus pyroides* (species group X), *Celtis africana* and *Zanthoxylum capense* (species group BB). Light penetration is restricted by the dense forests canopy, limiting the herbaceous layer.

11 *Brachylaena rotundata - Englerophytum magalismontanum* High Open Shrubland

This small community is restricted to the moist narrow ravines on the plateau in the northwestern section of the study area. The soils is of the shallow Glenrosa form or exposed bedrock. This vegetation community is characterised by the presence of diagnostic species group Y, Z and AA. Based on aspect this vegetation community can be divided into two sub-communities:

11.1 *Pittosporum viridiflorum - Halleria lucida* Short Open Shrubland

This sub-community is associated with deep narrow ravines opening on the upper northern slopes. Diagnostic species for this sub-community are *Pittosporum viridiflorum, Ilex mitis, Halleria lucida, Rothmannia capensis, Myrsine africana, Cyperus albostratus, Secamone alpini* and *Scadoxus puniceus* (species group Z). This sub-community shows similarities with the *Mimusops-Englerophytum-Apodytes dimidiata* variation as identified by van Vuuren *et al.* (1970). This variation occurs high up in the ravines on the northern slopes where the influence of the cliffs is least (Vuuren *et al.* 1970). It also demonstrates similar characteristics in terms of species composition than the *Pittosporum viridiflorum - Halleria lucida* Short Open Shrubland.

11.2 *Ancylobotrys capensis - Tricalysia lanceolata* Short Open Shrubland

This sub-community occurs in the upper regions of a ravine on the western facing slopes on the plateau. The ravine is shallower in this region, and the influence of the cliffs on either side of the ravine are less pronounced. This sub-community shows an affinity with the *Croton - Ancylobotrys capensis* variation as identified by van Vuuren *et al.* (1970). Although not dominant in this sub-community, *Croton gratissimus var. subgratissimus* were recorded in this sub-community (species group B; Table 6). *Setaria lindenbergiana* is described by van Vuuren *et al.* (1970) as subdominant in this sub-community, which were also found in this classification (species group D; Table 6). Other species associated with this sub-community are *Englerophytum magalismontanum* and *Brachylaena rotundata* (species group Y).

In this classification *Ancylobotrys capensis, Tricalysia lanceolata, Cymbopogon validus, Coleocloa setifera and Ochna holubi* (species group AA) are the diagnostic species for this sub-community. Other species present are *Maytenus undata* (species group W) and *Zanthoxylum capense* (species group BB).

12 *Cynodon dactylon - Panicum maximum* Tall Sparse Woodland

This community is situated on deep alluvial soils on pediments of the southeastern valleys in the study area. The *Cynodon dactylon - Panicum maximum* Tall Sparse Woodland community is associated with disturbed areas, old lands or areas previously over utilized by cattle. The community lies on relative flat areas with the gradient not exceeding 3°. Large rocks and boulders are absent. The texture of the soils varies from loam sand to sand loam *(MacVicar et al. 1991)*

Diagnostic species for this community are species group CC. This community is dominated by the grass *Cynodon dactylon* (cover-abundance values 50%), indicative of disturbed areas (van Oudtshoorn 1992). This grass is a valuable species as it protects the soil and provides palatable grazing (Gibbs-Russell *et al.* 1991).

Two sub-communities can be distinguished. One sub-community is found on the deep alluvial soils occurring on the lower foot slopes and the second is restricted to the alluvial soils of the valley. Sub-community 12.1 is associated with a slightly drier environment, whereas sub-community 12.2 occurs in the wetter areas in Langkloof and the southwestern facing slopes of the valley. The presence and absence of species groups can be attributed to different land use practises in the past. No specific soil analysis has been conducted in these relevés to establish possible differences.

12.1 *Tagetes minuta - Commelina africana* Sparse Open Woodland

This sub-community occurs on the dry east-facing foot slopes on alluvial soils. It is associated with disturbed areas such as cultivated lands.

The *Tagetes minuta - Commelina africana* Sparse Open Woodland is distinguished from the *Hyparrhenia hirta - Bidens pilosa* sub-community by the absence of species group DD. Dominant species in this sub-community are *Cynodon dactylon* and *Panicum maximum*. The woody layer is represented by single individual *Diospyros lycioides* (species group EE) and *Rhus leptodictya* trees (species group X; Table 6).

12.2 *Hyparrhenia hirta - Bidens pilosa* Short Sparse Woodland

This Short Sparse Woodland is strongly associated with the deep alluvial soils of the low lying areas in the southeastern range of valleys. The soil is fine-grained and has a sand clay texture (MacVicar *et al.*1991).

This sub-community is recognised by the presence of diagnostic species group DD, consisting of almost homogenous stands of *Hyparrhenia hirta* (cover-abundance values 25% - 75%) and *Bidens pilosa*. The woody layer is inconspicuous and limited to scattered individuals of *Acacia karroo*.

13 *Pteridium aquilinum - Miscanthus junceus* Tall Closed Grassland

The unique reed marsh in the central basin of the reserve is included in the *Pteridium aquilinum - Miscanthus junceus* Tall Closed Grassland community. The community is situated on the deep (>1m), black clay soils of the Willowbrook and Kroonstad soil forms. Boulders are absent, but rocks occur frequently. This community occurs on a high water table and certain sub-communities are submerged. Species diversity is low and confined to species associated with moist conditions.

Table 8: Phytosociological table for the *Pteridium aquilinum*-*Miscanthus junceus* Tall Closed Grassland and *Aristida junciformis*-*Arundinella nepalensis* Tall Closed Grassland

Community	13									14				
Sub-community	13.1					13.2		13.3						
Variation														
	3	3	3	3	3	0	3	3	3	3	3	3	3	3
	8	8	8	8	8	5	7	7	8	6	7	7	7	7
Species	1	2	3	4	5	1	5	8	0	8	4	7	9	6
Species group A														
Pteridium aquilinum	2	4	4	5	5	+	4		+					
Miscanthus junceus	2	2				+		4	4					
Species group B														
Phragmites australis	3	5	5	5	5									
Cyperus species	4	3	+	3	2									
Gunnera perpensa	+	+	+		+			+						
Species group C														
Persicaria attenuata					+			+	1					+
Buddleja saligna								+	+		+			
Conyza ulmifolia								+	+					
Species group D														
Aristida junciformis										2	5	4	5	1
Stiburus alopecuroides										1		+	+	
Berkheya speciosa							+				+	+	+	
Species group E														
Pycnostachys reticulata								+	+	+		+	1	
Helichrysum setosum								+	+		+	+	+	
Achyrocline stenoptera								+		+	2		2	
Imperata cylindrica									+				5	
Commelina species								+	+			+		+
Species group F														
Arundinella nepalensis						+		+	+	1	+	1	+	
Nidorella auriculata							+	+	+		2	1	+	
Vernonia hirsuta						+	1		+			+		

Species group A (Table 8) is diagnostic for this community, containing the fern *Pteridium aquilinum* (cover-abundance values 50%) and the grass *Miscanthus junceus.* Three variations, based on their distant from the reedmarsh, can be distinguished in this community:

13.1 *Phragmites australis - Cyperus species* Reedswamp

The reedswamp occurs in the centre of the basin area. It is underlaid by deep (2m+) humic soils of the Willowbrook soil form, submerged in water. The community is dominated by an extensive reedmarsh consisting of *Phragmites australis* (cover-abundance values 50%-100%) (species group A) . Two other species, an unidentified *Cyperus-* species and *Gunnera perpensa*, and also species from species group A are the only species present in this sub-community (Table 8).

13.2 *Vernonia hirsuta - Pteridium aquilinum* Tall Closed Grassland

The *Phragmites australis - Cyperus species* Reedswamp is encircled by a dense stand of *Pteridium aquilinum* and the species from species group F. This sub-community occurs around the *Phragmites australis - Cyperus species* Reedswamp, and extends further along the Waterkloofspruit to include a marshy area adjacent to the potholes. It can be distinguished from the *Phragmites australis - Cyperus species* Reedswamp by the absence of species group B,C,E and D. Other plants occurring in this community are *Arundinella nepalensis* and *Nidorella auriculata* (species group F;Table 8).

13.3 *Pycnostachys reticulata - Buddleja salviifolia* Tall closed Shrub land

This sub-community is restricted to riverine levees next to streams in the southern section of the central basin. Deep, coarse-grained sandy soils of the Hutton form are found in this sub-community.

This riverine vegetation is distinguished from sub-community 13.1 and 13.2 by the presence of species groups C, E and F. The vegetation is dominated by the grass *Miscanthus junceus*, the forbs *Arundinella nepalensis, Nidorella auriculata* (species group F), *Pycnostachys reticulata, Helichrysum setosum,* an unidentified *Commelina* species, (species group E), *Persicaria attenuata, Buddleja salviifolia* and *Conyza ulmifolia* (species group C).

14 *Aristida junciformis - Arundinella nepalensis* Tall Closed Grassland

The *Aristida junciformis - Arundinella nepalensis* Tall Closed Grassland is found in areas adjacent to the Waterkloofspruit. Coetzee (1975) described this community as being slightly elevated with a relative high water table. Certain parts of the sub-community is submerged in water. The texture of the soils varies from sand to sandloam and soil is deeper than one metre.

Species group D is diagnostic for the sub-community. It contains the *grass Aristida junciformis* (cover-abundance values 50%) and the forbs *Stiburus alopecuroides* and *Berkheya speciosa*. Other prominent species in the sub-community are *Arundinella nepalensis, Nidorella auriculata* (species group F), *Pycnostachys reticulata* and *Achyrocline stenoptera* (species group E).

IDENTIFICATION OF MANAGEMENT UNITS AS A BASIS FOR ASSESSING CHANGE

Variations in geology, soil and micro-climate result in a complex geographical arrangement of plant communities, on a scale that is usually impossible to use for management purposes. Plant communities are therefore the result of a unique combination of certain environmental conditions and represent a certain ecosystem (Bredenkamp & Theron 1976). These communities respond differently to similar environmental impacts and management practises (Bredenkamp & Theron 1976), i.e. grazing and burning. This requires the grouping of similar ecological units into management units for the purpose of practical conservation management.

The Braun-Blanquet method of vegetation classification enables the managers to conduct a hierarchical classification of the vegetation. Floristic and environmentally related communities can be grouped together into practical management units. Various factors influence the scale at which management and monitoring programmes have to be implemented.

Grouping of ecologically related units has taken place at various levels and a single descriptive definition for a management unit is difficult to formulate:

- MacVicar *et al.* (1974) defined a land type as

  " an area where the microclimate, terrain form and soil pattern each show a clear degree of uniformity. This degree of uniformity is of such nature that there would be little advantage to define smaller, more uniform landscapes on a country-wide basis. One land type differs from the other in one or more of the characteristics mentioned
- Coetzee (1983) described a landscape as

  " ...an area with recurrent patterns of plant communities with their associated fauna and abiotic habitat"
- Gertenbach (1983) redefined a landscape as

  "...an area with a specific geomorphology, microclimate, soil and vegetation and associated fauna
- Ludick (1987) defined a Reasonable Homogenous Farming Unit as

  " a demarcated area on a map with specific patterns of soil suitability classes. The climatic factors within each soil suitability class will not vary sufficiently to substantially influence production practises and agriculture potential within each land unit
- Edwards (1988) in Tainton (1988) named such a uniform area an agro-ecological unit and defined it as

  "... an area in which the climate, landscape, soil and vegetation are homogenous to the extent that the adaptability and response of any particular plant species would not change markedly from place to place within the unit

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  "...an area in which the different components will respond similarly to a specific set of treatments. The distribution and composition of plant species in the unit will ensure even utilization throughout the unit"

Successful management of natural vegetation depends on knowledge of the composition of the vegetation, the extent that it is being utilized and the rates and direction of changes that may take place in response to management practises such as herbivory and fire (Walker 1976). Such knowledge can only be obtained through a reliable and efficient programme to monitor whether the management practices in place do have the desired effect on the attainment of specific goals for conservation areas. Classification and mapping of landscape features and habitats are an essential first step in ecological monitoring, as it helps in the delineation of the ecosystem that will serve as a basis for data collection and analysis (Grimsdell 1978).

The floristic variation within savannas at a regional or local level is strongly influenced by topography and substrate (O'Connor 1992). On Rustenburg Nature Reserve this resulted in 51 different vegetation units and sub-units. Assessing change in vegetation at this scale will be impractical, ineffective and costly. It will be necessary to identify management units reflecting the major physiographic and physiognomic variations on the reserve to be used as a basis for monitoring. The associations of the different plant communities formed the basis for the delineation of homogenous physiognomic-physiographic units. Excessive variation in habitat data in these management units will complicate the interpretation of vegetation responses, as differences in environmental characteristics can also induce certain species responses.

Ordination

From the final phytosociological tables a synoptic table, representing constancy values for the different species in each vegetation community, was compiled. The synoptic table illustrate the association of the different vegetation communities with each other. The synoptic table was used in an ordination to identify the relation between the physical environment and the vegetation. The distribution of the different vegetation units is illustrated along the axes of a scatter diagram of the synoptic data set (Figure 22).

This diagram revealed an apparent discontinuity among these vegetation types. A distinct moisture gradient is evident along the first axis of the ordination. Communities associated with the drier environments on the plateau, hill slopes and the open areas of the central basin are situated to the left of the diagram, and the vegetation communities associated with the wet habitats along the vlei and water streams are positioned to the right of the diagram.

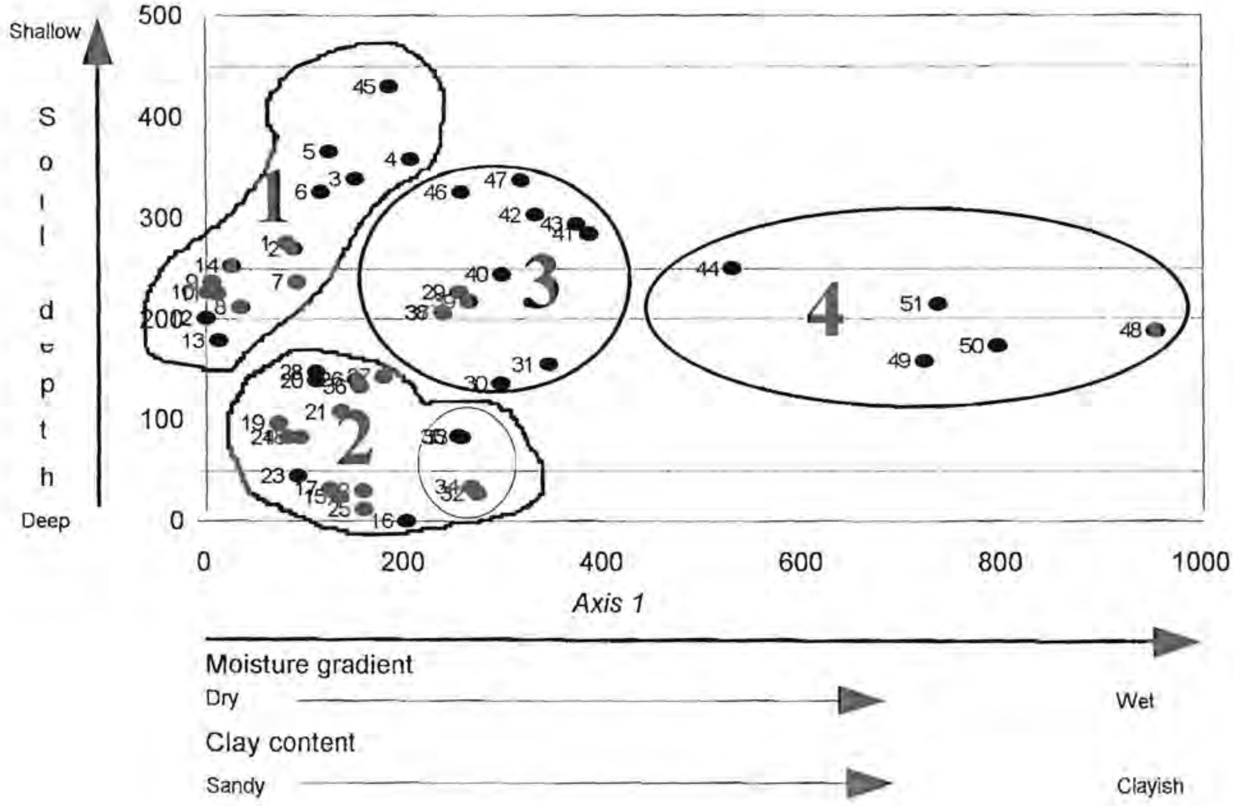

Figure 22: The positions of the different vegetation communities and sub-communities along the two axis of a DECORANA - ordination

A moderate gradient in soil depth exists along the second axes of the scatter diagram (Figure 22). Communities associated with exposed quartzite sheets and shallow Mispah and Glenrosa soils occurring on the plateau and upper hill slopes are situated to the top left of the diagram and communities occurring on the meduim-deep to deep Hutton soils in the central basin and small secluded pockets in the valleys are distributed to the bottom left of the diagram. A weak gradient in clay content is illustrated along the first axes. Clayish soils and associated communities, mainly confined to the alluvial soils in the valleys are situated to the right of the diagram, while communities associated with sandy soils are situated to the left of the diagram. Deep Hutton soils with moderate clay content (15% - 25%) are positioned in the centre of the diagram.

Management Units

The broken topography and associated diversity of habitats and environmental conditions resulted in the differentiation of 51 vegetation communities, sub-communities and variations on the reserve. Four management units were identified by using a DECORANA-ordination (Hill 1979a) (Figure 22), illustrating the principal differences of the habitats on the reserve.

The four management units distinguished in the synoptic table (Table 9) differ due to distinct differences in soil depth, percentage clay and moisture content (Figure 22).

I. *Selaginella dregei* - *Oldenlandia herbacea* Open Shrubland
II. *Becium obovatum* - *Elionurus muticus* Tall Grassland
III. *Ziziphus mucronata* - *Rhus leptodictya* Closed Woodland
IV. *Pteridium aquilinum* - *Miscanthus junceus* Moist Grassland

Management unit I:

***Selaginella dregei* - *Oldenlandia herbacea* Open Shrubland**

The *Selaginella dregei* - *Oldenlandia herbacea* Open Shrubland management unit comprise of the *Englerophytum magalismontanum* - *Ancylobotrys capensis* Tall Open Shrubland, the *Eragrostis nindensis* - *Cyperus rupestris* Short Open Grassland and the *Bulbostylis burchellii* - *Themeda triandra* Short Open Grassland (Table 9) . Species group D, consisting of the pioneer *Selaginella dregei* and the forbs *Oldenlandia herbacea, Coleocloa setifera*, the grass species *Cymbopogon validus,* and the shrub *Rhus magalismontanum* is diagnostic of this management unit. Species groups H, P, T and Z containing the grass species *Schizachyrium sanguineum, Melinis nerviglumis, Themeda triandra* and *Diheteropogon amplectens,* the forbs *Anthospermum rigidum, Pellaea calomelanos, Senecio venosus* and *Commelina africana* are also conspicuous in this management unit. The tree and shrub layer are confined to individual specimens of *Englerophytum magalismontanum* (species group D), *Zanthoxylum capense*, *Ancylobotrys capensis* and *Tapiphyllum parvifolium* (species group A).

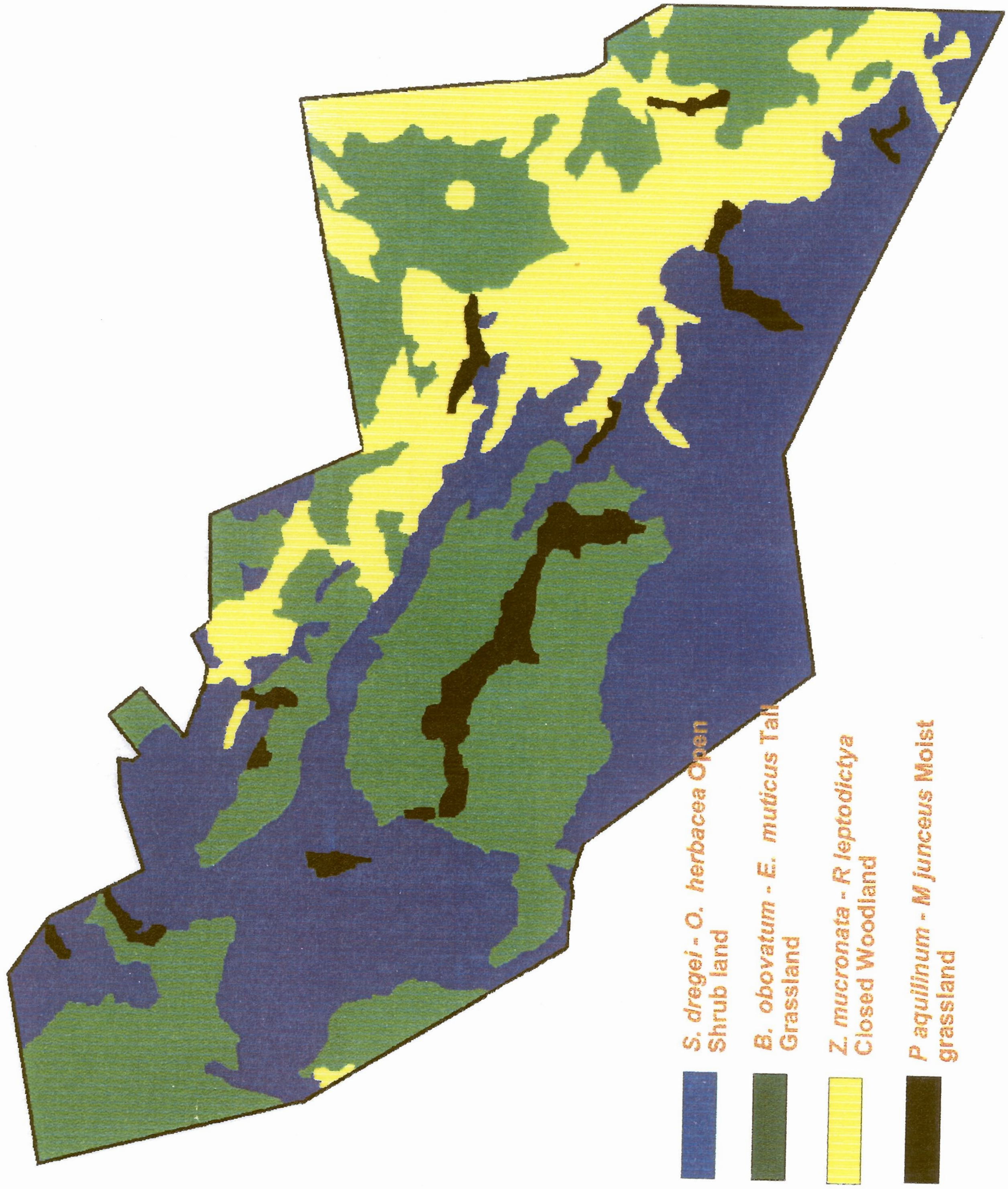

Figure 23: Vegetation map of Rustenburg Nature Reserve illustrating four management units

Table 9 : Synoptic table of the vegetation on Rustenburg Nature Reserve

Species	Relevés (Management Unit 1, Management Unit 2, Management Unit 3, Management Unit 4)
MANAGEMENT UNIT 1: *Selaginella dregei - Oldenlandia herbecea* Open Shrubland	
Species group A	
Zanthoxylum capense	[illegible]
Ancylobotrys capensis	[illegible]
Tapiphyllum parvifolium	[illegible]
Commelina erecta	[illegible]
Crassula species	[illegible]
Nuxia congesta	[illegible]
Asparagus krebsianus	[illegible]
Clutea pulchella	[illegible]
Canthium gilfillanii	[illegible]
Anthospermum hispida	[illegible]
Cyperus sphaerospermus	[illegible]
Ochna pulchra	[illegible]
Plectranthus madagascariensis	[illegible]
Ficus ingens	[illegible]
Speciesgroup B	
Cyperus rupestris	[illegible]
Eragrostis nindensis	[illegible]
Xerophyta viscosa	[illegible]
Microchloa caffra	[illegible]
Speciesgroup C	
Khadia acupetala	[illegible]
Laperosia sandersonii	[illegible]
Eragrostis stapfii	[illegible]
Ledebouria revoluta	[illegible]
Euphorbia claveroides	[illegible]
Frithia pulchra	[illegible]
Anacampseros subvelutinum	[illegible]
Helichrysum cerastioides	[illegible]
Brachiaria nigropedata	[illegible]
Speciesgroup D	
Selaginella dregei	[illegible]
Oldenlandia herbacea	[illegible]
Coleocloa setifera	[illegible]
Cymbopogon validus	[illegible]
Rhus magalismontanum	[illegible]
Englerophytum magalismontanum	[illegible]
Lopholaena corifolia	[illegible]
Euphorbia schinzii	[illegible]
Aloe peglarae	[illegible]
Aristia diffusa	[illegible]
Indigofera melinoides	[illegible]
Kalanchoe thyrsiflora	[illegible]
Speciesgroup E	
Pearsonia aristata	[illegible]
Vernonia sutherlandii	[illegible]
Speciesgroup F	
Pygmaeothamnus zeyheri	[illegible]
Raphionacme hirsuta	[illegible]
Tristachya rehmannii	[illegible]
Digitaria brazzae	[illegible]
Plexipus hederaceus	[illegible]
Silene burchelli	[illegible]
Ophresia oblongifolia	[illegible]
Speciesgroup G	
Dicoma anomala	[illegible]
Raphionacme burkei	[illegible]
Parinari capensis	[illegible]
Dichapetalum cymosum	[illegible]
Thesium cytisoides	[illegible]
Speciesgroup H	
Anthospermun rigidum	[illegible]
Aristida aequglumis	[illegible]
Albuca setosa	[illegible]
Loudetia simplex	[illegible]
Cyanotis speciosa	[illegible]
Thesium transvaalensis	[illegible]
Indigofera comosa	[illegible]
Speciesgroup I	
Indigofera hedyantha	[illegible]
Helichrysum coriaceum	[illegible]
Nolletia rarifolia	[illegible]
Cryptolepis oblongifolia	[illegible]
Senecio erubescens	[illegible]
Rhynchosia monophylla	[illegible]
Bulbostylis oritrephes	[illegible]
Speciesgroup J	
Rubia petiolaris	[illegible]
Gerbera piloselloides	[illegible]
Conyza aegyptica	[illegible]
Hyparrhenia filipendula var. pilosa	[illegible]
Speciesgroup K	
Acalypha angustata	[illegible]
Crabbea hirsuta	[illegible]
Ledebouria marginata	[illegible]
Rhynchosia nervosa	[illegible]
Felicia muricata	[illegible]
Burkea africana	[illegible]
MANAGEMENT UNIT 2: *Becium obovatum - Elionurus muticus* Tall Grassland	
Speciesgroup L	
Becium obovatum	[illegible]
Elionuris muticus	[illegible]
Vernonia galpini	[illegible]
Pentanidium angustifolia	[illegible]
Kohoutia amatymbica	[illegible]
Urelytrum angustifolia	[illegible]
Aloe greatheadii	[illegible]
Ipomoa ommaneyi	[illegible]
Protea caffra	[illegible]
Ruellia patula	[illegible]
Scilla nervosa	[illegible]
Speciesgroup M	
Eragrostis racemosa	[illegible]
Mohria caffrorum	[illegible]
Nidorella hottentottica	[illegible]
Panicum natalensis	[illegible]
Speciesgroup N	
Tristachya biseriata	[illegible]
Trachypogon spicatus	[illegible]
Speciesgroup O	
Eustachys paspoloides	[illegible]
Ipomoa bathycolpos var bathycolpos	[illegible]
Asparagus laricinus	[illegible]
Clematis oweniae	[illegible]
Thunbergia atriplicifolia	[illegible]
Setaria nigrirostris	[illegible]
Turbina oblongata	[illegible]
Cussonia panicoides	[illegible]
Nidorella resedifolia	[illegible]
Speciesgroup P	
Schizachyrium sanguineum	[illegible]
Andropogon schirensis	[illegible]
Tephrosia elongata	[illegible]
Pellaea calomelanos	[illegible]
Melinis nerviglumus	[illegible]
Oxalis oblongifolia	[illegible]
Speciesgroup Q	
Chaetachanthus setiger	[illegible]
Athrixia elata	[illegible]
Blumea alata	[illegible]
Conyza albida	[illegible]
Cymbopogon excavatus	[illegible]
Digitaria diagonalis	[illegible]
Helichrysum nudifolium	[illegible]
Indigofera burkeana	[illegible]
Vernonia natalensis	[illegible]
Hypoxis rigidula	[illegible]
Helichrysum setifolia	[illegible]
Speciesgroup R	
Setaria sphacelata	[illegible]
Heteropogon contortus	[illegible]
Elephantorriza elephantina	[illegible]
Ledebouria species	[illegible]
Eragrostis curvula	[illegible]
Asparagus suaveolens	[illegible]
Rhynchosia totta	[illegible]
Lippia javanica	[illegible]
Vernonia oligocephala	[illegible]
Speciesgroup S	
Solanum panicoides	[illegible]
Teucrium trifidium	[illegible]
Hyparrhenia hirta	[illegible]
Adia poiretti	[illegible]
Speciesgroup T	
Themeda triandra	[illegible]
Vangueria infausta	[illegible]
Senecio venosus	[illegible]
Diheteropogon amplectans	[illegible]
Brachiaria serrata	[illegible]
Chamaecrista mimisoides	[illegible]
Setaria lindenbergiana	[illegible]
Combretum zeyheri	[illegible]
Sphenostylis angustifolia	[illegible]
Faurea saligna	[illegible]
Speciesgroup U	
Solanum mauritanum	[illegible]
Setaria megephylla	[illegible]
Maytenus polycantha	[illegible]
Asparagus cooperi	[illegible]
Speciesgroup V	
Acacia caffra	[illegible]
Maytenus heterophylla	[illegible]
Rhus lancea	[illegible]
Rhus rigida	[illegible]
Lannea discolor	[illegible]
Lantana rugosa	[illegible]
Speciesgroup W	
Celtis africana	[illegible]
Grewia occidentalis	[illegible]
Panicum maximum	[illegible]
Pentharidium insipidum	[illegible]
Aloe transvaalensis	[illegible]
Berchemia zeyheri	[illegible]
Cynodon dactylon	[illegible]
Diospyros whyteana	[illegible]
MANAGEMENT UNIT 3: *Ziziphus mucronata - Rhus leptodictya* Closed Woodland	
Speciesgroup X	
Dombeya rotundifolia	[illegible]
Euclea crispa	[illegible]
Pappea capensis	[illegible]
Achyranthes aspera	[illegible]
Hypoestes forskaoli	[illegible]
Speciesgroup Y	
Ziziphus mucronata	[illegible]
Rhus leptodictya	[illegible]
Tagetes minuta	[illegible]
Diospyros lycioides	[illegible]
Melinis repens	[illegible]
Hermannia depressa	[illegible]
Rhus pyroides	[illegible]
Sida dregei	[illegible]
Acacia karroo	[illegible]
Speciesgroup Z	
Commelina africana	[illegible]
Combretum molle	[illegible]
MANAGEMENT UNIT 4: *Pteridium aquilinum - Mischanthus junceus* Moist Grassland	
Speciesgroup AA	
Pteridium aquilinum	[illegible]
Mischanthus junceus	[illegible]
Persicaria attenuata	[illegible]
Nidorella auriculata	[illegible]
Buddleja saligna	[illegible]
Arundinella nepaliensis	[illegible]
Pycnostachys reticulata	[illegible]
Gunnera perpensa	[illegible]
Commelina species	[illegible]

The *Selaginella dregei - Oldenlandia herbacea* Open Shrubland occurs on shallow Mispah soils and exposed quartzite sheets on the high lying areas of the reserve. Soils are shallow litholitic, confined to Mispah and Glenrosa soil forms. A lithosol-rock complex of sheetlike to broken quartzite occurs on the steep upper slopes (Coetzee 1975) in this management unit. The areas of exposed rock and shallow Mispah soils are mainly limited to the crest of the Magaliesberg, although a mosaic of these exposed areas is interspersed among the deeper soils on the middle and foot slopes. The deeper Glenrosa soils are found further down the slope where an accumulation of eroded material occur. Characteristic of the soils of the Mispah form on the reserve is the high content of decomposed organic matter (Coetzee 1975), the result of a high occurrence of pioneer plant roots in the top layer (% carbon > 3.04%).

Management Unit II:

Becium obovatum - Elionurus muticus Tall Grassland

The *Becium obovatum - Elionurus muticus* Tall Grassland consist of the *Tristachya biseriata -Protea caffra* Short Sparse Woodland, the *Protea gaugedi - Monocymbium ceresiiforme* Short Open Shrub land, *Indigofera comosa - Schizachyrium sanguineum* Tall Closed Grassland, *Plexipus hederaceus - Cymbopogon excavatus* Tall Closed Grassland, the *Tristachya leucotrix - Setaria sphacelata* Tall Sparse Woodland and the *Becium obovatum - Protea caffra* Tall Closed Woodland sub-community of the *Acacia caffra - Ziziphus mucronata* Tall Closed Woodland community (Table 9).

The *Becium obovatum - Elionurus muticus* Tall Grassland represents the vegetation associated with the medium deep Glenrosa to deep Hutton soils on the foot slopes and in the central basin area of the reserve. This management unit is spread over the study area on the slopes of the valley between the summit and the eastern range of quartzite ridges running through the reserve and the deeper soils on the slopes surrounding the central basin area and the central basin area. The soil texture are sandloam to sandclayloam (Soil Classification Working Group

1991), consisting of coarse to finely-grained sand. This management unit is situated on fairly mild gradients (3° - 6°), except for one community situated on a gradient of 3° - 30°. Conspicuous species in this management unit are the forbs *Becium obovatum, Pentharidium angustifolia, Vernonia galpinii, Kohoutia amatymbica* (species group L), *Pellaea calomelanos, Oxalis oblongifolia* (species group P), *Senecio venosus, Chamaecrista mimosoides* (species group T) and *Commelina africana* (species group Z). *Elionurus muticus* (species group L), *Schizachyrium sanguineum* (species group P), *Eragrostis racemosa* (species group M), *Melinis nerviglumis, Trachypogon spicatus* (species group N), *Themeda triandra, Loudetia simplex* (species group H), *Brachiaria serrata* (species group T) represent the dominant grass species in this management unit. The tree layer is relatively inconspicuous and confined to open stands of *Protea caffra* (species group L), *Ziziphus mucronata, Rhus leptodictya, Dombeya rotundifolia* (species group Y), *Acacia caffra* (species group V) and *Faurea saligna* (species group T).

The *Turbina oblongata - Phyllanthus glaucophyllus* High Closed Shrub land, the *Diospyros lycioides - Rhus rigida* Tall Closed Woodland and the *Hypericum aethopicum - Acacia karroo* variations of the *Acacia caffra - Ziziphus mucronata* Tall Closed Woodland community are regarded as a transitional group between the *Becium obovatum - Elionurus muticus* Tall Grassland and the *Ziziphus mucronata - Rhus leptodictya* Closed Woodland management unit. This group contains a variety of species conspicuous to both management units. Species from species groups R and T (Table 9) dominate the vegetation composition in this group, which are well represented in both management units.

Management Unit III:

***Ziziphus mucronata - Rhus leptodictya* Closed Woodland**

The *Ziziphus mucronata - Rhus leptodictya* Closed Woodland consists of the woodland and forest communities in the reserve. This management unit contains the *Heteropogon contortus - Faurea saligna* Tall Open Woodland, *Senecio venosus - Heteropogon contortus* Tall Closed Woodland, *Setaria sphacelata - Themeda triandra* Tall Closed Woodland, *Euclea crispa - Panicum maximum* Tall

Closed Woodland, the *Asparagus virgata - Celtis africana* and *Olea europaea - Grewia occidentalis* Tall Closed Woodland sub-communities of the *Acacia caffra - Ziziphus mucronata* Tall Closed Woodland community, the *Mimusops zeyheri - Hypoestes forskaoli* Tall Forest and *Cynodon dactylon - Panicum maximum* Tall Sparse Woodland communities (Table 9) .

The *Ziziphus mucronata - Rhus leptodictya* Closed Woodland is found on the low-lying slopes and low-lying areas of the eastern valleys in the study area. The soil has a coarse-grained texture and large rocks and boulders occur frequently throughout this management unit. The soils varies from medium-deep Glenrosa soil forms on the slopes to deep alluvial soils on the pediments of the valleys. The slopes vary from gentle to relative-steep with gradients of up to 37°.

The tree and shrub layer are very prominent and are characterises by the trees and shrubs *Ziziphus mucronata, Rhus leptodictya, Diospyros lycioides, Rhus pyroides* (Species group Y), *Pappea capensis, Euclea crispa, Dombeya rotundifolia,*(species group X), *Celtis africana, Grewia occidentalis* (species group W), *Acacia caffra, Maytenus heterophylla, Rhus lancea, Rhus rigida, Lannea discolor, Lantana rugosa* (species group V), *Combretum zeyheri* (species group T) and *Combretum molle* (species group Z). Dominant grass species in this management unit are *Melinis repens* (species group Y), *Panicum maximum* (species group W), *Setaria sphacelata, Heteropogon contortus* (Species group R), *Themeda triandra*, *Brachiaria serrata* and *Setaria lindenbergiana* (species group Y). Noticeable forbs include *Tagetes minuta* (Species group Y), *Hypoestes forskaoli* (species group X) and *Commelina africana* (species group Z).

Disturbed areas, orchards and old lands are also included in this management unit.

Management Unit IV:

***Pteridium aquilinum - Miscanthus junceus* Moist Grassland**

The *Pteridium aquilinum - Miscanthus junceus* Moist Grassland management unit represents the moist habitats on the reserve, consisting of the *Pteridium aquilinum* - *Miscanthus junceus* Tall Closed Grassland, including the *Phragmites mauritanus* - *Cyperus* species Reedswamp, the *Vernonia hirsuta* - *Pteridium aquilinum* Tall Closed Grassland and *Pycnostachys reticulata* - *Buddleja salviifolia* Tall closed Shrub land, and the *Aristida junciformis* - *Arundinella nepalensis* Tall Closed Grassland communities.

The soils in this management unit vary from deep, black clay soils of the Willowbrook and Kroonstad soil forms underlying the reed swamp to deep Hutton soils adjacent to the streams in the southern section of the central basin. This management unit occurs on a high water table and certain communities in this management unit are submerged.

Species diversity is low and confined to species associated with moist conditions. Species group AA contains the dominant species occurring in this management unit. Conspicuous species are *Pteridium aquilinum, Miscanthus junceus, Persicaria attenuata, Nidorella auriculata, Buddleja salviifolia, Arundinella nepalensis* and *Pycnostachys reticulata*. The unique reedswamp in this management unit consists of a homogenous stand of *Phragmites mauritianus* (Table 9) .

CHAPTER 5

ECOLOGICAL MANAGEMENT OBJECTIVES

INTRODUCTION

Assessing the condition of the vegetation and determining possible trends is a prerequisite in the sound ecological management and conservation of an area. Various methods and approaches of quantifying veld condition have been developed over the past few decades (Foran *et al.* 1978; Tainton *et al.* 1978; Tainton *et al.* 1980; Vorster 1982; Hurt & Hardy 1989; Westoby *et al.* 1989). These veld condition techniques are based on estimates of proportional species composition and the manipulation of this data is determined by the objectives of various methods (Hurt & Bosch 1991). Several of these methods are based on ecologically accepted principles. Dyksterhuis (1949) first recognised the importance of using a benchmark or climax veld against which the veld condition of a certain area should be measured. This notion was ensued and several other ecologically-based techniques were developed (Van den Berg & Roux 1974;Foran *et al.* 1978; Barnes *et al.* 1984; Vorster 1982; Tainton *et al.* 1978;1980; Heard *et al.* 1986). Although these techniques have been severely criticised, they formed the basis for monitoring and assessment of veld condition in the past two decades. The most important criticism against these ecologically-based methods are affirmed by Jordaan (1997). These methods are based on certain severely questionable assumptions which contests their objectivity and efficiency:

- The under-utilized climax vegetation is often regarded as the ideal situation or objective of veld management. In terms of biological diversity, veld composition under these circumstances tend to be homogenous. According to Mentis and Collinson (1979) maximal species diversity implies fair to good veld condition. In terms of wildlife management it is stated by various authors that game has preferences in terms of vegetation structure and species (Grunow 1980; Jooste & Palmer 1982; Novellie 1990; Wentzel *et al.* 1991, Pietersen *et al.* 1993; Dekker *et al.* 1996). This implies that the objective of management does not always requires climax vegetation to be the ultimate aim with vegetation composition and structure.

- Ecologically-based techniques also assumes that grazing is the only factor inflicting changes in vegetation composition and structure, while other important determinants such as climate (Snyman 1989; Peel *et al.* 1991; O'Connor 1991) and fire (Le Roux 1988; Glen-Leary 1990; Trollope *et al.* 1996; Scholes *et al.* 1993) are often ignored.
- Veld condition assessments have to be ecologically interpretable to provide a scientific basis for management decisions. Most techniques developed to assess the condition of vegetation are based on a subjective knowledge of species response to grazing (Bosch 1989; Bosch & Kellner 1991; Janse van Rensburg & Bosch 1990; Bosch & Gauch 1991; Hurt *et al.* 1993). Species are allocated to ecological classes based on their assumed response to grazing, and also according to the assumption that all species respond to grazing, which is incorrect (Mentis 1982; Hurt *et al.* 1993). The use of subjectively derived ecological classes and non-responsive and rare species in the interpretation of monitoring results will reduce or distort the sensitivity of such techniques (Hurt *et al.* 1991; Hurt *et al.* 1993). It can therefore not be used to evaluate the extent to which management objectives is achieved accurately.
- According to Jordaan (1997) a relieve in prolonged grazing pressure will not necessarily result in a recovery of the vegetation to its original composition and structure, as changes in soil conditions do take place when vegetation cover is removed (Westoby 1980).

Multivariate techniques was developed to improve objectivity and interpretability during veld condition assessments. Some of these techniques included the

Weighted Key Species Method (Hurt & Hardy 1989), the Degradation Gradient Method (Mentis 1983; Bosch & Gauch 1991), Multiple Benchmark Sites (Bosch *et al.* 1987). Ordination procedures were also introduced to define and create an understanding of the degradation process by using data representing known compositional differences induced mainly by grazing.

No ecosystem has a fixed composition. It fluctuates in space and time, influenced by changes in the individual components it consists of (Siegfried & Davies 1982). To be able to quantify these changes, it is important that there should be an understanding of the dynamics and responses of a system to different external influences such as grazing and fire. Vegetation gradient analyses are useful to determine plant species reactions to environmental parameters (Walker 1988). Subjectively qualified information obtained by using ecologically-based techniques does not provide a gradient along which a sample site can be positioned. Neither does these techniques recognised multiple benchmarks that distinguished different domains of attraction (stable conditions) that develops with the process of degradation (Hurt *et al.* 1991) or provide for the absence of "favourable" or "decreaser" species in areas where the physical conditions do not allow them to grow (Martens *et al.* 1990). During the process of degradation, the veld condition may deteriorate to levels below the limits of resilience of that system and biophysical transformations such as a degradation in soil structure and organic contents can cause an irreversible change in the system (Bosch & Gauch 1991).

Managing for biological diversity should not aim at a fixed pattern, but at a general range of possibilities. With the development of degradation models for each of the vegetation units, quantifying the effect of existing management on a specific vegetation unit will be possible. It also enables the user to determine the ecological significance of a specific position on the gradient (Bosch 1989). By evaluating this vegetation gradient according to parameters specifically pertaining to the objectives of the reserve, eg. species diversity, stability and resilience of the system, an understanding of the desired state of the vegetation system on the reserve can be developed. Subsequent monitoring will reveal progress or regression in the achievement of management objectives.

CONSTRUCTION OF THE DEGRADATION GRADIENT

Four management units were identified during the classification of the vegetation on Rustenburg Nature Reserve;

I. *Selaginella dregei - Oldenlandia herbacea* Open Shrub land
II. *Becium obovatum - Elionurus muticus* Tall Grassland
III. *Ziziphus mucronata - Rhus leptodictya* Closed Woodland
IV. *Pteridium aquilinum - Miscanthus junceus* Moist Grassland

The biological and physical characteristics of each of these management units were described in chapter 4.

Methods

Species compositional data for management unit I, II and III were obtained. The *Pteridium aquilinum - Miscanthus junceus* High Closed Grassland Management Unit, associated with wet conditions, were disregarded for the following reasons:

- It consists of homogenous stands of *Phragmites australis* and *Pteridium aquilinum* and riverine vegetation dominated by *Buddleja salviifolia*, *Miscanthus junceus* and *Imperata cylindrica*.
- The vegetation structure in this unit is dense and tall and utilization by herbivores is minimal.
- This unit is confined to a small area on either side of streams and inside depressions where water accumulate, which complicates the development of a degradation gradient.

The nearest plant technique was used and the plant nearest to a marked pin on a wheel-point apparatus (Tidmarsh & Havenga 1955) was recorded. The circumference of the wheel point is 3 m, resulting in a species recordence every 1.5m. A portable PSION organiser with a statistically justified point sampling programme PLANTS SURVEY[7], was used to determine plot size. A precision limit of 97% was used, as this made this survey compatible with surveys undertaken in the past (Booysen unpublished). After every set of 15 points, the programme statistically calculates a comparison index between the previous points and the succeeding set of 15 points. The influence of each addition of 15 points to the data set on the variation index is calculated and the survey is terminated as soon as the comparison index exceeds the variation limit (which was set for 97%) (Jordaan 1997).

Attention was given to the selection of plots, ensuring that the data represents the vegetation in various successional stages. Areas of animal concentration (e.g. areas of preferences, shade), distances from water points, under utilized areas along fences and outside the reserve were chosen. The management units were sampled as follows:

- *Selaginella dregei - Oldenlandia herbacea* Open Shrub land ➜ 47
- *Becium obovatum - Elionurus muticus* Tall Grassland ➜ 114
- *Ziziphus mucronata - Rhus leptodictya* Closed Woodland ➜ 64

In addition certain habitat data were recorded at each sample plot, which included

- Geology: Parent rock was identified and recorded
- Soil Type: Soil type was established according to the classification of the National Soil Classification Working Group, and the soil map (Fig. 5)
- Effective Soil Depth: Effective soil depth was noted
- Slope: The slope was determined in degrees

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7 Dept of Plant Sciences, Potchefstroom University for Christian Higher Education, P/bag X6001, Potchefstroom, 2520

- Land Type: The position of the site in the landscape was subjectively determined and expressed as being in landscape 1 (crests), 2 (cliffs),3 (scree slope),4 (foot slope) or 5 (drainage lines)
- Aspect (N,E,S,W): The aspect of the slope was determined and noted.
- Stoniness: This was expressed as the percentage of the surface covered by stones; 1; 1 - 10%, 2; >10%

Data analysis

Data analysis was done using the Integrated System for Plant Dynamics (ISPD) - package (Bosch & Gauch 1991;Booysen & Bosch 1992; Stols *et al.* 1992). The two main factors affecting plant growth and animal production, rainfall and soil type are beyond the control of management. Management options for wildlife managers in natural areas are limited to manipulating the stocking rate or the ratio of the different feeding classes of ungulates on an area/reserve/park, and thereby intensifying or reducing grazing pressure on a system, or the judicial use of controlled burning to change structure or composition of vegetation in an area (Scholes & Walker 1993). In the development of a monitoring system aimed at detecting changes in a system induced by management, an attempt should be made to isolates the effect of the former-mentioned management options on the system. The intent with this monitoring system is to aid the manager to apply the correct management option to obtain the appropriate ecological result and consistently endeavoured to achieve management objectives.

INTEGRATED SYSTEM FOR PLANT DYNAMICS -ISPD

The ISPD-computer package has been developed as a comprehensive system using new and existing data as basis for veld condition and grazing capacity assessment (Bosch *et al.* 1992a; Bosch *et al.* 1992b). Different computer technologies and statistical analytical procedures were incorporated to develop an integrated and comprehensive tool which can be used to analyse and develop vegetation models and species response curves.

The system consists of the following modules: (Figure 24)

- A relational Data Base that handles all the storage needs for the total system (Bosch *et al.* 1992a)
- The Analytical Module, that use different multiple statistical analytical techniques:
    - DECORANA (Gauch 1982), where two ordination procedures namely Detrended Correspondence Analysis (DCA) and Reciprocal Averaging (RA) is used, and
    - Degradation Model Construction (Bosch & Kellner 1991) that uses Centred Principle Component Analysis (PCA), Standard PCA and Reciprocal Averaging (RA)
- the Veld Condition Assessment Module, that can determine the condition of an area by means of either a quantitative or qualitative approach (Bosch *et al.* 1992a; Jordaan 1997)
- the Grazing Capacity Module, that calculates the grazing potential of an area through an expert system approach (Bosch *et al.* 1992a; Jordaan 1997)

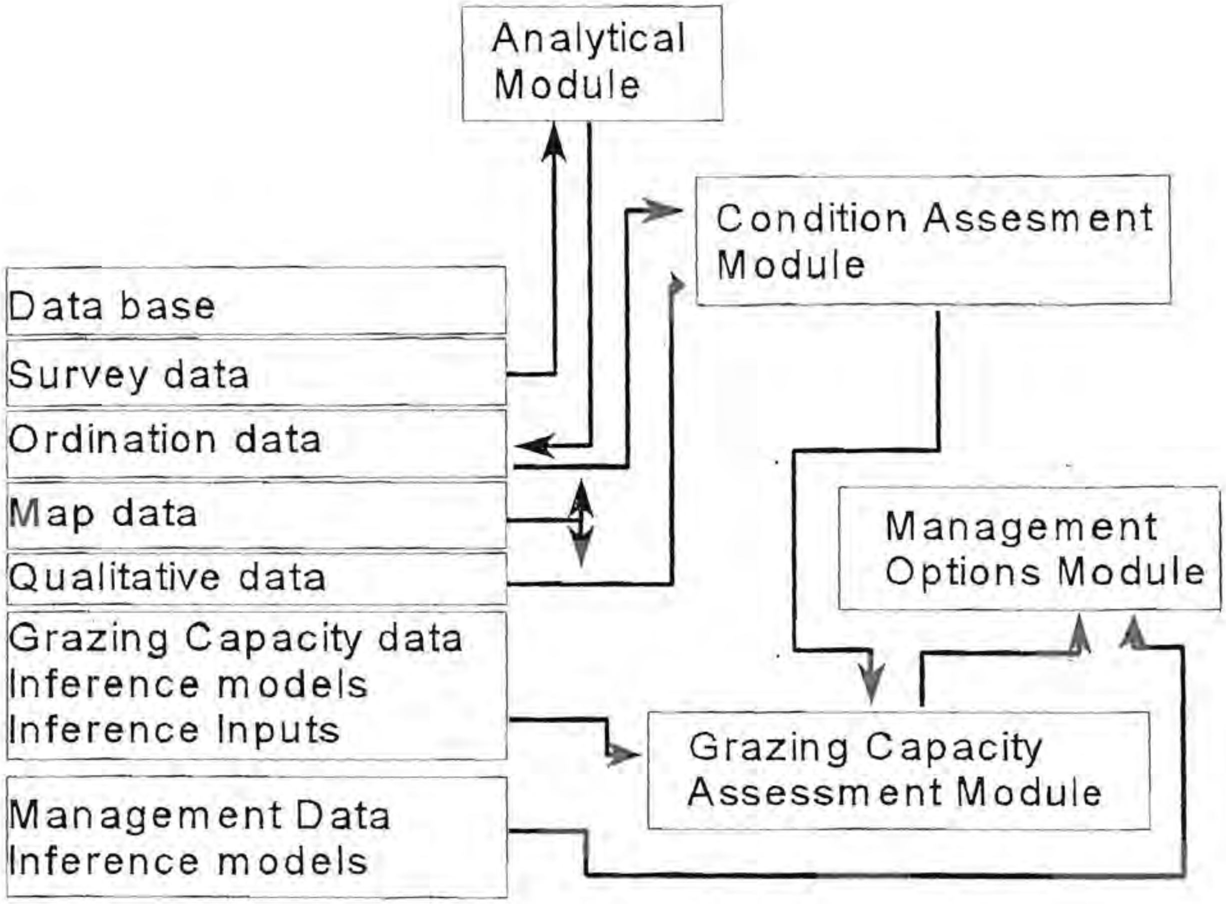

Figure 24: A diagrammatical representation of the ISPD computer system (Bosch *et al.* 1992)

ISPD is developed to be utilized by land managers directly as a decision support system. The main advantages of the system are: (Bosch & Booysen 1992a)

- The interdisciplinary approach ensures that all aspects of vegetation dynamics are considered;
- By integrating the various computer technologies the efficiency of the use of the computer medium is increased;
- Existing data can be used to obtain a workable system;
- The various stages of quantitative and qualitative data allow easy participation of specialists in various disciplines to contribute their knowledge in a particular section;
- The system is developed in such a way that data can be accommodated easy and inexpensive
- All the information needed for decision making are combined in a single outcome, although the opinions of all experts are included.
- The system can be applied universally, regardless of the amount of information available.

Identification and development of the vegetation-habitat groups of the three data sets

Variation in data due to differences in soil characteristics, management history, and time of survey does exists within a relative homogenous management unit. These differences can lead to large variations or noise in data sets (Gauch 1982) which can make the identification of reliable degradation gradients impossible (Bosch *et al.* 1991; Jordaan 1997). In the analysis of this data set, variation in habitat differences was minimized and particular attention was paid to seclude only vegetation data resulting from different grazing pressures.

Species composition data for each of the management units were ordinated separately to validate and redefine sub-data sets. Each of the three data sets was subjected to Detrended Correspondence Analysis (DCA) (Hill & Gauch 1980) and

Reciprocal Averaging (RA). These ordination procedures are suitable to delineate relative homogenous vegetation units from broad data sets (Bosch *et al.* 1991; Jordaan 1997).

Definition of a degradation gradient

Quantifying a degradation gradient within each management unit has been done by using **D**egradation **Mo**del **C**onstruction (DMOC) (Jordaan 1997). DMOC included three ordination methods (Bosch *et al.* unpublished)[8]:

- Standardized Principal Component Analysis;

  which performs a standardized transformation before a principal component analysis is performed;

- Centred Principal Component Analysis

  which performs a centering transformation before a principal component analysis is performed;

- and Reciprocal Averaging (RA)

  which performs a repeated weighted averages on species and sample vectors until the two vectors stabilized

Principle Component Analysis are very useful where ordination of data sets with a relative short vegetation gradient. All three these techniques were compared as each technique accentuate different properties of the data set (Jordaan 1997)

As the vegetation samples were separated by DCA into suitable subsets and the sites were deliberately selected to represent different degrees of vegetation degradation, the principal variation in these subsets ought to be associated with the degradation and were expected to appear on the first axis of the ordinations (Bosch & Gauch 1991;Bosch & Kellner 1991). The remaining (residual) variation should be as small as possible and be attributed to various other smaller effects such as habitat differences, sampling techniques, ect. These degradation

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8 Bosch, O.J.H., Gaugh, H.G., Booysen, J., Gouws, G.A., Nel, M.W., Stols, S.H.E. and van Zyl, F. Undated. User's Guide. Integrated System for Plant Dynamics.

gradients were confirmed by noting the positions of sites with known grazing histories in the ordinations.

In refining the degradation gradient, sample plots with residuals larger than an arbitrary 50% of the Euclidean length of axis 1 was considered outliers and subsequently discarded from the data matrix (Bosch & Gauch 1991; Bosch & Kellner 1991). The ordination was then repeated.

The responses of species to different levels of grazing impacts were modelled using regression techniques. Species abundance curves on the degradation gradient were fitted separately for each vegetation unit (Janse van Rensburg & Bosch 1990). This was done to determine the ecological status of species under different environmental and physical conditions, and to identify key species that will be used in the interpretation of the degradation gradients in each vegetation unit.

Results

The three data sets were located to new data sets in ISPD and an ordination for each data set was conducted. Both RA and DCA was applied to the data. The results of these ordinations are depicted in figure 25 (a, b & c).

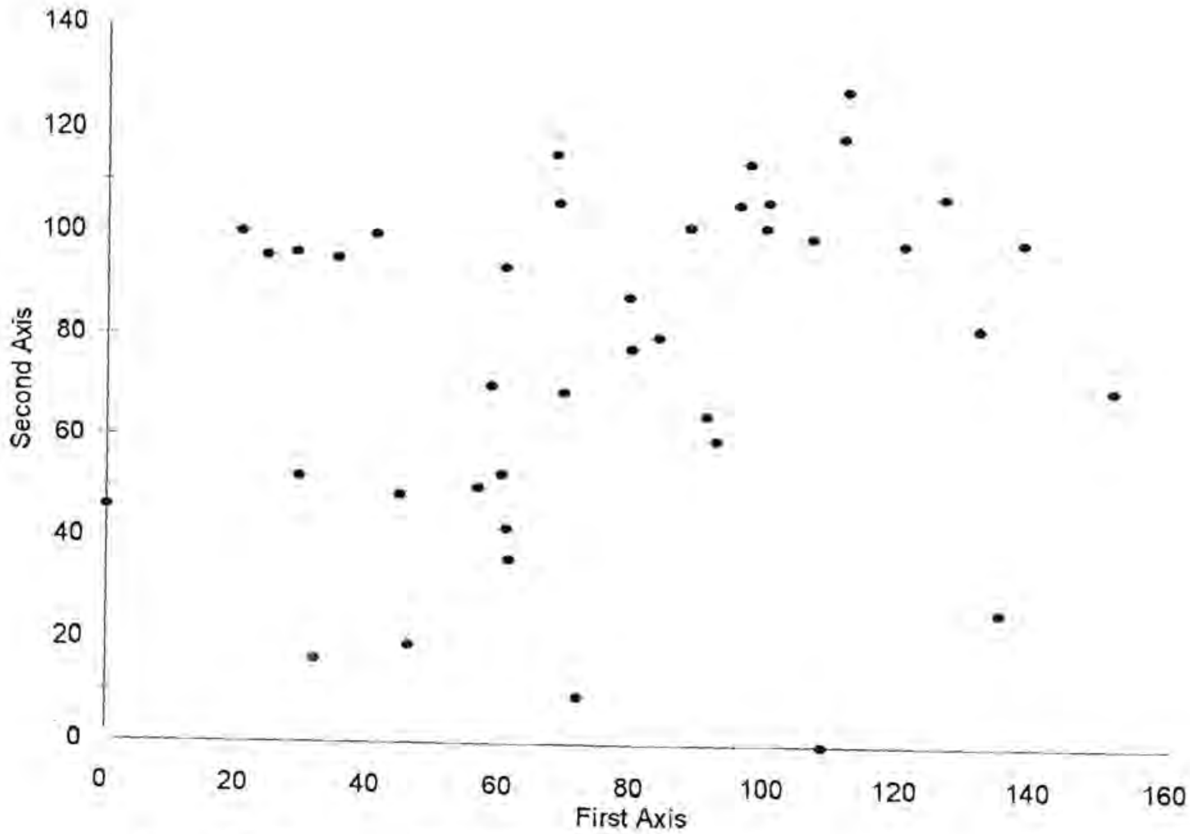


Figure 25 (a) Management Unit 1 (65 sites)

Figure 25 (a): Spatial distribution of the survey sites on the first and second axis of the DCA-ordination for Management unit 1.

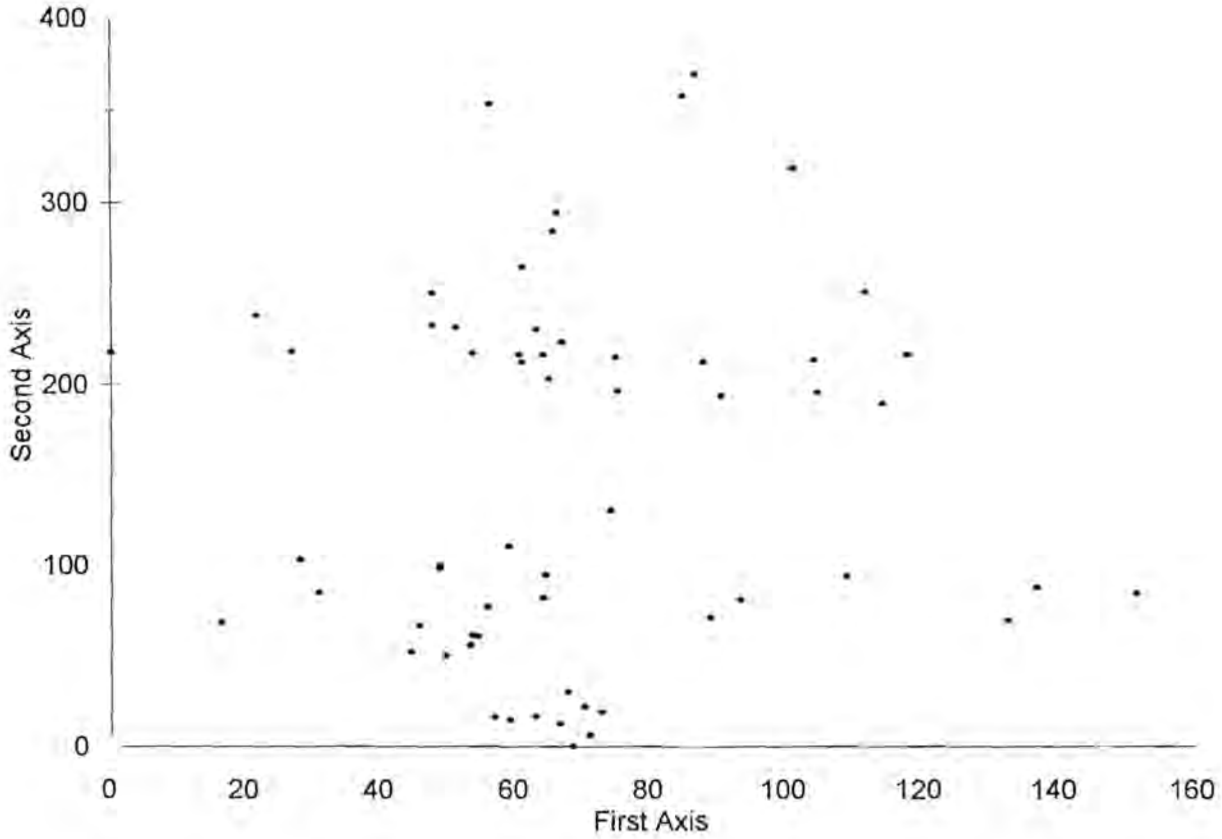


Figure 25 (b) Management Unit 2 (43 sites)

Figure 25 (b): Spatial distribution of the survey sites on the first and second axis of the DCA-ordination for Management unit 2.

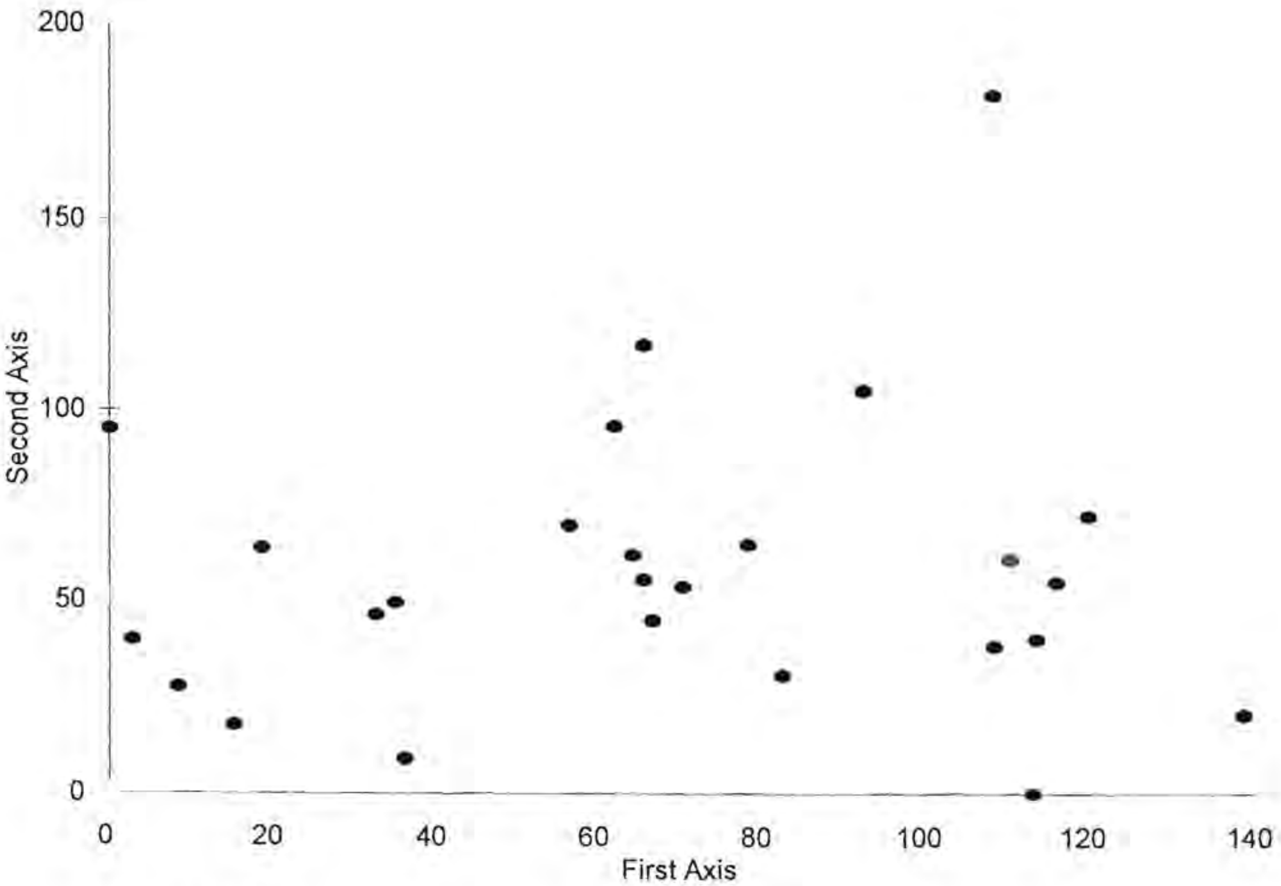


Figure 25 (c) Management Unit 3 (32 sites)

Figure 25 (c): Spatial distribution of the survey sites on the first and second axis of the DCA-ordination for Management unit 3.

These ordinations were refined and outliers were removed until a satisfactory eigen value for each of the ordination could be established. In the final ordination of the three management units 65, 43 and 32 sites respectively were used. From a management point of view the *Becium obovatum* - *Elionurus muticus* Tall Grassland management unit is the most important unit, as it does not only cover the largest area, but is more readily occupied by game. The *Selaginella dregei* - *Oldenlandia herbacea* Open Shrub land management unit is limited to the crests and upper slopes and are inhabited by Mountain Reedbuck and Klipspringers. The *Ziziphus mucronata* - *Rhus leptodictya* Closed Woodland management unit is confined to the bottom lands in the valleys on the reserve and comprise a relative small area on the reserve.

Construction of a degradation gradient for the *Selaginella dregei* - *Oldenlandia herbacea* Open Shrub land - Management Unit I

The spatial distribution of the sample sites according to the first and second axis of the CPCA, SPCA and RA ordination is illustrated in Figure 26 a, b and c. Evident is that the SPCA and RA (Fig 26 b and c) produced an unsatisfactory distribution of the sites along the first axis. A number of sites were also positioned above the Maximum Acceptable Residual Value. The CPCA (Fig. 26a) displayed an even arrangement of the sites along the first axes, representing the utilization of vegetation at various levels.

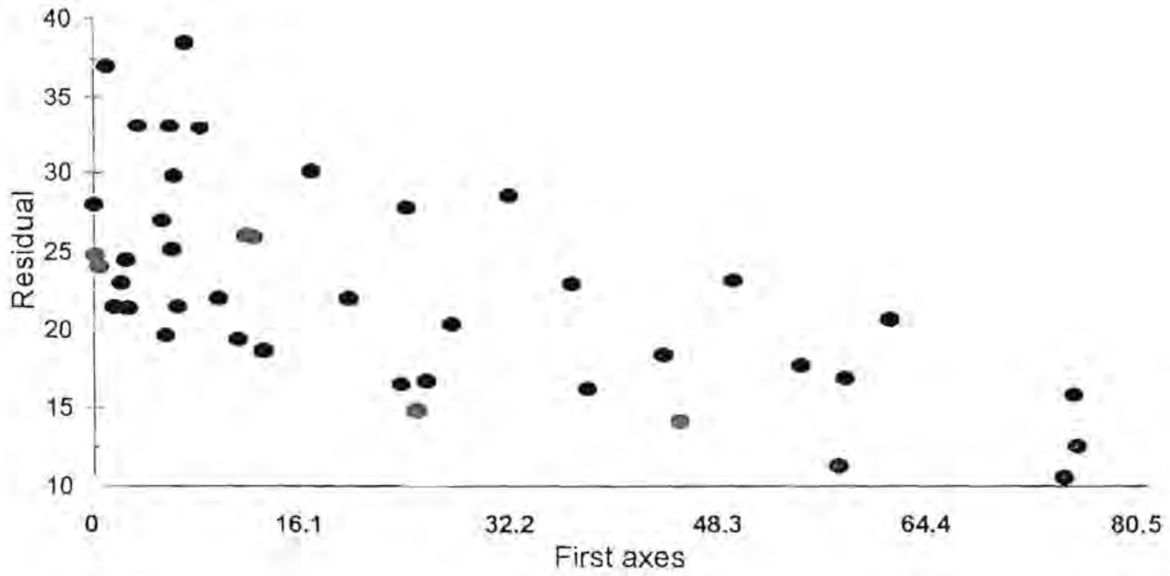
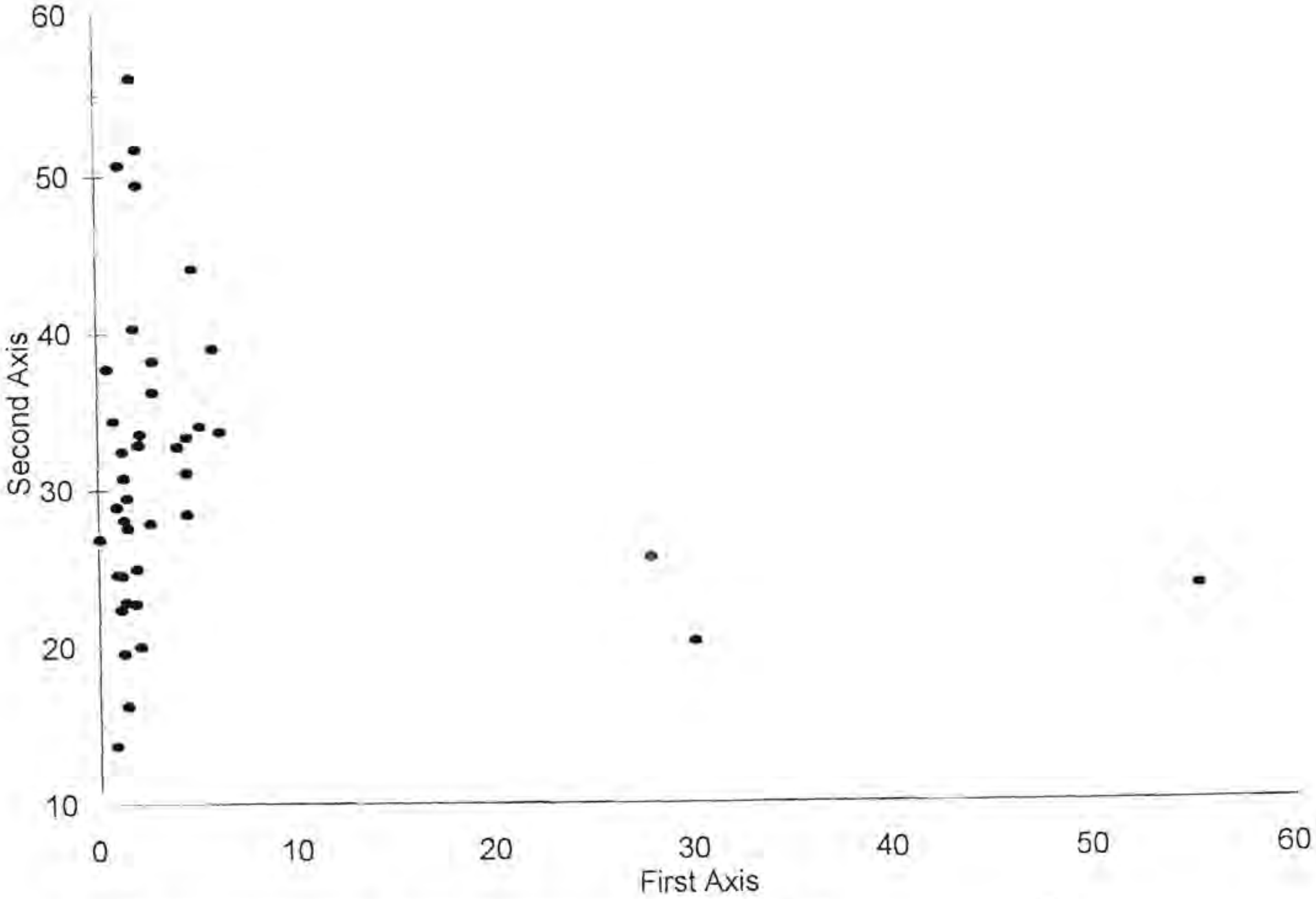


Figure 26(a): The spatial distribution of the sample sites in **Management Unit I** according to the first and second axis of the a Centralized Principal component analyses.



Management unit 1: Results of the Standardized PCA

Figure 26(b): The spatial distribution of the sample sites in **Management Unit I** according to the first and second axis of the Standardized Principal Component Analyses.

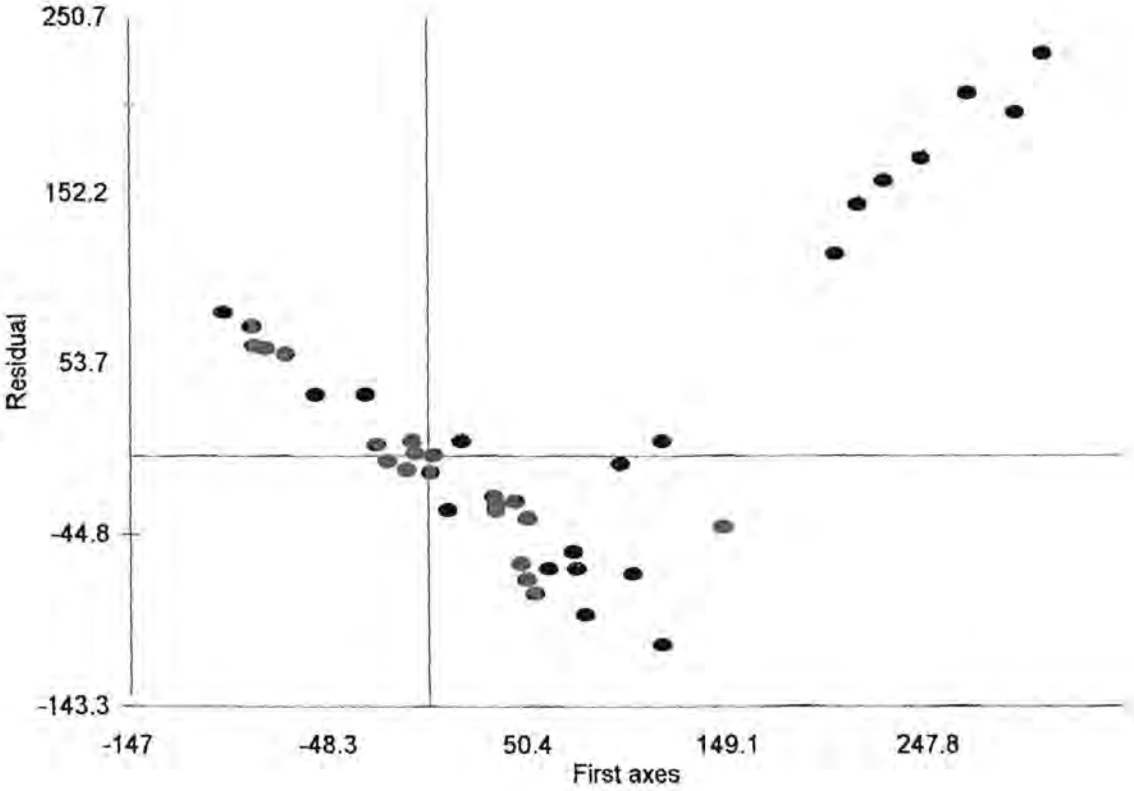
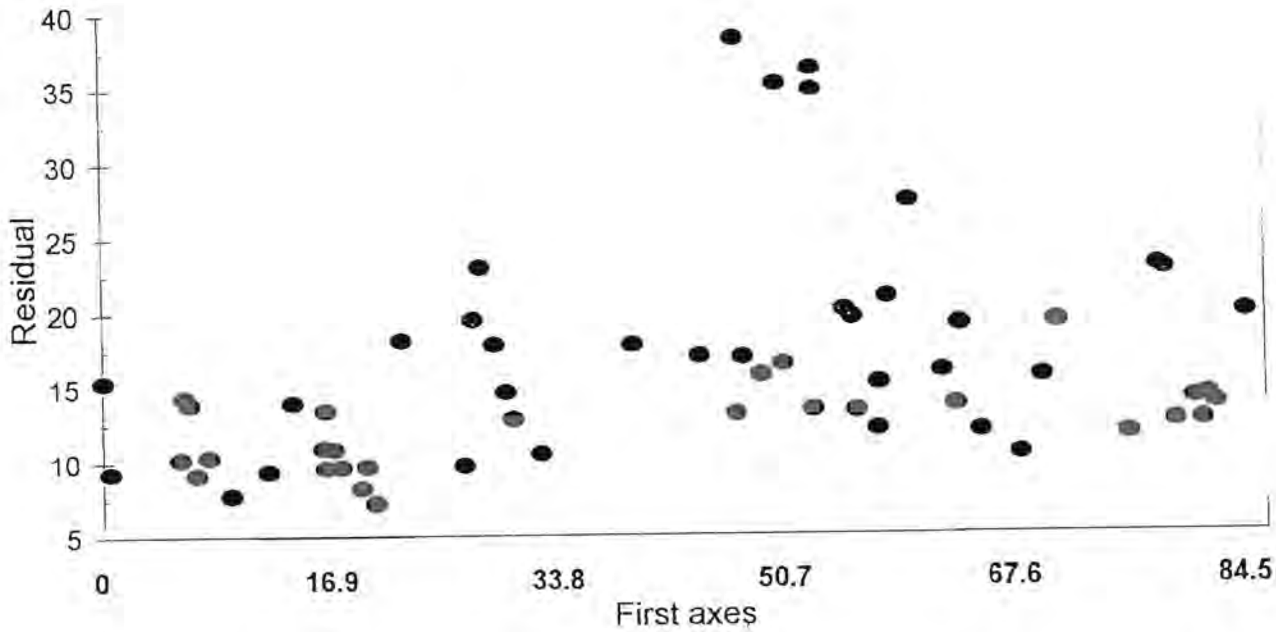


Figure 26(c): The spatial distribution of the sample sites in **Management Unit I** according to the first and second axis of the Reciprocal Averaging ordination.

Variations on the residual axis could be due to various habitat factors, such as clay content, soil depth, aspect, etc. as there still exists considerable variation in this macro unit. It could also be because of different compositions that have developed during the process of change (Bosch & Kellner 1991)

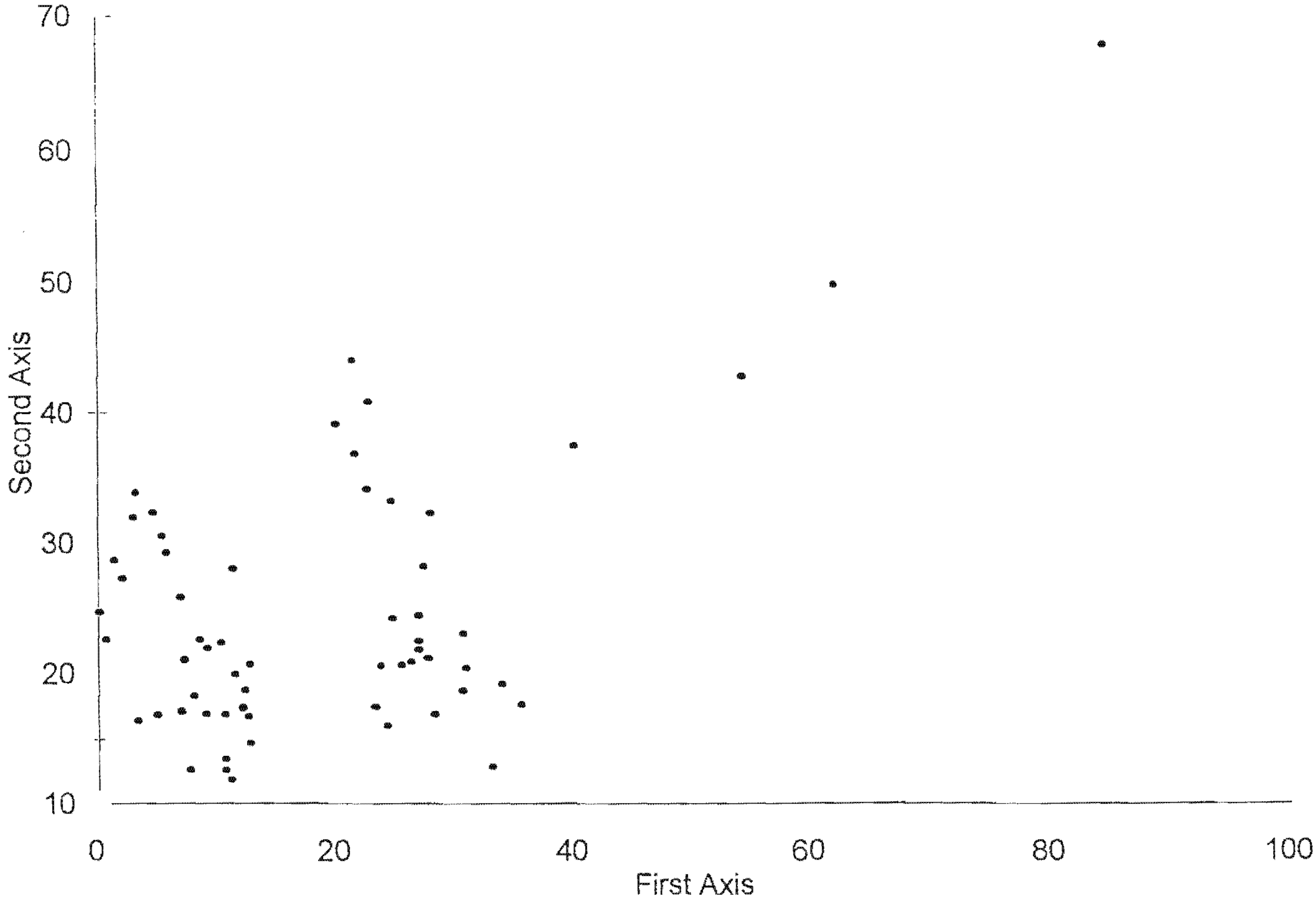
Construction of a degradation gradient for the *Becium obovatum - Elionurus muticus* Tall Grassland - Management Unit II

The results of the ordination of Management unit II is shown in Figure 27 a, b and c. Evident from the ordination is that the RA and standardized PCA (SPCA) tend to arrange the survey sites to the left of the scatter diagram (Figure 27 b and c). These ordinations also arranged a number of sites above the Maximum Acceptable Residual value, making the further use of these ordinations impossible. The Centered PCA (CPCA) (Fig 27 a) displayed an even arrangement of the sites along both axes. This is explained in terms of the relative low diversity acquired within each management unit, for which PCA is generally suitable (Bosch & Gauch 1991) . The maximum residual value of the ordination of these sample plots is 38.3.



Management unit 2: Results of the Centralized PCA

Figure 27(a): The spatial distribution of the sample sites in **Management Unit 2** according to the first and second axis of the Centralized Principal Component Analyses.



Management unit 2: Results of the Standardized PCA

Figure 27(b): The spatial distribution of the sample sites in **Management Unit 2** according to the first and second axis of the Standardized Principal Component Analyses

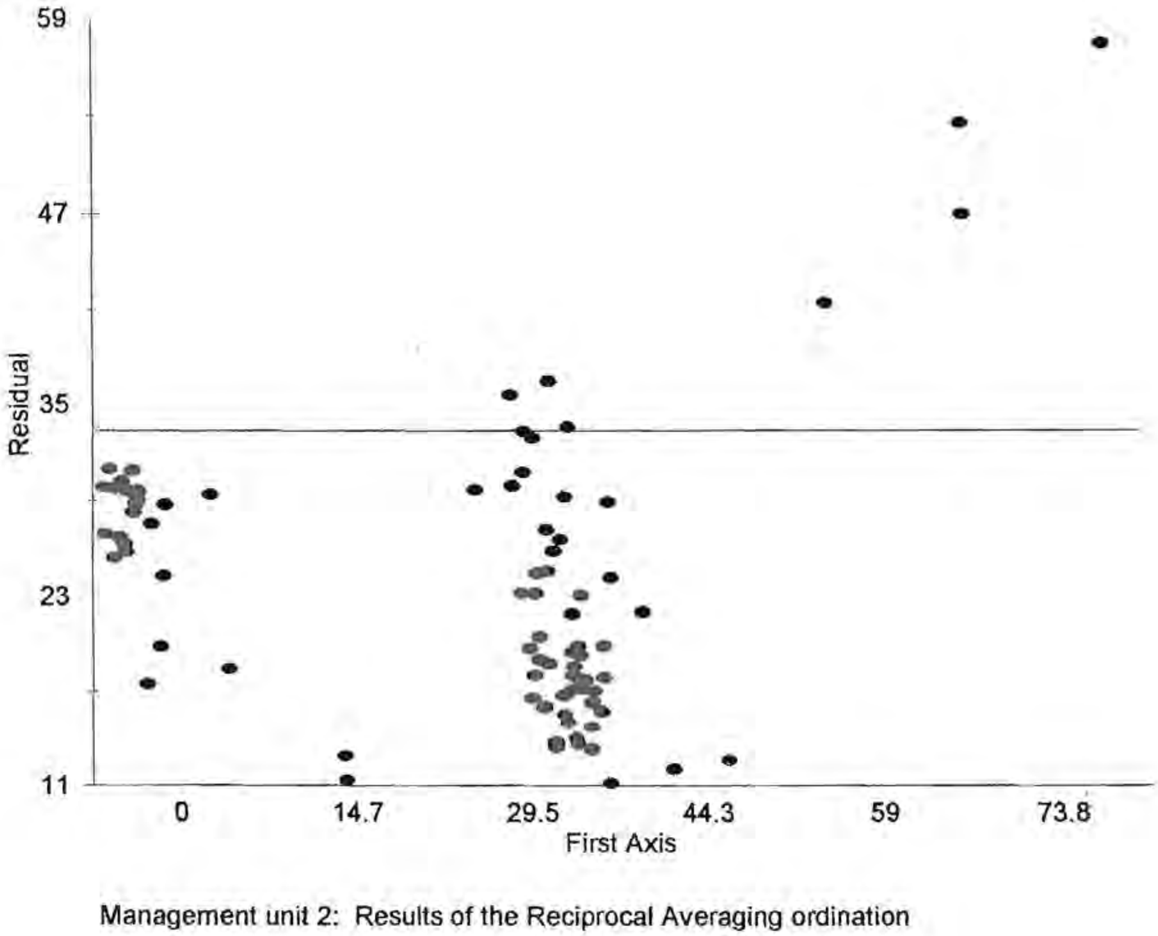


Figure 27(c): The spatial distribution of the sample sites in **Management Unit 2** according to the first and second axis of the Reciprocal Averaging.

The first axis of the CPCA ordination (Fig 27 a) represents a degradation gradient from left to right. The ungrazed plots are spatially distributed to the left of the scattered diagram, while the plots in grazed areas are located to the right of the diagram. The distribution of the plots along the first axis from ungrazed to grazed are confirmed by notes made during fieldwork on the level of utilization of the plots by game. No data on long term grazing pressures could be obtained and the gradient is therefore only described as varying from ungrazed to grazed. Species compositional data on the extremes of the gradient (severely grazed and ungrazed) were also not available and thus the gradients only represent the middle sector (moderately utilized to moderately unutilized) of a possible longer degradation gradient.

Construction of a degradation gradient for the *Ziziphus mucronata - Rhus leptodictya* Closed Woodland - Management Unit III

The results of the CPCA, SPCA and RA ordination in this unit is given in Figure 28 a,b & c respectively. The results obtained with SPCA and RA (Fig 28 b and c) in this unit are unsuitable for the construction of a degradation gradient. CPCA (Fig 28 a) provided better results with a maximum residual value of 48.5.

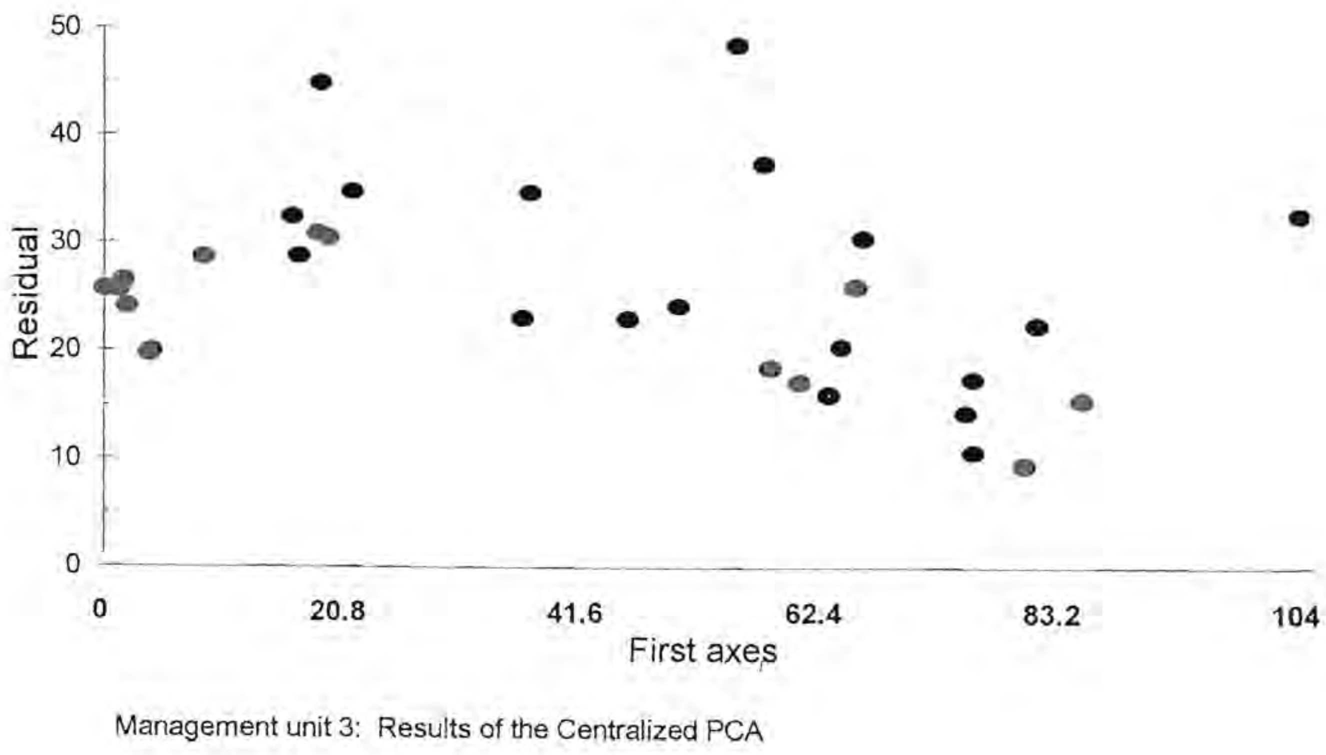


Figure 28(a): The spatial distribution of the sample sites in **Management Unit 3** according to the first and second axis of the Centralized Principal Component Analyses

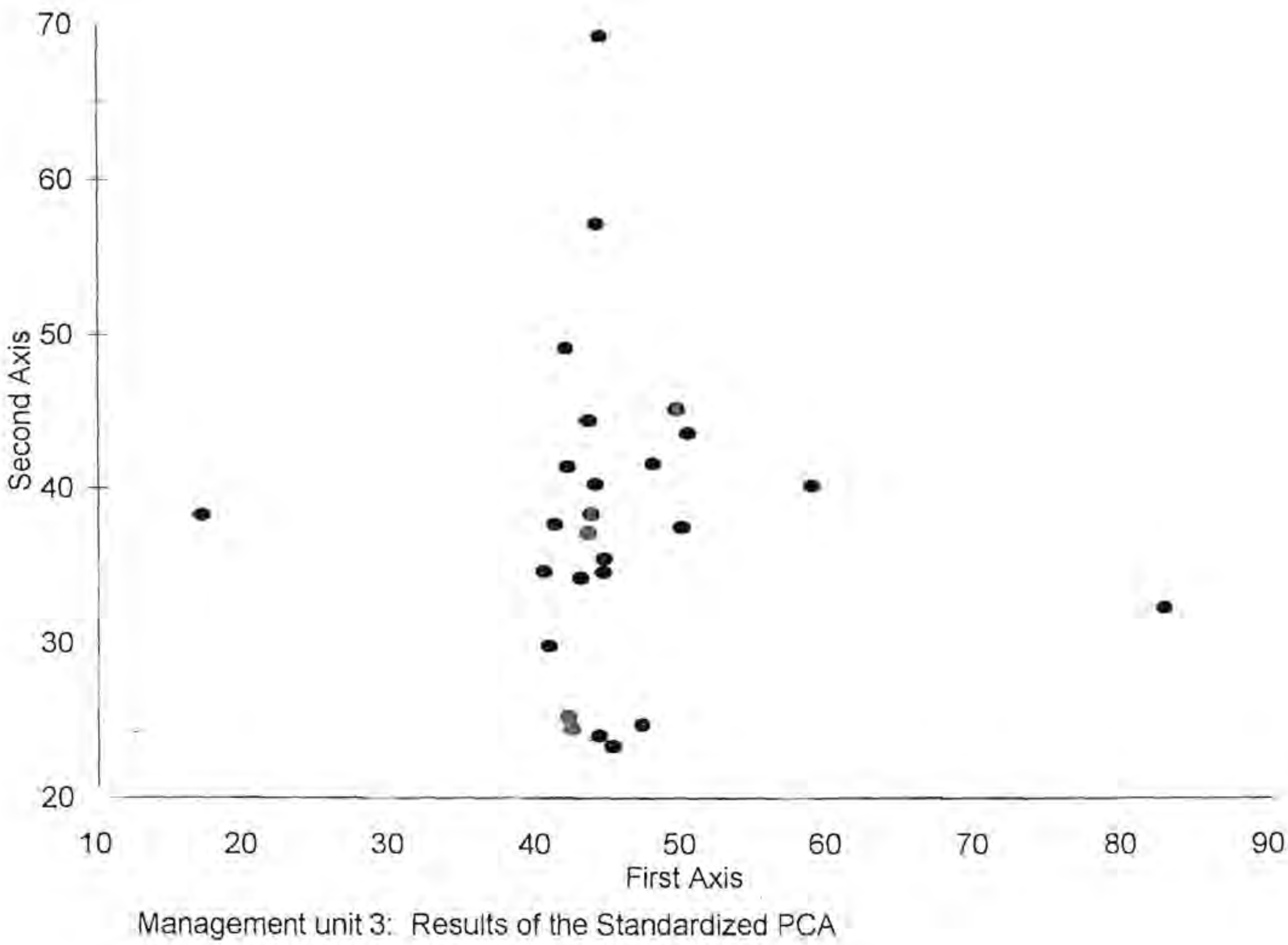
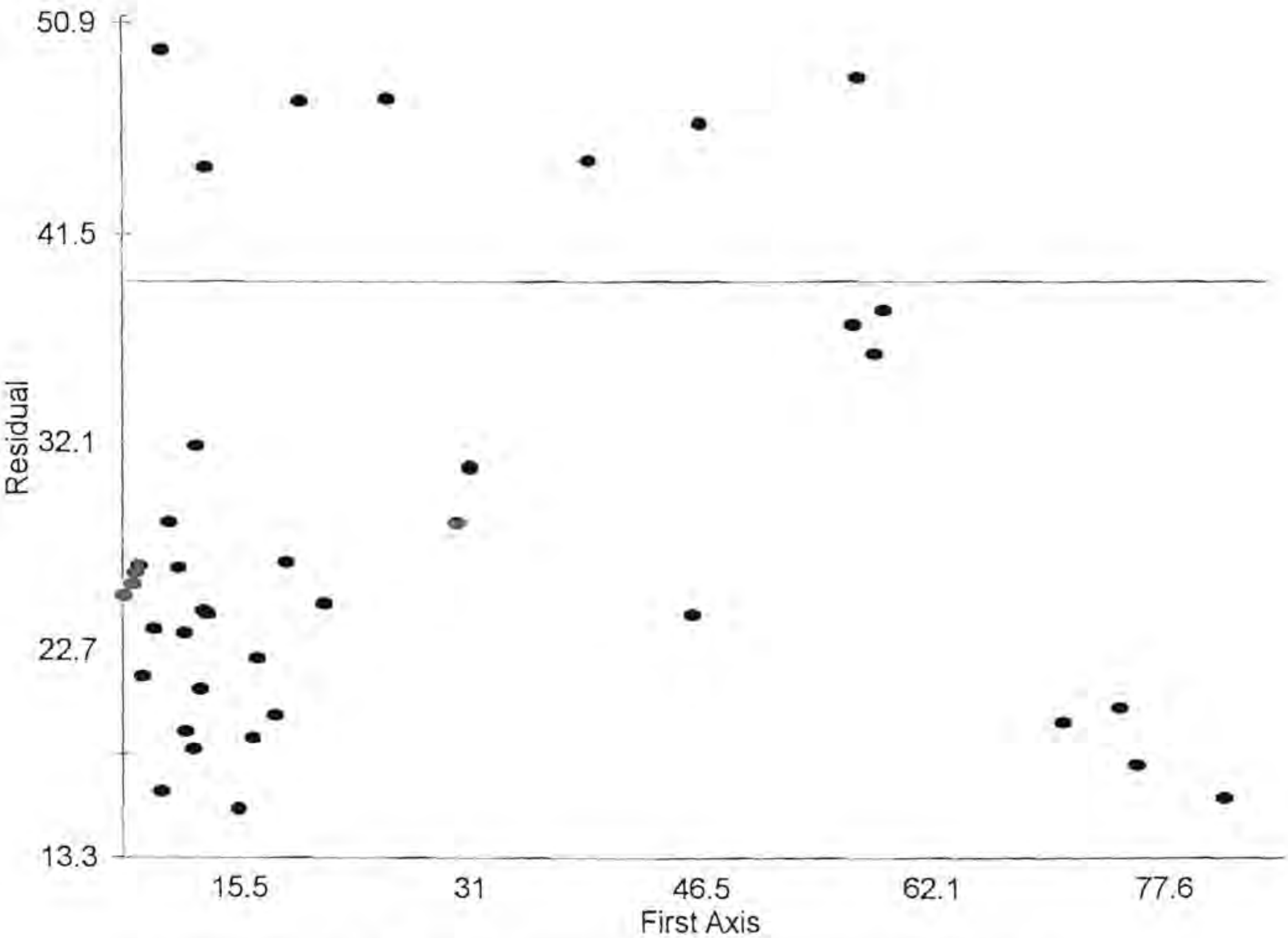


Figure 28(b): The spatial distribution of the sample sites in **Management Unit 3** according to the first and second axis of the Standardized Principal Component Analyses.



Management unit 3: Results of the Reciprocal Averaging ordination

Figure 28(c): The spatial distribution of the sample sites in **Management Unit 3** according to the first and second axis of the Reciprocal Averaging ordination.

It was noted that more variation occurs in this unit than the other two. This variation can be attributed to dissimilarities in various habitat factors, such as clay content, soil depth, aspect, which, from a practical management point of view, had to be merged.

Identification of key species in different vegetation units

Regression analysis was used to establish the reaction of the individual species to the process of change of vegetation due to herbivory. Gaussian models provided the best fit for species abundance data on the degradation gradients. Species with a low index of agreement (D-statistics; Wilmott 1982) were regarded as non-responsive to the process of retrogression of vegetation caused by grazing. These species cannot be considered as indicators of the probable position of a site along the degradation gradient. The result of the ordination of the species according to their response to different levels of grazing is illustrated in table 10.

Table 10 Identification of key species in the different vegetation units based on their response to grazing.

Category	Species	Management unit 1 D-stat	Management unit 2 D-stat	Management unit 3 D-stat
Decreasers	*Urelytrum agropyroides*	0.766	-	-
	Eustachys paspaloides	-	-	0.566
	Aristida junciformis	0.934	-	-
	Hyparrhenia tamba	-	-	0.819
	Heteropogon contortus	-	-	0.925
	Eragrostis lehmanniana	-	-	0.997
	Eragrostis chloromelas	0.994	0.509	-
	Brachiaria brizantha	-	-	0.94
	Loudetia simplex	0.843	-	-
	Melinis nerviglumis	0.562	-	0.994
	Aristida transvaalensis	0.57	-	-
	Schizachyrium sanguineum	0.669	-	-
	Tristachya leucotrix	0.537	0.813	-
	Bewsia biflora	-	0.817	-
	Aristida congesta barbicollis	-	-	0.784
	Triraphis andropogonoides	0.853	0.952	-
	Eragrostis nindensis	0.668	-	-
	Digitaria eriantha	-	0.998	0.989
	Setaria sphacelata	-	-	0.973
	Themeda triandra	-	0.994	0.961
Increaser 1	*Aristida junciformis*	0.926	-	-
	Bewsia biflora	0.985	-	-
	Andropogon schirensis	0.998	-	-
	Setaria sphacelata	0.967	0.621	-
	Tristachya rehmannii	0.736	-	-
	Eragrostis racemosa	0.666	-	-
	Schizachyrium sanguineum	0.895	-	-
	Digitaria eriantha	0.974	-	-

Category	Species	Management unit 1 D-stat	Management unit 2 D-stat	Management unit 3 D-stat
	Eragrostis curvula	0.979	-	-
	Andropogon schirensis	0.999	-	-
	Setaria nigrirostis	-	0.613	-
	Trachypopgon spicatus	-	-	0.944
	Asclepias aurea	-	0.791	-
	Cymbopogon excavatus	0.591	-	-
	Heteropogon contortus	0.566	-	-
	Panicum coloratum	-	0.999	-
	Hermannia depressa	-	0.956	-
	Eragrostis rigidior	-	-	0.989
	Setaria pallide-fusca	-	0.999	-
	Elephantorrhiza elephantina	-	0.5	-
	Hyparrhenia hirta	-	0.994	-
	Tristachya rehmannii	-	0.781	-
	Eragrostis chloromelas	-	0.509	-
	Urelytrum agropyroides	-	0.828	-
	Themeda triandra	0.835	-	-
Increaser 2	*Aristida congesta barbicollis*	-	0.849	-
	Aristida congesta congesta	-	0.999	-
	Diheteropogon amplectens	-	0.469	-
	Cymbopogon excavatus	0.871	-	-
	Tagetes minuta	-	-	0.586
	Eragrostis chloromelas	-	-	0.795
	Hyparrhenia hirta	-	-	0.566
	Parinari capensis	-	0.956	-
	Heteropogon contortus	-	0.926	-
	Eustachys paspaloides	-	0.888	-
	Pogonarthria squarrosa	-	-	0.928
Increaser 3	*Eragrostis racemosa*	0.894	0.903	-
	Indigofera melionodes	-	0.577	-
	Cyperus rupestris	-	0.595	-

Category	Species	Management unit 1 D-stat	Managemen t unit 2 D-stat	Managemen t unit 3 D-stat
	Schizachyrium sanguineum	-	0.472	-
	Elephantorrhiza elephantina	-	0.5	-
Increaser 4	*Brachiaria nigropedata*	-	0.923	-
	Cymbopogon plurinodes	-	0.903	-
	Coleocloa setifera	0.994	-	-
	Bulbostylis burchellii	-	0.781	-
	Sporobolus africanus	-	-	0.984
	Cynodon dactylon	-	-	0.993
Non responsive	*Aristida transvaalensis*	-	0.421	-
	Brachiaria serrata	0.245	0.269	-
	Trachypogon spicatus	0.348	0	-
	Melinis repens	-	0.25	-
	Elionurus muticus	-	0.413	-
	Diheteropogon amplectens	0.46	-	-
	Eragrostis chloromelas	0.459	-	-
	Panicum maximum	-	-	0.372

It was possible to establish the individual species reaction to degradation and according to the Gaussian curve obtain through the regression analysis, responsive species could be divided into Decreasers, Increaser 1, Increaser 2, Increaser 3 and Increaser 4 categories. (Janse van Rensburg 1987; Janse van Rensburg & Bosch 1990; Jordaan 1997).

- ***Decreasers:*** ***Species that occur in veld which is lightly to moderately utilized, but decreases in abundance when the vegetation is over-utilized.***
- ***Increaser 1:*** ***Species that occur in veld which is not utilized, or under-utilized and increase in abundance when the vegetation is continuously under-utilized.***
- ***Increaser 2:*** ***Species that do not occur in well-managed veld, and increases in abundance when the vegetation is moderately***

over-utilized.

- *Increaser 3:* ***Species that do not occur in well-managed veld, and increases in abundance when the vegetation is moderately to seriously over-utilized.***
- *Increaser 4:* ***Species that do not occur in well-managed veld, and increases in abundance when the vegetation is seriously over-utilized.***

The responses of these species are indicated in Figure 29, 30 and 31. A definite pattern in the occurrence of certain species along the degradation gradient in the different management units can be noticed. It is also evident from these analysis that species responded differently to grazing impacts under different physical and environmental conditions (Bosch & Janse van Rensburg 1987). *Urelytrum agropyroides, Eustachys paspaloides, Heterpogon contortus, Digitaria eriantha, Themeda triandra, Setaria sphacelata, Eragrostis curvula* and *Triraphis andropogonoides* can be classified into more than one category, indicating that they react differently to grazing in the three different management units . Each management unit also demonstrated a different set of key species indicating the level of utilization of that particular management unit. Certain key species also responded inconsistent to degradation between the different management units.

Also evident from these species response curves are the misperception that species tend to react similar to grazing impact and that a generally accepted ecological status can therefore be allocated to it (Vorster 1982; Tainton 1988; Pauw 1989; van Oudtshoorn 1992; Smith 1992; Nel 1992). *Brachiaria serratta, Trachypogon spicatus, Melinis repens, Elionurus muticus, Panicum maximum, Diheteropogon amplectens* and *Eragrostis chloromelas* are species which have historically been classified into very specific ecological classes, but did not show any significant response to grazing impact in this study ($D < 0.500$). This confirms that the broad standardization of species is of no real value in the objective interpretation of monitoring results (Janse van Rensburg & Bosch 1990; Jordaan 1997)

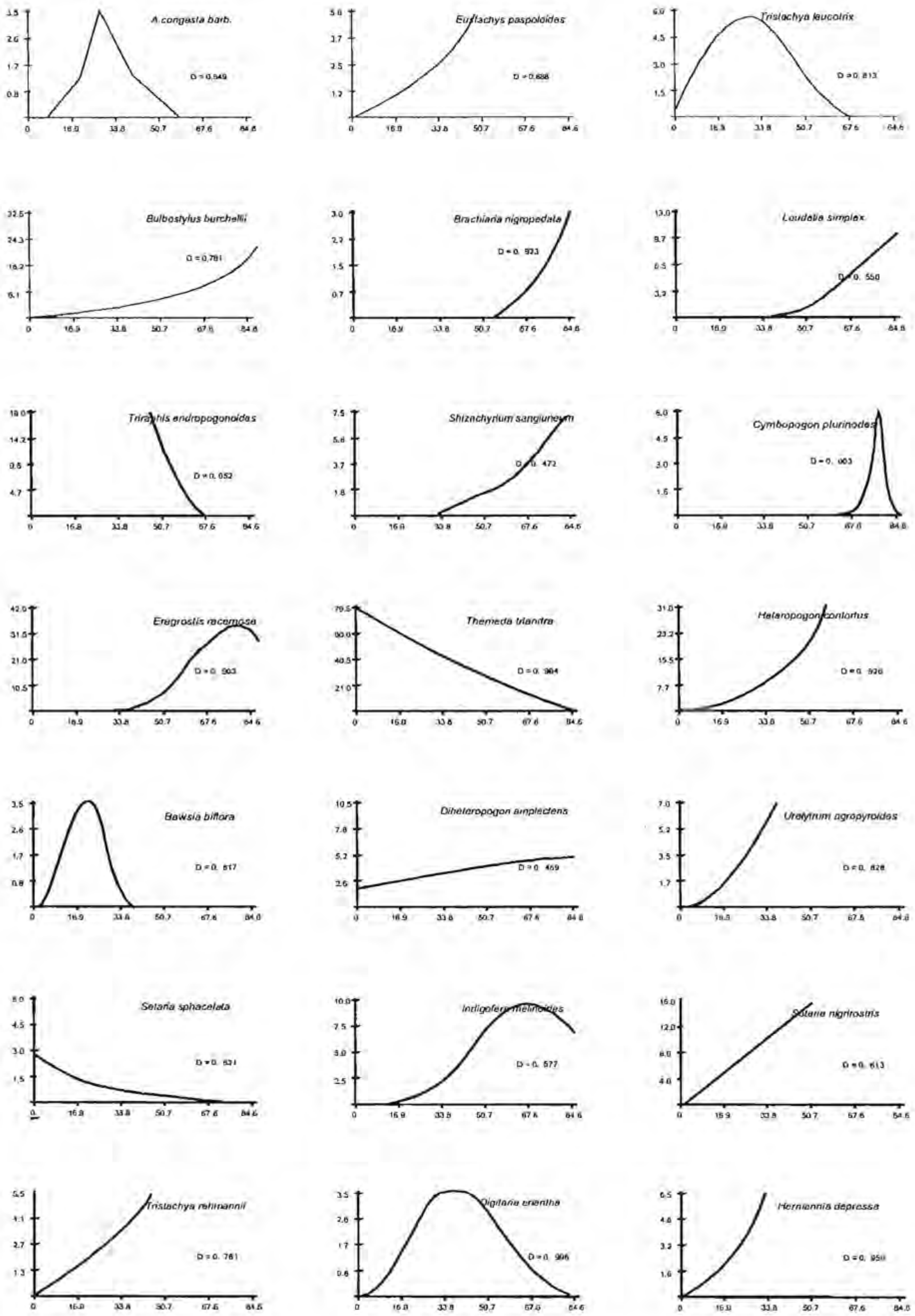


Fig 29: The classification of individual species in Management Unit I according to their response to different levels of utilization

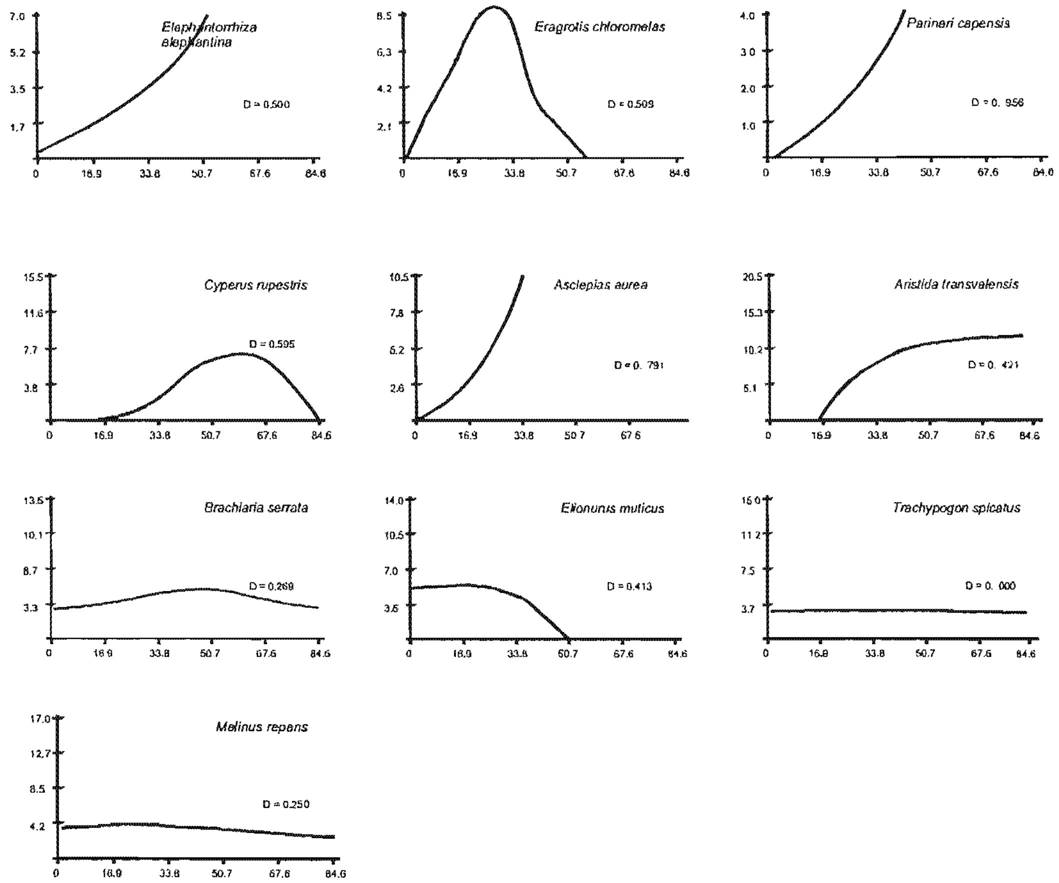


Fig 29 (cont.}: The classification of individual species in Management Unit I according to their response to different levels of utilization

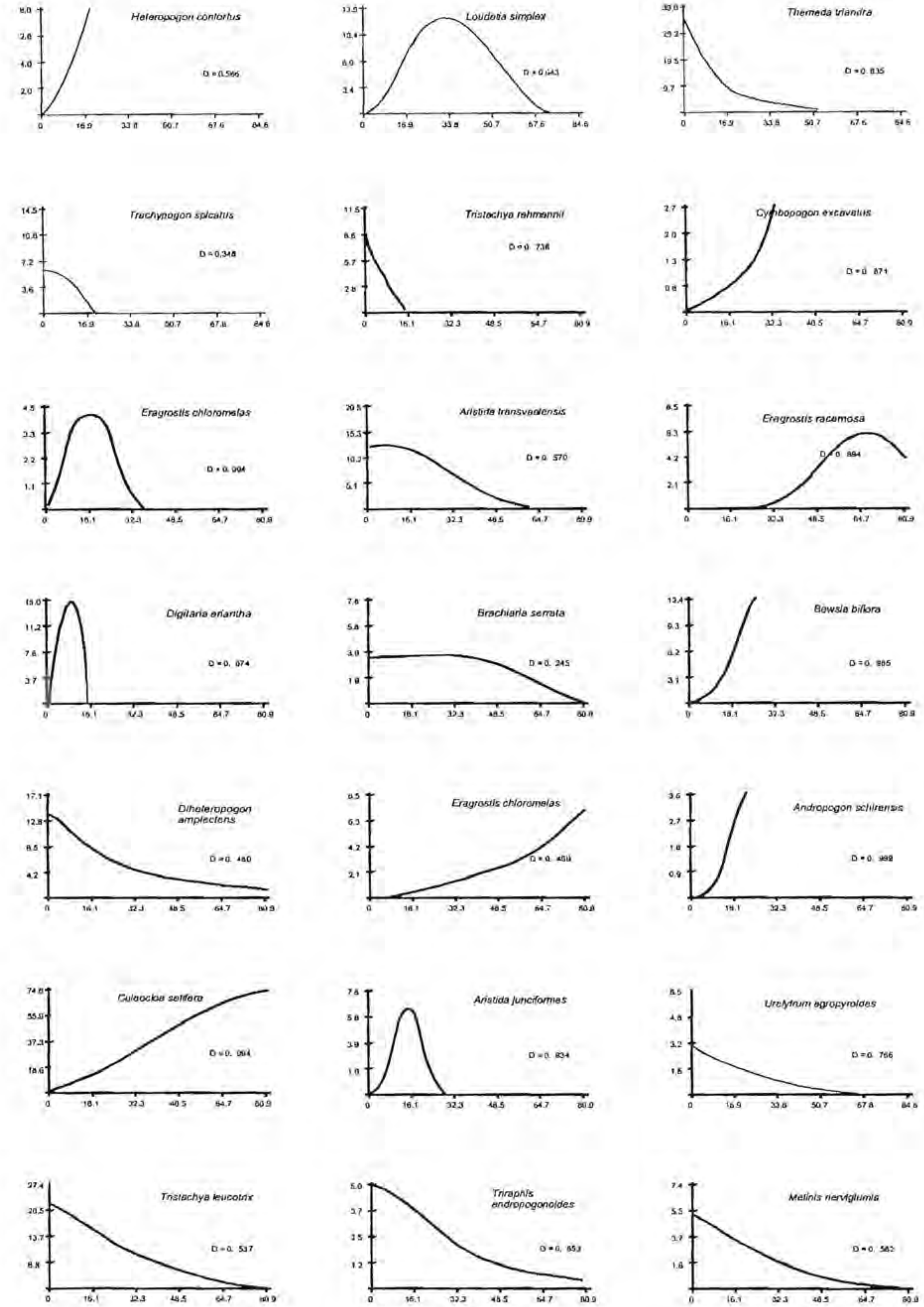


Fig 30: The classification of individual species in Management Unit II according to their response to different levels of utilization

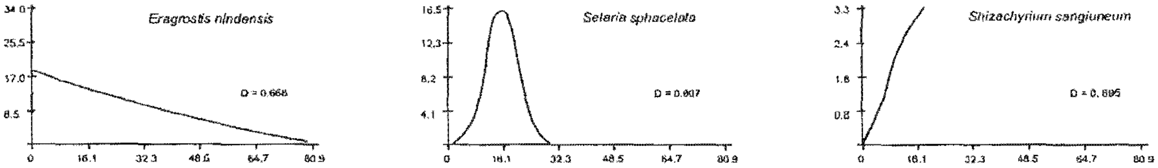


Fig 30(cont): The classification of individual species in Management Unit II according to their response to different levels of utilization

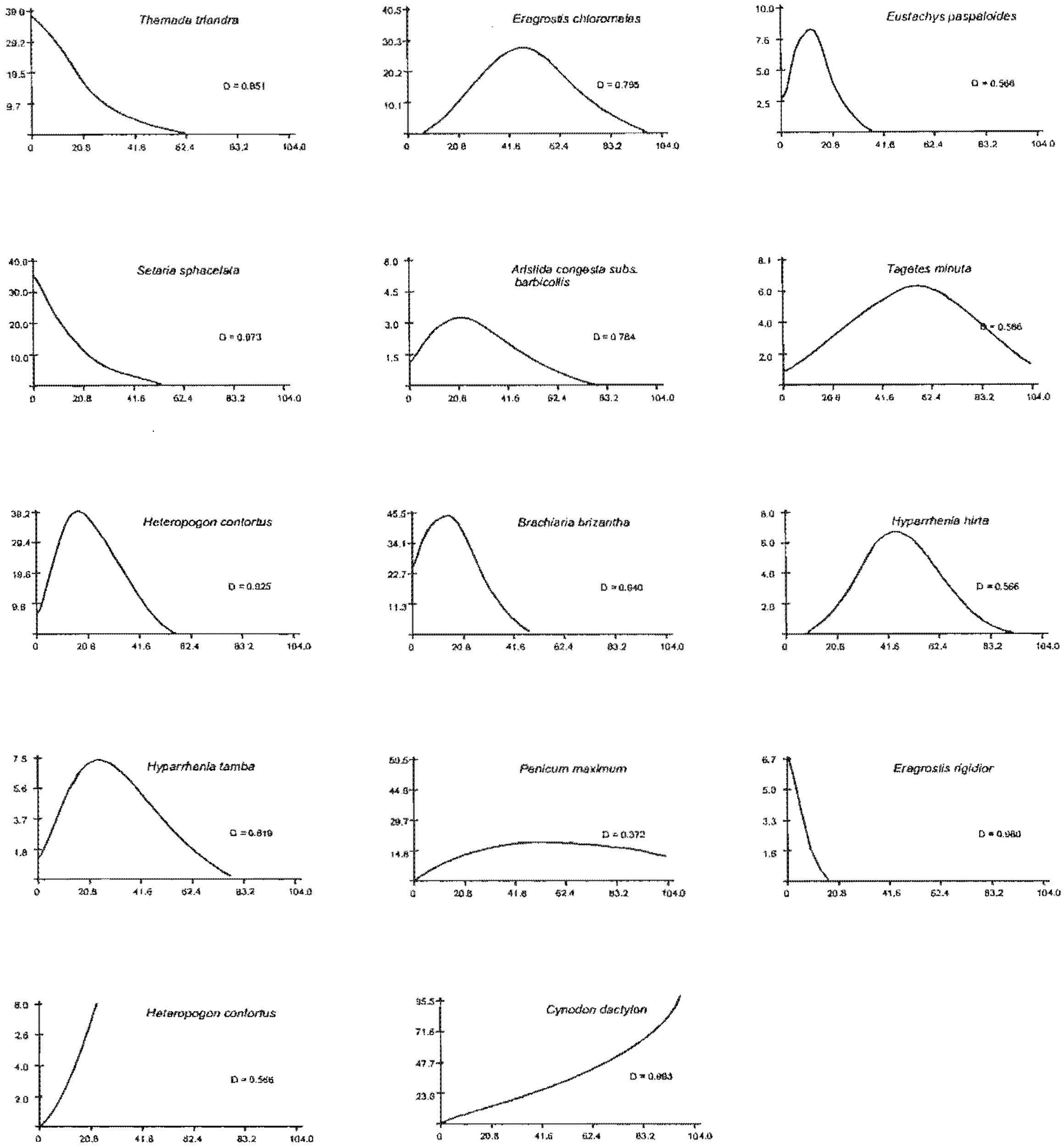


Fig 31: The classification of individual species in Management Unit III according to their response to different levels of utilization

DESCRIPTION OF THE DEGRADATION GRADIENT FOR THE MANAGEMENT UNITS AS A BASIS FOR INTERPRETATION OF MONITORING RESULTS

The degradation gradients will act as basis for an objective interpretation of results obtained during the monitoring of the condition of the vegetation in the different units. The abundance value of the different key species which was identified for the different management units will be used to describe the changes taking place along the degradation gradient.

The X-axis is subjectively divided into five utilization categories, providing a guideline to management to interpret the condition of a site according to its position along the degradation gradient. The five utilization categories are (Jordaan 1997):

- lightly utilized
- lightly to moderately utilized
- moderately utilized to moderately over-utilized
- moderately to seriously over-utilized
- seriously over-utilized.

The degradation gradient in each management unit were evaluated according to the ecological objectives of the reserve: (Chapter 2)

- Presence of the different categories of herbaceous species, which are an indication of the stability of the whole system, and the
- occurrence of erosion in the more utilized sectors of the degradation gradient, both which will influence the quality and amount of effluent from this catchment.
- The amount of plant species present in each utilization sector and the
- general ability of that unit to sustain wildlife in its various forms,

which relates to the objective of promoting and sustaining biological diversity on the reserve.

MANAGEMENT UNIT I - *Selaginella dregei - Oldenlandia herbacea* Open Shrubland

The results of the CPCA ordination for Management Unit I are displayed in Figure 32. The sites associated with more utilized veld is positioned to the right of the ordination, while those associated with less utilized veld is situated to the left of the ordination. The under-utilized sector of the degradation gradient is characterise by a diversity of herbaceous species. Species diversity decreases significantly along the degradation gradient.

Setaria sphacelata, Tristachya rehmannii and *Themeda triandra* dominate the species composition in the under-utilized sector of the degradation gradient. In this management unit these species decrease along the degradation gradient, but increases in abundance when the veld is not utilized. These species are classified as Increaser I species (Janse van Rensburg 1987; Jordaan 1997), species that increase in abundance when the veld is under-utilized. The high abundance of species such as *Themeda triandra* and *Setaria sphacelata* in the unutilized sector of the degradation gradient was also found by Bosch & Kellner (1991).

The lightly and moderately utilized sector is dominated by *Aristida junciformis, Loudetia simplex, Melinis nerviglumis, Aristida transvaalensis, Triraphis andropogonoides* and *Eragrostis nindensis.* These species all prefer poor sandy soils associated with shallow rocky slopes (van Oudtshoorn 1992) of the Magaliesberg. These species decreases in abundance along the degradation gradient and have been classified as Decreaser-species (Janse van Rensburg 1987; Jordaan 1997).

Species diversity decreases significantly along the degradation gradient in this management unit (Figure 33). Except for the non-responsive species (D-stats < 0.5) *Brachiaria serratta, Diheteropogon amplectens, Melinis repens, Cymbopogon* *validus* and *Triraphis andropogonoides* the species composition in the moderately utilized, moderately seriously over-utilized and seriously over-utilized sectors of the degradation gradient is limited to the forb *Coleocloa setifera.* This species is markedly absent in the under-utilized sector of the degradation gradient. It is classified as an Increaser IV, a species that do not occur in well-managed veld, and increases in abundance when the vegetation is seriously over-utilized.

Figure 33 displays the relation between the number of plant species in the sample plots and its position along the degradation gradient. In this management unit plant species diversity seems to be significant higher in the under-utilized sector of the degradation gradient than in the lightly- to severly-utilized sectors. This corresponds with the findings by Foran (1976) in the Dry tall Grassveld, Moist tall grassveld and the Mistbelt.

Figure 34 shows the ordination of the sample plots, indicating the amount of erosion. No significant erosion were recorded in this management unit. This is due to the large areas of open bedrock and shallow soils underlying this management unit and *Coleocloa setifera,* being a densely tufted perrenial (van Wyk & Malan 1988), is seemingly able to colonize and stabilized bare areas of bedrock effectively.

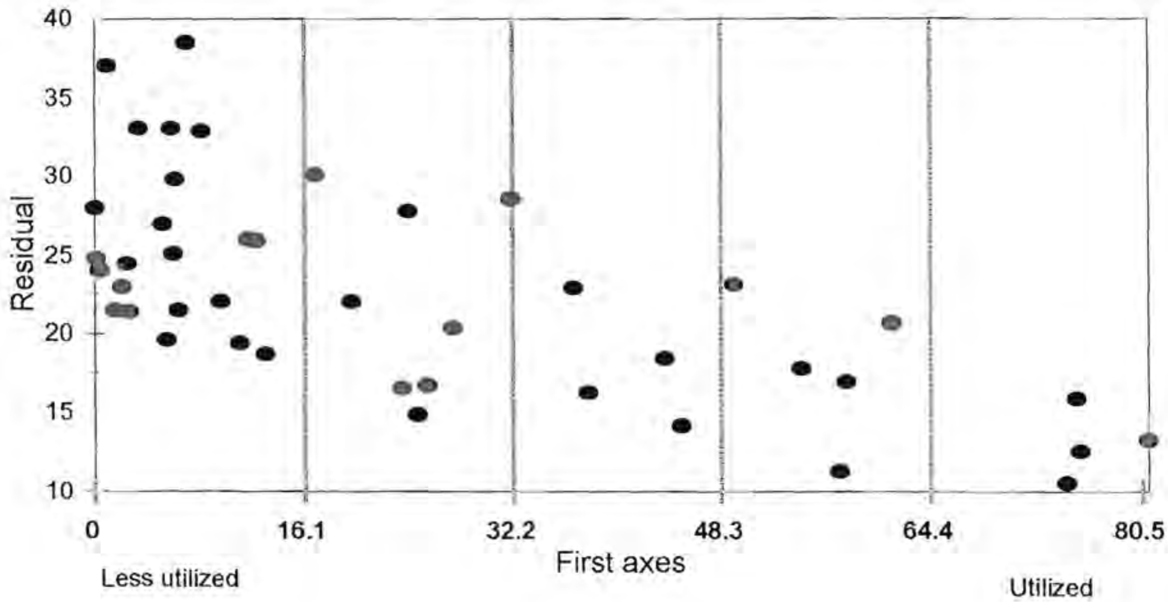


Figure 32: Ordination results of the CPCA ordination of the sites in management unit 1.

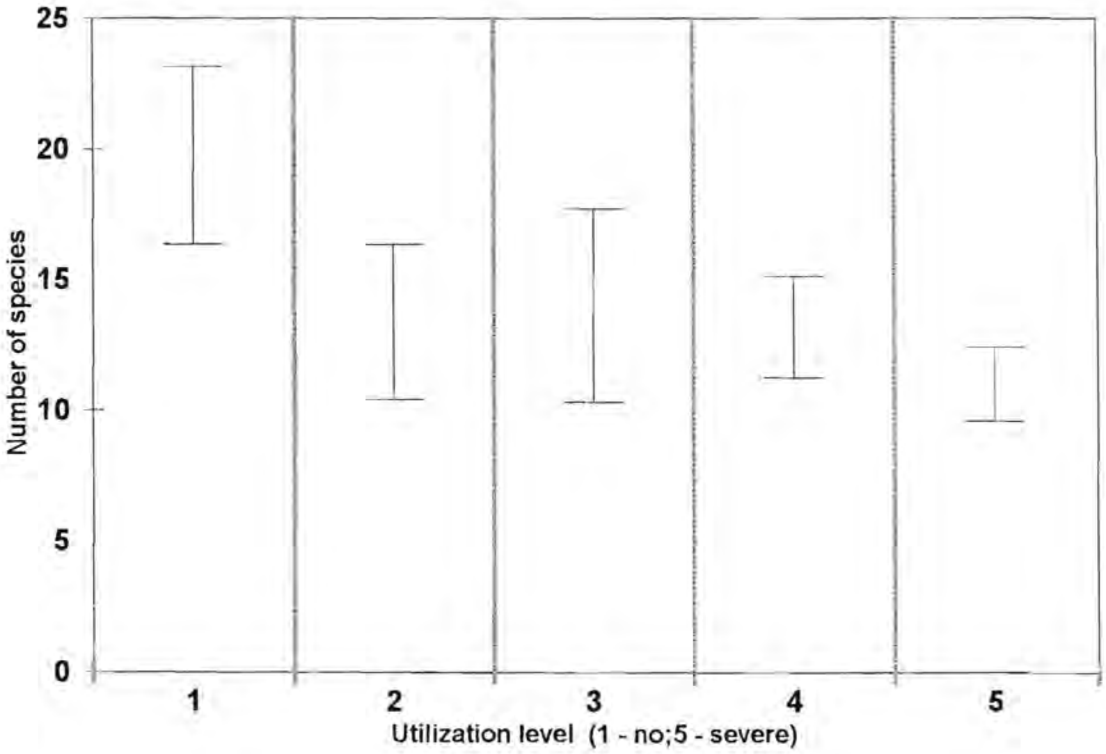


Figure 33: The total number of plant species encountered in each utilization class along the degradation gradient in Management unit 1.

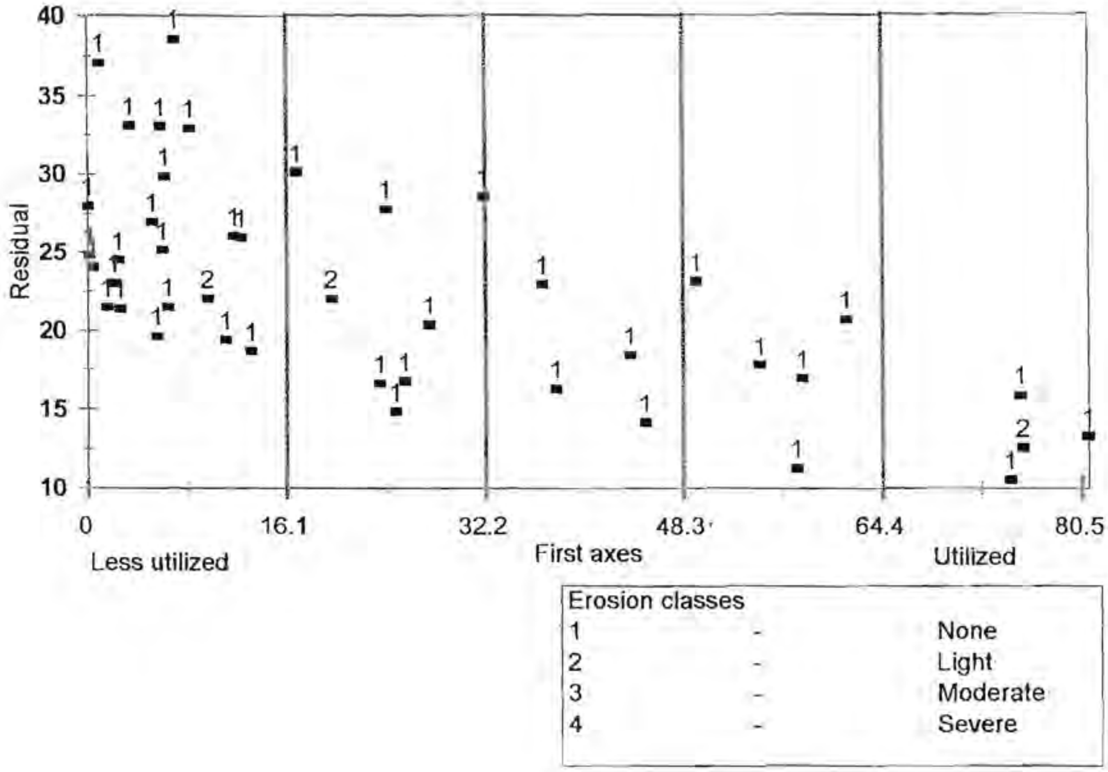


Figure 34: Ordination results of the CPCA ordination of the sites in management unit 1, indicating the amount of erosion in each site.

MANAGEMENT UNIT 2 - *Becium obovatum* - *Elionurus muticus* Tall Grassland

The results of the CPCA ordination for management unit 2 are represented in figure 35.

The sites associated with more utilized veld is positioned to the right of the ordination, while those associated with less utilized veld is situated to the left of the ordination.

Themeda triandra is a very distinct perennial species through-out this gradient. It is abundant in the unutilized sector of this vegetation unit, but decreases consistently in abundance to low frequencies in the utilized sector of the gradient. *Eragrostis chloromelas* and *Tristachya leucotrix*, both tufted perennial grasses, depicted similar response to increased levels of utilization, although these two species occurred at lower frequencies. These three species were classified as decreasers species. *Digitaria eriantha* and *Bewsia biflora* also reacted similar, but occurred in frequencies of less than 5% and can therefore not be regarded as a significant indicator to the process of gradual retrogression or secondary succession in this unit (Jordaan 1997) *Triraphis andropogonoides* displayed a decrease in abundance with increased levels of utilization, but was only present in three sample plots and are therefore discarded as an indicator.

Setaria sphacelata displayed the same downward trend, but disappears faster than *Themeda triandra* when utilization levels are increased. These species are classified as Increaser 1 species. *Asclepias aurea* is also confined to the less utilized sectors of the gradient.

A number of unpalatable species increases in abundance along the vegetation gradient as utilization levels increases. Certain species such as *Bulbostylis* *burchellii*, *Eragrostis racemosa*, *Indigofera melinoides* and *Cyperus rupestris* show a gradual increase (Increaser 2 species) , while other species such as *Loudetia simplex* and *Cymbopogon plurinodes* only appear in the moderate to severely utilized sectors of the gradient (Increaser 4 species). *Hermannia depressa* displays an intermediate reaction and are classified as an Increaser 3 species. This increase in abundance of unpalatable species associated with moderate to severe overgrazing was also found by Bosch & Kellner (1991) and can be attributed to the fact that unpalatable grasses are only lightly grazed and therefore stimulated and palatable perennial species are severely grazed (Trollope 1981).

Although species such as *Aristida transvaalensis, Schizachyrium sanguineum, Diheteropogon amplectens, Eragrostis curvula, Brachiaria serrata, Elionurus muticus, Trachypogon spicatus, Cassia comosa* and *Melinis repens* occurred in meaningful numbers, (frequency > 5%), they did not show a significant response to changes in vegetation due to different levels of utilization (D-stats < 0.5).

Figure 36 indicates the relationship between the number of plant species and the level of utilization in this management unit. No significant relationship exist between the level of utilization and the number of plant species recorded in the sample plots, but species seems to disappear when the veld is not utilized. This was found by Foran (1976) in the Highland Sourveld.

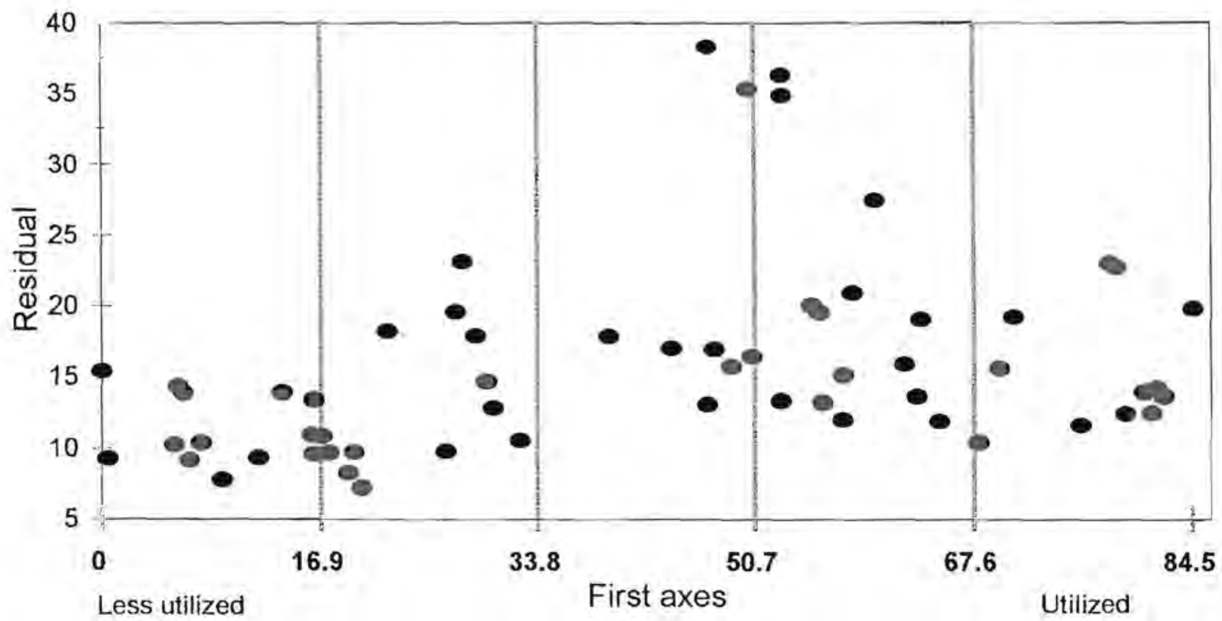


Figure 35: Ordination results of the CPCA ordination of the sites in management unit 2.

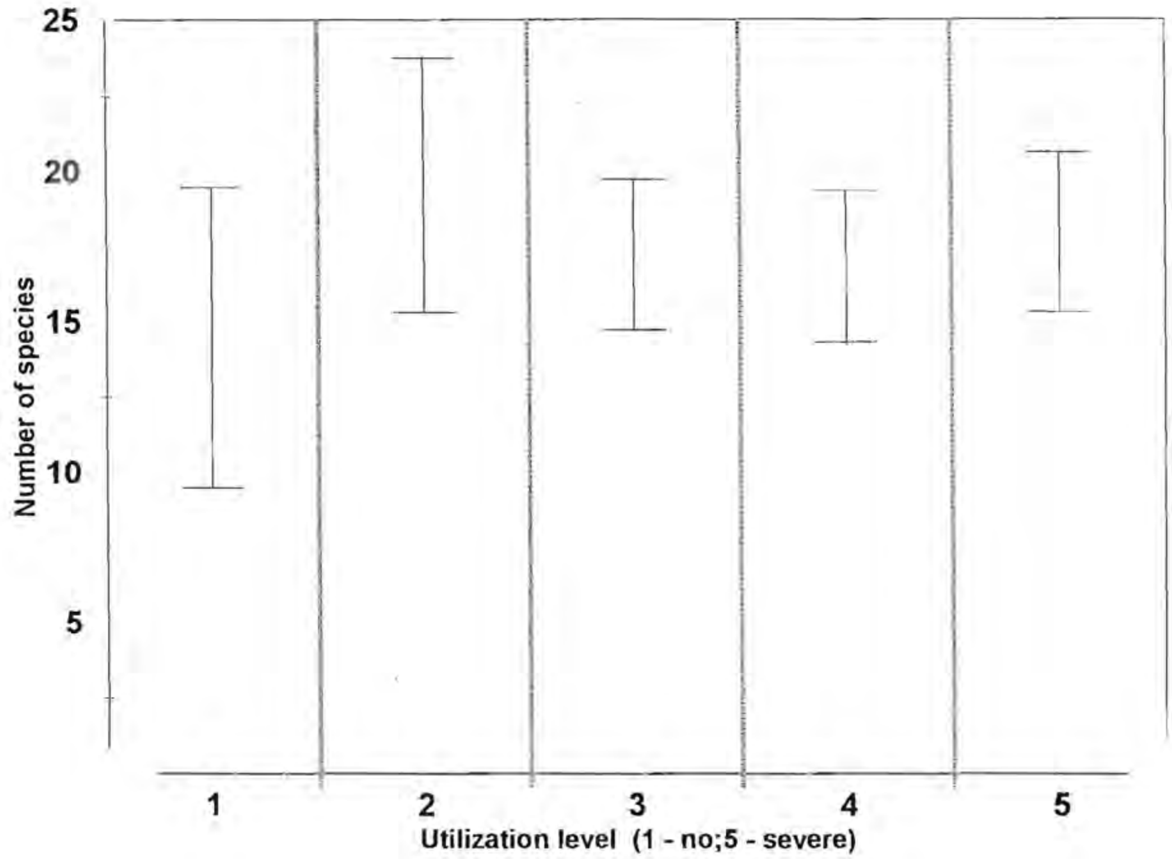


Figure 36 The number of plant species in the different utilization classes along the degradation gradient in management unit 2

Figure 37 displays the arrangement of sample sites in this management unit along the degradation gradient with the degree of erosion found in each site. No significant erosion were detected in the under-utilized, lightly utilized and moderately utilized sectors of the gradient. Fourteen percent of the sites in the moderately seriously over-utilized sector revealed light (Scaled 2; 1=none and 4=severe) erosion. Thirty six percent of the sites in the seriously over-utilized sector of the degradation gradient are moderately eroded (Scaled 3; 1=none and 4=severe). Light erosion were recorded in 18% of the sites in this sector. Further degradation along this gradient will encourage excessive erosion in this management unit, which will impact negatively on the objective of ensuring controlled and high quality runoff. In this regard the seriously over-utilized sector of the degradation gradient needs to be avoided in the management of this unit.

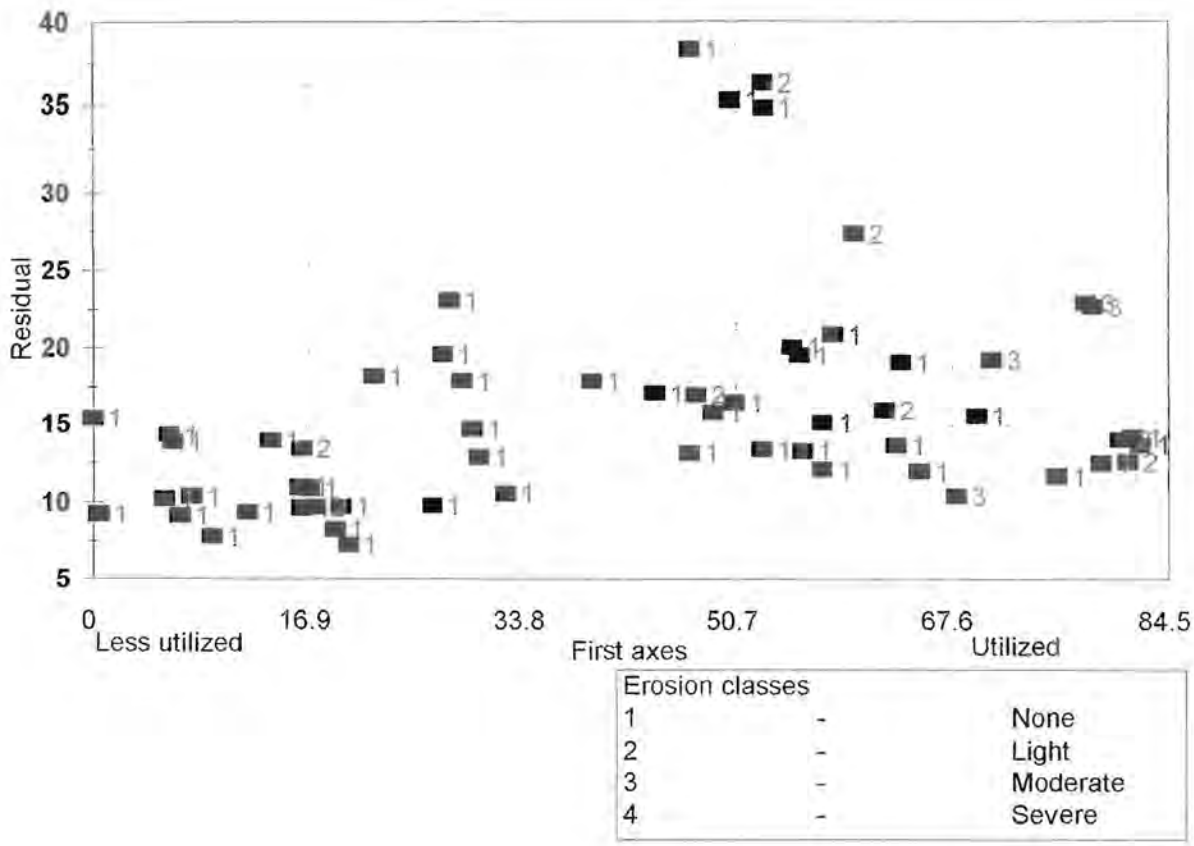


Figure 37: Ordination results of the CPCA ordination of the sites in management unit 2, indicating the amount of erosion in each site.

MANAGEMENT UNIT 3 - *Ziziphus mucronata - Rhus leptodictya* Closed Woodland

The CPCA ordination for this management unit is depicted in Figure 38. The sites associated with more utilized veld is positioned to the right of the ordination, while those associated with less utilized veld is situated to the left of the ordination.

The under-utilized sector in this management unit, which is underlaid by deep alluvial soils, are, as in the other management units, characterized by a high abundance of *Themeda triandra* (also found by Nel *et al.* 1993) and *Setaria sphacelata.* These two species displayed similar responses in all three major habitat groupings on the reserve, being abundant in under-utilized veld and inconspicuous in severely utilized areas. These two species respond inconsistent in findings by Jordaan (1997). She categorize *Themeda triandra* as a Decreaser in all but one land type (Land type 6018 - situated in the northern variation of the Cymbopogon-Themeda Veld (Acocks No 48B) where it responded as an Increaser II. The response of *Setaria sphacelata* along the degradation gradient in her study was much more inconsistent, from not present in significant numbers in certain land types, to reacting as an Increaser II in Land types 6042 (underlaid by mudstone and sandstone) and 6024(underlaid by mudstone, shale and sandstone) and a Decreaser-species in land types 6018 and 6002 (flat landscape on shallow soils underlaid by dolemite and chert). In this management unit both species react as Decreaser-species. This sector is further characterised by the presence of other palatable species. *Brachiaria brizantha, Eustachys paspaloides, Hyparrhenia tamba, Hyparrhenia hirta* and *Heteropogon contortus* (Nel *et al.* 1993) are prominent in this sector of the degradation gradient, decreasing in abundance as the veld is progressively more utilized. The categorization of *Hyparrhenia hirta* as an Increaser II agrees with the results of Jordaan (1997), who classified it as a Decreaser-species on deeper soils.

Two species, *Trachypogon spicatus* and *Eragrostis rigidior*, are abundant in the under-utilized sector of the degradation gradient, but do not appear in the moderately to severely utilized sectors of the gradient. Although *Trachypogon* *spicatus* is regarded as an Increaser 1 (Bosch & Janse van Rensburg 1987; van Oudsthoorn 1992; Smith 1992), *Eragrostis rigidior* is generally considered to be an Increaser 2 or 3 (Pauw 1988; van Oudsthoorn 1992; Schulze 1992;). In this management unit this species is strongly associated with the under-utilized sector of the degradation gradient, responding as an Increaser I as utilization levels are increased.

The lightly-utilized to moderately-severe utilized sectors of the degradation gradient are characterised by the presence of less palatable herbaceous species. *Eragrostis chloromelas* and *Pogonarthria squarrosa* dominates the species composition in these sectors. Other conspicuous species in these sectors of the degradation gradient are *Aristida congesta* var. *barbicollis* and *Tagetes minuta*. These species are all classified as Increaser II species (Jordaan 1997), species that increases in abundances when the veld is moderately to moderate-severely utilized. The grouping of *Eragrostis chloromelas* in this category corresponds with the findings by Nel *et al.* (1993) in the Springbok Flats Turf Thornveld, and Jordaan (1997) who classified it similarly for sand soils and as an Increaser III on shallow sand soils. Various authors categorize *Aristida congesta var. barbicollis* (Bosch 1989; van Oudtshoorn 1991; Nel *et al.* 1993; Jordaan 1997;) and *Pogonarthria squarrosa* (van Oudtshoorn 1991; Jordaan 1997) as either Increaser II or Increaser III-species. *Tagetes minuta*, a forb associated with disturbed areas (van Wyk & Malan 1988), also responds as an Increaser II species in this management unit.

The moderate-severely utilized to severely over-utilized sectors of the degradation gradient are dominated by *Cynodon dactylon*, a species known to colonises areas that suffered from overgrazing (Gibbs-Russell *et al.* 1991). In the severely over-utilized sector, this species accounted for more than 90% of the composition, with species such as *Eragrostis chloromelas*, *Panicum maximum* and *Mariscus congesta* contributing for the rest.

Figure 39 indicates the relationship between the number of plant species and the level of utilization in this management unit. A significant difference exist between the number of species in the less utilized sectors of the degradation gradient and the species numbers recorded for the severely over-utilized sectors. Maximum species diversity is obtained when the veld is lightly utilized, but species seems to disappear when the veld is severely over-utilized. This was also found by Foran (1976) in the Highland Sourveld.

Figure 40 depicted the arrangement of sample sites in this management unit along the degradation gradient with the degree of erosion in each of them. No significant erosion were detected in the under-utilized and lightly utilized sectors of the gradient. In the moderately utilized sector of the degradation gradient 33.3% of the sites (n=6) revealed light (Scaled 2; 1=none and 4=severe) erosion, with the same percentage showing moderate erosion. Forty-four percent of the sites (n=9) in the moderately seriously over-utilized were lightly eroded. The extreme degraded site on the degradation gradient were moderately eroded. Although only two sites represent the seriously over-utilized sector of the degradation gradient, erosion was detected in both sites. Allowing the condition of the vegetation in this management unit to deteriorate to the level of severely over-utilized sector is in conflict with the set objectives of ensuring controlled and high quality runoff. In this regard the seriously over-utilized sector of the degradation gradient needs to be avoided in the management of this unit.

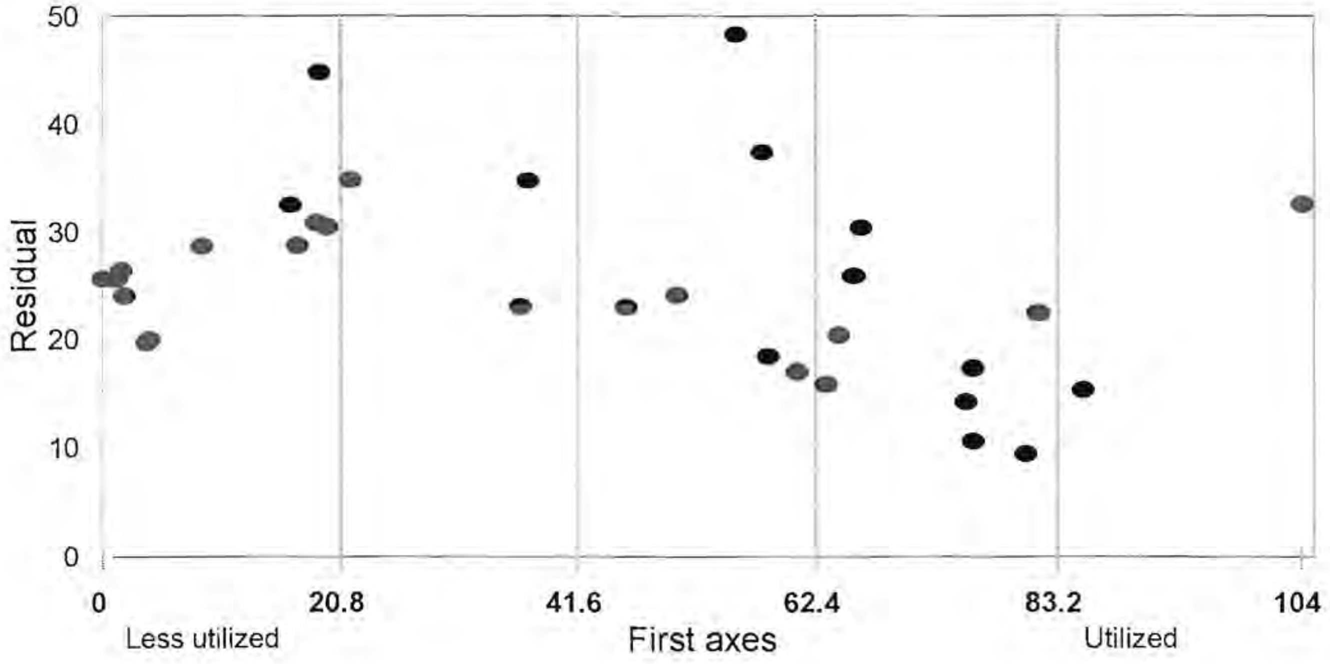


Figure 38: Ordination results of the CPCA ordination of the sites in management unit 3.

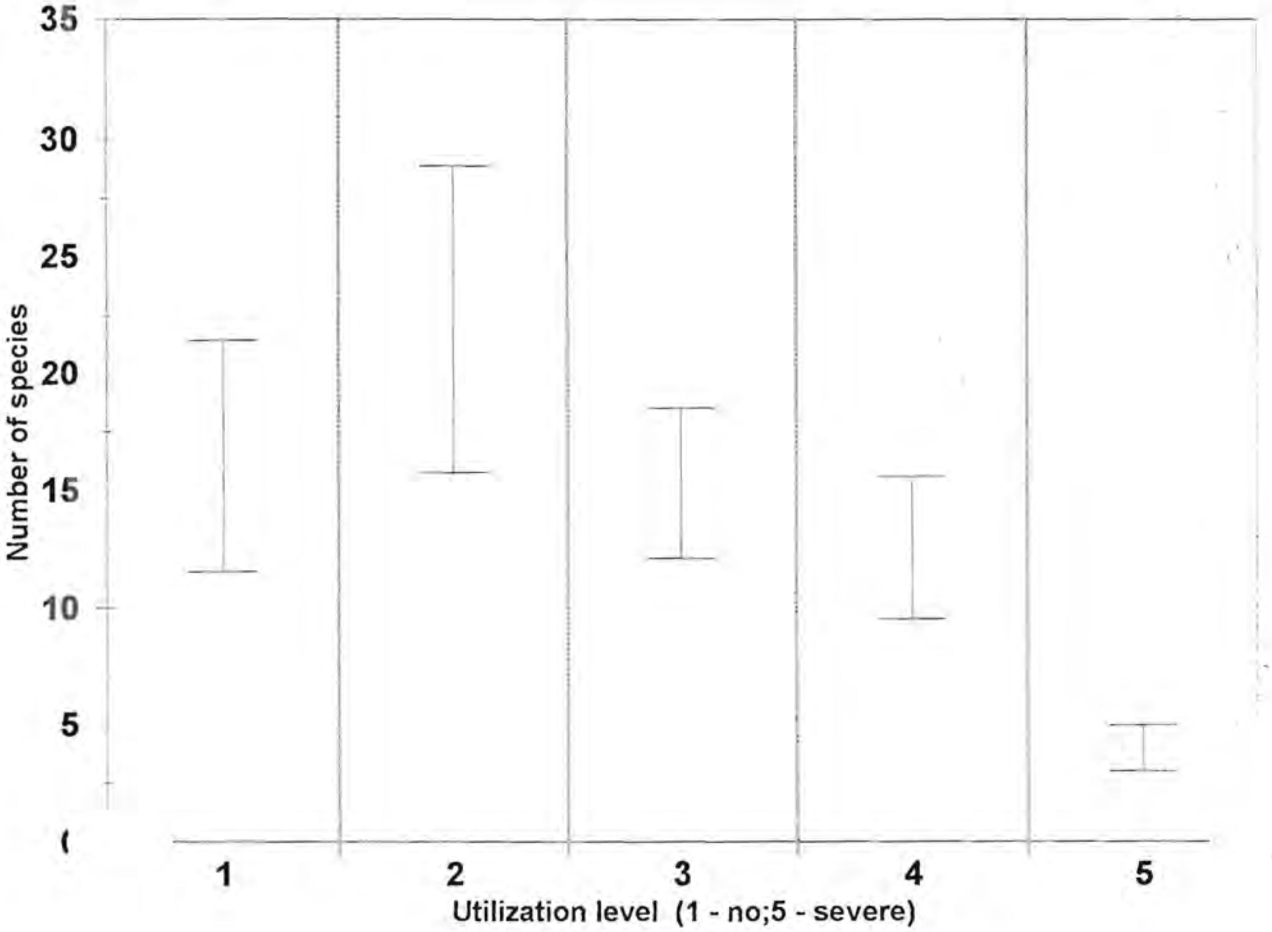


Figure 39 The number of plant species in the different utilization classes along the degradation gradient in management unit 3

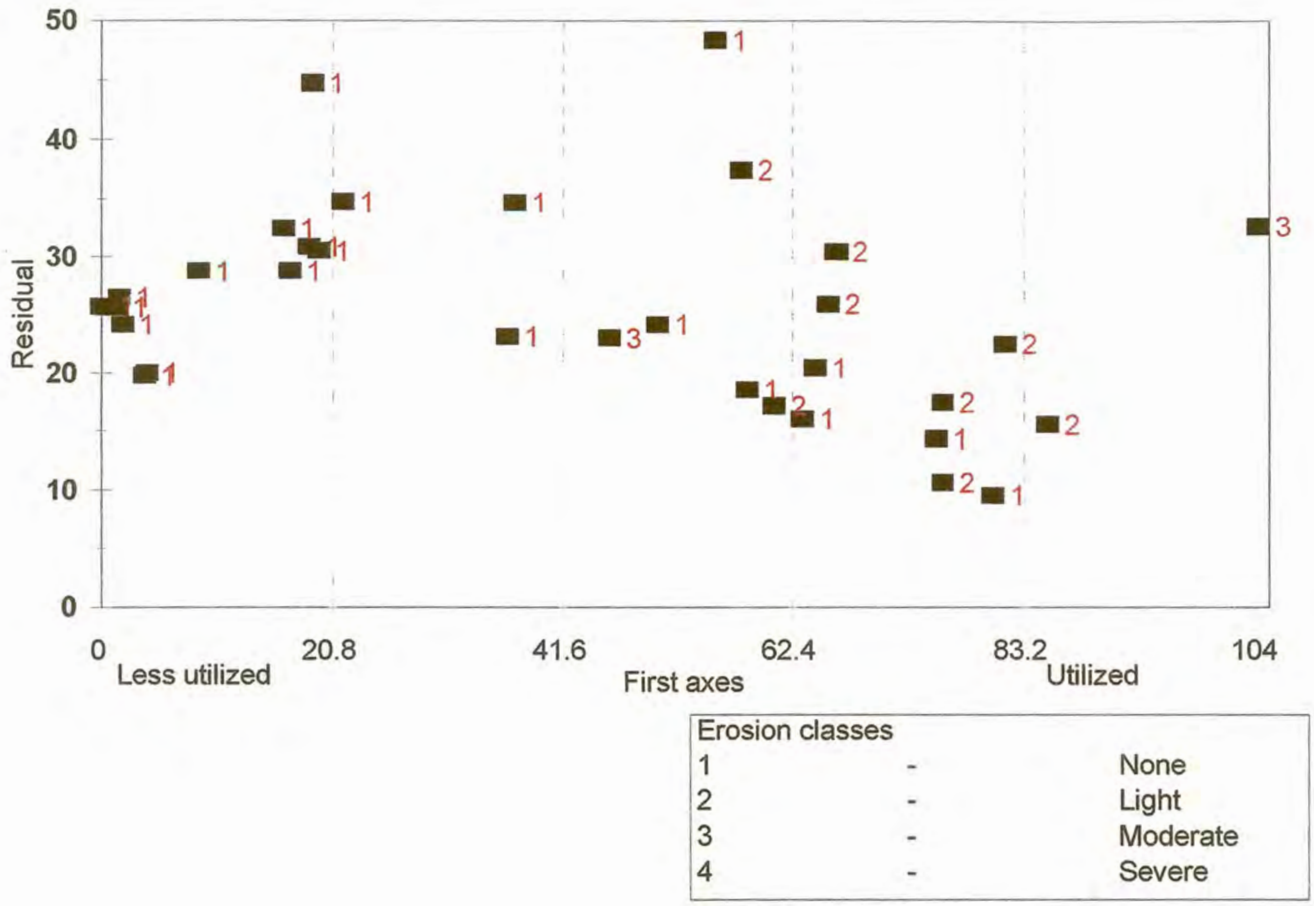


Figure 40: Ordination results of the CPCA ordination of the sites in management unit 3, indicating the amount of erosion in each site.

Application of degradation gradient analysis to monitor veld condition in Rustenburg Nature Reserve

To determine the degree of success of a management strategy, critical parameters must be regularly surveyed and compared with pre-determined goals. The only mechanism to enable a manager to measure the degree to which goals are being achieved, is by regular surveillance and comparing it against pre-determined goals. Without this it is impossible to judge the success of management strategies. Through a process of adaptive management, the management of the reserve can be altered or re-evaluated if proven not to produced the desired effect. Through this process objectives are frequently re-evaluated and refined, which will result in cost-effective management.

An understanding of the process of degradation provides information to interpret the impact of management strategies on the vegetation. This information can be used as a basis for evaluating the impact of a specific management strategy on veld composition and trends (Bosch 1989).

The degradation gradients developed for each of the three management units will be used as a basis for interpreting change in plants species composition over time. These degradation gradients outline the main attribute affecting the achievement of ecological objectives in each of the management units, *viz.* ability of the system to ensure sustained flow of quality water, which is depicted by the ecological status of the veld, species diversity and erosion.

Inserting new samples in the degradation gradient for monitoring purposes

A new sample can be entered onto the degradation gradient in the following two ways (Jordaan 1997; Bosch & Kellner 1991; Bosch & Gauch 1991):

- The new sample is added to the original data set and the ordination is repeated. According to Bosch & Gauch (1991) this method has two principal disadvantages:

  - It requires much more computation, and
  - the ordinations positions of the old data is shifted for each new sample, complicating the ecological interpretation of the data

- Alternatively, and more functional, is that the existing ordination of the data sets of the different vegetation units is retained as is. New samples are brought into the same ordination and the position of the plot on the gradient will provide an indication of the condition of the veld in which the samples were taken. This will enable comparisons between sites (Jordaan 1997).

This second option of including new samples into a stored ordination and retaining the original ordination as it is was used in this study. The ISPD package possesses an option to compare successive veld condition assessments on the same degradation graph using this option. This procedure are fully described in Bosch & Kellner (1991) and Bosch & Gauch (1991).

Although the general habitat conditions for each management unit seem homogenous, the residual values of the CENTRALIZED PRINCIPAL COMPONENT ANALYSES ordination indicate variation in these units. If a new site is inserted into the ordination, it's residual value is calculated (Bosch & Kellner 1991) which provides an indication of its fit in the degradation gradient. A new sample (monitoring site) is regarded appropriate for this model if its residual value is less than half of the Euclidean length of the first axis. ISPD has the ability to incorporated new sites which falls outside the degradation gradient boundaries, without changing the ordination result (Jordaan 1997). In developing a reliable model to assist in the interpretation of ecological monitoring, it is essential that habitat variation inside a management unit be minimised and that focus be placed around the elements that causes change.

Methods

Five monitoring sites were visually selected for each of Management Units 1 and 2 (Jordaan 1997). As a result of the variation in Management Unit 3, 10 sites were selected in this unit. An attempt was made to include veld in different successional stages. These sites were permanently marked and their coordinates were determined by means of a Global Positioning System. These sites were surveyed as described earlier in this chapter and the results of each sample were inserted into the data sets through the screen input option in ISPD. The site was excepted as representative if it's residual value were less than half of the Euclidean length of the first axis.

The results of the analysis indicates that the residual value of all five sites in Management Unit 1 are less than the Maximum Acceptable Residual value, which is half of the Euclidean length of the first axis. This indicates that they are representative of the vegetation in the management unit. The five sites are evenly distributed along the degradation gradient.

In management unit 2, the residual value of four sites are less that the acceptable value. The residual value of the fifth site is unacceptably high and can therefore not be considered for this gradient.

The residual value of three sites in management unit 3 are more than the maximum acceptable value and can not be fitted into the constructed models. The residual value of the remaining seven sites are within the acceptable maximum value.

Figure 41, 42 & 43 depicts the positions of new sites that was entered into the ordination to test the validity of each model, and to evaluated the appropriateness of the sites that was selected inside each management unit.

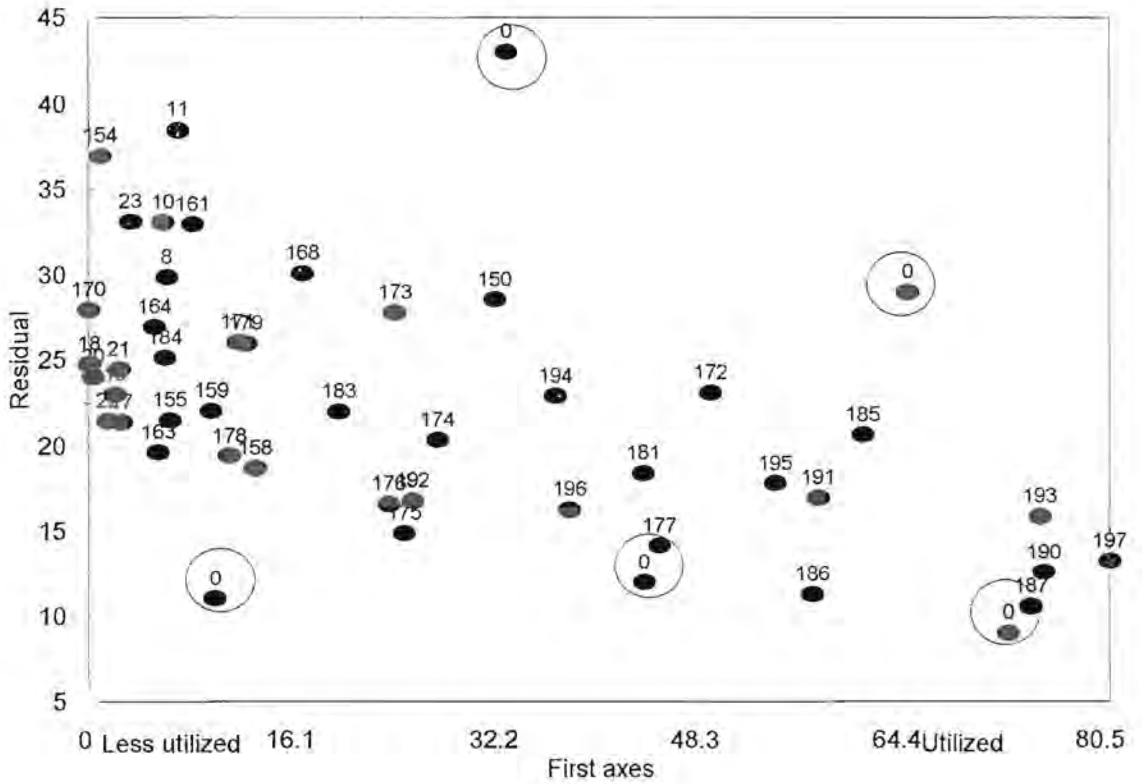


Figure 41 : Positioning of selected monitoring sites on the degradation gradient of the management unit 1

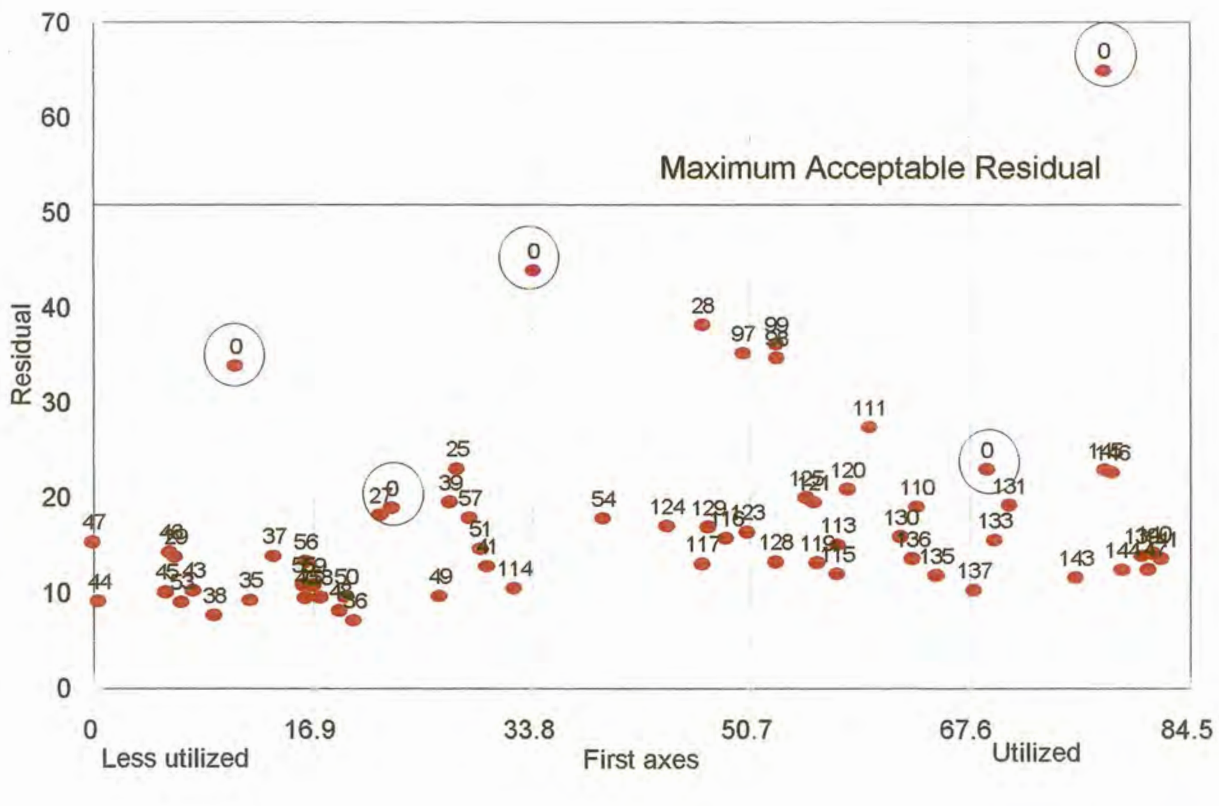


Figure 42: Positioning of selected monitoring sites on the degradation gradient of the management unit 2

CHAPTER 6

MANAGEMENT RECOMMENDATIONS

Veld management

Conservation of "natural areas" are often associated with non or minimal human intervention (Lajeunesse *et al* 1995). Although this may be possible to some extend in huge open conservation areas, small enclosed areas require intervention at certain levels to ensure achievement of objectives.

Two strategies in applied ecology can be identified; deferred action type, which implies that no management can be applied until a system is fully researched and understood, and the adaptive management type, which is management through a process of learning, a "trail and error" - approach (Mentis 1980). Last-mentioned approach has been suggested by several wildlife managers and ecologists as being appropriated in wildlife reserves and game ranches (Pauw 1988; Stuart-Hill 1988; Smith 1992). To qualify and quantify the impact of a management action on the system in order to evaluate the effectiveness thereof, a monitoring system aimed at detecting the rate and direction of change at an appropriate level need to be in place.

The rate and direction of plant succession can be influenced through management in three ways (Lajeunesse *et al* 1995):

- Accelerating natural succession
- Inhibiting the process
- Allowing natural succession to take place (nonintervention option)

These three options will be applied at different levels of ecosystem management in Rustenburg Nature Reserve to achieve specified objectives.

A park manager's influence on the vegetation composition and structure is generally very limited and confined to control over the fire regime and the type and numbers of herbivores (Scholes & Walker 1993). Other more drastic management intervention measures to be applied includes selective or non-selective removal of woody plants to achieve open grassland, active rehabilitation of disturb or denuded areas, active removal and treatment of alien plants and mowing of grassland to reduce vigour or to remove moribund material.

The elements impacting on runoff are best expressed through the water balance (Bosch *et al* 1984):

$$P = (T + I + E_{s+w}) + Q + S$$

where

P	=	gross precipitation
T	=	transpiration
I	=	interception
E_{s+w}	=	evaporation from soil and water surface
Q	=	stream flow
S	=	change in soil moisture storage

and

$$Q \text{ (stream flow)} = P - (T + I + E_{s+w}) - S$$

Figure 44 is a systems representation of the hydrological cycle at catchment level (Wicht 1971).

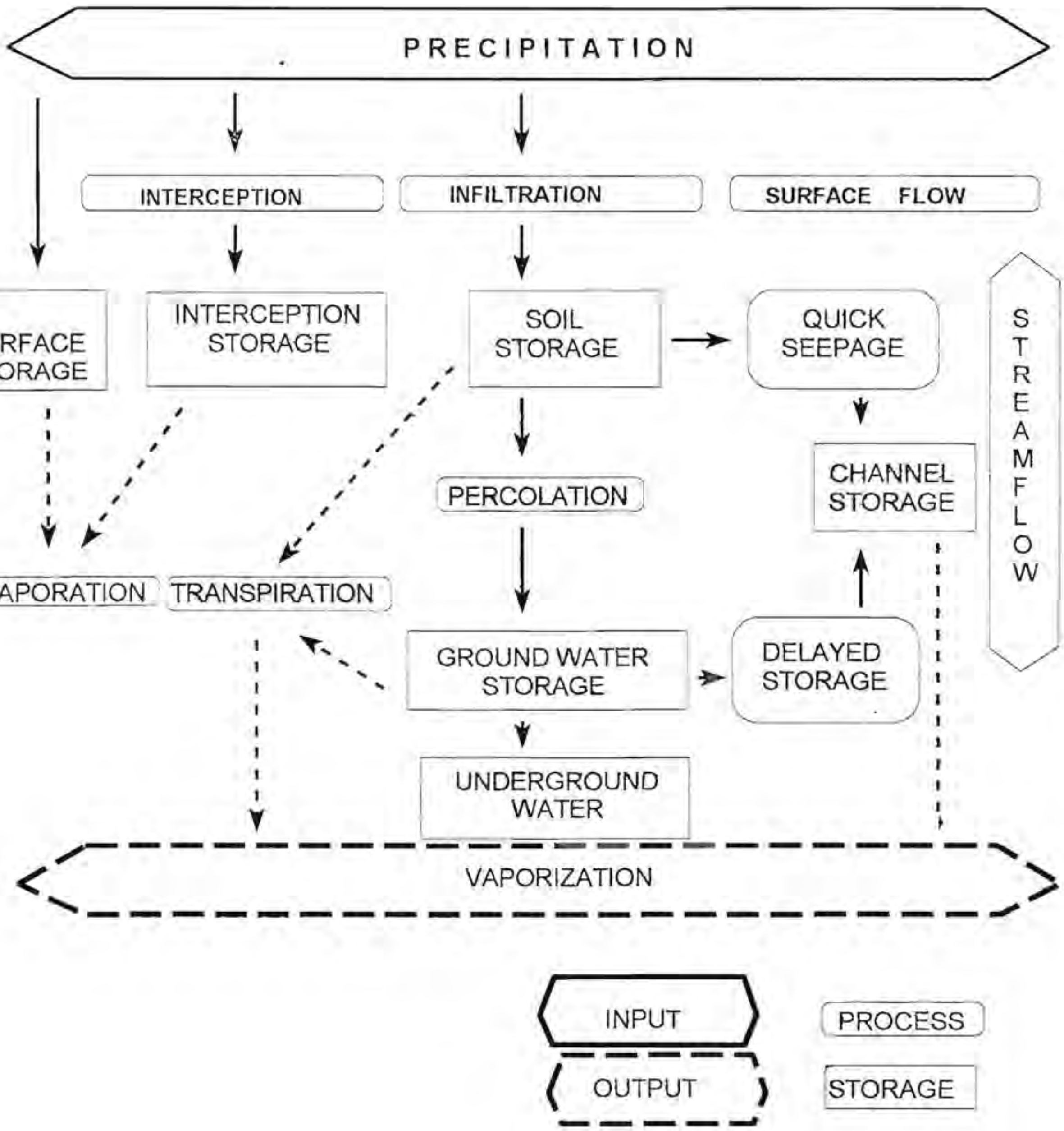


Figure 44: A systems representation of the hydrological cycle at catchment level (Wicht 1971)

As little can be done to effect the gross precipitation, management actions must focus on reducing transpiration, interception, evapotranspiration and changes in soil moisture storage. Transpiration can be reduced by removing or reducing the canopy, which will have other obvious negative impacts, i.e. increased run-off speed with increased risk of erosion and its associated impacts. It does however require the removal of alien vegetation with high water requirements, i.e. *Eucalyptus, Jacaranda, Salix babylonica* and *Populus*.

Precipitation is intercepted by canopy cover and directly returned to the atmosphere through evaporation (Bosch *et al* 1984). Studies in the Western Cape indicated the gross interception loss in a *Pinus radiata* plantation to average 30% of rainfall (Versfeld 1978) in Bosch *et al* 1984). Schulze (1980) calculated values for potential interception losses:

Veld type	Interception loss (mm.day^{-1})
Indigenous forest	+ 3,2
Bush veld and Savanna	1.6 - 4.4
Fynbos	0.8 - 2.0
Grassland	1.2 - 2.6

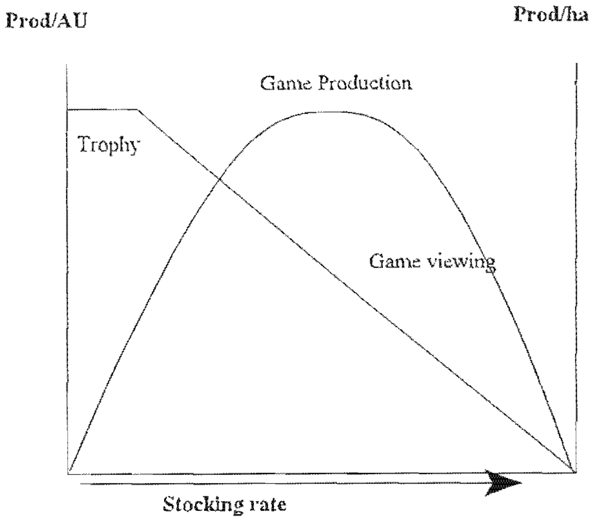
Fire and herbivory will reduce interception losses, but the magnitude of the effect will depend on a number of factors, i.e. post-fire recovery (Bosch *et al* 1984) and the long term effect of frequent fires and intensive herbivory on vegetation composition and structure.

Water infiltration into soil depends on surface factors, such as initial wetness, texture and structure, cover, topographical features and other physical characteristics of the soil profile (Bosch *et al* 1984). Factors such as structure, organic content and cover can be manipulated to some extend through management to improve or reduce water infiltration. By reducing the vegetation cover or organic content of the soil through an indiscriminate burning programme (very intense or frequent fires) or intensive herbivory, the structure and therefore water retention capabilities of the soil will be reduced, which results in increased runoff speeds and a decrease in the rate of water absorption. It can also increases soil evaporation, since the shading effect of vegetation is no longer present and net radiation increases (Bosch *et al* 1984).

The management of the vegetation on Rustenburg will be aimed at maintaining a high canopy and basal cover in order to ensure high infiltration and percolation rate. Within this limitation, it will also be managed to obtain a high plant species diversity and reduced erosion.

GAME MANAGEMENT AND STOCKING RATE

The stocking rate of different game species in an enclosed park or nature reserve is determined by the type and condition of the different available habitats as well as the management objectives for the ranch (Trollope 1990). It must primarily be a function of the grazing and browsing capacity of the veld, which in turn depends on veld condition.



The relation of production of animals against stocking rate

The stocking rate of game should vary in accordance to the management objectives of the reserve (Thompson 1986; Bothma 1989). Stocking rate can be expressed as a percentage of the ecological carrying capacity (ECC). The ECC is the maximum population of animapls that an area can support without deterioration of the habitat (Thompson 1986; Bothma 1989). For maximum venison or animal production it is recommended that the stocking rate should be between 50 and 75% of the Ecological Carrying Capacity (See figure). At this level the rate of increase of an animal population is at its maximum. For trophy hunting, the stocking rate should be below 50% of the ECC, since, at this level, the environmental influences, such as forage is at an optimum for animal performance (Trollope 1990). Conversely for sport hunting and game viewing as is the situation on Rustenburg Nature Reserve, the stocking rate should be higher than the maximum rate of increase, because here the emphasis of management is on maximizing animal numbers within the limitations of catchment conservation (Trollope 1990).

The objectives for the introduction and management of game on the reserve is :

- To be used as a tool in the management of the vegetation structure and composition
- to increase the numbers of the game currently on the reserve to levels where they can be used on a sustainable basis. Given the realities of shrinking government support, pressure on optimising income from natural resources is increasing. To improve the visitor's experience to the reserve, it is envisaged to improve game viewing in the reserve by optimizing the number and diversity of game in the park, especially the highly visible species suitable to this environment such as sable antelope and waterbuck (*Kobus ellipsiprymnus*). Further introductions should be considered against their role in the achievement of reserves goals and objectives.
- where feasible, to breed endangered and valuable species, i.e. sable antelope and roan antelope.

Initial carrying capacity estimates can only be used as a guideline. Changes in veld condition as a result of variable rainfall and management affect carrying capacity of the veld continuously. Rainfall is considered a determining factor in the production of the herbaceous layer in the arid and semi-arid areas, and as carrying capacity is closely related to rainfall , it should be adjusted annually. The principle of adaptive management, which will be applied in the management of Rustenburg Nature Reserve, require continuous evaluation and adjustment of management strategies as their impact on the system become evident. This principle will also be applied in the management of game and in the refinement of the stocking rate of the game. The impact of herbivory on cover and structure of the vegetation will be evaluated against the primary goal of catchment conservation and management. The rate and direction of change of monitoring sites along a degradation gradient will dictate the impact of current stocking levels on veld condition.

Optimal production of key animal species

If the general effect of stocking rate on animal performance is considered(Jones & Sandland 1974), it is clear that, at low stocking rates production per animal unit is at maximum. After a certain period, when competition for forage occurs, production per animal unit decreases linearly to zero.

Conversely, at low stocking rates animal production per hectare is low, but increases with an increase in stocking rate until it reaches a maximum after which animal performance decreases to zero. If the objective of management is to maximize production per animal unit (as in trophy hunting) a low stocking rate should be applied. If the emphasis is on venison production, a stocking rate should be applied that will maximize production per hectare.

Fairall (1985) constructed a population simulation model using biological data from wild populations of impala to illustrate the effect of sex and age ratio manipulation on productivity. A model population of 1000 animals was assumed to be the economic carrying capacity of the environment and the population growth rate was seen to be 13%. When the sex ratio was changed from 1♂:3♀ to 1♂: 10♀, productivity was shown to increase by 30%. If all individuals older than three years were harvested, an increase of 138% was achieved. It must however be stressed that this model is only applicable to impala.

The following are principles regarding optimal production:

* Non-productive excess animals must be removed
* Skewed sex ratios can have a negative influences on production
* Competition between animals for food and space should be minimized if they are expected to perform optimally
* Production per hectare is reduced if all potential habitat is not in healthy state

Mentis (1981) classified ruminant and non-ruminant ungulates according to their relative potential for defoliation and selective grazing:

- Bulk grazers: large animals which normally do not exercise a high degree of selection, i.e. zebra, waterbuck, buffalo and cattle.
- Concentrate/Selective grazers : Small animals which are predominantly grazers, i.e. springbuck, red hartebeest, roan antelope, sable antelope and oribi
- Mixed feeders: Animals that feeds both on grass and brows, pods, leaves, forbs, i.e. eland, impala
- Browsers: Animals that feed mostly on leaves, flowers, pods and fruits, i.e. kudu, bushbuck.

Mentis & Duke (1976), and Mentis (1977) suggest that the metabolic mass of concentrate grazers should not be permitted to exceed that of bulk grazers in any grazing unit.

Collinson & Goodman (1982) classified herbivores in Types 1 to 4 according to their impact on their habitat, their ability to change their habitat and the effects the change have on other species:

- Type 1: Animals that affect significant changes in the structure and composition of their habitat; i.e elephant, zebra and buffalo
- Type 2: Animals that tend to decrease because of the impact of Type 1 and Type 3 animals on their habitat. These are generally low density species that are negatively affected by competition, i.e. roan antelope, sable antelope and tsessebe
- Type 3: Animals that increase as a direct result of the impact that type 1 species have on their environment. These are species such as red hartebeest, springbuck, impala and oribi
- Type 4: Game species that increase in numbers because of the effect of Type 1 & 3 animals, i.e Kudu, Giraffe

Current performance of important game species and general discussions

Introduction

Game were introduced into the reserve in the early seventies. Various game census techniques, ranging from drive counts to modified road strip counts were applied. The data, collated in the game register, is very inconsistent and trends are difficult to distinguish and explain. During the analyses of the data, the need for a standardized, repeatable census technique become evident. A standardized census technique for Rustenburg Nature Reserve was developed in this study and is described later in the chapter. It was implemented in 1995. Count results have since improved and comparisons between data sets are now possible.

Game numbers collected through annual censusses were analysed to provide an indication of trends in the different game populations in the reserve. These trends provide the basis for future management of the various populations.
During the analysis of the count data on the reserve since 1985, two procedures

to determined the rate of growth in game populations were applied to the data sets. These procedures were used to "smooth - out" fluctuations between successive counts, due to inconsistent counting techniques and human error. These two procedures produced growth curves, which when applied to the data sets gives an indication of fit to the actual data, and also future responses and growth in the population

The finite growth rate - the growth in a population between successive counts - is determined by the following formula (Bothma 1995):

$$\lambda = (N_{t+1})/N_t$$

where	λ	=	finite rate of growth
	N_t	=	Population size in year t
	N_{t+1}	=	Population size in year t+1

The exponential growth rate can be used to determined the average growth rate in a population where annual fluctuations is significant as a result of changing environmental factors or count results (Bothma 1995). The exponential growth rate is calculated as follows:

$$r = \frac{\Sigma\, Nt - (\Sigma N)\Sigma\, t/n}{\Sigma t^2 - (\Sigma t)^2/n}$$

where	r	=	average exponential growth rate
	N	=	natural logarithm (base e) of each count
	t	=	time
	Σ	=	sum of
	n	=	number of counts

These two formulas were applied to the data and growth curves were produced, which, when fitted to the actual counts, provided an indication of population response and trends.

Discussion

Sable antelope have been classified as type II herbivores (Collinson & Goodman 1982). Rustenburg Nature Reserve provide adequate habitat for sable antelope, provided protein and phosphorous deficiencies are addressed (Wilson 1975). Sable antelope were introduced into the reserve in 1967 (Wilson 1975). Twelve animals were brought into the reserve and the population increased very slowly initially. The proportions of juveniles seen annually were higher to the proportion of yearlings. However, the number of adults, especially cows remained constant. Wilson (1975) suggested a high mortality rate amongst this sex and age class, although no carcasses could be found.

The actual counts of the sable antelope population in the reserve since 1985 indicates an average finite growth of 8.9%, and a exponential growth rate of 6.47% over the 15 year period (Figure 45). The actual count figures over this period also indicate a distinct period between 1990 and 1995 where the population trend suddenly stabilized between 36 and 42 animals. The count for 1993 (n = 53) does not fit the population trend, due to sampling error and human factor. From 1996 the growth in the sable antelope population resumed at an increased rate of 17.9%. In 1996 a strategy was adopted to apply control burns at the end of the growing season. (See Burning program). The rationale for applying late summer burns was to ensure green flush during winter. Estes (1990) indicated that green plants, forbs and foliage makes up 20% of their diet. Forage quality is dependant on the removal of tall, dormant leave material within a month after the rains end (Estes 1990). Observations by park staff (Crowther[9] & Goosen[10] *pers comm*) indicated that the sable antelope used these burned areas extensively during the dormant season.

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9 Michael Crowther, Former warden, Rustenburg Nature Reserve, currently Pilanesberg National Park, North West Province

10 Magda Goosen, Warden, Rustenburg Nature Reserve

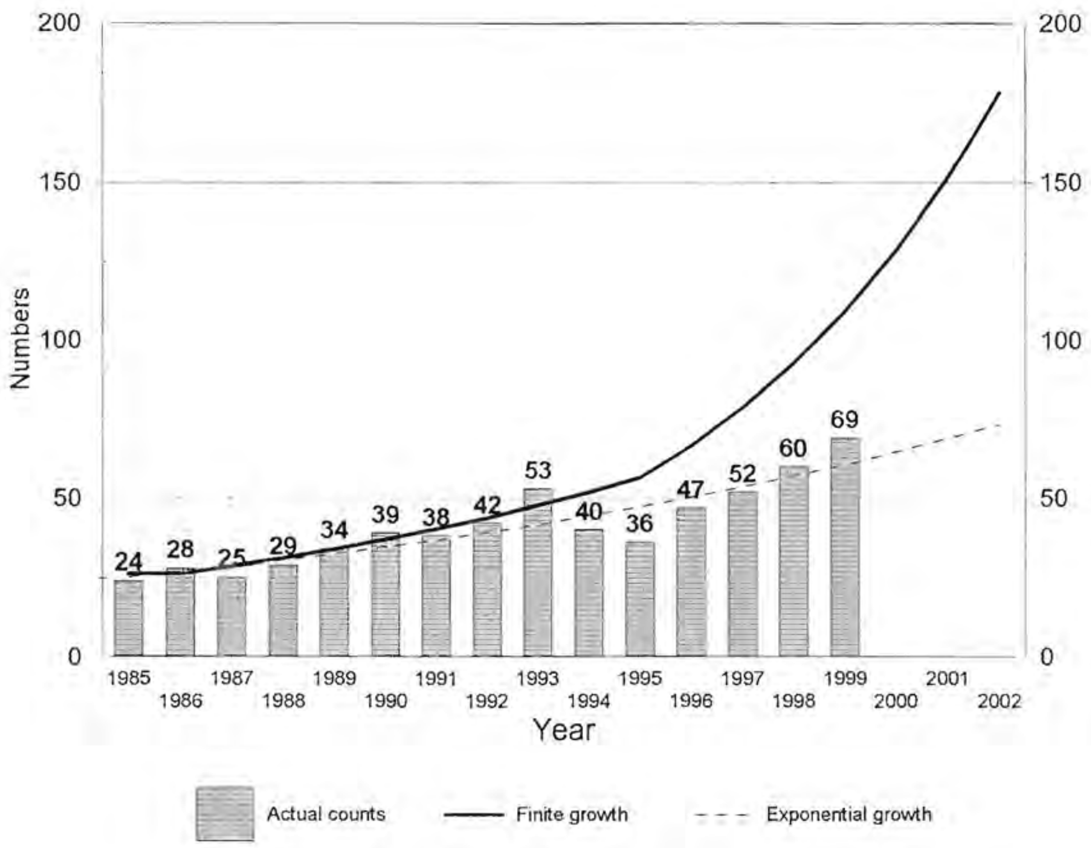

Figure 45: The trend in the population of sable antelope on Rustenburg Nature Reserve since 1985

Natural salt blocks were placed out for the use by the sable. Sable antelope uses salt regularly (Estes 1990). Calf survival rates increased significantly. At the current finite growth rate the sable population will reach a 100 animals in 2002. Sable antelope is vêry sensitive to competition from other species (Wilson 1975), especially zebra (Grobler 1974) and waterbuck (Du Toit 1992). They favour a mosaic of open woodland and medium to tall grassland, in the mid-succession to climax stage(Estes 1990). These species compete directly with sable antelope and their numbers should be controlled at levels where they do not adversely affect the performance of the sable antelope population. The habitat requirements for sable antelope, and the management of their preferred habitat are compatible with the vegetation objectives of the reserve, *viz.* the maintenance of a resilient ecosystem inside the reserve, capable of enduring excessive runoff and maximise absorption of water. The sable antelope population should be managed at approximately 75% of ecological carrying capacity. It is recommended that removals only be considered once the sable antelope number on the reserve has passed this level significantly and a sufficiently sized group animals can be removed at once. As a conservation organization, the North West Parks & Tourism Board should encourage founder groups of these animals of adequate size (~ 15+) to be introduced into areas where they do not occur.

Impala are predominantly grazers while the nutritional quality and palatability of grasses are still at acceptable levels (Estes 1990; Pietersen *et al* 1993; Brown 1997). In the winter months and during droughts they will revert back to browse. (Dunham 1981). Atwell & Bhika (1985) found that impala meet the requirements of an optimal forager, as its dietary range of reflects selection for high protein components. Studies by Beardall *et al* (1984) in Kruger National Park indicated that they prefer the lower lying areas along drainage lines, with short grass and generally more trampled and disturbed, under an open woodland (Estes 1990). A further important feature is the indication of an ecological segregation between impala and zebra (Beardall *et al* 1984). This segregation was also found by Dekker *et al* (1996) in a study in the Northern Province of South Africa. The situation on Rustenburg Nature Reserve confirm this finding. Impala are mainly found on the edges of the *Becium obovatum - Protea caffra* Tall Closed

Woodland in the central basin, and in the open areas in the south easterly valleys. The population in the reserve has stabilized despite removals (Figure 46). However, the accuracy of the aerial census for estimating impala numbers is unknown, as is the precision. Aerial counts have the disadvantage that relative inconspicuous animals are difficult to locate from the air, especially in densely wooded areas (Collinson 1985). Counts must be replicated to detect variances between the counts (Reilly *et al* 1998).

Eland are classified as mixed grazers (Buys 1990), selecting only high quality food. They use grasses only when young, but revert back to browsing when the nutritional quality of the grass decreases in the winter months (Melton & Snyman 1989). This is also evident in Rustenburg Nature Reserve. Newbery (*pers.comm*)[11] observed eland causing extensive damage to the trees and shrubs in the *Becium obovatum - Protea caffra* Tall Closed Woodland during the winter months. In Rustenburg Nature Reserve they were observed browsing on woody plants such as *Acacia caffra, Ziziphus mucronata* and *Diospyros lycioides* (Newbery (*pers.comm*); personal observation). The eland population has increased from 19 animals in 1985 to 67 in 1999, growing at an exponential rate of 8,5% and an average finite growth rate of 14,1% (Figure 47). Although the population is still growing exponentially, their impact on key vegetation features in the reserve is becoming visible. At the current growth rate, it is estimated that the eland population should reach a 100 animals by 2002. However, it is recommended that the population be kept at 80 animals.

The waterbuck population in the reserve is increasing at a mean finite growth of 17.4%, and exponentially at 8.67%. The population stabilized at between 30 and 45 animals since 1997, and 15 individuals were introduced, bringing the current population to 60 animals (Figure 48). An important component in the waterbuck habitat is their association with water. This feature, in combination with cover and open grassland are the main characteristics of waterbuck habitat (Estes 1990).

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11 Newbery, RE. Field ecologist, Rustenburg Nature Reserve, Rustenburg

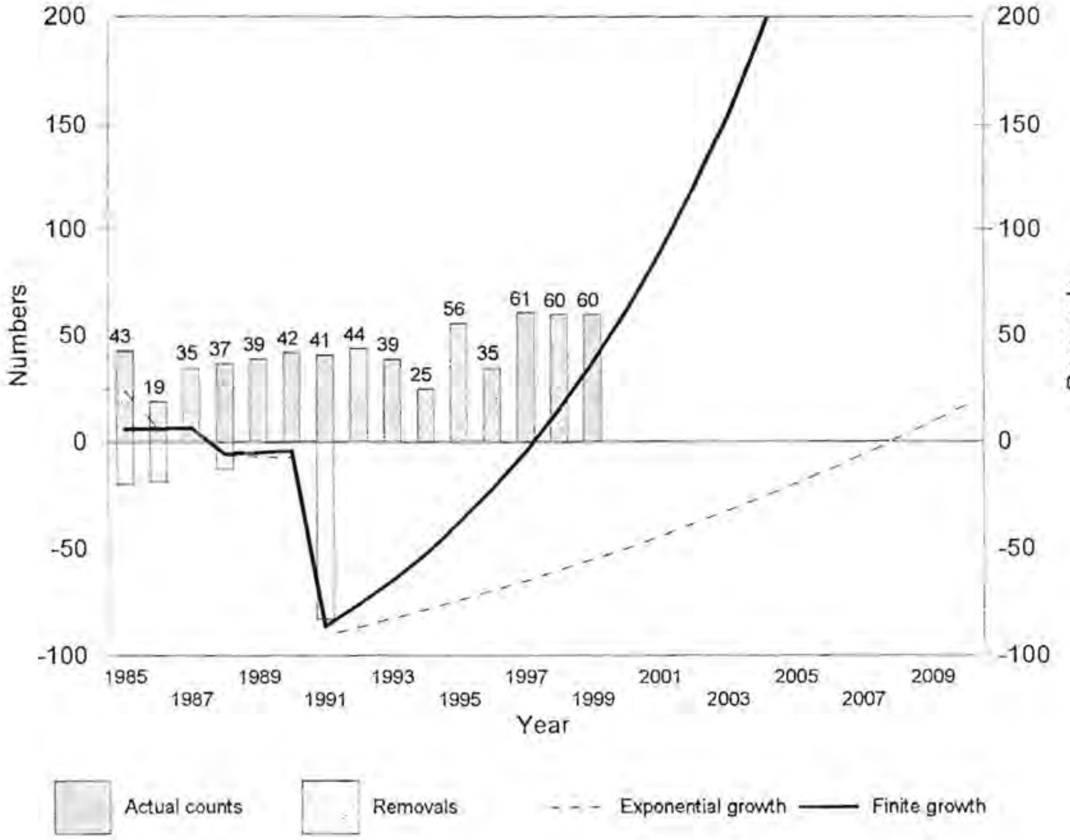

Figure 45: The trend in the population of impala on Rustenburg Nature Reserve since 1985

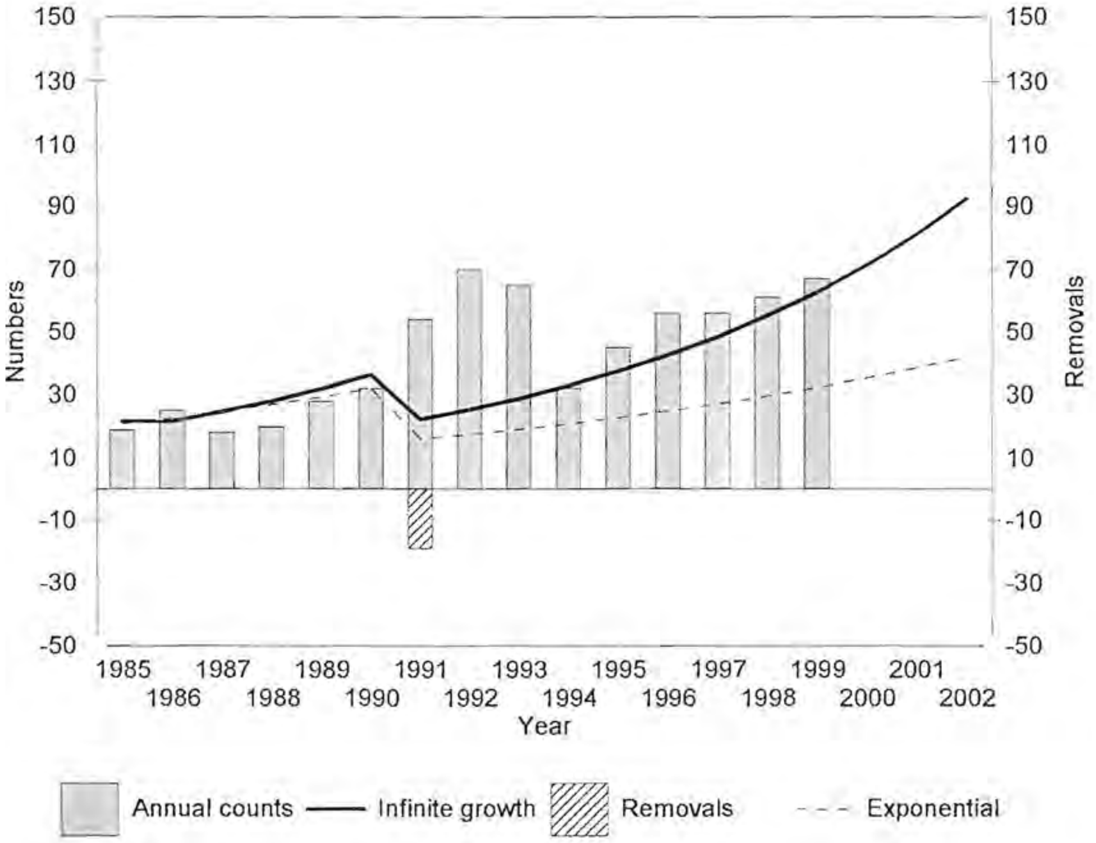

Figure 47: The trend in the population of eland on Rustenburg Nature Reserve since 1985

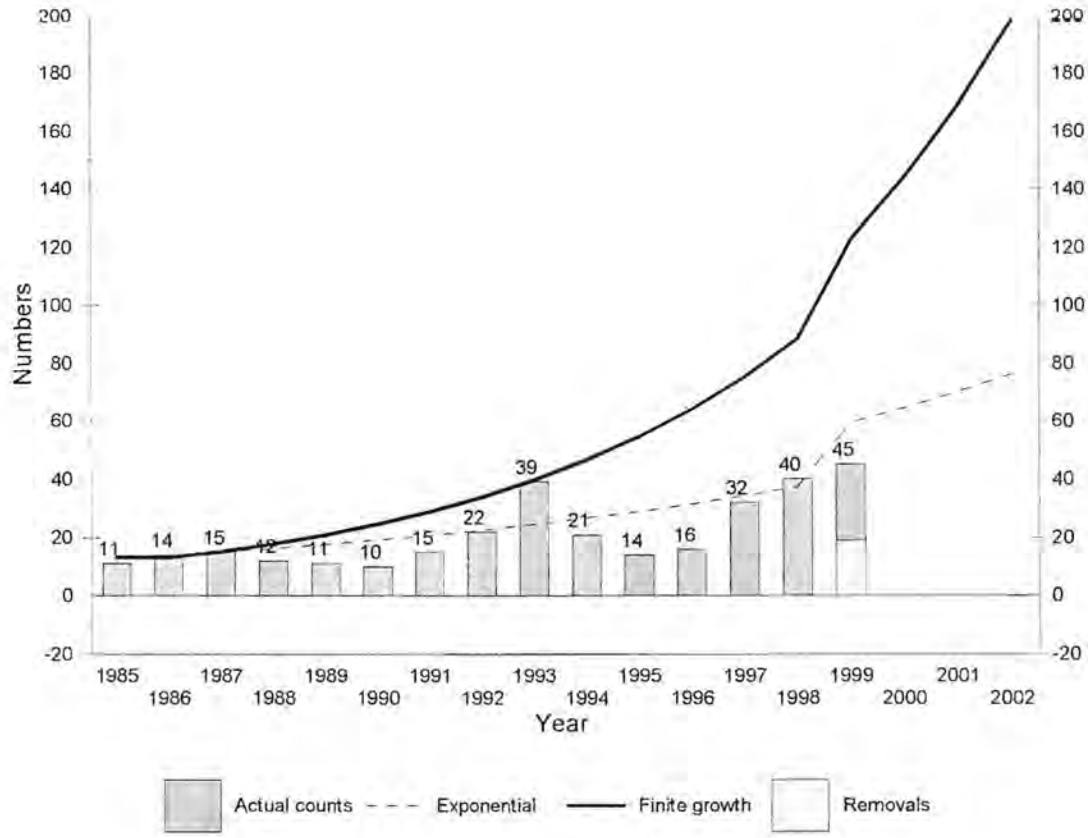

Figure 48: The trend in the population of waterbuck on Rustenburg Nature Reserve since 1985

They also prefer areas with tall grass and accumulated litter (Beardall *et al* 1984). This is contradicted in a study by Wentzel *et al* (1991). His studies indicated a significant difference between the preferred areas of buffalo and waterbuck, with waterbuck preferring areas with low phytomass in varying degrees of over utilization. In the Zambesi valley they also occur on rocky slopes near the river (Skinner *et al* 1990). In Rustenburg Nature Reserve they are associated with areas of long grass in and around the reedmarsh in the central basin, and the bottom lands in the southeasterly valleys. The herbaceous layer in the lowlying areas of these valleys is dominated by *Panicum maximum*, a good quality grass preferred by waterbuck (Skinner *et al* 1990). As waterbuck is in direct competition with sable antelope, their numbers should not be allowed to increase to levels where they will impact on sable.

Zebra uses a wide range of habitats, from open areas with long grass (De Wet 1988; Wentzel *et al* 1991) to open woodland (Estes 1990). Although they are not very selective for specific grass species, they, however, prefer long palatable grasses (De Wet 1988; Dekker *et al* 1996) and will avoid unpalatable woody species (Wentzel *et al* 1991). Zebra is successful and prolific in Rustenburg Nature Reserve, making up the bulk of the animal biomass on the reserve. The population increases at a mean finite growth rate of 12,9%, and an exponential rate of 9.66%(Figure 49). Burchell's zebra are classified as Type I herbivores and they can, together with Type III herbivores cause drastic changes in the habitat, which can be to the detriment of Type II animals, i.e. sable and roan (Collinson & Goodman 1982) and also impact adversely on the primary objective of Rustenburg Nature Reserve. Zebra numbers on the reserve should be allowed to flux between 150 and 200 animals.

Red hartebeest occur in open grasslands and open woodland, avoiding dense woodland (Estes 1990; Skinner *et al* 1990). Kok (1975) have found that hartebeest preferred the transitional zones between open woodland and grassland in the Willem Pretorius Nature Reserve. Bull herds will move into thicker woodland, allowing the females to use the grasslands and fringes of open

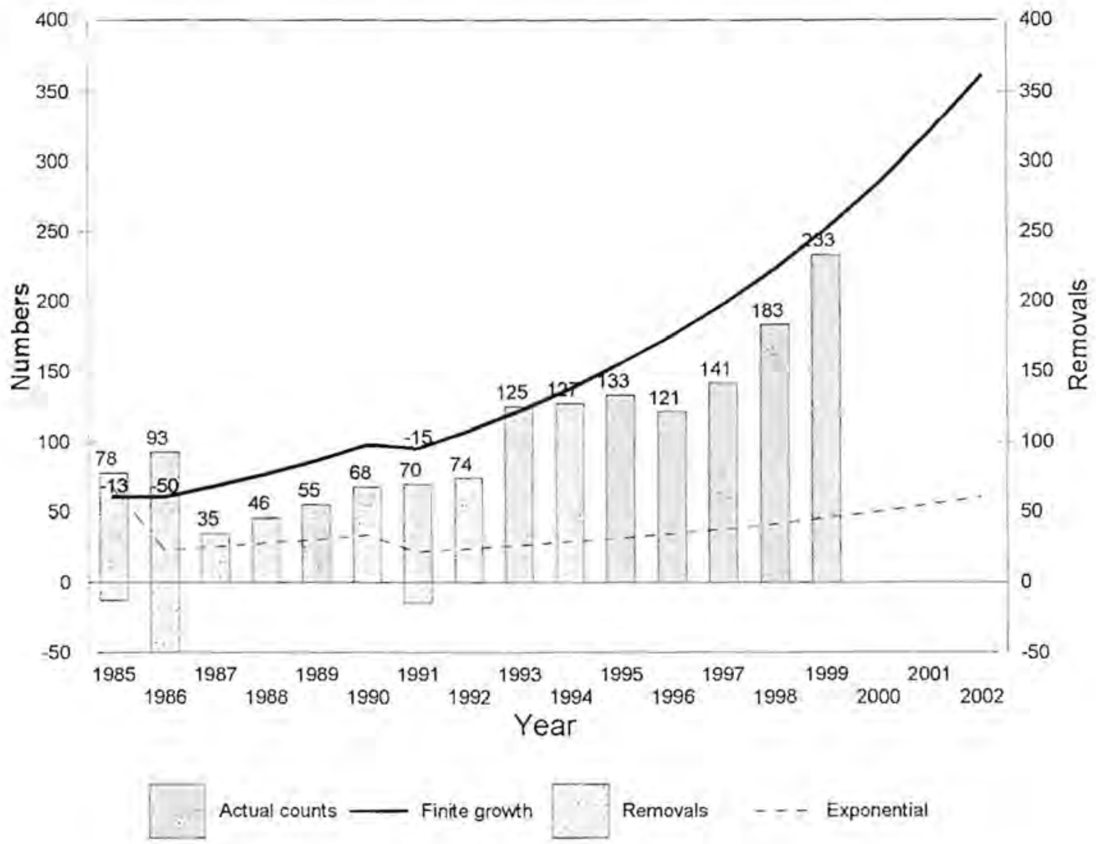

Figure 4?: The trend in the population of zebra on Rustenburg Nature Reserve since 1985

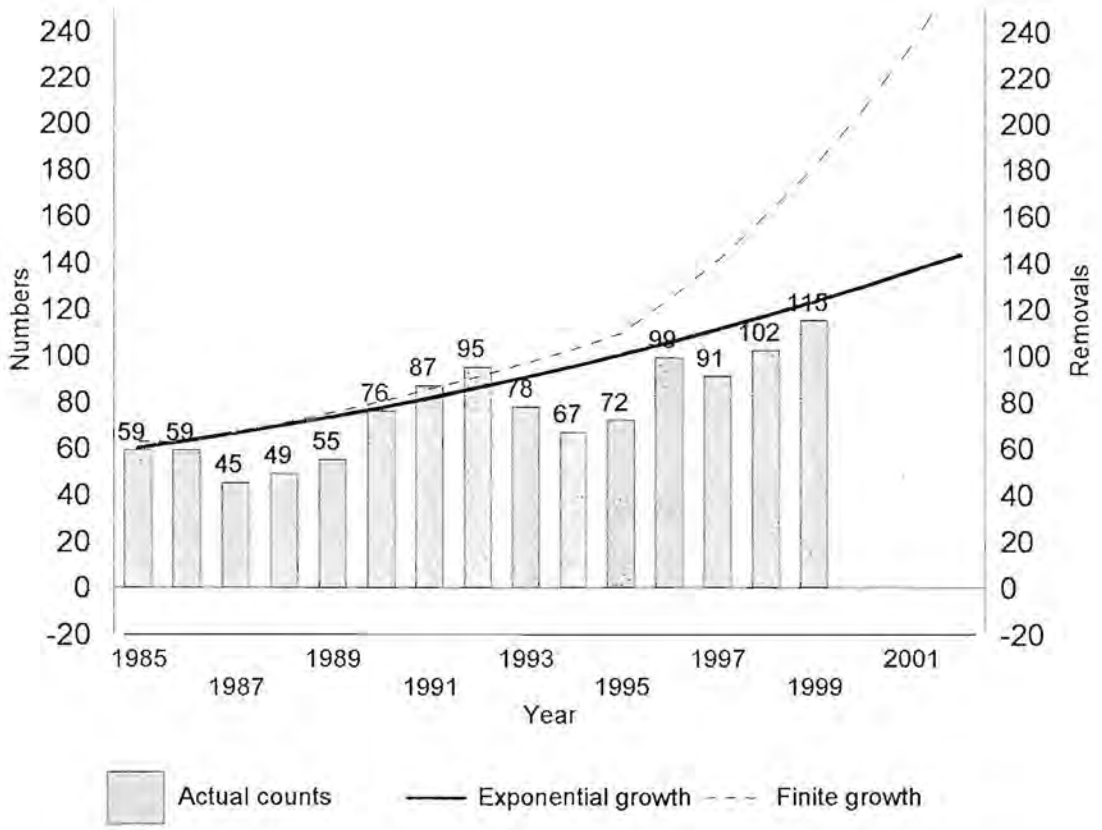

Figure 50: The trend in the population of red hartebeest on Rustenburg Nature Reserve since 1985

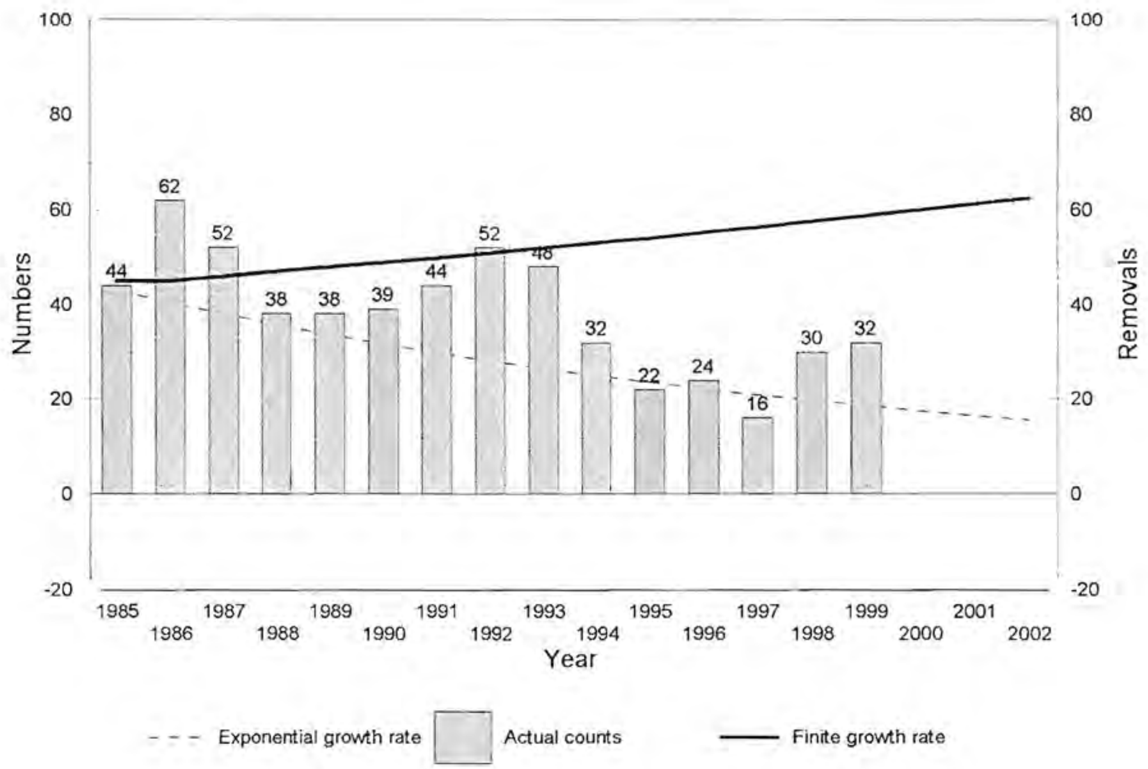

Figure 51 : The trend in the population of springbuck on Rustenburg Nature Reserve since 1985

woodlands (Kok & Opperman 1975). This segregation between the sexes in a specific area is a possible mechanism to reduce intraspecies competition (Kok & Opperman 1975). The trend in the red hartebeest population on the reserve shows distinct inclines and declines, and increasing to levels beyond the previous peak. The population are growing slowly at a mean finite rate of 6.4% and exponentially at a rate of 5.26%(Figure 50). They occur predominantly in the grassland in the central basin and the open *Protea caffra* woodlands on the northern plateau. They do not compete directly with sable, but as a Type III animal (Collinson & Goodman 1982), their numbers should be closely monitored.

Springbuck prefer open plains in the arid parts of the country (Estes 1990). They avoid mountainous areas, rocky hills, thick woodlands and areas of tall grass (Skinner *et al* 1990). They are generalist feeders, preferring more dicotyledons than monocotyledons (Liversidge & Gubb 1994). This makes the reserve a very marginal area for springbuck. This fact is reflected in the performance of springbuck on the reserve. The population grew at a very slow mean finite rate of 2.1%, and shows a negative exponential growth of -5.81%, indicating that the population is heading towards extinction on the reserve (Figure 51). A weak negative correlation (r^2 =0.35) exist between rainfall and springbuck numbers, where springbuck numbers increased during dryer periods and decreased during the wetter years. Managing habitat for springbuck on the reserve will imply a strategy of transforming the status of the veld from climax and sub-climax to veld dominated by pioneer grass species and forbs. This is not compatible with the primary objective of the reserve, *viz.* catchment conservation. Springbuck should therefore be removed from the reserve, or merely be managed as a species to enhance diversity for game viewing. The latter option is recommended.

Kudus prefer the bottom lands and foot slopes of the eastern range of valleys in the reserve. The trend in the kudu population in the reserve is difficult to explain, and it is excepted that the population is a relative open population, moving in and out of the reserve as the environment changes. The precision and accuracy of the kudu counts is not known. However, the same complexities and problems in the use of aerial counts in wooded areas are also applicable to kudu (Collinson 1985).

Kudu is not regarded as an important species to be managed and seems to be regulating their own numbers by moving in and out of the reserve. As residential development moves closer to the reserve's boundaries, this will have to be reviewed.

Giraffe is essentially browsers (Oates 1972), but will also graze grass and shrubs. They have a broad habitat preference ranging from dry savannas scrub to woodland (Goodman & Tomkinson 1987). They avoid forests and open grassland (Skinner *et al* 1990). Males tend to retract into densely wooded habitats which promotes sexual segregation. Another important habitat requirement is a horizontal or gently undulated surface. Giraffe avoids rocky hills and steep slopes (Ebedes[12] *pers.comm*). Gerber (1989) attribute the steep and rocky slopes on the reserve as a limiting factor in niche selection on the reserve. According to Furstenburg (1991) the feeding selection of giraffe is determined by:

- Condensed tannins in browse material
- Palatability and moisture content of the feeding material
- Nutritional value of food
- Availability of feeding plants
- Physical defence agents on the feeding plants and anatomical structure of plant material
- Structure of habitat
- General suitability of the habitat

Gerber (1989) found *Acacia karroo, Acacia caffra* and *Rhus lancea* to be the important feeding plants of giraffe in Rustenburg Nature Reserve. The percentage dry mass condensed tannin concentrations (DCTC) for the three species as determined by Gerber (1989) were 25.03%, 17.16% and 22.78% respectively, relatively high compared to other species favoured by giraffe in the reserve, i.e. *Ziziphus mucronata, Tapinanthus rubromarginatus* and *Diospyros lycioides*. Gerber (1989) also found that giraffe used *R. lancea* significantly more than *Acacia caffra* and *A. karroo*, despite its high DCTC. The reason she gave is that

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R. lancea as an evergreen tree have more leaf material available than the other two species.

Giraffe were introduced into the reserve in the late seventies. Their numbers increased slowly to 14 animals in 1992. Four animals were removed in 1992. In 1993 six giraffe died over a period of two months during June and July. A *post mortem* investigation did not reveal any conclusive reason for these sudden mortalities. Bone pieces found in the rumen suggest osteophagia. This is an indication of mineral deficiencies in their diet. According to Skinner *et al* (1990) giraffe tends to revert to osteophagia in the dry season to gain a balanced ratio of calcium and phosphorous in their diet. According to Ebedes (*pers. comm*) giraffe is very susceptible to infection by *Clostridium botulinum*, causing botulism. This bacteria occurs in carcasses. Further giraffe mortalities resulted in the population currently being a single male. The reserve does not appear to have sufficient habitat for giraffe. Giraffe is a very visual species and important for tourist viewing. The economic implications of re-introducing giraffe into the reserve and managing them intensively needs to be investigated thoroughly.

Roan antelope are very sensitive to changes in their habitat, be it changes in vegetation structure or composition. They select open woodland with tall perennial grasses, often growing in leached, nutrient poor soils (Joubert 1976; Estes 1990; Dörgeloh *et al* 1996), and close to flood plains or steams (Pienaar 1974). In the Weenen Nature reserve, Perrin and Taolo (1999) found that roan antelope are selective feeders, feeding on only two or three grass species in the reserve. They were also observed browsing on dicotyledons in the dry winter months, a possible indication of insufficient grassland habitat (Perrin and Taolo 1999). Palatable perennial species, i.e. *Themeda triandra* were selected throughout the year. Increaser I grass species *Hyparrhenia* species were only selected in the late summer months. As these species became more stemmy, unpalatable and low in nutritional value, they were avoided and Increaser II species, i.e. *Melinus* species and *Eragrostis* species were selected (Perrin and Taolo 1999). A study in Nylsvlei nature reserve indicated that roan selected newly burnt areas (younger than six months) significantly (Dörgeloh 1998). According to Nel (1992) roan antelope calves are very susceptible to infestation by ticks and cytoxcynose and the control of ticks is important in the survival of the calves. Dörgeloh *et al* (1996) also indicated a significant correlation between supplementary feeding and population growth. In two case studies high population growth rates were obtained through intensive management. Animals were fed with a combination of lucerne, antelope cubes and lick, and parasite and predator control were implemented. Competitive species were removed or significantly reduced. Roan were introduced into the reserve in 1999. Only four animals were released. This population needs to be supplemented with at least another 20 animals to make this repatriation viable. The protein and phosphorous deficiencies (Wilson 1975) must be addressed through appropriate licks and supplementary feeding. Both roan antelope and sable antelope are extremely suspicious of any form of supplement block, but will take salt in the field. This offers a way of supplementing minerals as well (Wilson 1975)

Monitoring

To be able to achieve the objective of maximum sustained yields, information on the population dynamics should be collected. Monitoring of these populations will have to be intensified and regular game censuses will have to be done.

Game censusses

To enable the managers to make informed decisions on game management and habitat manipulation, it is necessary to know the number of animals in a protected area and the trends of the different populations (Collinson 1985;Peel 1990; Reilly 1994; Bothma 1995; Reilly & Emslie 1998).

A comprehensive monitoring plan for game needs to provide for the objective of game management in the area. It should also provide management with the correct information, the way in which information on the different species will be collected and the analysis and interpretation of population trends.

Reliable estimates of game numbers depends on accuracy and precision (Peel & Bothma 1995). The results of a census are accurate when it compares favourably with the real situation. Achieving accurate counts are very difficult, as nobody knows exactly how many game are present on the land. The precision is the variation within the counting technique applied, i.e. the difference between successive counts. The smaller the variability, the higher the precision.

Two approaches or strategies can be followed to determined the number of game, depending on the size of the area and distribution of the animals (Collinson 1985; Reilly 1994):

- *Sampling strategy*, where only part of the area is counted. The actual number of animals is determined by extrapolating it to the rest of the area
- *Non sampling strategy* where the total area is counted, assuming that all animals are spotted and counted.

The following criteria are used to select a census technique (Collinson 1985):

- Size of the area
- Game species to be counted
- Funds available
- Manpower available
- Objective of the count

In the development of a census technique for Rustenburg Nature Reserve, three counting techniques were compared with each other. Based on the criteria for selecting a census technique (Collinson 1985), three techniques were selected. These techniques were replicated to determine the variation between them. Unless counts are repeated to estimate variance, a management decision based on unknown variation in the technique can lead to Type I or Type II errors (Reilly & Emslie 1998).

The objective with a game census programme for Rustenburg Nature Reserve is:

- To obtain an accurate estimate of the population numbers and trends:

- Sable	Rare and endangered species, valuable key species, managed for maximum production, needs intensive monitoring, herd composition must be known, sex and age
- Roan	Rare and endangered species, valuble key species, managed for maximum production
- Waterbuck	Key species, competing with sable, roan, need to establish any negative impact on sable and roan species immediately

- To obtain an accurate estimate of the population trends of the following species:

  - Zebra
  - Red hartebeest
  - Eland
  - Kudu
  - Impala

- To obtain an index of the populations of :

  - Oribi
  - Klipspringer
  - Common reedbuck
  - Mountain reedbuck

1. Method

Based on the above-mentioned criteria, a non-sampling census strategy has been adopted on Rustenburg Nature Reserve. The size, variation in habitat types, vegetation characteristics, topography and the distribution of water on the reserve affects the dispersal of animals on the reserve significantly. According to Collinson (1985) these factors will disqualify a sampling strategy completely. Three non-sampling techniques, *viz.* drive census, aerial census and a modified road strip counting technique were evaluated to develop a suitable and reliable census technique.

a. Drive census

Twenty-two observers were used to conduct a drive census. All observers were briefed on the technique the day before the count. A series of slides on the different game species in the reserve was shown to the group. This was to ensure everybody are familiar with the different game species. They were also briefed on the data sheets that would be used, recording of data, radio procedures, consolidation points, each persons' position in the line and reporting lines. A numbering system was used to check for any over-counts or undercounts.

All observers were lined-up on the north-western boundary of the reserve. The line then moved southwards, spreading gradually to cover the "width" of the reserve, with an average maximum distance of 300m between adjacent observers. The northern plateau, the northeastern valley and the central basin were cover between 7:00am to 12:00am, and the southwestern valley were done in the afternoon from 13:00pm to 15:00pm. All game crossing the line of observers was recorded. Radio-communications and strategically positioned lookout posts were used to prevent duplications or undercounts. All recordings were consolidated at the end of the count.

b. Aerial census

A four-seat Bell Jet Ranger III with a pilot, a navigator/recorder seated next to the pilot, and two observers seated in the back were used. The reserve was divided into seven counting blocks, using natural boundaries and similar habitats as basis for delineating boundaries between counting blocks. Each block were systematically search in 400m wide strips at a speed of approximately 60km/h and an altitude of 60 - 100m. The helicopter is easily manoeuvrable to count the herds once they were spotted. All animals were counted, and the counts of bigger herds were confirmed. Information were recorded and consolidated at the end of the count. Counts were done in July after leaf drop. Data were recorded on data sheets.

c. Road strip count

Using the existing road system, a route of 66km in length were laid out throughout the reserve. Care were taken to ensure all habitats in the reserve were covered sufficiently within the constrains of the existing road system. A motorcycle and one observer were used to drive the route through the reserve, visiting high spots and counting all game along the route.

Precision of the counts were reflected as the coefficient of variation, i.e. *x/s* were *x* is the average of the three counts, and *s* is the standard deviation (Reilly & Emslie 1998).

2. Results

The numbers of animals counted during the three techniques represented in Table 11. The aerial census could not be repeated because of cost constrains, and the precision of this technique on Rustenburg Nature Reserve could not be determined. Aerial counts are generally considered to be precise rather than accurate (Peel & Bothma 1995; Bothma *et al* 1990).

Despite the preparations, the drive census yielded poor results for most species, except springbuck (CV = 9.5%). The variation between the counts for the other species were unacceptably high. The poor results can be attributed to the skills level of the staff used during the count, their ability to distinguished between different species, observer fatigue, attitude and visibility between adjacent observers.

Although the road strip count yielded more precise counts for common reedbuck (CV = 0.25%), kudu (CV = 4.7%), sable (CV = 3.5%) and springbuck (CV = 9.5%) numbers were generally much lower than the aerial counts and the drive censusses, except for the sable. This is due to a lot of dead ground that were not covered.

Table 11: Results of aerial counts, drive census and road strip census of game on the Rustenburg Nature Reserve

Species	Aerial						Drive census						Road strip count					
	Replicates			Mean	SD	CV (%)	Replicates			Mean	SD	CV (%)	Replicates			Mean	SD	CV (%)
	1	2	3				1	2	3				1	2	3			
Bushbuck	-	-	-	-	-	-	3	3	0	2	1.414	57.7	-	-	1	1	0	0
Common reedbuck	4	-	-	-	-	-	8	10	6	8	1.633	22.2	1	2	-	1.5	0.5	0.25
Eland	45	-	-	-	-	-	36	28	58	40.67	12.68	48.5	23	4	45	24	16.75	280.7
Giraffe	3	-	-	-	-	-	3	2	3	2.667	0.471	23.1	2	2	2	2	0	0
Impala	23	-	-	-	-	-	8	10	56	24.67	22.17	301.7	14	23	15	17.33	4.028	16.2
Kudu	20	-	-	-	-	-	12	26	12	16.67	6.6	42.5	5	4	9	6	2.16	4.7
Mount. reedbuck	49	-	-	-	-	-	141	108	150	133	18.06	17.8	21	33	18	24	6.481	42
Oribi	2	-	-	-	-	-	6	8	5	6.333	1.247	21.8	-	2	2	2	0	0
Red hartbeest	72	-	-	-	-	-	78	56	108	80.67	21.31	39	76	59	63	66	7.257	52.7
Sable	36	-	-	-	-	-	30	50	47	42.33	8.807	27	38	38	34	36.67	1.886	3.5
Springbuck	22	-	-	-	-	-	31	33	27	30.33	2.494	9.5	24	17	18	19.67	3.091	9.5
Waterbuck	12	-	-	-	-	-	15	26	47	29.33	13.27	79.3	15	5	11	10.33	4.11	16.8
Zebra	133	-	-	-	-	-	127	118	169	138	22.23	22.2	87	43	76	68.67	18.7	349.6

A helicopter count on a farm in the Northern Province yielded a figure that were closest to the control (Peel & Bothma 1995). This count was done on a farm with similar topography and vegetation than Rustenburg Nature Reserve. The road strip and drive census techniques used did not yield significant results at Rustenburg Nature Reserve, except for springbuck, sable and common reedbuck. It is recommended that the helicopter count be use to census game on Rustenburg Nature Reserve, and it be supplemented with ground data collected with the road strip counts.

3. *Frequency of counts*

The following criteria to establish frequency of counts, were developed at a game census workshop held in Pilanesberg National Park, North West Province[13]

- Where animals are harvested intensively, counts must be conducted frequently to pick up numbers after each removal
- By only conducting counts every second year, harvesting models can be complicated and confused
- At high stocking rates and use, annual counts are important
- At low numbers and low utilization levels, counts can be conducted every second year
- Important and valuable species must be monitored as frequent as possible (Sable, roan antelope, waterbuck)

13 Game census workshop, North West Parks & Tourism Board, held in Pilanesberg on the 12th May 1998

The recommended census strategies for game on Rustenburg Nature Reserve are:

Species	Census strategy
Sable, roan & waterbuck	Aerial census every second year, supplement data with ground observations annually, collect population dynamics data, i.e. sex and age
Zebra, impala, red hartebeest, eland,	Use aerial census every second year, model population numbers for in between years using growth rate of populations
Oribi, klipspringer, common reedbuck, mountain reedbuck	Use an index method to determine population trends

VELD BURNING AS A MANAGEMENT PRACTICE

Fire is an important determinant in the structure and functioning of African savannas(Scholes & Walker 1993). The impact of fire on these systems, depends on, among others, the seasonality, fire frequency and intensity (Shackleton & Scholes 2000).

Fire is an efficient means to manage predefined states of natural vegetation. Fire can be used to:

- remove surplus vegetation and improve access by game,
- to remove moribund and/or unacceptable grass material and improve the nutritional value of the vegetation for grazing and browsing species,
- maintain or achieve plant composition as desired by management objectives,
- reduce fuel load and thus the intensity of fires,
- aid in the control of live stock parasites,
- to recycle nutrients (Scholes & Walker 1993),
- stimulate out-of-season flush,

- and to manipulate animal movement on a farm to promote the homogenous utilization of the veld (Trollope 1989).

Frequency of fire has a marked effect on the woody structure. Studies in the Kruger National Park, South Africa indicated that the density, height, biomass, basal area and stem circumference decreases when fire frequency is increased (Shackleton & Scholes 2000). However, Enslin *et al* (2000) stated that a longer fire return-period does not necessarily enhance tree height. A longer fire return period leads to increased built-up of fuel, resulting in high intensity fires and more top kill, and potentially affecting structure. Mid-summer burns, and fire exclosure resulted in a reduction of woody plants less than 1.75m in height (Enslin *et al* 2000). Research in the Eastern Cape has shown however that burns applied during early summer, when the grass was actively growing, had a negative effect on the productivity, basal cover and botanical composition of the grass sward (Trollope 1989).

Trollope (1984) has stated that the interaction between burning and grazing after fire probably has a greater effect on vegetation than any other aspect of burning, and emphasised that serious damage can be caused by heavy grazing when applied too soon after a burn.

The effect of burning on vegetation depends to a large extent on the type and intensity of a fire (Trollope 1978). Fires can be classified into three broad types of fires:

A *ground fire* that burns below the surface of the ground

A *surface fire* that burns in the herbaceous layer, also referred to as a cool fire

A *crown fire* that burns in the canopies, also referred to as a hot fire.

Depending on the objective of the burn, each type of fire can artificially be created by manipulating the intensity of the fire. The intensity of a fire depends on the amount of fuel available, air temperature, relative humidity and the presence of wind. A ground fire is of no real importance to a wildlife manager, although ground fires have been recorded in Rustenburg Nature Reserve (Momberg, pers.comm[14]). Ground fires are not dealt with any further.

The intensity of fires can be manipulated through applying fires at specific atmospheric conditions and fuel loads. When burning to remove moribund material a cool fire is required to remove the material while doing the least damage to the vegetation. Such a fire will be obtained when air temperature is < 20° C and relative humidity >50%. The minimum fuel load required to carry a fire is at least 1500 kg/ha. These conditions generally prevail during the morning until 11h00 and in the afternoon after 15h30 (Trollope 1989).

When burning to eradicate and/or prevent the encroachment of undesirable plants, a hot fire is required. For this type of fire the air temperature should be >25 to 30°C and the relative humidity < 30%. These conditions generally prevail between 11 h00 and 15 h 30 (Trollope 1989). To obtain an intense fire that will destroy the aerial growth of bush, a grass fuel load of >3500 kg/ha is required.

– Fire regime in Rustenburg Nature Reserve over the past 27 years

Fire has been used as a management tool in Rustenburg Nature Reserve for the past 30 years. A block burning system was designed by Krynauw[15] in 1975 in which the reserve were divided into 5 burning blocks. Each block were visited and subjectively evaluated using the following criteria:

- Grass species composition and whether it was stable, dominated by perennial grass species.
- Visual assessment of fuel
- Signs of moribund material
- Time since previous burn

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15 D.J. Krynauw, Previous Ecologist, currently lecturer at Faculty Agricultural Sciences, Dept. Nature Conservation, Pretoria Technikon, Pretora

Fire was mostly applied at the end of the growing season, after the first summer rains and immediately before spring growth. Under these conditions, the recovery of the vegetation is fast (Bosch *et al* 1984).

In 1994, early winter burns were implemented in Rustenburg Nature Reserve. The first fires of the burning season were ignited in April. Mid-winter and late-winter fires were ignited depending on the size of the area already burnt during that year.

– Methods

Since 1972 each fire, controlled, lighting or accidental, in Rustenburg Nature Reserve were mapped on a 1:10 000 topographical map. A 25ha grid map was overlain onto a 1:10 000 map of the reserve (Brockett *et al* in press). Each cell was evaluated and an estimate of the percentage of the cell that burnt was entered into a spreadsheet, where each cell represented a 25ha square. The burnt area for each year was then calculated. The burn/unburnt of each cell were calculated over the period 1972-1999 and the average fire intervals for each cell were determined.

– Results

The fire regime of an ecosystem has four components (Scholes & Walker 1993):

- Frequency, reciprocal of the time between fires
- Intensity, rate of energy release
- Season of burning
- Type of fire

Until the mid-nineties, most fires in the reserve were applied in the early spring, after the first rains. This philosophy of early spring burns was applied in most other savanna-areas. It was argued that this will cause most damage to trees, and least damage to herbaceous (Scholes & Walker 1993). The impact of this philosophy on the vegetation structure and composition is not clear, but from research done in Kruger National Park (Shackleton & Scholes 2000, Enslin *et al*

2000) on the impacts of season of burning on the woody component, it can be deducted that it should have had an effect on the woody structure in the reserve.

The results of the analysis are depicted in figures 52 and 53. Figure 52 represents the percentage of the reserve burnt each year. The results indicated that an average of 13.71% of the reserve burnt each year. However, the area burnt each year increased slowly from 7.9% in the seventies to 19.6% in the nineties. In 1989, 45.01% of the reserve was burnt. From 1981 to 1986 a very conservative burning policy was applied, and less than 2% of the reserve was burnt each year, except for 1983 when 2.11% was burnt. This was followed by a period between 1987 to 1991 when more than 20% of the reserve were burnt each year for five consecutive years. The conservative approach and small areas burnt resulted in increased fuel loads and very high intensity fires were recorded (Drotski, pers comm[16], Krige, pers. comm[17]). This was due to a less conservative fire management policy been adopted and followed on the reserve since the mid-eighties.

The fire interval, that is period between successive fires, for the reserve is 8.21 years. Certain cells have not been burnt for the past 18 years (Fig 53). These cells are located on swallow bedrock, where fuel loads have not sufficient to carry the fire.

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16 Andre Drotski, previous warden Rustenburg Nature Reserve, now stationed at Roodeplaatdam Nature Reserve, Gauteng Nature Conservation

17 Frans Krige, previous warden, Rustenburg Nature Reserve, now stationed at Dullstroom, Mpumalanga Parks Board

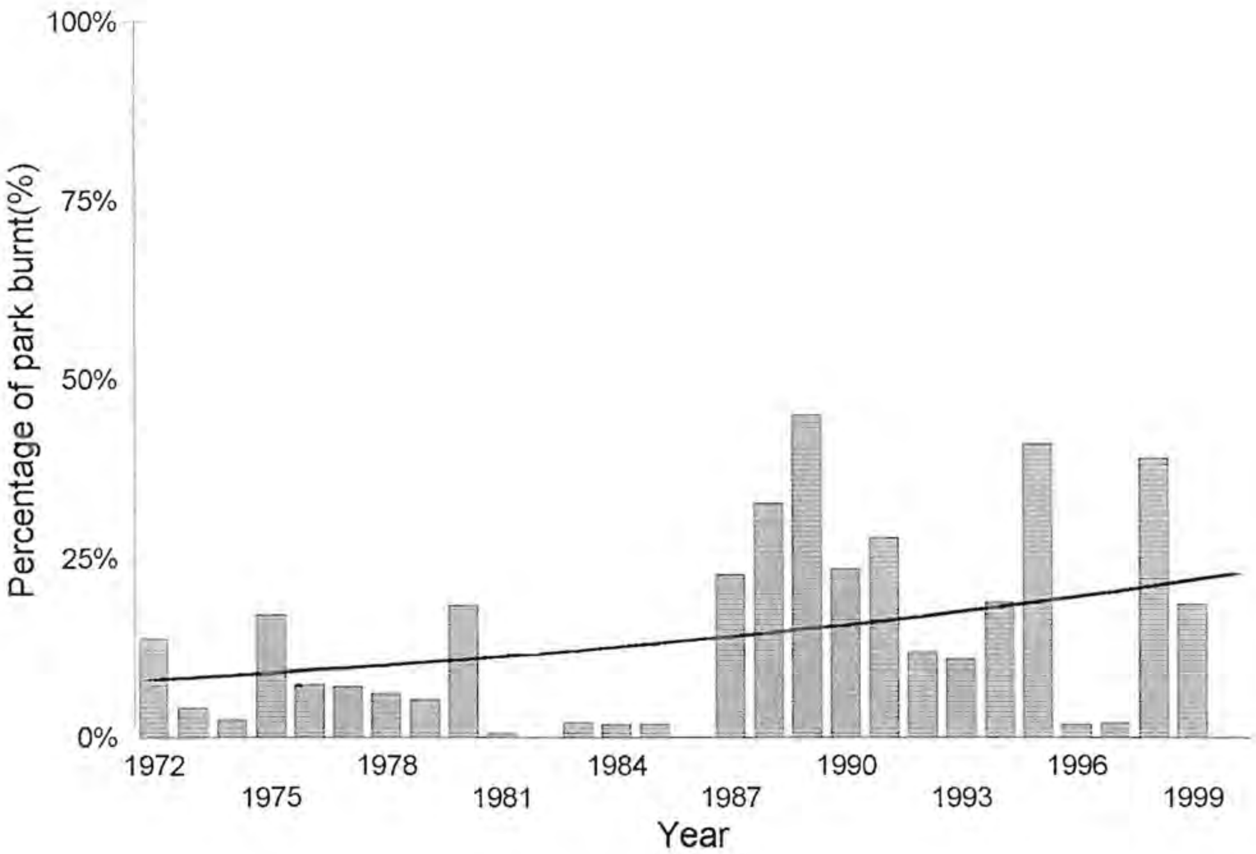

Figure 52: The size of the area of the Rustenburg Nature Reserve reserve that burnt each year since 1985

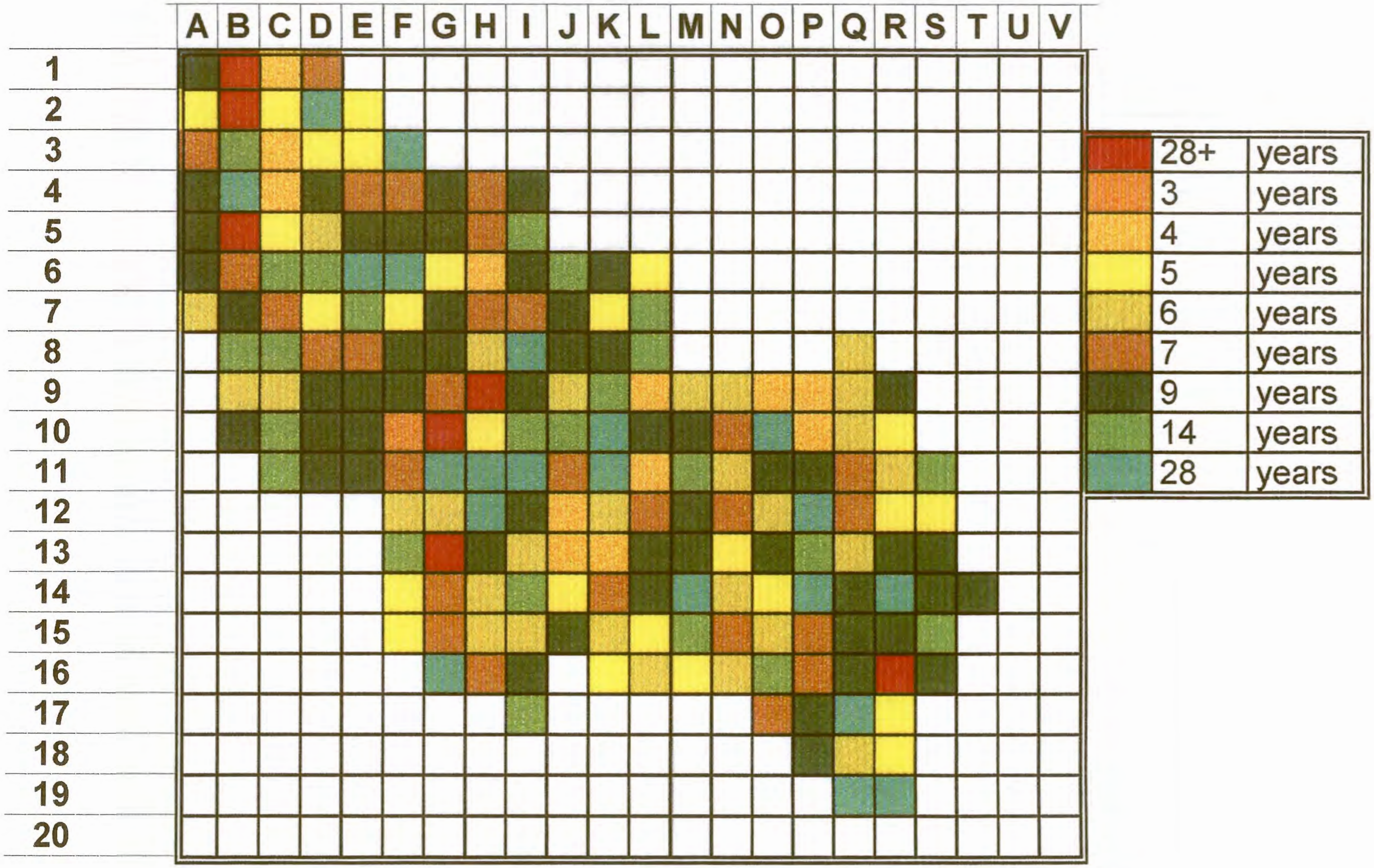

Figure 53: The fire interval in a 25 ha cell in the Rustenburg Nature reserve since 1985

– Discussion

Fire is an important ecosystem driver (Scholes & Walker 1993). The interaction between a multi-species herbivore complex and the effects of a "natural" fire regime have been important on the evolution of African savannas (Scholes & Walker 1993). No conclusive evidence exists that burning *per se* increases water yields (Bosch *et al* 1984). However, uncontrolled burning may lead to a deterioration of the factors that ensure good infiltration, water yield regulation, low sediment and high biomass production (Edwards 1984).

The fire regime for Rustenburg Nature Reserve must primarily aim to sustain stream flow and to optimize water quality. In order to achieve this dense vegetation cover should be maintained during the rainy season (Edwards 1984) to maximize infiltration and peculation rates. Secondary, fire will also be used at as tool to improve the grazing value of the vegetation for game species such as sable and roan. An appropriate fire regime aimed at achieving the vegetation and faunal objectives on the reserve will only be developed and refined through the process of adaptive management. Environmental factors such as rainfall, prolonged drought, herbivory and accidental or unplanned fires are variables impacting on vegetation structure and composition, thus preventing a rigid or prescribed burning program.

Protea caffra trees in the *Aloe greatheadii- Themeda triandra* Tall Open Woodland on the northern plateau of the reserve suffered damage during a hot fire in 1994. The extreme intensity of the fire was due to large fuel loads, combined with high day temperatures (<25 °C) and low humidity(late winter)(Drotski, pers. comm)[18]. The *Burkea africana-Themeda triandra* Tall Open Woodland has been identified as an important feature to be conserved in the reserve. Research in the Kruger National Park indicated that high fuel loads associated with dry atmospheric

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18 Andre Drotski, previous warden Rustenburg Nature Reserve, now stationed at Roodeplaatdam Nature Reserve, Gauteng Nature Conservation, Gauteng Province

conditions leads to increased top kill among larger trees(Shackleton & Scoles 2000). It is therefore recommended that these conditions be avoided in order to maintain the current structure, and to allow for the recruitment of young *Burkea africana* seedlings. . To achieve this, high fuel loads in this community need to be avoided, as well as fires at the end of the winter season.

To ensure sufficient vegetation cover to maximize water infiltration, no fires should be introduced during the rainy season. In situations of severe run-off, the absence of cover can lead to accelerated erosion and sedimentation, which will affect the quality of water and the infiltration rate.

CHAPTER 7
CONCLUSIONS

The management of Rustenburg Nature Reserve as a mountain catchment area implies optimal use of natural resources to ensure continuous delivery of a sustained flow of good quality water. The effect of management practises and development inside the reserve on these objectives must be measurable.

The aims of the study are summarized as follows:

- To develop a monitoring system to detect changes in the ecosystem that can affect the sustained flow of water from this mountain catchment.
- To achieve this, the scale at which monitoring should take place, needed to be established.
- It also required a complete description of the physical and biological environment and the delineation of functional units for management
- The basis for monitoring is the evaluation and interpretation of change along degradation gradients which needed to be developed for each management unit.
- The development of guidelines for the monitoring of other components at appropriate scale and level.

The description of the physical environment entailed a literature study of the geology and geomorphology of the area and subsequent development of the geology map. The geological map and topographic characteristics of the reserve were used to develop a soil map for the reserve. The soil map gives an overview of the broad soil differences on the reserve.

To delineate management units at an appropriate and practical scale, that will respond uniformly to management practises, the vegetation of the reserve was described and relative homogenous management units were delineated.

The floristic variation within the management units in Rustenburg Nature Reserve is influenced by topography and substrate. Phytosociological differences between vegetation communities and management units were distinguished on the basis on aspect, moisture content, soil depth and clay content. A distinct difference between communities associated with the drier environments on the plateau, hill slopes and the open areas of the central basin and the communities associated with the wet habitats along the vlei and water streams were detected. Variations in soil depth resulted in differentiation between vegetation communities. Communities associated with open bedrock and shallow soils occurring on the plateau and upper hill slopes were distinguished from communities occurring on the meduim-deep to deep Hutton soils in the central basin and small secluded pockets in the valleys. A weak gradient in clay content was detected. Clayish soils and associated communities, mainly confined to the alluvial soils in the valleys were distinguished from the communities associated with sandy soils.

These units form the basis for management and monitoring of the vegetation component of the reserve. Four units were described:

I. *Selaginella dregei - Oldenlandia herbacea* Open Shrubland
II. *Becium obovatum - Elionurus muticus* Tall Grassland
III. *Ziziphus mucronata - Rhus leptodictya* Closed Woodland
IV. *Pteridium aquilinum - Miscanthus junceus* Moist Grassland

The *Selaginella dregei - Oldenlandia herbacea* Open Shrubland management unit occurs on shallow soils and exposed quartzite sheets on the high lying areas of the reserve.

The *Becium obovatum - Elionurus muticus* Tall Grassland management unit is associated with the medium deep to deep soils on the foot slopes and in the central basin area of the reserve, the valley between the summit and the eastern range of quartzite ridges.

The *Ziziphus mucronata - Rhus leptodictya* Closed Woodland consists of the woodland and forest communities in the reserve. This management unit is found on the low-lying slopes and low-lying areas of the eastern valleys in the study area. The tree and shrub layer are very prominent.

The *Pteridium aquilinum - Miscanthus junceus* Moist Grassland management unit represents the moist habitats on the reserve. The soils in this management unit vary from deep, black clay soils underlying the reed swamp to deep apedal soils adjacent to the streams in the southern section of the central basin. This management unit occurs on a high water table and certain communities in this management unit are submerged. Species diversity in this management unit is low and confined to species associated with moist conditions.

The dynamics of the vegetation in the first three management units and the response thereof to disturbances were described along a vegetation gradient. Vegetation gradients were developed for each of the units using multivariate techniques. The response of herbaceous species to different levels of grazing impacts was modelled to identify key species to be used in the interpretation of the degradation gradients in each vegetation unit. Regression analysis was used to establish the reaction of the individual species. Responsive species were divided into Decreasers, Increaser 1, Increaser 2, Increaser 3 and Increaser 4 categories. Evident from analysis were that species responded differently to grazing impacts under different physical and environmental conditions, and certain species were classified into more than one category. Species also displayed an inconsistent response to utilization between different management units. A set of key species were distinguished for each management unit.

No significant erosion levels of were recorded in the *Selaginella dregei* -

Oldenlandia herbacea Open Shrubland management unit, due to the large areas of open bedrock and shallow soils underlying this management unit. *Coleocloa setifera* colonizes and stabilizes bare areas of bedrock in this management unit effectively.

In the *Becium obovatum* - *Elionurus muticus* Tall Grassland management unit no significant relationship between the level of utilization and the number of plant species recorded were detected, but species seems to disappear when the veld is not utilized. In this unit, erosion appears in the seriously over-utilized sector of the degradation gradient, jeopardising the objective of slow release of high quality effluent.

The *Ziziphus mucronata* - *Rhus leptodictya* Closed Woodland management unit shown a significant difference between the number of species in the less utilized sectors of the degradation gradient and the species numbers recorded for the severely over-utilized sectors. Maximum species diversity is obtained when the veld is lightly utilized, but species seems to disappear when the veld is severely over-utilized. No significant erosion was found in the under-utilized and lightly utilized sectors of the gradient. Moderate levels of erosion were detected in the seriously over-utilized sector of the degradation gradient of this management unit, thus indicating that this level of utilization in this management unit will result in undesired veld condition in terms of management objectives for the reserve.

Fixed monitoring sites were positioned in each management unit. The residual value of all five sites in Management Unit 1 is less than the Maximum Acceptable Residual value, which is half of the Euclidean length of the first axis. These are therefore representative of the vegetation in the management unit. In Management unit 2, the residual value of four sites is less that the acceptable value. The residual value of the fifth site is unacceptably high and can therefore not be considered for this gradient. The residual value of three sites in management unit 3 is more than the maximum acceptable value and cannot be fitted into the constructed models. Seven sites of the ten sites elected are within the acceptable maximum value. A three-year survey interval is recommended, as it reduces noise and allows a particular management action to take effect.

Rustenburg Nature Reserve's secondary management objectives, to maintain the scenic beauty and integrity of this area in the Magaliesberg, to conserve biological diversity and natural processes and to preserve the cultural and archaeological heritage, and to allow public access to the reserve, have to be achieved within the limits imposed by its primary objective, *viz.* sustained yield of quality water. It is recommended that the management of the vegetation on Rustenburg be aimed at maintaining a high canopy and basal cover. This will ensure the desired soil structure, which will improve the water retention capabilities of the soil. Also, alien vegetation with high water requirements must be removed.

The stocking rate of game should vary in accordance to the management objectives of the reserve. On Rustenburg Nature Reserve the objective with game management to use game as a management tool to manipulate vegetation structure and composition, to use a sustainable basis, to improve the visitor's experience to the reserve and, where feasible, to breed endangered and valuable species, i.e. sable antelope and roan antelope.

The principle of adaptive management will be applied to refine the stocking rate of the game on the reserve. Game census strategies were also recommended for the various game species in accordance with the census objectives.

The fire regime in Rustenburg Nature Reserve over the past 27 years was analysed. An average of 13.71% of the reserve burnt each year. The fire interval for the reserve is 8.21 years, although certain cells located on swallow bedrock have not been burnt for the past 18 years.

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Ecological management objectives and monitoring procedures for Rustenburg Nature Reserve, North West Province

by

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SUMMARY

The objectives of the Rustenburg Nature Reserve were analyzed and the optimal use of natural resources to ensure continuous delivery of a sustained flow of good quality water was set as the primary ecological management objective for the reserve. This aims at maintaining the vegetation composition and structure on the reserve to maximize water retention. The effect of management practices and development inside the reserve on these objectives must be evaluated and must be measurable.

An analysis of the geology, soils, climate and hydrology of the Rustenburg Nature Reserve were used to classify and described the vegetation on the reserve. Fifty-one vegetation communities, sub-communities and variations were identified. The association of these communities towards each other was modeled through ordination and four relative homogenous management units were delineated.

I. *Selaginella dregei - Oldenlandia herbacea* Open Shrubland
II. *Becium obovatum - Elionurus muticus* Tall Grassland
III. *Ziziphus mucronata - Rhus leptodictya* Closed Woodland
IV. *Pteridium aquilinum - Miscanthus junceus* Moist Grassland

These units form the basis for management and monitoring of the vegetation component of the reserve.

Multivariate processing techniques were used to develop degradation gradients for management unit 1,2 & 3. Management unit four represents the moist habitats on the reserve, and includes the reed marsh and riverine vegetation along the Waterkloof spruit. These gradients were developed to gain an understanding of the dynamics of the vegetation in the different management units, and the responses thereof to disturbances. These gradients will provide the basis for evaluating and interpreting change along degradation gradients in each management unit. The response of herbaceous species to different levels of grazing impacts was modeled to identify key species to be used in the interpretation of the degradation gradients in each vegetation unit. Regression analysis was used to establish the reaction of the individual species. Responsive species were divided into Decreasers, Increaser 1, Increaser 2, Increaser 3 and Increaser 4 categories.

A monitoring system aimed at detecting changes in the ecosystem that can affect the sustained flow of water from this mountain catchment was developed. Fixed monitoring sites were positioned in each management unit. The residual value of monitoring sites in all management units was less than the Maximum Acceptable Residual value, which is half of the Euclidean length of the first axis. A three-year survey interval is recommended, as it reduces noise and allows a particular management action to take effect.

The stocking rate of game should vary according to the management objectives of the reserve. On Rustenburg Nature Reserve the objective with game management to use game as a management tool to manipulate vegetation structure and composition, to be used on a sustainable basis to supplement income, to improve the visitor's experience to the reserve and, where feasible, to breed endangered and valuable species, i.e., sable and roan antelopé. The principle of adaptive management will be applied to refine the stocking rate of the game on the reserve. Game census strategies were also recommended for the various game species in accordance with the census objectives.

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Ekologiese bestuursdoelwitte en moniterings prosedures vir Rustenburg Natuurreservaat, Noordwes Provinsie

deur

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OPSOMMING

Die doelwitte van die Rustenburg Natuurreservaat is ontleed en die optimale gebruik van die reservaat se natuurlike hulpbronne om 'n volgehoue lewering van hoë kwaliteit afloop te verseker is as die primêre ekologiese bestuursdoelwit geidentifiseer. Dit impliseer die bestuur van die plantegroei samestelling en struktuur om water retensie te maksimaliseer. Die effek van bestuurspraktyke en ontwikkeling binne die reservaat

op hierdie doelwitte, moet voortdurend evalueer word en moet derhalwe meetbaar wees.

'n Ontleding van die geologie, grond, klimaat en hidrologie van die Rustenburg Natuurreservaat is gebruik om die plantegroei op die reservaat te klassifiseer en te beskryf. Een-en-vyftig plantegroei gemeenskappe, sub-gemeenskappe en variasies is geidentifiseer. Die verhouding tussen die gemeenskappe is deur ordinering gemoduleer en vier bestuurseenhede is onderskei:

I. *Selaginella dregei* - *Oldenlandia herbacea* Oop Struikveld
II. *Becium obovatum* - *Elionurus muticus* Lang Grasveld
III. *Ziziphus mucronata* - *Rhus leptodictya* Geslote Boomveld
IV. *Pteridium aquilinum* - *Miscanthus junceus* Nat Grasveld

Hierdie eenhede vorm die basis vir die bestuur en monitering van die plantegroei komponent op die reservaat.

Meerveranderlike ontledingstegnieke is gebruik om degradasie gradiente vir bestuursgebiede 1, 2 & 3 te ontwikkel. Bestuurseenheid 4 verteenwoordig die klammer habitats op die reservaat, insluitende die rietbeddings en oewerplantegroei langs die Waterkloof spruit. Hierdie gradiente is ontwikkel om die dinamika van die plantegroei in die verskillende bestuursgebiede te verklaar, asook die reaksie daarvan op versteuring. Hierdie gradiente voorsien 'n basis om veranderinge wat langs die gradient plaasvind mee te evalueer en te verklaar. Die reaksie van die kruidlaag op verskillende vlakke van benutting is ook gemodelleer, en is gebruik om sleutel kruidspesies te identifiseer om te gebruik in die interpretering van die degradasie gradient in elke plantegroei eenheid. Regressie analises is gebruik om die reaksie van individuele spesies te ondersoek. Spesies wat betekenisvolle reaksies getoon het, is in Afnemers, Toenemers 1, Toenemer 2, Toenemer 3 en Toenemer 4 kategorieë ingedeel.

'n Moniterings stelsel wat die veranderinge in die ekosisteem wat die volgehoue vloei van afloop vanuit die opvanggebied kan opspoor, is ook ontwikkel. Vaste moniteringspunte is in elke bestuursgebied uitgeplaas. Die residuele waarde van die punte wat uitgeplaas, is minder as die Maksimum Residuele Waarde wat toegelaat kan word, dit is die helfde van die Euklidiese afstand van die eerste as. 'n Opname elke drie jaar word aanbeveel, aangesien dit korttermyn variasies wat met kort opeenvolgende opnames gepaard gaan, sal elimineer.

Die wildlading op 'n reservaat moet varieer na gelang van die bestuursdoelwitte van die reservaat. Op Rustenburg Natuurreservaat word wild gebruik as 'n meganisme om plantegroei samestelling en struktuur mee te manipuleer, dit word op 'n volhoubare wyse benut om inkomste aan te vul deur lewende verkope, om besoekers se ondervinding tydens 'n besoek te verbeter en skaars en waardevolle diere soos swartwitpens en bastergemsbok sal ook hier geteel word. Die beginsel van aanpassingsbestuur sal gebruik word om die wildlading te verfyn. Wildsensus strategieë in lyn met die sensus doelwitte vir die onderskeie spesies word ook voorgestel.

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Appendix 1

A list of the plant species founded during the study

<u>Acanthaceae</u>

Thunbergia batriolicifolia E.Mey. ex Nees
Thunbergia neglecta Sond.
Chaetacanthus costatus Nees.
Chaetacanthus setiger (Pers.) Lindl.
Ruellia cordata Thunb.
Ruellia patula Jacq.
Crabbea hirsuta Nees.
Barleria pretoriensis C.B.Cl.
Hypoestes forskaoli (Vahl) R. Br.
Justicia anagalloides T. Anders

<u>Adiantaceae</u>

Adiantum c.f. Adiantum poiretii Wikstr.
Cheilanthes viridus (Forsk.) Swartz var. **glauca** (Sim) Schelpe & N.C Anthony
Pellaea calomelanos (Sw.) Link

<u>Aizoaceae</u>

Delosperma herbeum (N.E.Br.) N.E. Br.
Frithia pulcra N.E. Br.
Khadia acutipetala N.E. Br.

<u>Amarantaceae</u>

Achyranthes aspera L.
Gomphrena celosioides Mart.

<u>Amaryllidaceae</u>

Haemanthus humilis Herb.
Boophane disticha Herb.
Crinum graminicola Verdoorn.
Crinum bulbispermum (Burm.f.)Milne-Redh. & Schweick.
Scadoxus puniceus (L) Friis & Nordal
Hypoxis rigidula Bak.
Hypoxis obtusa Burch. ex Edwards

<u>Anacardiaceae</u>

Rhus zeyheri Sond.
Rhus discolor E.Mey. ex Sond.
Rhus lancea L.f.
Rhus leptodictya Diels
Rhus magalismontanum Sond.
Rhus pyroides Burch.
Rhus rigida Mill.
Lannea edulis (Sond.) Engl.
Lannea discolor (Sond.) Engl.

Apocynaceae

Acokanthera oppositifolia (Lam.) L.E. Codd
Ancylobotrys capensis Oliv.

Aquifoliaceae

Ilex mitis (L.) Radik.

Araliaceae

Cussonia paniculata Eckl. & Zeyh.

Asclepiadaceae

Cryptolepis oblongifolia (Meisn.) Schltr.
Raphionacme burkei N.E. Br.
Raphionacme hirsuta (E.Mey.) R.A. Dyer.
Asclepias aurea Schltr.
Pentarrhinum insipidum E. Mey.
Sarcostemma viminale R.Br.
Brachystelma barberiae Harv. ex Hook
Stapelia leendertziae N.E.Br.
Huernia hystrix (Hook.f.) N.E. Br, var **hystrix**

Asparagaceae

Asparagus cooperi Bak.
Asparagus krebsianus Kunth. (Jessop)
Asparagus laricinus Burch.
Asparagus suaveolens Burch.
Asparagus virgatus (Bak. & Oberm.)

Aspleniaceae

Ceterach cordatum (Thunb.) Desv.

Asteraceae

Dicoma anomala Sond. subsp. **circoides** (Harv). Wild
Blumea mollis (D.Don) Merr
Athrixia elata Sond.
Senecio oxyriifolius DC.
Aster peglerae H.Bol.
Vernonia hirsuta (DC.) Sch. Bip.
Vernonia natalensis Sch. Bip.
Vernonia oligocephala (DC.) Sch. Bip. ex Walp.
Vernonia poskeana Vatke & Hildebr. var. poskeana.
Vernonia staehelinoides Harv.
Vernonia sutherlandii Harv.
Adenostemma caffrum DC.
Felicia muricata Nees.
Aster harveyanus Kuntze.
Psiadia punctula (DC.) Vatke
Nidorella anomala Steetz.
Nidorella auriculata DC.

Nidorella residifolia subsp. **residifolia**
Nidorella hottentottica DC.
Conyza bonariensis Cronquist.
Conyza albida Spreng.
Conyza podocephala DC.
Conyza ulmifolia (Burm.) Kuntze.
Nolletia rarifolia (Turcz.) Steetz.
Brachylaena rotudata DC.
Tarchonanthus camphoratus L.
Denekia capensis Thunb.
Helichrysum aureonitens Sch. Bip.
Helichrysum caespititium Sond.
Helichrysum cerastioides DC.
Helichrysum coriaceum Sond.
Helichrysum nudifolium (L.) Less.
Helichrysum rugulosum Less.
Helichrysum setosum Harv.
Stoebe vulgaris Levyns.
Bidens pilosa L.
Tagetes minuta L.
Artemisia afra Jacq.
Lopholaena coriifolia (Sond.) Phill. & C.A. Sm.
Senecio affinis DC.
Senecio erubescens Ait. form.
Senecio inornatus DC.
Senecio pentactinus Klatt.
Senecio serratuloides DC.
Senecio venosus Harv.
Ursinia nana DC. subsp. **nana**
Gazania krebsiana Less. subsp. **serrulata** (DC.) Roessl.
Berkheya zeyheri (Sond. & Harv.) Oliv. & Hiern subsp. **zeyheri**.
Dicoma zeyheri Sond.
Gerbera piloselloides (L.) Cass.
Sonchus dergeanus DC.
Sonchus oleraceus L.

Boraginaceae

Ehretia rigida (Thunb.) Druce.

Brassicaceae

Cassia mimosoides L.

Campanulaceae

Wahlenbergia caledonica Sond.

Capparaceae

Cleome monophylla L.

Caryophyllaceae

Silene burchelli Otth.

Ceasalpiniaceae

Burkea africana Hook.

Celastraceae

Maytenus tenuispina (Sond). Marias
Maytenus polycantha (Sond). Marias
Maytenus heterophylla (Eckl. & Zeyh.) N.K.B. Robson
Maytenus undata (Thund). Blakelock

Chrysobalanaceae

Parinari capensis

Combretaceae

Combretum apiculatum Sond. subsp. **apiculatum**
Combretum erythrophyllum (Burch.) Sond.
Combretum molle R. Br ex G. Don.
Combretum zeyheri.

Commelinaceae

Commelina africana L.
Commelina benghalensis L.
Commelina erecta L.
Cyanotis speciosa (L.) Hassk.

Convolvulaceae

Ipomoea bathycolpos Hall.f. var. **bathycolpos.**
Ipomoea crassipes Hook.
Ipomoea ommaneyi Rendle>
Turbina oblongata (E.Mey. ex Choisy) A. Meeuse.

Crassulaceae

Cotyledon orbiculata L. var **oblonga** (Haw.) DC
Andromischus umbraticola C.A. subsp **umbraticola**
Crassula alba Forsk.var.**alba**
Crassula capitella Thunb. subsp. **nodulosa** (Schonl.)
Crassula lanceolata (Echl. & Zeyh.) Endl. ex Walp. subsp. **transvaalensis** (Kuntze)
Kalanchoe paniculata Harv.
Kalanchoe thryrsiflora Harv.

Cyatheaceae

Cyathea dregei Kze.

Cyperaceae

Cyperus albostriatus Schrad.
Cyperus rupestris Kunth.
Cyperus sphaerospermus Schrad.
Bulbostylis burchellii C.B. Cl.
Bulbostylis oritrephes (Ridl.) C.B. Cl.
Coleochloa setifera (Ridl.) Gilly.
Mariscus congesta C.B. Cl.

Ficinia filiformis (Lam.) Schrad.
Kyllinga alba Nees

Dennstaedtiaceae

Pteridium aquilinum (L.) Kuhn.

Dichapetalaceae

Dichapetalum cymosum (Hook.) Engl.

Dipsacaceae

Scabiosa columbaria L.

Ebenaceae

Euclea crispa (Thunb.) Guerke var. **crispa**.
Euclea undulata (Thunb.)
Diospyros lycioides Desf. subsp. **guerkei** (Kuntze) de Wint.
Diospyros whyteana (hiern) F. White.

Ericaceae

Erica woodii H.Boll

Euphorbiaceae

Acalypha petiolaris Hochst.
Acalypha angustata Sond. *glabra* Sond.
Euphorbia shinzii Pax
Clutia pulchella L.
Croton gratissimus Burch. var. **subgratissimus** (Prain) Burtt Davy
Phyllanthus parvulus Sond.
Tragia rupestris Sond.

Fabaceae

Tephrosia elongata E. Mey. var **elongata**
Tephrosia longipes Meisn. subsp **longipes**
Sphenostylis angustifolia Sond.
Ophrestia oblongifolia (E.May) H.M. Forbes
Mundulea sericea A. Chev.
Lotonis calycina (E,Mey) Benth. var. **hirsutissima** Duemmer
Crotolaria lotoides Benth
Rhynchosia monophylla Schltr.
Rhynchosia nitens Benth
Rhynchosia totta (Thund.) DC
Indigofera burkeana Benth. ex Harv.
Indigofera comosa N.E. Br.
Indigofera hedyantha Eckl. & Zeyh.
Indigofera melandenia Benth. ex Harv.
Pearsonia cajanifolia (Harv.) Polhill subsp **cajanfolia**

Flacourtiaceae

Kiggelaria africana L.

Gentianaceae

Chironia purpurascens (E.Mey.) Benth. & Hook.f. subsp. **humilis** (Gilg) Verdoorn.

Gunneraceae

Gunnera perpensa L.

Guttiferae

Hypericum aethiopicum Thunb. subsp. **sonderi** (Bred) Robson.

Halorrhagidaceae

Gunnera perpensa L.

Hypoxidaceae

Hypoxis obtusa Burch. ex Edwards
Hypoxis rigidula Bak.

Iridaceae

Moraea thomsoni Bak.
Schizostylis coccinea Backh. & Harvey.
Dierama medium N.E. Br. var. **mossii** Ne. Br.
Gladiolus crassifolius Bak.
Gladiolus edulis Burch. ex Ker.
Lapeirousia sandersonii Bak.
Anomatheca laxa (Thunb.) Goldbl.
Anomatheca grandiflora Bak.

Labiatae

Leonotis microphylla Skan.
Pycnostachys reticulata Benth.
Plectranthus madascariensis Pers. Benth. var **ramosior** Benth
Becium obovatum (E. Mey. ex Benth.) N.E. Br.

Lamiaceae

Acrotome hispida Benth.
Teucrium trifidum Retz.

Lentibulariaceae

Utricularia arenaria A.DC.

Liliaceae

Aloe greatheadii Schonl.
Aloe marlothii Berg.
Aloe mutabilis Pillans.
Aloe peglerae Schonl.
Albuca sp. cf. *A. setosa* Jacq.
Aloe transvaalensis Kuntze
Bulbine narcissifolia Salm-Dyck
Ledebouria ovatifolia Jessop
Ledebouria marginata (Bak.) Jessop.

Ledebouria revoluta (L.f.) Jessop.
Scilla nervosa (Burch.) Jessop.
Eucomis autumnalis (Mill.) Chitt. var. *clavata*

Loganiaceae

Strygnos pungens Solered.
Nuxia congesta R. Br. ex Fresen.
Buddleja saligna Willd.
Buddleja salviifolia (L.) Lam.

Loranthaceae

Tapinanthus rubromarginatus (Engl). Danser

Malpighiaceae

Sphedamnocarpus pruriens (Juss.) Szyszyl. var **pruriens**

Malvaceae

Sida cordifolia L.
Pavonia burchellii (DC) R.A. Dyer.
Hibiscus aetiopicus L. var. ovatus Harv.
Hibiscus calyphyllus Cav.
Hibiscus engleri K. Schum.
Hibiscus microcarpus Garcke.
Hibiscus trionum L.

Mimosaceae

Acacia karroo Hayne
Acacia caffra (Thunb) Willd.
Elephantorrhiza elephantina (Burch.) Skeels
Dichrostachys cinerea (L.) Wight & Arn. subsp. **africana** Brenan & Brumm.

Moraceae

Ficus ingens (Mig.) Miq.

Myrsinaceae

Myrsine africana L.

Ochnaceae

Ochna pulchra Hook

Olacaceae

Ximenia caffra Sond.

Oleaceae

Olea europaea L. supsp **africana** (Mill.)

Oliniaceae

Olinia emarginata Burtt Davy.

Onagraceae

Kohautia amatymbica Eckl. & Zeyh.

Orchidaceae

Eulophia ovalis Lindl. subsp. **bainesii** (Rolfe) Hall.

Oxalidaceae

Oxalis obliquifolia Steud. ex Rish.

Pittosporaceae

Pittosporum viridiflorum Sims

Poaceae

Urelytrum agropyroides Hack.
Elionurus muticus (Spreng.) Kunth
Imperata cylindrica (L.) Raeuschel.
Miscanthus junceus (Stapf) Stapf.
Schizachyrium sanguineum (Retz.) Altz
Diheteropogon amplectens (Nees) W.D. Clayton.
Andropogon appendiculatus (Steud.)
Andropogon huillensis Rendle
Andropogon schinzii Hack.
Andropogon schirensis A. Rich.
Cymbopogon plurinodes Stapf.
Cymbopogon validus Stapf.
Hyparrhenia filipendula (Hochst.) Stapf var. **pilosa** (Hack.) Stapf.
Hyparrhenia hirta (L.) Stapf
Monocymbium ceresiiforme (Nees) Stapf.
Trachypogon spicatus (L.f.) Kuntze.
Heteropogon contortus (L.) Beauv.
Themeda triandra Forsk.
Digitaria diagonalis (Nees) Stapf.
Digitaria eriantha Steud.
Digitaria monodactyla (Nees) Stapf.
Digitaria tricholaenoides Stapf.
Brachiaria brizantha (Hochst) Stapf.
Brachiaria nigropedata (Munro) Stapf.
Brachiaria serrata (Spreng) Stapf.
Urochloa panicoides Beauv.
Panicum maximum Jacq.
Panicum natalense Hochst.
Setaria lindenbergiana (Nees) Stapf.
Setaria sphacelata (Schumach) Stapf. & C.E. Hubb.
Melinus repens (Willd) C.E. Hubb.
Melinus nerviglume (Franch.) Zizka
Tricholaena monache (Trin.) Stapf & C.E. Hubb.
Arundinella nepalensis Trin.
Tristachya biseriata Stapf.
Tristachya leucotrix Nees.
Tristachya rehmannii Hack.
Loudetia flavida (Stapf) C.E. Hubb.
Loudetia simplex (Nees) C.E. Hubb.
Phragmitis mauritianus Kunth.
Aristida aequiglumis Hack.

Aristida congesta Roem. & Schult. subsp. **barbicollis** (Trin. & Rupr.) De Wint.
Aristida diffusa Trin. var. **burkei** (Stapf) Schweick.
Aristida junciformis Trin. s Rupr. subsp. **galpinii** (Stapf) de Wint.
Bewsia biflora (Hack.) Goossens
Alloteropsis semialata (R.Br) Hitchc.
Tragus berteronianus Schult.
Perotis patens Gand.
Sporobolus fimbriatus Nees.
Eragrostis capensis (Thunb.) Trin.
Eragrostis curvula (Schrad.) Nees.
Eragrostis gummiflua Nees.
Eragrostis racemosa (Thunb.) Steud.
Eragrostis stapfii De Wint.
Eragrostis superba Peyr.
Harpochloa falx (L.) Kuntze.
Eustachys paspaloides (Vahl) Lanza & Mattei.
Pogonarthria squarrosa (Licht.) Pilger.
Diplachne biflora Hack.
Cynodon dactylon Pers. Rich.
Triraphis andropogonoides (Steud.) Phillips.
Trichoneura grandiglumis (Nees) Stapf & C.E. Hubb.
Enneapogon scoparius Stapf.

Polygonaceae

Polygonum lapathifolium L.
Polygonum pulchrum Blume.
Oxygonum dregeanum Meisn.
Persicaria attentuata (R.Br) Sojak subsp **africana** K.I. Wilson

Portulacaceae

Talinum caffrum (Thunb.) Eckl. & Zeyh.
Anacampseros subnuda Von Poelln.
Portulaca kermesina N.E. Br.

Proteaceae

Faurea saligna Harv.
Protea caffra Meisn.
Protea welwitschii Engl. subsp. **glabrescens** (Beard).
Protea gaguedi Gmel.

Ranunculaceae

Clematis oweniae Harv
Clematis brachiata Thund.

Rhamnaceae

Berchemia zeyheri (Sond). Grubov
Ziziphus mucronata Wiild. subsp **mucronata**
Helinus integrifolius (Lam.) Kuntze

Rosaceae

Rubus rigida J.E.Sm.

Rubiaceae

Tricalysia lanceolata Sond.
Rubia petiolaris DC
Vangueria infausta Burch
Oldenlandia herbacea (L.) Roxb.
Rothmannia capensis Thunb.
Pentanisia angustifolia Hochst.
Vangueria infausta Burch.
Pygmaeothamnus zeyheri (Sond.) Robyns.
Tapiphyllum parvifolium (Sond.) Robyns.
Canthium suberosum Codd.
Canthium gilfillani (N.E. Br) O.B. Miller.
Anthospermum hispidulum E. Mey.
Anthospermum rigidum Eckl. & Zeyh.

Rutaceae

Zanthoxylum capense (Thunb.) Harv.

Santalaceae

Osyris lanceolata Hochst. ex Steud.
Thesium cf. costatum A.W. Hill
Thesium magalismontanum Sond.
Thesium transvaalensis Schltr.
Thesium utile A.W. Hill

Sapindaceae

Pappea capensis Eckl. & Zeyh.

Sapotaceae

Englerophytum magalismontanum Heine & J.H.Hensley.
Mimisops zeyheri Sond.

Schizaeceae

Mohria caffrorum (L.) Desf.

Scrophulariaceae

Cycnium adonense E. Mey ex Benth.
Striga elegans Benth
Nemesia fruticans Thund. (Benth)
Halleria lucida L.
Sutera caerulea Hiern.
Sutera burkeana (Benth) Hiern.
Zaluzianskya katharinae Hiern.
Craterostigma wilmsii Engl.
Hebenstretia elongata Bolus.
Walafrida densiflora Rolfe.
Cycnium adonense E. Mey.
Striga elegans (L.) Kuntze.
Graderia subintegra Mast.

Selaginellaceae

Selaginella dregei (Presl) Hieron.

Solanaceae

Solanum giganteum Jacq.
Solanum incanum L.
Solanum panduriforme E.·Mey.
Solanum retroflexum Dun.
Datura stramonium L.

Sterculiaceae

Dombeya rotundifolia (Hochst.) Planch.
Hermannia depressa N.Br

Thymelaeaceae

Triumfetta sonderi Ficalho & Hiern.

Tiliaceae

Grewia occidentalis L.
Ulmaceae

Celtis africana Burm.f.

Urticaceae

Urera tenax N.E. Br.
Droguetia iners (Forsk.) Schweinf. subsp *iners*
Obetia tenax (N.Br.)

Velloziaceae

Xerophyta retinervis Bak.

Verbenaceae

Lippia javanica (Burm.f.) Spreng.
Verbena bonariensis L.
Lantana rugosa Thunb.
Plexipus hederaceus Sond.

Vitaceae

Cyphostemma lanigerum (Harv.) Descoings ex Wild
Rhiocissus tridentata (L.f) Wild & Drum. subsp. **cuneifolia**